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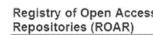
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COMPARATIVE STUDY OF MORPHO-HISTOLOGICAL TRAITS OF *LEUCOJUM IONICUM* TAN ET AL IN FIVE HABITATS OF VLORA SEACOAST, ALBANIA

Abstract: In this study was performed comparative morpho-histological study of *Leucojum ionicum* Tan et al in five habitats of seacoast of Vlora region. For morphological analysis has been measured vegetative and reproductive organs, while for histological analysis was used the colloidal technique with nail polish which consist in taking stomatal traces in the upper and lower epidermis of the leaves. Within five populations we found morphological and histological differences.

Keywords: *Leucojum ionicum*, morphological analysis, histological analysis, colloidal technique.

Introduction

L. ionicum = *Leucojum valentinum* Pau subsp. *vlorense* Paparisto et Qosja is a herbaceous, bulbous perennial plant, part of the family Amaryllidaceae. Until today is found on the islands of western Greece and in Eastern Spain. Its location in Albania is declared by botanists in 1977. From subsequent studies of this species taken in the area Vlorë-Jonufër resulted that a subspecies of *L. valentinum* Pau was in Albania, named subsp. *vlorense* from Prof. Xh. Qosja and Prof. K. Paparisto. Studies at chromosomal and cytological level were carried out for *L. valentinum* Pau subsp. *vlorense* in three habitats; Kalaja, Orikum and Dukat [13, P. 45–46]. Other researchers have estimated morphologically this specie, and together with the widespread populations in Greece, named it

Leucojum ionicum Tan, K. et al (2004). In this paper was considered *Leucojum ionicum* subsp. *vlorense* Tan et al in five habitats along the seacoast of Albania. These new locations of this specie were found and suggested from Prof. L. Kashta. The purpose of the study is to compare the five populations of this specie in terms of morphological and stomatal traits. Epidermal traits i. e. epidermal cells, stomata and hairs have proved to be an important tool in delimitation of taxa in many plant families [12, P. 2–11]. The use of leaf epidermal characters in the taxonomy of Angiosperms is on the increase and has been practiced for decades [12, P. 2–11; 1, P. 8–13] opined that of all the non-reproductive organs, the leaf is the most widely used in plant taxonomy while [6, P. 165–227] described the leaf epidermis as the

second most important character after cytology for resolving taxonomic and evolutionary problems.

Materials and methods

Plant material for study was taken in September-October 2014 in five habitats along the seacoast of Albania from the Llogara area (Fajeo) to Portopalermo. Species after being taken from their natural habitat are planted in pots. For morphological analysis has been measured the height of flower stalk, length and width of leaves, number of flowers, bulb dimensions. For histological analysis was performed the colloidal technique with nail polish [2, P. 67–77]. which consist in taking stomatal traces in the upper and the lower epidermis, the technique of peeling off the epidermis with the help of needles and forceps for studying stomatal types. Preparations were made from at least 5 leaves for each population and were observed using a microscope PARALUX with objective magnification 40x and eyepiece 10X. Measurement of stomatal dimensions was realized through microgiciel software. Photography was realized with Apple iphone directly in ocular tube. Through the lens tube was conducted count of stomatal cells/field, total number of cells/field, was determined type of stomata. It has been determined stomatal index, stomatal density and stomatal dimensions.

Stomatal types

Stomatal types were determined based on the classification of stomata on the grounds of nature and number of subsidiary cells [10, P. 242–252; 7, P. 23–38].

Stomatal Index

Stomatal Index (SI) was determined using the formula, given by [3; 11]:

$$SI = \frac{S}{E + S} \times 100$$

S: Number of stomata per unit area. E: Number of epidermal cells per unit area.

Stomatal frequency. The stomatal frequency was determined as percentage occurrence of each stomatal type in 1mm² of the microscopic field at 40x magnification under Paralux microscope.

Results and discussions

• Ecological traits

Leucojum ionicum Tan et al was located in five habitats with coordinates:

Fajeo (Llogara): 496 m above the sea level with geographical coordinates N 40,184425° E 19,606256°, located on the side of the road. Plant association of *Leucojum* in this habitat consisted of *Phlomis fruticosa*, *Salvia officinalis*, *Pteridium aquilinum*, *Quercus coccifera* etc.

Dhermi: 150 m above the sea level with geographical coordinates 40.155376°N 19.639420°E. *Leucojum* population in Dhërmi, are located near the source of Potami in the side of the road, in a limited space of 2–3 m². The terrain where was found a few individuals is rocky terrain filled with little humus with high humidity being that were located on the side of a stream. Plant association of the specie in this habitat consisted of *Salvia triloba*, *Salvia officinalis*, *Hedera helix*, *Phlomis fruticosa*, *Quercus coccifera*.

Gjipe 210–250 m above the sea level with geographical coordinates N 40,142606° E 19,675446°, located on the side of the road. Plant association consisted of *Arbutus unedo*, *Quercus coccifera*, *Pistacia lentiscus*, *Salvia triloba*, *Cistus sp.*, *Myrtus comunis*.

Palase. In this habitat *L. ionicum* is located in Palasa village in the side of the street. Palasa population plants were located in a limited space, rocky and humid terrain with geographical coordinates: 40.162809°N, 19.625999°E, 200 m above the sea level. Plant association consisted of *Arbutus unedo*, *Quercus coccifera*, *Pistacia lentiscus*, *Salvia triloba*, *Cistus sp.*, *Myrtus comunis*.

Portopalermo. In this area *Leucojum* is located at 53 m above sea level with geographic coordinates N 40.050565, E 19.798055 and 200 m away from the sea. Specie in this area is rare, with an average 4 individuals/m² and long distance from each other. Plant association consisted of *Euphorbia dendroides*, *Calicotome villosa*, *Salvia triloba*, *Paliurus spinacristi*, *Phlomis fruticosa*, *Drimja didima*.

In all habitats *Leucojum ionicum* Tan et al was distributed in a limited space in a rocky humid terrain (Figure 1).



Figure 1. *Leucojum ionicum* Tan et al. in their natural habitat: 1) Fajeo (Llogara); 2) Palase; 3) Dhermi; 4) Gjipe; 5) Portopalermo (Photo M. Shehu)

• *Morphological traits*

Leucojum ionicum Tan et al have white flowers, with 6 petals, 6 stamens and 1 pistil that bloom in August-September. The flowers contain 3 narrow petals and 3 wide petals alternating with each other.

The scape in *Leucojum* is variously hollow and solid [8, P. 85] which appears before the leaves. The leaves are filiform and the fruit is a little pressed capsule at the top.

Table 1. – Morphological traits of *L. ionicum* Tan et al in five habitats

<i>Leucojum ionicum</i> L.	Average length of bulb (cm)	Average width of bulb (cm)	Average length of leaves (cm)	Average width of leaves (cm)	Nr. of flowers/each scape	Height of the flower stalk (cm)
Fajeo	2.9 ± 0.6	1.22 ± 0.3	27.7 ± 3.9	1.5	2–4	23
Palase	2.7 ± 0.4	1.8 ± 0.19	40 ± 3.9	3 ± 0.4	4–7	25
Dhermi	2.4 ± 0.2	1.5 ± 0.1	34 ± 3.3	2.2 ± 0.3	4–7	32
Gjipe	2.14 ± 0.2	1.28 ± 0.1	32 ± 2.9	1.8 ± 0.3	2–5	25
Portopalermo	1.82 ± 0.1	0.7 ± 0.1	32 ± 2.6	1	2–4	14

Leucojum in this five habitats shows variation in terms of morphological features. As we may see in the (Table 1). Palasa individuals outstrip other

populations regarding height and width of the leaves, while Dhermi individuals outstrip other populations regarding height of the flower stalk.

Palasa and Dhermi populations differ from other three populations for powerful development of reproductive organs (flowers). Regarding bulb

dimensions Palasa and Fajeo individuals have long and narrow bulbs while Portopalermo individuals have small size bulbs (Figure 3).



Figure 2. *Leucojum ionicum* Tan et al transferred in pots:
1) Gjipe; 2) Fajeo; 3) Dhermi; 4) Palase; 5) Portopalermo



Figure 3. Bulb of *Leucojum ionicum* Tan et al:
1) Gjipe; 2) Fajeo; 3) Dhermi; 4) Palase; 5) Portopalermo

• *Histological traits*

In *Leucojum ionicum* Tan et al stomatal cells are arranged in parallel rows and rounded by four subsidiary cells. For that reason stomata are classified at tetracytic type (two polar and two lateral subsidiary cells) Figure 4. Epidermal cells are elongated and lo-

cated parallel to the axis of the leaf. Generally the stomata of monocotyledones are parallel to the axis of the leaf [4]. We performed observations in the upper and lower epidermis of the leaves of potted plants and resulted to be amphystomatous leaves (stomata are present on both epidermal faces).

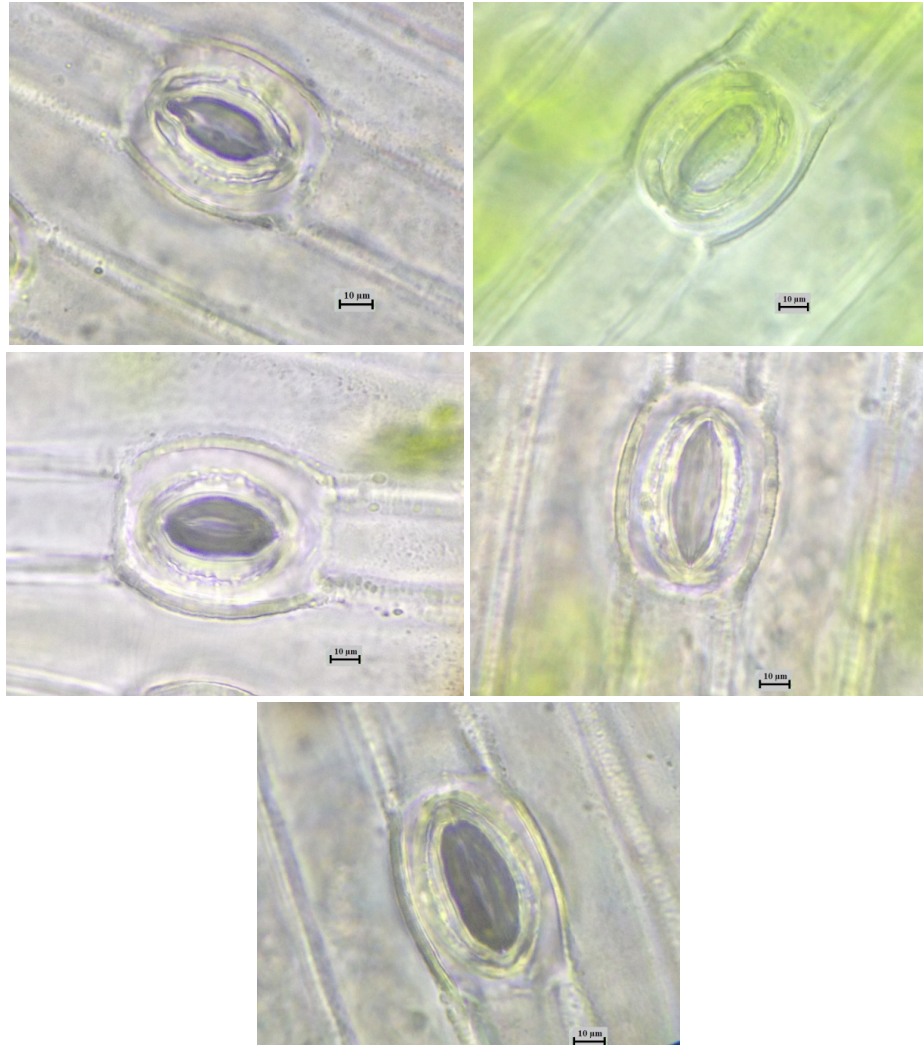


Figure 4. Stomatal apparatus at leaf epidermis of *Leucojum ionicum* Tan et al (Gjipe, Fajeo, Dhermi, Palase, Portopalermo)

In general in monocotyledonous, stomata occur in parallel rows and are more or less evenly distributed on both sides [5]. From the statistical data shown in Table

2 we may see that individuals of Palasa population differ from other populations for the higher stomatal density at upper and lower epidermis.

Tabela 2. Average values and standard deviation (SD) of traits of adaxial (AD) and abaxial (AB) leaf epidermis of *Leucojum ionicum* Tan et al.

<i>Leucojum ionicum</i> subsp. <i>vlorense</i> Tan et al		Nr. of stomata	Length (µm)	Width (µm)	SI (%)	SD (mm ²)
1	2	3	4	5	6	7
Fajeo	E.S	19.92 ± 1.9	35.9 ± 1.1	31.1 ± 1.6	34.2 ± 2.3	105.9 ± 10.2
	Cv	9.62	3	5.05	6.79	9.62
	E.P	20.04 ± 1	36 ± 1.4	30.7 ± 1.4	34.8 ± 1.4	106.6 ± 5.5
	Cv	5.18	4.01	4.46	4.05	5.18
Palasë	E.S	20.8 ± 1.7	37.22 ± 0.95	31.7 ± 1.7	36.18 ± 2.1	110.6 ± 9.5

1	2	3	4	5	6	7
Palasë	Cv	8.6	2.54	5.38	5.9	8.6
	E.P	22.72 ± 1.1	37.25 ± 1.05	31.9 ± 1.8	36.9 ± 3.3	120.8 ± 5.9
	Cv	4.9	2.81	5.77	8.94	4.9
Dhërmi	E.S	19.96 ± 1.14	37.1 ± 1.4	36.24 ± 1.3	34.8 ± 1.3	106.2 ± 6.1
	Cv	5.75	3.81	3.12	3.7	5.75
	E.P	21.96 ± 1.5	37.1 ± 1.4	36.4 ± 1.2	35.7 ± 1.6	116.8 ± 7.9
	Cv	6.75	3.77	3.22	4.55	6.75
Gjipe	E.S	19.36 ± 1.05	34.9 ± 1.64	32.11 ± 1.1	31.21 ± 2.03	102.98 ± 5.6
	Cv	5.44	4.69	3.43	6.49	5.44
	E.P	19.68 ± 1.2	34.9 ± 1.7	32 ± 1.1	31.1 ± 2.4	104.7 ± 6
	Cv	5.88	4.95	3.53	7.88	5.88
Portopalermo	E.S	19.24 ± 1.2	37 ± 1.1	29.2 ± 1.5	33.7 ± 1.7	102.3 ± 6.4
	Cv	6.28	2.99	5.3	5.1	6.28
	E.P	20.72 ± 1.8	37 ± 1	29.2 ± 1.6	34.2 ± 1.7	110.2 ± 9.7
	Cv	8.79	2.56	5.57	4.85	8.79

The (figure 5) shows comparatively the stomatal density for the five populations of *Leucojum ionicum* Tan et al.

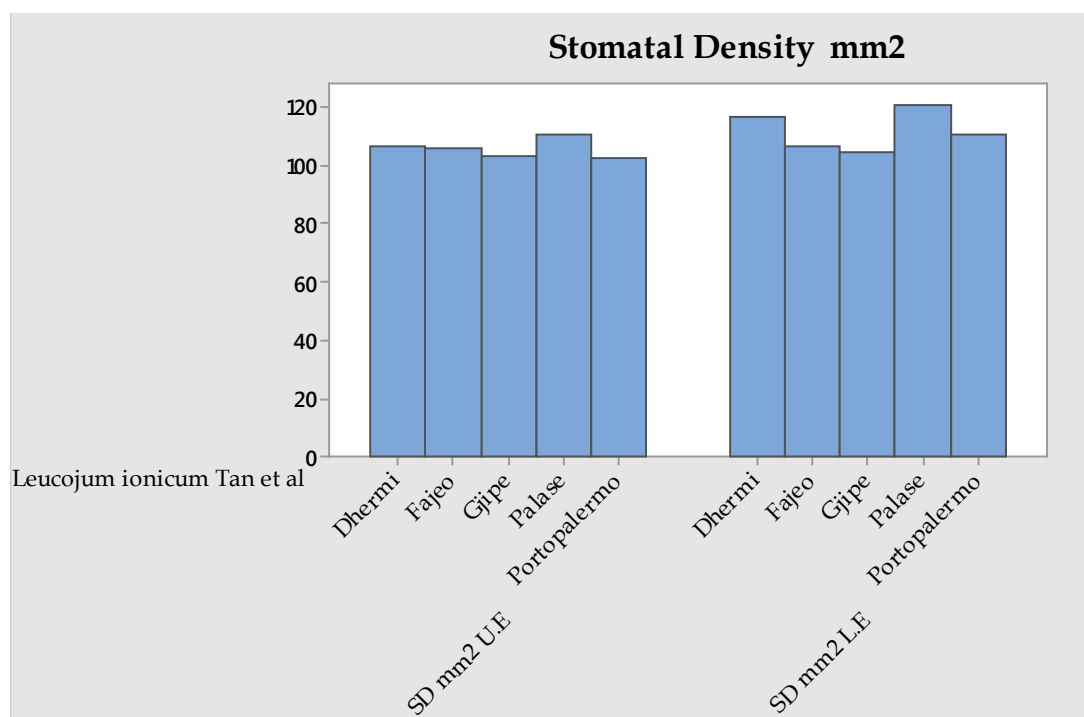


Figure 5. Stomatal Density at upper and lower epidermis of leaves of *Leucojum ionicum* Tan et al in five habitats

We can say the same for Stomatal Index which appears higher in individuals of Palasa (the stoma-

tal index is independent from environmental conditions). We may see clearly the difference in Figure 6.

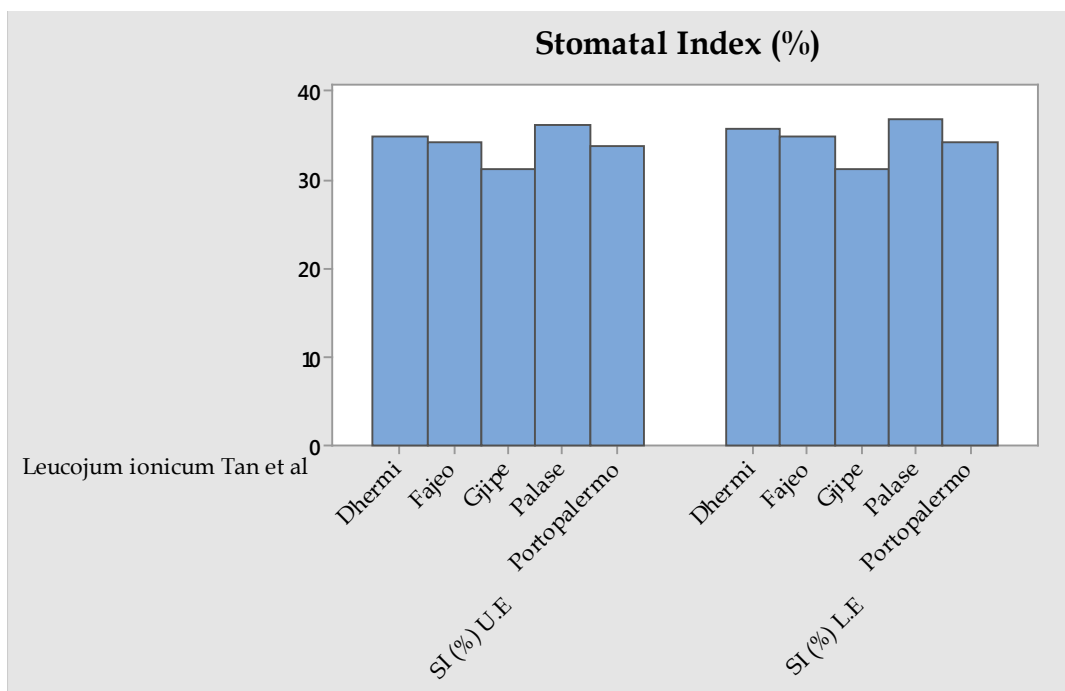


Figure 6. Stomatal Index at upper and lower epidermis of leaves of *Leucojum ionicum* Tan et al in five habitats

Regarding stomatal dimensions, individuals of Dhermi population exceed other populations, while individuals of Gjipe appear smaller in size than

the individuals of other four populations for the upper epidermis. The same situation appears also for the lower epidermis (Figure 4 and Figure 7).

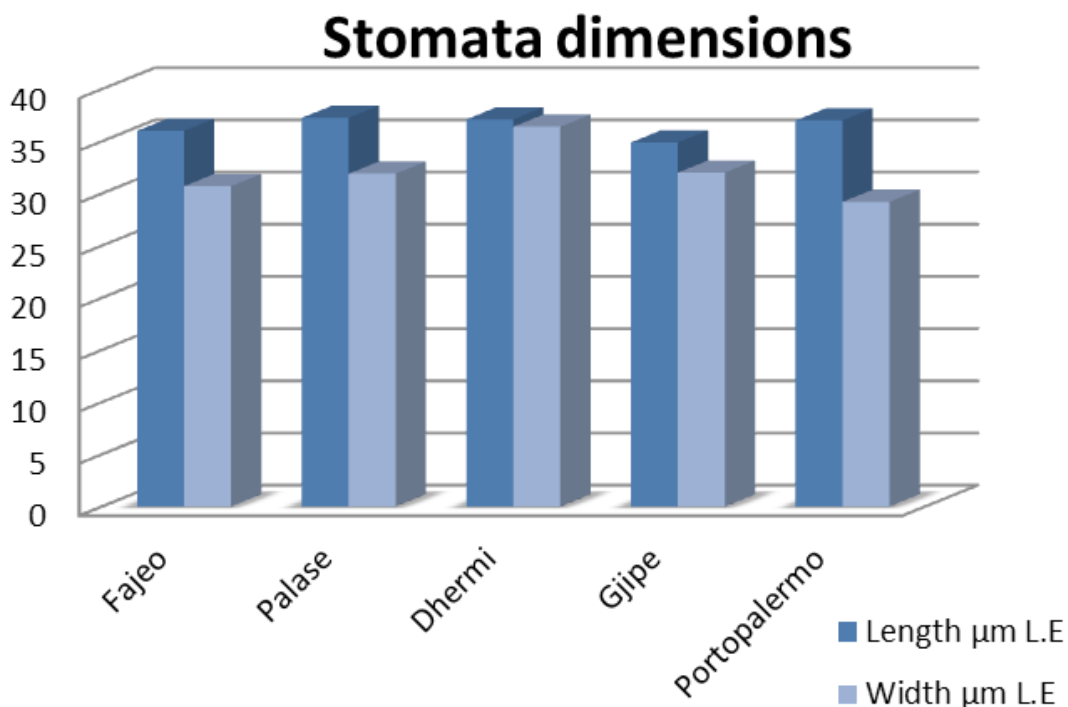


Figure 7. Stomatal dimensions at lower epidermis of leaves of *Leucojum ionicum* Tan et al in five habitats

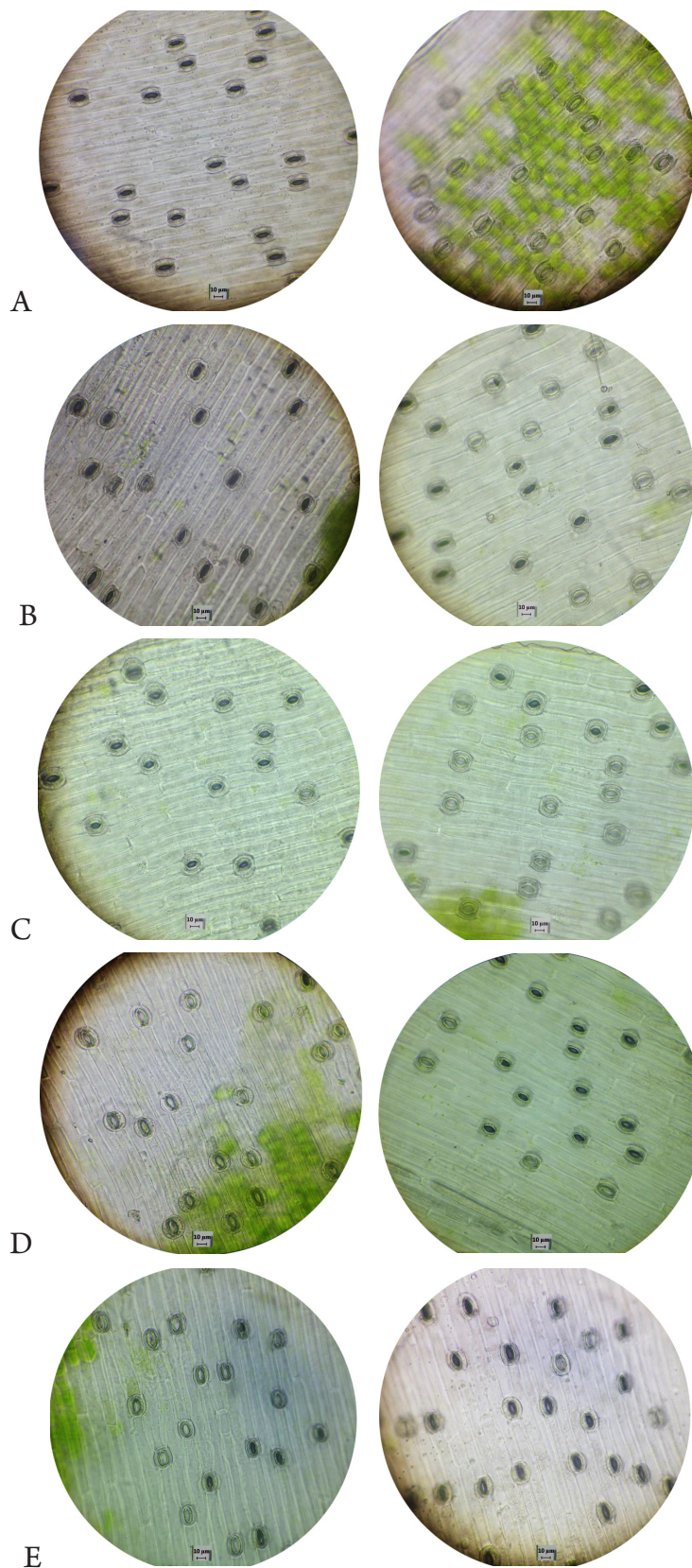


Figura 8. Stomatal distribution for five populations of *Leucojum ionicum* Tan et al. A) Gjipe; B) Fajeo; C) Dhermi; D) Palase; E) Portopalermo (left upper epidermis, right lower epidermis)

Conclusions

In this study we found morphological and histological differences between five populations of *Leucojum ionicum* Tan et al

1. Palasa individuals outstrip other populations regarding height and width of the leaves.
2. Dhermi individuals outstrip other populations regarding height of the flower stalk.
3. Palasa and Dhermi populations differ from other three populations for powerful development of reproductive organs (flowers).

4. Regarding bulb dimensions Palasa and Fa-jeo individuals have long and narrow bulbs while Portopalerma individuals have small size bulbs

5. Individuals of Palasa population differ from other populations for the higher Stomatal Density and Stomatal Index at upper and lower epidermis.

6. Regarding dimensions of stomata individuals of Dhermi population exceed other populations.

7. Gjipe individuals appear smaller in size than individuals of other four populations for the upper and lower epidermis

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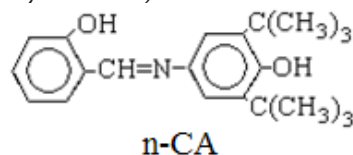
CATALYTIC ACTION OF N – (3,5-DI-TERT-BUTYL-4-HYDROXYPHENYL) SALICYLALDIMINE (N-CA) IN THE SILKWORM MIDGUT AND β – ELIMINATION OF GLYCOPROTEINS

Abstract: *N* – (3,5-di-tert-butyl-4-hydroxyphenyl) salicylaldimine (n-CA) has alkali properties of Schiff. In the digestive tract of silkworm caterpillars, this preparation has a catalytic action, aimed at the midgut, and it induces β -elimination of glycoproteins, which are contained in the gnawed food, before the enzymatic digestion of their proteins. As a result, hydroxy-amino acid residues are removed from the peptide macromolecule chain, thereby reducing the sericin biosynthetic rate. Thus, the amount of this protein in the cocoon shell is significantly reduced.

Keywords: fibroin, sericin, serine, threonine, hydro amino acids, biosynthesis rate, azine group, electro-donor activity, antioxidant activity, azomethine dye, alkyl substituents.

As far as hydroxy-amino acids are the main components of sericin, the nature of serine biosynthesis in silk gland differs significantly by the amount of serine and threonine in the hemolymph of silkworm caterpillars. In order to increase fibrine masses in the process of biosynthesis by means of reduction of the sericin amount, we have taken a shot to slow down sericin biosynthesis rate using the important capability of hydroxy-amino acid, namely, capability for β -elimination (Elimination is peculiar to α -amino acids, in which electron-accepting functional groups, such as hydroxyl and thiol ones, are contained in side radical in β -position to carboxyl group. Their splitting results in intermediate reactive α -enamino acids, which are easily transformable into tautomeric α -imino acids. α -Imino acids are transformed into α -oxo acids as a result of hydration reaction by imine group and subsequent splitting of ammonia

molecule. Such type of transformations is called elimination-hydration.) of serine and threonine.



The best result has been obtained when *N*–(3,5-di-tert-butyl-4-hydroxyphenyl) salicylaldimine (n-CA) is used. There are 2 electro-donor substituents–C (CH₃)₃ in the molecule of this preparation, thus, activity of the antioxidant (n-CA) is increased, as there is –C=N– azine group and branched alkyl substituents, like ionol, which is an azomethine dye and antioxidant with increased electro-donor activity.

The procedure of experiment. Hemolymph, yielded through cuts in pseudopodia of 150 caterpillars, has been used to demonstrate the inhibiting effect mechanisms of the preparation

n-CA in the process of sericin biosynthesis. From each batch $5 \cdot 10^{-6}$ kg of the material has been collected into the tubes, cooled to a temperature of 273 K. The lyophilization drying method has been applied to dry the hemolymph. Weighted amounts of the hemolymph were fixed with boiling alcohol. After fixation, the residues have been separately processed in a centrifuge ILK-1 at the rate of 3000 rpm for 5 minutes. The centrifugate has been drained, and residues have been extracted with 95% alcohol three more times, alcohol has been separated by means of centrifugation. We have also performed purification of the obtained solution from mineral salts and other substances, alcoholic extracts have been flown through ion-exchanger – cation-exchange material KU-2, according to the established procedure [1, 2]. Proteins and other admixtures have been removed, after that 1 ml of 50%-trichloroacetic acid (TCA) has been added to each 10 ml of the solution. Then the solution of amino acids has been boiled dry on a bath in porcelain cups, after adding of 20 ml of water three times, boiling has been repeated to remove ammonia traces. After removal of water and ammonia traces, dry residue of amino acids has been dissolved in 2 ml of 10% isopropyl alcohol acidified with hydrochloric acid; the extract has been stored frozen in a fridge (at a temperature of 263 K). Standard solutions of amino acids have been prepared in a concentration of 10 mg of amino acid per 1 ml. Unidimensional paper chromatography has been applied to evaluate amino acids. For this purpose, chromatographic paper No. 2 with dimensions of 50x60 cm has been used.

When chromatogram spots are dried up, a solvent, namely, phenol, saturated with phosphate buffer (pH 12.0), has been settled and poured into a chamber. The solvent has been flown on the paper only in one direction. The method of chromatographic splitting of amino acids is a descending one, i. e. the solvent has moved on the paper downwards. The phosphate buffer (pH 12.0) has been flown through

a paper preliminary, in order to achieve more clear separation of serine and threonine amino acid. After that it has been dried and used in chromatography.

The table 1 shows the results of chromatographic analysis of amino acid composition of the silkworm caterpillars hemolymph for reference and test batches. It is known, that water solubility of sericin is related to comparatively high content of amino acids with OH-groups. In sericin they are represented by serine and threonine (mainly). As you can see from the table 1, when silkworm caterpillars are fed with a stuff, where N- (3,5-di-tert-butyl-4-hydroxyphenyl) salicyl aldimine is added, serine and threonine content in caterpillars hemolymph drops sharply. At the same time, the content of other amino acids, namely, alanine and glycine 5–10%, increases.

Table 1. The content of amino acids in silkworm caterpillars hemolymph.

Amino acids	Reference specimens	Test specimens
Alanine	25.79	30.35
Arginine	3.64	4.06
Aspartic acid	3.03	0.71
Valine	3.27	3.68
Histidine	1.60	1.56
Glycine	29.05	34.43
Isoleucine	0.56	1.20
Leucine	0.85	1.05
Lysine	1.23	1.89
Serine	20.02	9.78
Tyrosine	2.73	3.45
Threonine	3.31	1.20
Phenylalanine	1.27	1.63
Glutamine	1.01	1.23
Total	97.26	96.22

Discussion of the obtained results. Based on the obtained results, it was supposed, that the preparation n-CA has no effect on free hydroxy-amino acids. The same way, as Schiff bases in a midgut, it results in β -elimination of glycoproteins, containing residues of serine or threonine, according to the following patterns:

Section 2. Mathematics

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THE GOLDEN SECTION GIVES RISE TO A PRIME NUMBERS

Abstract: The connection made of the numbers of Fibonacci numbers with the canonical decomposition themselves Fibonacci numbers and give the formula generating the Prime numbers. Found a method of determining the composition of the Fibonacci numbers.

Keywords: Prime numbers, Fibonacci numbers, the canonical decomposition.

This article examines the relationship of the Fibonacci numbers (FN) and primes (PN). It turns out that the equation of comparison that allows you to create PN, i. e. actually formula is a PN, similar to the theorem of Wilson, but it is much easier to use. The FN created by the formula $F(n+2) = F(n+1) + F(n)$ and have the numbering: $F(-1) = -1; F(0) = 0; F(1) = 1; F(2) = 1; F(3) = 2; F(4) = 3; F(5) = 5; \dots$. FN find a wide application in mathematical, physical and technological tasks and even in art. This is the reproduction of rabbits, arrangement of leaves on the branches and seeds in a sunflower, the structure of the shells, the system of the adjacent squares, the ratio of phalanges, etc. FN associated with the Golden section with the number:

$$\varphi = \left(\frac{1 + \sqrt{5}}{2} \right) = 1.618033989 \dots$$

There is a huge set of formulas and ratios on the properties of $F(n)$. [1; 2]. For example, there is the Binet formula for the calculation of the FN

$$F(n) = \frac{\varphi^n - (\varphi - \sqrt{5})^n}{\sqrt{5}} = \left[\frac{\varphi^n}{\sqrt{5}} \right] \quad (1)$$

In (1) we use special bracket x which gives the integer closest to x . For example, $[3.9] = [4.2] = 4$. PN will be denoted $p \in \mathbb{P}$, in this case divide all odd PN, except for $p = 5$, two classes: $\bar{p} = 10t \pm 1$ and $\tilde{p} = 10t + 5 \pm 2$. It is known that FN have property: $F(n)$ is divisible by $p(F(n):p)$, then all $F(nt)$, $t \in \mathbb{N}$, are also divided into p . In symbols, this property can be written as

$$F(n):p \Rightarrow F(nt):p \quad (2)$$

Write a table of the multiplicities of some of the FN:

$$\begin{aligned} F(3t):2; F(4t):3; F(5t):5; F(7t):13; \\ F(8t):7; F(9t):17; F(10t):11; \\ F(11t):89; F(13t):233; F(14t):29; \\ F(15t):61; F(16t):47; \\ F(17t):1597; F(18t):19; F(19t):37; \\ F(20t):41; F(21t):421. \end{aligned} \quad (3)$$

Note that if $F(n):p$ and n is a composite number a multiple of s it is not always $F(n/s)$ is divisible by p . For example, $F(14) = 13 \cdot 27$, but $F(7) = 13$ is not divisible by $\ll 27 \gg$.

In the paper [3] we have shown that Prime numbers among $F(n)$ an infinite number, although they

meet with increasing n less. Us using the Binet formula, we proved the following new properties of the FN (theorem I):

$$\text{If } \bar{p} = 10t \pm 1, \text{ then } (F(\bar{p}) - 1) : \bar{p}; \quad (4)$$

$$\text{if } \tilde{p} = 10t + 5 \pm 2, \text{ then } (F(\tilde{p}) + 1) : \tilde{p}. \quad (5)$$

Proof. By the Binet formula, if $p = 2m + 1$,

$$F(p) \pm 1 = \sum_{t=0}^{m-1} \binom{p}{2t+1} \frac{5^t}{2^{2m}} + \frac{5^m \pm 2^{2m}}{2^{2m}}. \quad (6)$$

The first term in the right side is a multiple of p because of the binomial coefficients, $2^{2m} \equiv 1 \pmod{p}$ for small Fermat's theorem, $5^m \equiv 1 \pmod{\bar{p}}$, $5^m \equiv -1 \pmod{\tilde{p}}$ in terms of Legendre. Hence, the second term in the right part of (6) is also a multiple of p . For example, $F(11) = 89$, $F(11) - 1 = 8 \cdot 11$, $F(7) = 13$, $F(7) + 1 = 2 \cdot 7$.

Similarly, using (1), we prove such divisibility rules FN on PN (theorem II):

$$\text{If } \bar{p} = 10t \pm 1, \text{ then } F(\bar{p} - 1) : \bar{p}; \quad (7)$$

$$\text{if } \tilde{p} = 10t + 5 \pm 2, \text{ then } F(\tilde{p} + 1) : \tilde{p}. \quad (8)$$

$$\text{For Example, } F(11 - 1) = 5 \cdot 11, \quad F(7 + 1) = 3 \cdot 7.$$

A consequence of theorem I and II, obtained from the recurrence formula for creating the PN the following:

$$\{F(\bar{p} - t) + (-1)^{t+1} F(t - 1)\} \equiv 0 \pmod{\bar{p}}; \quad (9)$$

$$\{F(\bar{p} + t) - F(t + 1)\} \equiv 0 \pmod{\bar{p}}; \quad (10)$$

$$\{F(\tilde{p} - t) + (-1)^t F(t + 1)\} \equiv 0 \pmod{\tilde{p}}; \quad (11)$$

$$\{F(\tilde{p} + t) + F(t - 1)\} \equiv 0 \pmod{\tilde{p}}. \quad (12)$$

$$\text{Examples: } F(11 - 4) - F(3) = 13 - 2 = 11;$$

$$F(11 + 4) + F(5) = 610 - 511 = 55;$$

$$F(13 - 2) + F(3) = 89 + 2 = 7 \cdot 13;$$

$$F(13 + 2) + F(1) = 610 + 1 = 47 \cdot 13.$$

If m is even, then from (9) and (11) follows the necessary and sufficient condition for the connection of FN and the PN: if $F(n)$ composite number that is a multiple of p , $F(m) > p$, then

$$F(m) = 0 \pmod{\bar{p}}; F(m + 1) = 0 \pmod{\tilde{p}}. \quad (13)$$

$$\text{Forexample, } F(20) = 165 \cdot 41; F(30) = 321824 \cdot 61;$$

$$F(9) = 2 \cdot 17; F(7) = 13.$$

If m is odd, then we have a comparison

$$\begin{aligned} \{F(m + 1) + F(m - 1)\} &= 0 \pmod{\bar{p}}; \\ \{F(m + 2) + F(m)\} &= 0 \pmod{\tilde{p}}. \end{aligned} \quad (14)$$

$$\text{For example, } F(6) + F(4) = 11; F(13) + F(11) = 14 \cdot 23.$$

Knowing the table the multiplicity of FN you can make a sieve of Eratosthenes for PN on the table FN. Among the first 200 FN, there are only twelve PN:

$$F(3) = 2; F(4) = 3; F(5) = 5; F(7) = 13;$$

$$F(11) = 89; F(13) = 233; F(17) = 1597;$$

$$F(23) = 28657; F(29) = 514229;$$

$$F(43) = 433494437; F(47) = 2971215073;$$

$$F(137) = 19134702400093278081449423917.$$

The above relations allow to generate the PN according to the canonical decomposition of the FN. For example, find the composition $F(19)$. As for $\tilde{p} = 37$, then (8) $F(38 = 19 \cdot 2) : 37$. The multiplicity property $F(19) : 37$. Since $\tilde{p} = 113$, $F(114 = 19 \cdot 6) : 113$. Hence, we find the composition $F(19) = 4181 = 37 \cdot 113$. The second example, there are $F(25) = 75025 = 25 \cdot 3001$, as there are no other options. Another example: find the composition $F(20)$. Since $20 : 4; 20 : 5; 20 : 10$, then in the decomposition $F(20)$ is a number $\ll 3 \cdot 5 \cdot 10 \gg$. Further, since $2 \cdot 20 = 40$ is located in the neighborhood with $F(40) : 41$, and (7) give $F(20) : 41$. The multiplicity property (2) $F(20) : 41$. Here $F(20) = 3 \cdot 5 \cdot 10 \cdot 41 = 6765$.

Finding the PN through the FN according to equations

$$\begin{aligned} \left[\frac{\varphi^{2m}}{\sqrt{5}} \right] &\equiv 0 \pmod{(\bar{p} = 4m + 1)}; \\ \left[\frac{\varphi^{2m+1}}{\sqrt{5}} \right] &\equiv 0 \pmod{(\tilde{p} = 4m + 1)}, \end{aligned} \quad (15)$$

resembles the famous theorem of Wilson: if $\{(n - 1)! + 1\} : n$, then n is the PN. However, the formula (13) operates with a much smaller numbers

than Wilson's theorem. For example, check the number $61 = 4 \cdot 15 + 1$. (15) taking $F(30) = 832040 = 13640 \cdot 61$. It follows that «61» is the PN. According to a theorem of Wilson, we need to work with a number $60! \approx 8.32 \cdot 10^{81}$, that not every computer will handle.

Thus, the formula connection of the Golden ratio and Prime numbers, on the one hand, allow us to find the canonical decomposition of the FN, and, on the other hand, gives a relatively efficient algorithm for generating PN.

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Section 3. Machinery construction

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INFLUENCE OF THE COW MANURE ON THE INTENSITY OF HEAT EXCHANGE IN THE BIOGAS INSTALLATIONS WITH A HEAT RECUPERATOR

Abstract: The current work covers opportunities of transformations of waste energy into the useful one. Also the means of improvement of the process efficiency are investigated. There are given Experimental data on the intensification of the recuperator 1.2–2.6 times with a humidity increase from 86 to 98%.

Keywords: Biogas, bioshlam, fermentation, recuperator, bioreactor.

1. Introduction

Actuality of the work: In modern biogas installations the methane fermentation is an energy-consuming process. Providing a portion of the energy demand of the biogas stations with the help of waste bioshlam which is obtained in the thermophilic regime is of a considerable importance. Maintenance of the energy consumption is covered by a significant amount biogas (70%, sometimes up to 100%), which can be used as a goods. Energy is spent on the grinding and transporting biomass and compensating the heat losses to the external environment in order to keep the required biomass temperature in the fermentation process, on mixing the biomass. It is known that the energy spent on grinding and transporting the biomass, as well as heat losses through the bioreactor surfaces to the external environment, depending on the applied mechanisms and the heat insulations, account for a small

share of the total expended energy (up to 7%). High-temperature (thermophilic) regime of anaerobic fermentation, which has become quite popular lately, conditions a higher rate of the decompositions of organic substances, a higher biogas output and a higher degree of disinfection. In addition, waste fermentation in the thermophilic temperature range are considered to be inefficient by some investigators because of high energy demand and already existing imagination on the instability of bioreactor exploitation at high temperatures. Comparatively quickly renewed biomass in the bioreactor usually requires more energy expenditure on maintaining the heat conditions of the fermentation. Analyzes show that most of the expended energy (higher than 75%) comes to heating the manure up to the fermentation temperature, but for the thermophilic regime this is of big importance. Scientists believe that the evaluation of the thermal

balance is possible if, in every specific case, the manure flow rate and humidity, biogas composition as well as the amount of heat released during the combustion of biogas are known for an installation of a certain construction and geometry and also for a specific type of manure (cow, swine, ovine, chicken, etc.). In order to choose, justify and evaluate the thermal apparatus included in the suggested manure processing technology and to evaluate the thermal balance of the line on the whole, it is necessary to know the principal characteristics of the fermented manure (thermal diffusivity α ; viscosity ν ; density ρ ; heat capacity C), the expressions characterizing the heat release on the boundary "fermented manure-the separating surface of the installation" [1; 2]. These figures, in turn, depend on the temperature regime of the fermentation. Taking into account what has been written above, we developed and created an installation and technology for the recuperation of the heat of the fermented bioslam [3; 4]. The main requires of the heat extraction are specified, as well as the ways to intensify the heat extraction [5]. The installation passed natural tests in the cattle farm in Karaulbazar district of Bukhara region in a biogas installation which can process the manure up to 25 tons/day.

2. Schematic representation and the working principle of the biogas installation with a heat recuperator

(Fig. 1) shows the scheme of the biogas installation with a heat recuperator (Fig. 2) illustrates the recuperator working in the reciprocating motion of the phases with a pulsing loading and unloading of the biomass. The cycle of heat exchange in the recuperator, working according to the proposed technological method of manure processing is described in (Fig. 3). On (Fig. 1) and (Fig. 2) specific elements of the biogas installation are designated as follows: 1-Bioreactor, 2 – recuperator, 3 – mixing chamber, 4, 17 – holder, 5 – gaseous cave, 6 – hole, 7 – separating tube, 8, 12, – vacuum pumps, 9 – underpressure sensors, 10, 15 – sleeve, 11 –

electromagnetic valve, 13 – programmable device, 14 – temperature regulator; 16, 20 – heat exchangers; 18, 23 – loading pipelines; 19 – unloading pipe; 21 – input sleeve; 22 – recuperator; 24 – unloading sleeve of the recuperator; 25 – unloading pipe for the bioslam; A and B – pipe and interpipe cave of the recuperator (Fig. 3) shows the heat exchange cycle in the recuperator working according to the proposed technological method of manure processing [1].

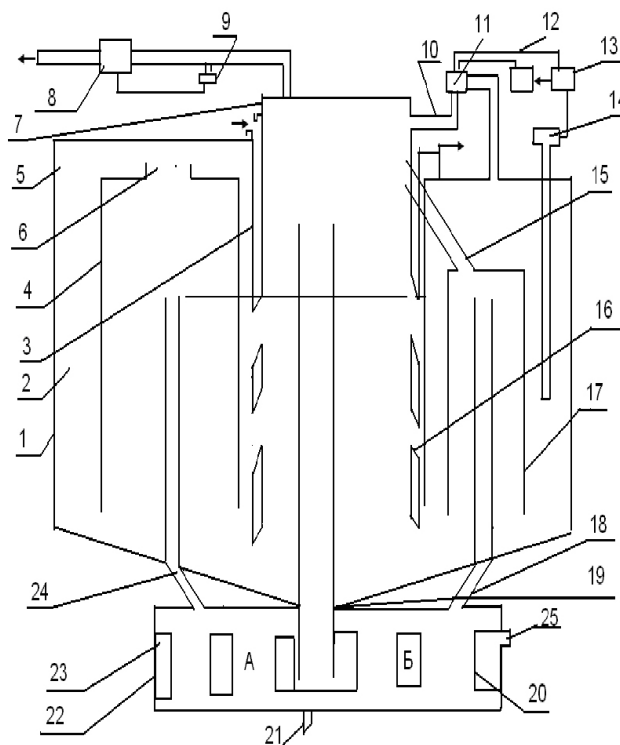


Figure 1. Schematic representation of the biogas installation with the recuperator

The scheme of the pipe recuperator in the reciprocating mixing of biomass is illustrated in (Fig. 2). The proposed installation includes a vertical cylindrical bioreactor 1, with coaxially located mixing chamber 2 which is positioned inside and has gaseous cave 5 and heat exchanger 3, located in the bioreactor 1 with holders 4.17 whose internal cave is combined with the mixing chamber 2, the upper part of one of the holders is connected to the gaseous cave 5 of the mixing chamber 2, and also connected to the recuperator 22. This recuperator is linked with the caves of the holders 4.17 and with

the loading pipelines 18.23 of biomass incoming to the bioreactor 1, which is combined with the recuperator 22 (more detailed information on the working principle of the biogas installation is provided [6]). The processed bioslam is extracted through the unloading pipe 19 from the recuperator. Simultaneous mixing of heat carriers in both the cavities of the recuperator is done in a pulsing regime with the help a vacuum pump.

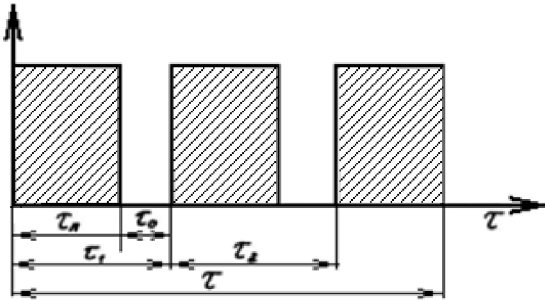


Figure 2. Recuperator Scheme working in reciprocating motion of the phases with a pulsing loading and unloading of the biomass

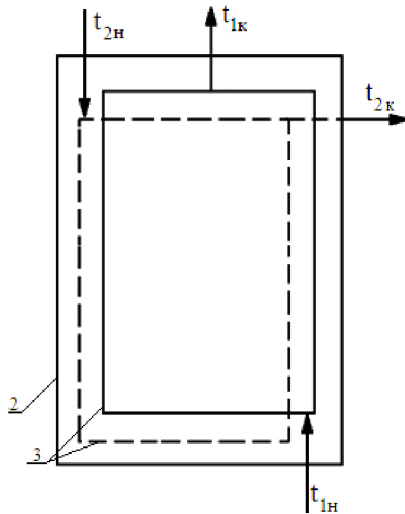


Figure 3. Cycle structure of heat exchange in the recuperator.

The cycle structure of the heat exchange in the recuperator working according to the proposed technological method of manure processing [1] is shown in (Figure 3). The heat exchange takes place by means of a mixing compressor which is switched to time τ and switched off in some time τ_o . The cycles are repeated every $\tau_{u,i}$ time (τ – duration of the heat

exchange process, minutes; τ_n – duration of a unit mixing cycle, minutes; $\tau_{u,i}$ – the first cycle mixing-storing; $\tau = \sum_i^n = 1\tau_{u,i}$; n – number of unit cycles mixing-storing). It is known [2] that for a periodically acting apparatus the equation of heat transfer is:

$$dQ = K[\bar{t}_2(\tau) - \bar{t}_1(\tau)] \cdot F d\tau \quad (1)$$

Where dQ – amount of heat transferred to the cold heat transfer material in the apparatus through the heat exchange surface over time $d\tau$, J , F – heat exchange surface in the considered heat exchange apparatus, m^2 ; From this equation we can identify the true coefficient of heat transfer K . Let's transform this equation taking into account C_1 ($C_1 = C_2$) – specific mass heat capacity of the hot and cold heat transfer material they are assumed to be equal, J/kgK) and mass G_1 ($G_1 = G_2$) – mass of the loaded heat transfer materials into the recuperator, they are supposed to be equal) – mass of the cold heat transfer material which is loaded into the recuperator. So we can introduce K^* – modified coefficient of heat transfer:

$$K^* = \frac{K \cdot F}{C_1 \cdot C} \quad (2)$$

Now we separate variables and integrate the obtained expressions between and for the first expression and between $\bar{t}_{1,u}$ and $\bar{t}_{1(\tau)}$ for the second one, assuming the specific heat capacity $C_1 = \text{const}$. Transforming the equation (2), we obtain

$$K^* = -\frac{tg\gamma_1}{2} \quad (3)$$

From these results we found a relation of the kind $\ln: \theta = f(\tau) = -2K \times \tau$; For studying the influence of manure humidity on the intensity of heat transfer in the experimental installation, prepared manure with humidity 86%, 95%, 98% was sequentially loaded in the working chamber. At the same time other technological parameters of the process in the recuperator were kept unchanged and equal: duration of the unit cycle of mixing $\tau = 15$ min; duration of heat transfer material motion in the heat exchanger pipes $\omega = 0.023 \text{ c}^{-1}$, storing duration between mixing cycles $\tau_o = 30$ min. In order to

determine the range of technological parameters of working conditions for the biogas installation with

heat recuperator, mathematical planning of the experiment was adopted.

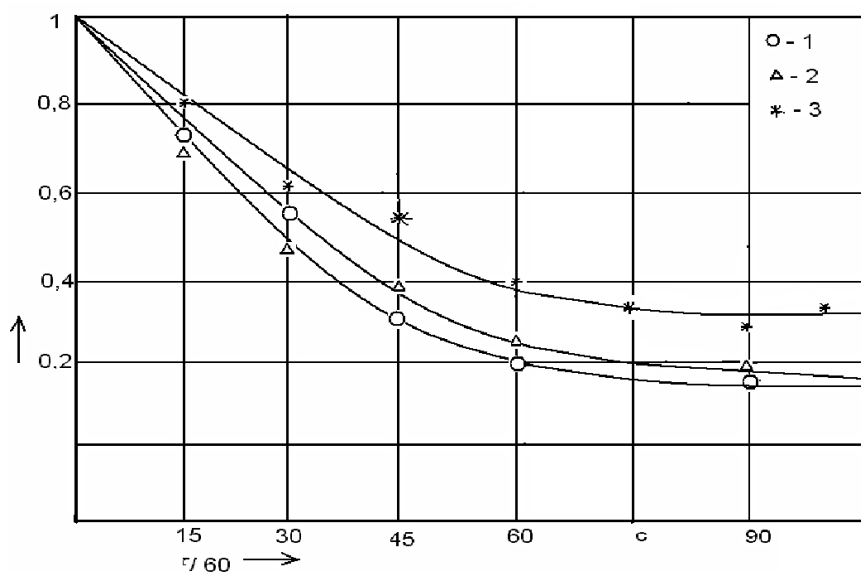


Figure 4. Relation between dimensionless temperature θ on the heat extraction time τ : 1 – $w = 98\%$; 2 – $w = 95\%$; 3 – $w = 86\%$ ($\tau_n = 15 \text{ min}$; $\omega = 0.023 \text{ s}^{-1}$; $\tau_0 = 30 \text{ min}$)

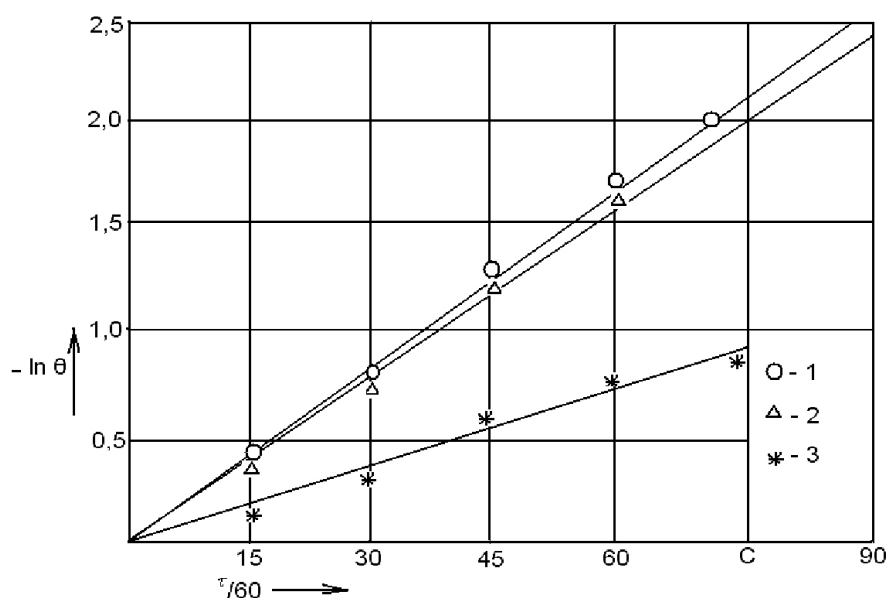


Figure 5. Relation $-\ln \theta = f(\tau)$ 1 – $w = 98\%$; 2 – $w = 95\%$; 3 – $w = 86\%$ ($\tau_n = 15 \text{ min}$; $\omega = 0.23 \cdot \text{s}^{-1}$; $\tau_0 = 30 \text{ min}$)

The experiment results are provided in (Fig. 4) and (Fig. 5) in the relation $\ln \theta = f(\tau)$. It is seen in the picture the graphs of the functions pass through the origin and have linear behavior. Analyzing the kinetics of heat transfer (Fig. 4), it is possible to see that the heat transfer process is intensified

with an increase of manure humidity. This is explained by the fact the thermal diffusivity α increases when manure humidity rises. As a result, the heating process becomes faster. Intensive heat transfer in the beginning of the process is a consequence of a large driving force of the process-temperature differ-

ence between the cold and hot heat transfer material. For a comparison of heat transfer intensities at different manure humidities and evaluation of the heat transfer coefficient K^* included to the mathematical modelling, new relations $\ln \theta = f(\tau)$ as a result of experiments (Fig. 4). With their help the modified heat transfer coefficient K^* was computed.

Then using the equation (2) the values of the true heat transfer coefficient K were defined (Table 1). The evaluation results have shown that when the manure humidity increases from 86% to 98% the heat transfer coefficient increases from $56.97 \text{ W}/(\text{m}^2\text{K})$ to $141.98 \text{ W}/(\text{m}^2\text{K})$, which corresponds to an increase of intensity by 250%.

Table 1. – Values of heat transfer coefficients obtained from experiments and provided in (Figure 5)

Line number in Fig.5	1	2	3
Heat transfercoefficient			
Modified K^* , s^{-1}	2.5×10^{-4}	2.4×10^{-4}	1.04×10^{-4}
True K , $\text{W}/(\text{m}^2 \times \text{K}^\circ)$	141.91	131.47	56.97

Summary

Actuality of providing energy demand of biogas installation has been justified at the expense of wasted thermally processed bioslam which is obtained after processing in thermophilic regime.

Perspectives of the indicated biomass mixing methods in bioreactors have been demonstrated. It was experimentally illustrated that the heat transfer process in the recuperator is intensified 1.2–2.6 fold with a manure humidity increase from 86% to 98%.

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Section 4. Mechanics

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DETERMINATION OF THE RATIONAL ARRANGEMENT OF GRAINS IN THE CUTTING EDGE OF MILLING TOOL AND THEIR IMPACT ON MILLING PROCESS PRODUCTIVITY

Abstract: An increase of the operating characteristics of the well cutting tools depends on cutting power and wear resistance of tool. The posed problem requires the thorough examination of forces influencing the cutting power of tool.

It is known that the cutting edge of drilling tool is deposited with the composite material consisting of the crushed hard alloy and its bond. The conducted investigations show the effectiveness of cutting power also depends on the arrangement of grains in the cutting edge. The rational distributions of forces can substantially influence the output of shaving in cutting metal cutting. Therefore, in this considered article study of distribution of forces and arrangement of cutting edge grains for the normal output of shaving in metal cutting is of great importance.

For the authenticity of assigned task a research was carried out under laboratory conditions imitating milling process.

As a result of research, the rational location of grains creating more favorable conditions for chip removal from the surface has been determined the obtained results allow to recommend the rational parameters of cutting edge designing and producing of well cutting tools.

Keywords: Destruction, load, stress, cutting elements, milling tool.

Solving the number of the questions, connected with the increase of the cutting power and wear resistance of drilling cutting tools, requires the thorough examination of cutting tool forces.

The posed problem was solved by studying of the cutting power of the well milling tool models under laboratory conditions.

Studies were carried out in laboratory conditions in ASOIU, in a special developed installation making it possible to imitate the process of destruction and cutting of metal in the bore hole.

Study of the cutting forces will allow to lay the basis of milling tool designing and producing in more rational parameters.

Study of the characteristic of the cutting forces represents interest in the determination of the stability conditions of cutting elements and their bond.

The composite materials consisting of the crushed hard alloys and bonds, deposited on the housing of drilling cutting tool, possess the highest indices of cutting power and wear resistance. The self-sharpening occurs in the process of the cutting of emergency metallic object by such tools since the new cutting elements come into contact with the surface of the destroyed object as a result volumetric wear of cutting edge. The metal layer under the considered conditions is cut off by several cutting angles of hard alloy. All milling tools developed in AzSRIPM (Azerbaijan Research Institute of Petroleum Machinery) and serially produced by other plants work on this principle.

The crushed hard alloys have the numerous sharp angles of indefinite form and in the mass of bond occupy arbitrary positions.

A similar process of cutting is classified as restricted cutting, and cutting by single grain is considered as free cutting.

It should be noted that the cutting effect of the cutting edge, besides other factors, depends on the arrangement of crushed hard alloys on the contact surface of cutting edge (see Fig.1).

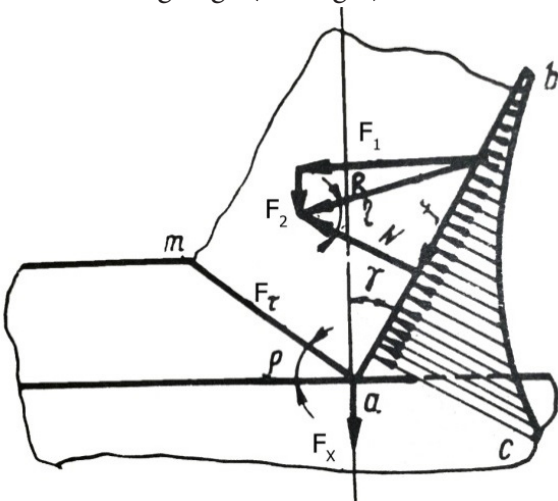


Figure 1. Diagram of the distribution of the forces acting on the front of cutting element

The cutting elements, that is, crushed solid particles, fixed by bonds, throughout entire volume of the cutting edge of are located arbitrarily and at the moment of contact with the surface of cutting sharp angles can be located in the position when the value of rake angle γ can have positive, negative and zero values. With the negative zero the values of back rake angle the force of cutting on the front surface of the cutting element reaches greatest value. It should be noted that this condition is correct for the case, when the sharp angles of the cutting element remove from the surface of cutting to the spoke shave of the specific thickness. In the considered conditions in $\gamma \leq 0$ the cutting elements enter into the contact with the milled object in $\gamma > 0$ favorable condition is created for cutting and making a chip.

In this case the value of cutting forces on the front cutting element changes depending on the value of the back rake angle (cutting force on the rear surface in the considered conditions practically is not important for this investigation; therefore they are disregarded).

Thus, the position of grains in the tool cutting edge and value of back rake angle represent interest for the practice of milling in the shaft of borehole.

In Fig.1 the diagram of the forces acting on the forward section of the cutting element (the solid particle of the working edge of cutter in the cutting process carrying out output of chip) is shown.

Distribution of normal stresses along the contact line of the front surface is characterized by the diagram of abc. Normal forces N is a resultant of normal stresses. As a result of the friction of shaving against the front surface of the cutting element shearing stress appears, their sum composes frictional forces. The sum of forces $f_{fric.}$ and N composes the force of chip formation R .

Conducting experience, the theory of the cutting and condition of milling the emergency metals by the drilling forces appearing in the process interaction of the cutting element from the surface of cutting are distributed according to the diagram of that shown over (Fig. 1).

It should be noted that during milling of metal in the shaft of borehole cutting (with the formation spoke) and abrasive actions occur. For simplification of the task impacts and fluctuations and some other characteristics of cutting are not considered in the study. In the cutting process forces influence on the front surface of the cutting element (single grain) F_z is tangent in the direction of the movement trajectory of the circular working part the instrument and F_x is axial, determined from the value of axial load from the mass of boring column. Unlike the other types of milling the radial force of F_r is absent in the condition of drilling milling. The shift of the element of shear occurs in the plane of the line am , where the deformation reaches the great value. In the shear plane the force acts. The equations the cutting forces are known from the theory of the cutting of metals [1; 2]. Formula obtained from the conditions of the equality of the specific works of plastic deformation while cutting and compression has the form:

$$\rho = \frac{\frac{n\xi^2 - 2\xi \sin \gamma}{\xi \cos(\eta - \gamma)} \cdot s \cdot t \cdot \frac{\sigma_0}{n}}{1 - \frac{\xi \sin \eta}{\sin \eta}} \quad (1)$$

While milling in the stem the circulation of the cooling fluid is taken into account.

For simplification of the task the condition of strengthening the metal in the zone of cutting is disregarded. Then the shearing stress in the zone of the shift will be:

$$\tau = \frac{2}{3} \sigma_0 = \text{const}, n = 0 \quad (2)$$

Consequently,

$$F = \frac{2}{3} \sigma_0 s \cdot t \cdot \frac{\xi^2 - 2\xi \sin \gamma + 1}{\cos \gamma [\xi - \sin \gamma - \cos \gamma \operatorname{tg}(\eta - \gamma)]} \quad (3)$$

Where F – is the force acting in the direction of cutting speed; n – is the index of the polytropy of stress; s – is width of shear; t – is the depth of shear; σ_0 – is yield limit; ξ – is the shrinkage of shaving; η – is the angle of friction, γ – is the value of back rake angle.

Equation (3) shows that the force F is determined by physical characteristics of a cutting body (σ_0, n), the size of cut area (t, s), rake angle of the cutting element (γ), friction angle (η), shrinkage of chips (ξ), and others.

Other important condition of increasing of the cutting speed is the value of the back rake angle γ , which considerably influences the cutting forces. Projecting the cutting forces (see Fig.1) on Z axis and X , we will have:

$$\rho_z = \sigma_0 \cdot t \cdot s \cdot \xi \cdot n (\cos \gamma + \mu \sin \gamma) \quad (4)$$

$$\rho_x = \sigma_0 t \cdot s \xi n (\mu \cos \gamma + \sin \gamma) \quad (5)$$

where μ – coefficient of friction;

$$\mu = \frac{f}{N} \operatorname{tg} \eta \quad (6)$$

$$\gamma = 90^\circ - (2\rho - \gamma) \quad (7)$$

from the equation

$$\xi = \frac{\cos(\rho - \gamma)}{\sin \rho} \quad (8)$$

we find

$$\rho = \operatorname{arctg} \frac{\xi \sin \gamma}{\cos \gamma} \quad (9)$$

In accordance with the experiences value of contraction ξ is equal to 2. For the regime of milling in the shaft of borehole, that is for the conditions of the absence of metal strengthening the index of polytropy of the stresses in $n = 0$. Equations (4) and (5) show that there is a specific connection between the force components of cutting F_z and F_x the dimensions of shear (t, s) and back rake angle γ , its study can reveal more rational design solution of drilling milling tool.

One of the requirements, presented to the cutting tool is the creation of the greatest shear of metal (t, s) with the smallest values of force components on interaction of which strength condition of the cutting element depends. In this case back rake angle must be more optimum. On the basis of equation (4) the graph of dependences $cF_z = f(\gamma)$ and $c_\lambda \cdot t \cdot s = f(\gamma)$ (Fig. 2). In this case for simplification of the calculation it is accepted:

$$c_\lambda \cdot t \cdot s = f(\gamma), \frac{F_z}{\sigma_0 \cdot \xi \cdot n} = c_1$$

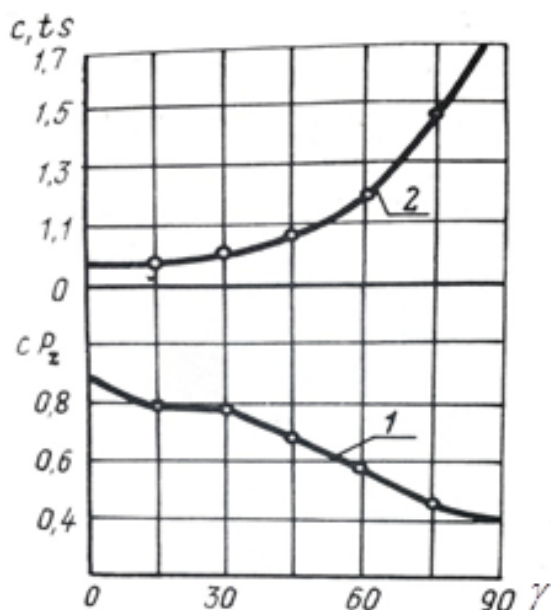


Figure 2. Dependence of the given sizes of the diagram of the metal of cF_z and component (tangential) cutting force on $c_\lambda \cdot t \cdot s$ the value of back rake angle (γ)

It is evident from the curve $cF_z = f(\gamma)$ that in the interval of $\gamma = (0^\circ \div 30^\circ)$ value cF_z decreases slowly and has the greatest value in $cF_z = 1 - 0.88$, but in the interval of $\gamma = (0^\circ \div 30^\circ)$ considerably decreases $cF_z = 0.88 - 0.52$; curve $c_\lambda \cdot t \cdot s = f(\gamma)$ in

the intervals of back rake angle indicated first rises insignificantly and then sharply grows. It gives the opportunity to judge the fact that in the interval $\gamma = (0^\circ \div 30^\circ)$ cutting occurs with the great significances of the components of efforts, but the dimensions of shear minimum and barely have a tendency toward the increase. The nature of curves gives the opportunity to assume that the optimum regime of cutting is created the value of the back rake angle of $\gamma = (0^\circ \div 75^\circ)$.

Cutting at high force components of cutting, i. e. with the smallest values of back rake angle, leads to an increase in shearing stresses in the zone of the formation of shaving, and thereby cutting speed reduces and the wear of cutting element rises [1]. This law must be considered with the design of drilling cutting tool.

Conclusion:

1. The study of the cutting power of tool creates more favorable conditions for chip removal from the surface of metal.

2. The experiments conducted make it possible to recommend more the thermoresistant construction of the drilling cutting tools.

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Section 5. Food processing industry

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INVESTIGATION OF THE PROCESS OF DRYING RAW MATERIALS

Abstract: The article deals with the process of drying medicinal plants and the results of laboratory analyzes of samples. The technique for drying medicinal plants for the preservation of biologically active substances has been studied.

Keywords: convection drying, product, installation, extractives, polysaccharides.

Throughout the world, the consumption of medicines based on natural plant ingredients has a steady growth trend. Worldwide, 40% of pharmaceutical products are made from medicinal plants [1].

The urgency of the development of the food and pharmaceutical industry is connected with solving the problems of nutrition imbalance in the population, the lack of functional food products, and reducing the cost of production of food products of mass consumption.

Today, an important task of a global scale is the development of processes and apparatus for drying forest products, including medicinal plants. Particular attention is paid to improving the technology of drying raw materials by applying new methods, taking into account the results of scientific research in this field, focused on preserving the medicinal properties of components in the final product.

The healing properties of plants for thousands of years have been used by all the peoples of the world. It is with their help that people treated many diseases, referring to nature, to its gifts. Today there are about 12,000 medicinal plants in the world that have healing properties and are used both in traditional and in

folk medicine. In this case, often medicinal plants are perfectly combined with other types of treatment.

But medicinal plants are used not only in therapeutic, but also for preventive purposes, for example, for cleansing the body. It is regular cleansing is one of the secrets of people who in old age can boast of excellent physical and mental health.

However, it is important to remember that only a doctor can diagnose and prescribe a medicinal plant, whereas self-medication may not lead to the desired result (at best) or worsen the state of health (in the worst case).

What is the secret of the effectiveness of herbal medicines?

The fact is that plants are a biogenetically developed complex, consisting of active substances and other (secondary) elements, among which:

1. Metabolites;
2. Proteins;
3. Various essential oils;
4. Chlorophyll;
5. Microelements;
6. Vitamins of different groups;
7. Inorganic salts.

This kind of complex, which is formed in a living cell, has a great similarity with the human body, rather than an active substance created chemically. Therefore, medicinal plants are more easily assimilated by the body and have fewer side effects.

Therefore it is not surprising that scientific medicine, which considers folk methods of treatment as imperfect and archaic, nevertheless resorts to the help of medicinal plants that have proved their effectiveness and usefulness during their existence.

Moreover, modern science not only examines and carefully tests the experience of traditional medicine, but also replenishes the arsenal of medicines.

As a raw material, plants were selected as plantain, mint and zizifora. Plantain is used as a medicinal plant for at least a thousand years. The most commonly known is the wound healing effect of plantain leaves when they are applied topically. It is generally believed that it consists of two components: firstly, it is the plantain's ability to stop bleeding (not arterial), and secondly, the so-called disinfecting effect, for which the plantain leaves are used also for suppurating wounds and various abscesses, is of no small importance. There is a harmful effect of plantain great on *Staphylococcus aureus* [2].

Medicinal raw materials are leaves. Infusion of plantain leaves stimulates the activity of cilia of ciliated epithelium of the respiratory tract, which leads to increased secretion of bronchial mucus, while sputum is liquefied, and its separation is facilitated by coughing. Infusion is used as an anti-inflammatory and expectorant for bronchitis, whooping cough, bronchial asthma, pulmonary tuberculosis. Infusion and fresh juice contribute to the rapid cleansing and healing of wounds. They are applied externally in the form of lotions and rinses with bruises, fresh cuts and wounds, chronic ulcers, fistulas, abscesses, boils. When purulent wounds, furunculosis, freshly washed fresh leaves are used as a compress.

In the stems and inflorescences of zyziphora, alkaloids, flavonoids, coumarins, lactones, saponins,

phytocinids, essential oil (0.50–0.56%), which contains alcohol, menthol, and pulegon are found.

With the therapeutic purpose of preparing the aboveground part – the grass during flowering plants – and dried in the shade. Ibn Sino recommended crushed leaves for healing wounds, used herb plants to treat skin purulent diseases (furuncle, carbuncle and others). The aerial part of zyziphora is a part of the teas used for certain cardiovascular diseases. In folk medicine decoctions of the leaves of zyziphora are used for pain in the throat in children, stomach pain, nausea.

Infusions and decoctions from the plant have hypotensive, cardiostimulant and anti-inflammatory effects. They also have a diuretic and antispasmodic properties [3].

Peppermint has analgesic as well as vasodilating properties. Mint oil is a part of many medicinal preparations: mint drops, stomach pills, various ointments.

Peppermint improves digestion, eliminates nausea, has choleric properties, is used for asthma, flatulence. Broths of mint drink as a soothing agent, with inflammatory processes in the bronchi, lungs, as well as with cardiovascular, gynecological diseases.

Decoctions of mint leaves disinfect the oral cavity with various inflammatory processes. They relieve pain in the abdomen, heart pain, heartburn. Mint baths have soothing properties. Menthol – the main component of mint essence. The latter is added to various toothpastes, powders, colognes, elixirs, etc [4].

Peppermint is used as a tonic heart remedy, relieving palpitation, stimulating the activity of the heart and blood circulation, which also has a diaphoretic property. Mint is used to fight against colds and fever. The relaxing and anti-inflammatory properties of mint make it an excellent remedy for pain and spasms, such as stomach pain, colic, intestinal swelling, heartburn, indigestion, hiccoughs, headaches, migraine, nausea and seasickness. The tannins contained in the mint protect the intestines from irritation, which is very useful for removing rubbing

with diarrhea, for fighting spastic constipation and ulcerative colitis. The bitter taste of mint stimulates the liver and gallbladder, so it is used to purify the liver and remove gall stones [5].

Experimental studies of the drying process of plant raw materials were conducted by us in the laboratory of the Tashkent State Technical University. The main requirement for these experiments was the most accurate reproduction of heat and mass transfer processes in the convective drying of medicinal plants.

This installation allows you to conduct research: the dynamics of heat and moisture transfer in the layer of a drying medicinal plant; values of specific moisture capacity and moisture conductivity of grass; aerodynamic drag of a layer depending on humidity and density of a dehydrated plant.

The water-heating dryer operates on natural gas (or coal, wood, briquettes, electricity, oil products) using a boiler.

In a container-type dryer, the heat transfer medium is supplied by a line of heat conducting pipes. Metal tubes withstand the long-term impact of active elements released from the product during the drying process. Heat-transfer pipes are attached to the frame of the drying chamber by means of special fastening elements. Hot water is used as a heat agent. A removable pallets are placed in the water heating dryer [6; 7].

Preservation of biologically active substances in the dried objects depends on a properly selected dryer and technology. The study of the composition and medicinal and thermophysical properties of the plant

makes it possible to create a technique and technology designed for their drying with maximum preservation of biologically active substances (BAS). The author carried out experimental works on dehydration of medicinal plants like peppermint (*Mentha*), plantago (*Plantago*) and ziziphora (*Ziziphora*) on a water-heating convective drying (WCD) installation. After the work on dehydrating the drying facilities – mint, plantain and ziziphora, the numbered samples were prepared in the following order:

1. “Option 1” – drying in a natural way;
2. “Option 2” – drying in a water-heating convection dryer;
3. “Option 3” is the product of the manufacturer;
4. “Option 4” is the raw material.

The dried plants were examined for residual moisture, ash content and extractive substances of mint and ziziphora plants, and polysaccharides of plantain plant. All types of laboratory tests performed were performed according to the State Pharmacopoeia of the tenth edition.

As can be seen in the table below, the indicators of the second option, that is, the dehydrated products in WCD contain more extractive substances and polysaccharides than those dried under natural conditions and products manufactured in production. The data of variant 4, that is, the raw material, show the content of extractive substances and polysaccharides in the fresh plant. Judging by the original and dried sample in WCD, one can see that the preservation of BAS reaches its maximum level.

Table 1. – The results of the analyzes for the determination of biologically active substances in medicinal plants

Indicator name	Drying in a natural way	Drying in a water-heating convection dryer	Product of the manufacturer	Raw material
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
Indices of plant plantain (<i>Plantago</i>)				
Humidity,%	6.3	6.0	5.9	6.2
Total ash content,%	6.3	6.42	6.29	6.3
Mass fraction of polysaccharides,% 10	12.8	13.7	12.6	12.92

1	2	3	4	5
Indices of plant peppermint (<i>Mentha</i>)				
Humidity,%	5.4	5.3	5.25	68
Total ash content,%	5.92	6.3	6.0	6.2
Mass fraction of extractive substances,% 20	20.3	23.30	21.56	23.2
Indices of plant ziziphora (<i>Ziziphora</i>)				
Humidity,%	6.2	6.32	6.0	58.9
Total ash content,%	7.2	7.0	7.3	7.25
Mass fraction of extractive substances,%15	17.7	19.19	16.55	17.0

Thus, the introduction of the proposed type of technology and technology is justifiable for laboratory research and for cost-effectiveness, it can be recommended for use in business entities, small

businesses, agriculture and forestry, food and pharmaceutical industries, which is consistent with the innovation policy being implemented.

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Section 6. Agricultural sciences

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ATMOSPHERIC POLLUTANTS OF AIR AND THEIR INFLUENCE ON THE VEGETABLE FORMATION

Abstract: The article is dedicated to atmospheric pollutants of air and their influence on the vegetable phytocenosis, compositions, construction of their development. The intensive growth of industry, motor transport means favour to a considerable pollution of natural environment, atmospheric air, at the result takes place change of natural processes in biosphere, leads to redistribution of various gasiform toxic combinations, which exert a definite influence on the vegetable formation.

It has been revealed that the gasiform toxic pollutants exert a certain influence on the photosynthetic activity of sheep-plate, reducing the synthesis of organic combinations. Dusty form pollutants accumulated on leaves reduce the photosynthesizing area. The leaves are able to keep the dusty form matters and by this way they can purify air from dusts.

Keywords: pollutants of air, toxic matter, oxides of heavy metals, sulfur, carbon, ash, dust, selection of stable species.

Introduction

The negative after-effect of economic activity reaches such a scale that the danger of irreversible changes of natural environment have become true, the abilities of biosphere for self-purification is near to limit.

During the historical period majority of natural-territorial complexes this or that degree have been subjected to human's influence.

There are a great number of natural complexes on the surface of Earth. They occupy various area, have various origin.

A notion and similar term of “natural utilization” has been included in the scientific literature at the end of 60s of the XX century, when clearly appeared negative after-effects of technogenesis, threatening the existence of life in the Earth, that is the humanity with its own eyes encountered with possibility of ecological catastrophe.

1 milliard tons of conditional fuels are burnt up, millions of tons of oxides of nitrogen, sulphur, carbon, soot, ash and dust are thrown into the atmosphere every year.

Soils and waters are polluted with industrial and domestic sewages, oil-products, pesticides, fertilizers and heavy metals. All these favour to a considerable pollution of natural environment, atmospheric air and bring to redistribution of various gasiform toxic combinations, which exert influence on the vegetable formation.

There arose a question of conservancy, which its aim is to provide present and coming generations with natural resources and favorable life conditions in preserving the integrity and structure of natural systems, their abilities for reestablishment and production-line of ecosystem services.

The development of ecosystem takes place at the result: 1) change of physical environment under the influence of community as a whole, and 2) concrete interaction and coexistence between component community of populations.

The evolution of biosphere is formed under the influence of: 1) outside forces, such as geological and climatic changes, and 2) inside processes, being conditioned by activity of living components of ecosystem.

The principles of development of ecosystem have an important relation to intervention between the man and nature, because the development tendency of natural environment, consisting in increasing the level of structurality and complexity by unit of energy-line often act in contradiction of man's aspiration to obtain the maximum production.

The natural-anthropogenic landscape may be created at the result of purposeful activity of the man. In their development they continue to subordinate to the natural regularities and at times outwardly differ little from alike them natural formation.

The human always tries to get more production as possible from landscape, developing and supporting the ecosystems in earlier stages of succession, usually monoculture. But the human needs not only food and dress, it is necessary him to balance CO_2 and O_2 of atmosphere, mild climate, which are provided by oceans and green massives.

The number of population of the terrestrial globe and interference of the human in environment grew up to such degree that began to influence on regional and global balance.

The danger of uncontrolled change of environment and threat the existence on the Earth of the living organisms and including the human need practical measures for protection, rational utilization and reestablishment of natural resources of the Earth.

Natural regulation the purity of biosphere is not able to manage with different concentrations of toxic matters. As a result of long term accumulation of gaseous combinations and dusty form fractions of phone load and types, level of population of atmospheric air in industrial regions and large towns increased considerably.

The help for the purity of town environment, including the atmospheric air, comes from different tree-bush species, which the results of long-term carried out experiments are introduced in the given article.

Methods and objects of research. Calculation the amount of toxic gaseous pollutants in 1 m^3 of air were carried out by the help of universal gas-analyser (UYA-1) with the use of different indicators, the amount of oxygen (O_2) with the use of tescometer “Oxygenpen”, the amount of anions and cations ($\text{SO}_4^{-2}-\text{Cl}_2$) “Palintegtnom”. The objects of research were industrial enterprises of Baku, Sumgait and Ganja. The representatives of veg-

etables species have been selected from the flora of Azerbaijan.

Discussion and Conclusions. As a result of anthropogenic factor the dusty form fractions and gaseous matters – SO_2 , Cl_2 , F_2 , CO_2 , CO and oth. enter into the atmospheric air. In distillation of raw oil and production of sulfuric acid, functioning of HES and oth. objects the air is saturated with sulfuric anhydride. 1 ton raw oil having in the composition 1,5% – 2,0% containing matters in the distillation process discharges 60 kg SO_2 . The sulphuric anhydride, active combination entering in vegetable leaves is able to form the sulphuric acid (H_2SO_4). Formed sulphuric acid vegetable tissue gives rise to destructive action. As far as increasing the concentration of entered SO_2 in the leaves the burn is formed of various objects and on the expiry of some time the leaves die out completely and photosynthetic activity decreases correspondingly. Some species do not bear the impact of toxic matters and perish (1, 2, 3).

Molecular chlorine and flore (Cl_2 and F_2) enter the atmospheric environment in production of polymers and syntetic dyes. These hologens are distinguished for their higher toxicity and exert dangerously influence on vegetable organism. These toxicants exert both the outside and the innerside influence, damaging the leaf plate and wood.

The speed of damaging increases in cloudy weather conditions. Wood, shrub, grass and flower plants near industrial objects actually do not bear the impact of named pollutants. For this reason it was needed to renew plants from time to time (Fig. 1).

Dynamics the accumulation of dust on the surface of leaves depending on remoteness from the sources of pollutants amount in m^2 .

In the (Figure 1) is represented a schematic illustration the intensity of pollutants distribution. The height and diameters of excretory chimney is directly proportional with distribution of pollutants, and it was determined that depending on moving off from the sources of throws the

amount and concentration of pollutants decrease some times.

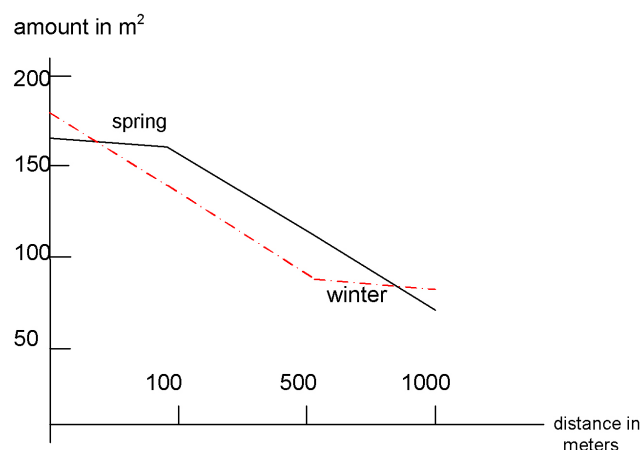


Figure 1. Character the accumulation of dust on the surface of leaves depending on remoteness of the sources of pollutants

The plants having dense leaves or wax coating are distinguished by higher resistance. Such kinds of species are: olive european, common oleander, silver oleaster, Eldar pine, Japanese sophora, stone oak, stone ivy, pyramidal cypress, vertical cypress, Arizona junipar, Eastern plane.

We have determined a scale of impact limit for above mentioned species both the short-term and the long-term action, criterion of their resistance and was revealed a group of indicated plants.

Oxide metals accumulated in the plants and soils favour the increase of electric saturation of soils, some ions join to the compositions of chlorophyll (Mg), participate in iron (Fe) synthesizing with anti-cyanogens, oleander accumulate arsenic (As), funguses – tin (Pb). Some information on availability of metals in the composition of dust is given in the (table 1).

The amount of dust accumulated on the surface of leaves at a kg/g per ha area in a year both the broadleaved and the coniferous species is given in the table. It has been determined that 1 ha coniferous species (Eldar pine) during a year can accumulate 35 kg dust narrow-leaved oleaster about 32 kg and they are able to purificate 15–20 mln. t^3 air during a vegetation period.

Table 1. – Amount the ions of metals in the leaves of different species of plants, introduced in the territory of tube – rolling mill

ions species of plants	Iron (Fe ²⁺)		Magnezium (Mg ²⁺)		Zink (Zn ²⁺)	
	Zeaf	Fruit	Zeaf	Fruit	Zeaf	fruit
	100 M From The Source					
White acacia	65.1	58.3	7.8	5.0	4.0	2.3
Stone oak	48.3	40.0	10.0	3.3	6.1	5.0
Olive european	44.0	23.0	9.1	3.0	7.0	4.3
Common oleander.	34.0	24.1	7.3	2.4	2.8	2.0
Pyrocant	30.2	24.7	7.0	2.0	3.0	2.3
	500 M From The Source					
White acacia	45.1	18.0	5.3	4.0	2.0	2.0
Stone oak	36.4	13.0	4.0	3.2	2.2	2.7
Pyrocant	32.0	20.0	3.5	2.0	2.2	1.5
	1000 M From The Source					
White acacia	33.4	14.0	4.3	2.0	2.0	1.3
Stone oak	23.0	17.2	4.2	2.0	2.1	1.0
Olive european	25.0	12.1	10.0	10.2	12.3	1.6
Common oleander	32.4	–	8.3	–	2.1	–

Table 2. – Quantitative content of dust on the leaves of wood – shrub plants, in a years kg/g, dry matter

Species	Area of leaves in a shoot, cm ²	Amount of dust accumulated on the leaves, kg/g
1	2	3
	Woods	
White acacia	170	25.4
Caspian haney locust	96	8.3
White mulberry	200	24.7
Black mulberry	180	22.1
Green ash tree	160	27.3
Stone oak	145	41.8
Horizontal cypress	135	40.9
Vertical cypress	130	33.4
Eldar pine	148	37.5
Common junipar	127	30.3
Common spruce	135	28.9
	Shrubs	
Yellow acacia	18	10.0
Olive European	23	19.7
Common oleander	17	10.4
Narrow – leaved oleaster	25	17.1
Common lilac	39	12.4
Yellow pyrocant	32	10.6

1	2	3
Red pyrocant	35	10.0
Eastern mulberry	19	9.0
Caucasian mulberry	20	9.7

Table 2. The amount of dust accumulated on the surface of leaves at a kg/g per ha area in a year both the broadleaved and the coniferous species is given in the table. It has been determined that 1 ha

coniferous species (Eldar pine) during a year can accumulate 35 kg dust narrow – leaved oleaster about 32 kg and they are able to purificate 15–20 mln.t³ air during a vegetation period.

Table 3. – Amount of dust on the surface of soils and leaves o wood species, introductioned in industries areas, g/mg

Remoteness from the source in meters	Amount of dust at 1 m² of soils in gr	Amount of dust on the surface of leaves		
		Eldar pine	Green ash tree	Silver oleaster
100	9.4	4.7	2.4	6.3
500	7.7	3.6	1.7	5.7
1000	7.3	3.0	1.4	4.3

The quantitative indecies of dust accumulated on the surface of soils and leaves of introductioned plants are given in the (table 3).

It has been revealed that the gaseous toxic pollutants exert a certain influence on the photosynthetic activity of leaf plate, decreasing the syntheses or organic combinations. The photosynthesized area is decreased by dusty pollutants accumulated on the leaves. The leaves being hanged and wenever hold the dusty matter and by this may purificate air from dust.

From above mentioned may be come to conclusions:

1) The plants having adaptable ability to drought and saltness of soils bear the impact of toxic pollutants differently;

2) The broadleaved woods and shrubs are more sensible to toxic pollutants than the coniferous species;

3) Small – leaved and leaves being hanged are able to hold dusty fractions of air and purificate the air environment;

4) The woods and shrubs stable to pollutants are recommended for planting of greenery of industrial towns and arterial roads.

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Section 7. Technical sciences

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QUESTIONS OF ENVIRONMENTAL PROTECTION IN FUEL AND ENERGY COMPLEXES

Abstract: Assessment of a role of energy industry and the decision ecological and power problems in regions of Kazakhstan are considered. Results of a research of process of production of the oil and gas enterprises, structure, properties and purification of the oil-containing sewage which are formed at an obessolivaniye and dehydration of oil of the considered field are shown.

Keywords: power, energy industry, environmental protection, technology, sewage treatment, composite materials.

The Republic of Kazakhstan has achieved significant progress in the field of regulatory reform in support of the Concept of green economy, klyuchy development of the Kazakhstan Scheme of trade in quotas for emissions (K-ETS), energy efficiency and policy of usage of renewables [1; 2]. The Republic of Kazakhstan has assumed obligations for implementation of the program and integration of the principles of global conventions of the UN (Rio de Janeiro, 1992), Declarations of the Millennium Summit (New York, 2000) and the World Summit on sustainable development (Johannesburg, 2002). In August, 2016 the Parisian agreement is signed by the Government of

Kazakhstan. The Republic of Kazakhstan I have also successfully eaten the World specialized Fair Astana EXPO-2017 with the subject “Energy of the Future”.

Kazakhstan advances interregional cooperation in the direction of development of “green economy” within implementation of the program of partnership “Green Bridge” between the countries of Europe and the Pacific Rim and also the public, private sector, NGO and the international organizations. The president of Kazakhstan has stated the idea about interregional cooperation at the 66th session of the United Nations General Assembly in September, 2011. Later this idea has

been reflected in the text of the Initiative of Astana “Green Bridge”.

The Program of Partnership Green Bridge (PPGB) for 2011–2020 has been approved in 2012 by all states at the Conference of the United Nations on sustainable development (Rio + 20) as a cross-regional voluntary initiative of sustainable development which is open for participation of all partners [3].

Oil-containing sewage is the drains polluted by oil products and also the weighed substances and in certain cases specific connections. In sewage oil products can be in the free, connected and dissolved states. Coarse, free oil products are removed as a result of upholding. For removal of fine and connected oil products traditionally use floatation ways of cleaning, methods of electrothermic coagulation and electroflotation. As a result of these processes in water there are oil products up to 20 mg/l. Deeper cleaning from fine, especially emulsified,

oil products up to 10 mg/l is reached in filtering processes. Removal of the dissolved impurity up to 0,5–1 mg/l happens at a stage of sorption tertiary treatment [4].

The structure and properties of the oil-containing sewage which are formed at an obessolivaniye and dehydration of oil of the Zhylankabak field, the characteristic of the received samples of composite materials and results of a research of process of sorption water purification from oil on laboratory installation with use of the specified materials are given in a research.

The research of waste water by method of infakrasny spectroscopy (IFS) has shown that the main polluting component are oil hydrocarbons. Besides, in small amounts (up to 4–5% of the general contents) presence of connections of the oxidized character and oxygen-containing substances is noted. Ex-remental researches of process of cleaning were conducted on laboratory installation.

Table 1. – The characteristic of the received samples of composite materials is provided

Samples	Weight%				Keeping of sour groups, mg-eqv/g		
	C	H	O	N	COOH	OH	COOH+OH
KM	73.70	5.34	19.84	1.12	3.84	2.60	5.44
KM	24,32	3.63	17.47	1.60	2.31	2.90	5.21
KM	20.82	4.21	20.63	6.23	2.78	1.91	4.59
KM	22,45	4.01	20.72	5.11	2.01	3.02	5.03
ГKM	65,40	4.64	18.07	2.03	3.92	2.44	6.36

Apparently, from the results of element and functional analyses presented in the table, broad variation of data demonstrates differences in structure the nerabotannykh of samples. The obtained data show what in the course of modification of composite materials occurs okislitelno – hydrolytic destruction and an otshchepleniye of side aliphatic structures.

It is revealed that on contents and phenolic hydroxyl groups depends such properties of composite materials as absorption capacity, ability to exchange and formation of complex connections, etc.

On the basis of the received results for further work the sample of KM-1a and GKM which is char-

acterized by the high content of carbon, carboxyl and phenolic hydroxyl groups is chosen.

In this regard, further works were carried out with use of sorbents of KM-1a and GKM of the specified form. It is established that increase in the size of sorbents from 0,8 to 1,5 cm promotes to increase of extent of water purification from oil, and further increase in the size of sorbent to 4,0 cm leads to some decrease in this indicator (figure 1).

For example, at concentration of oil in water – 250 mg/l, in 30 min. process when using a sorbent of KM – 1a the extent of water purification 0,8 cm in size from oil of the Zhylankabak field makes 76,30%, in the specified conditions at application.

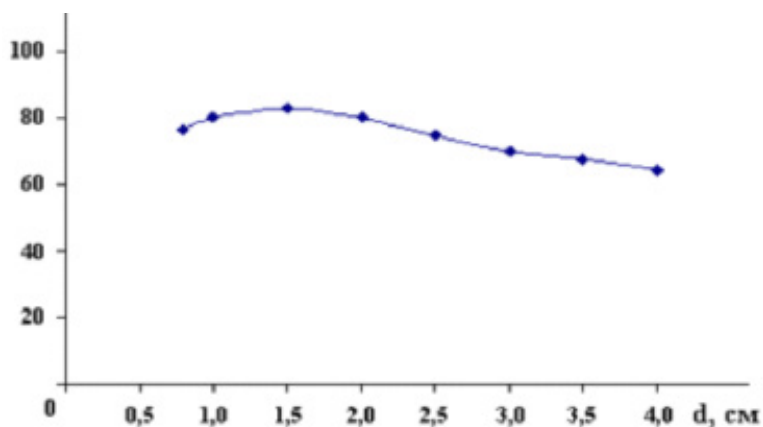


Figure 1. Change of extent of water purification from oil depending on the tablet size (C oil — 250 mg/l, m (KM-1a) — 0,5 weig. h., — 30 min.)

According to 1 cm – 80,21%, 1,5 cm – 82,63%, 2,0 cm – 80,00%, 2,5 cm – 74,70%; 3,0 cm – 69,60; 3,5 cm – 67,70% and 4,0 cm – 64,50%. Follows from the analysis of the obtained data that when using as sorbents of composite materials of tablets of 1,5 cm in size the maximum water purification from oil is observed.

From the figure 2 it is visible that temperature increase of process from 20 to 60°C leads to increase in extent of water purification from oil medicine KM – 1a. For example, at 20°C in 30 min. contact of the medicine KM-1a from 200 mg of oil extent of water purification makes 95,30%, and at temperature increase of

process to 600 C under the same conditions extent of water purification reaches 98,80%. The received results demonstrate what the main amounts of oil is occluded at a temperature of 20–30°C. Further increase in temperature of contact doesn't lead to the noticeable growth of efficiency of process of sorption.

It is established that with increase in duration of process of sorption from 5 to 60 min. extent of water purification raises from 66,10 to 95,70% (figure 2). Further increase in duration of process doesn't lead to the noticeable growth of efficiency of sorption, the basic of amount of oil is occluded within 30 min.

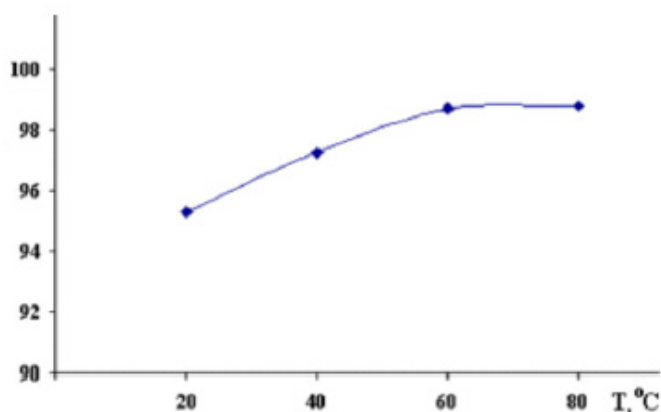


Figure 2. Dependence of extent of water purification on process temperature (C oil – 250 mg/l, m (KM – 1a) – 0,5 weig. h., – 30 min.)

Approbation of assembled laboratory installation is carried out, during tests water purification conditions from oil of the Zhylankabak field are defined. Process of sorption water purification was

carried out in two options: 1) with medicine KM use – 1a; 2) with medicine GKM use.

By the first option: on model installation influence of concentration of oil (100–300 mg/l),

temperatures (20–60°C), time (5–60 min.) and quantity of a sorbent is established (0,02–1,0 IAU. w) on process of sewage treatment of the Zhylankabak field (The Atyrau Region).

Has shown the analysis of infrared ranges (IK – ranges, the figure 3) that with increase in quantity of a sorbent of KM-1a the intensity of strips of absorption, Zhylankabak fields, characteristic of oil, increases.

For example, strips of absorption of valent fluctuations – CH_2 – and – CH_3 – group of ali-

phatic molecules in the field of 2920,2855 cm^{-1} , deformation fluctuations of CH – groups – are found at 1460–1455 cm^{-1} , deformation fluctuations OH – groups in the field of 1140,1100 cm^{-1} and valent fluctuations the galogenproizvodnykh of alkenes to areas 670 and 600 of cm^{-1} . X follows from the analysis of data that with increase in amount of the medicine KM-1a the content of the oil occluded on the surface of composite material increases.

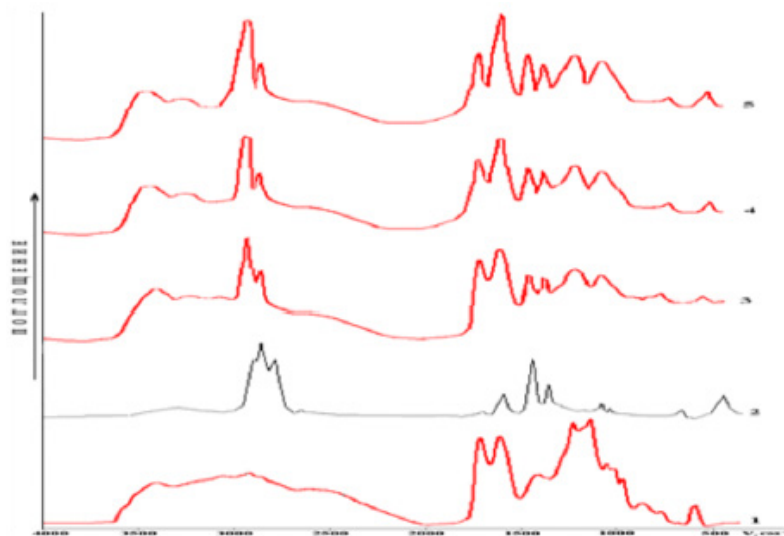


Figure 3. IK – ranges of the studied samples; – 1 medicine KM – 1a; 2 – oil; the samples received when using KM-1a in quantity, an weig. h.: 3–0,02; 4–0,1; 5–0,5

At the heart of green economy to – clean or “green” technologies. According to experts, development of “green” economy will allow to avoid to our country of ecological crisis which has affected by the scales already many post-industrial countries [5; 6].

Conclusion: proceeding from the analysis of impact of oil objects on the environment it is possible to note that one of the main reasons worsening the environment when developing oil fields

are insufficient observance of the solution of ecological tasks in technological processes in projects of development and arrangement of oil fields and low-quality implementation of design decisions because of neediness of modern technical means of the increased operational reliability, control devices and automation of technological processes and the system of environmental control, necessary for more rational use of fuel and energy of energy industry and all economy.

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TO A QUESTION OF RECYCLING OF ENRICHMENT OF TAILS OF TUNGSTEN ORES IN PRODUCTION OF CEMENT

Abstract: In work results of researches on studying of a possibility of use of waste of enrichment of tails of tungsten ores as additives are covered by production of additional cements. By the researches conducted in the accredited laboratory of the research and test center "Strom" together with LLC INGICHI METALS it is established that the additional cements containing 10–15% of waste of enrichment of tungsten ores on indicators of durability don't concede to a bezdobavchny portlandtsement of PTs 400 D20.

Keywords: tungsten waste, secondary raw materials, utilization, additive to clinker, additional cement, physicomechanical properties, trial tests.

Introduction. Intensive development of a construction complex of the republic dictates need of the solution of the interconnected problems on resource- and energy saving and also on decrease in prime cost of construction production. From the point of providing cement plants with raw materials, it is necessary to take into account the progressive growth of prices for natural mineral resources and additives to cement. The constant increase in prices for energy carriers raises the cost of the clinker component and additional cements as a whole, which actualizes the problem of replacing the expensive clinker component with fillers, the quality of which will allow obtaining cements with reduced cost without deterioration in their physical, mechanical and structural properties.

Onsequently, the complex processing of mineral technogenic raw materials in the production of highly

effective building materials, in particular, in the production of additional cements, is an actual problem. The methods of utilization are based on physical and chemical studies of the properties and structure of waste, which makes it possible to determine the principal possibility (or impossibility) of their use in a particular production. On the basis of this provision, the identification of reserves for expanding the use of accumulated industrial waste, it is necessary to analyze the chemical, physical and special (specific) properties of general scientific statistics, special (sectoral) statistics and laboratory analyzes conducted by laboratories of enterprises with the aim of summarizing the results and identifying possible errors in determining their properties [1–4].

Formulation of the problem. From our point of view, such a promising additive is the tungsten

ore enrichment tailings formed by the production of tungsten concentrate from scheelite ores. On the territory of our republic, tungsten deposits located in the territory of Navoi, Samarkand and Djizak regions are scheelite ores. The total reserves of waste recycling tailings in the waste storage facilities of JV LLC "INGICHI METALS" are more than 15 million tonnes. Involvement of these wastes is a significant factor in the intensification of resource use, since without increasing the extraction of primary raw materials, the potential and efficiency of using the mineral and raw materials complex is increased through the receipt of additional volumes and types of products, reducing the total costs of their production, reducing the rates of development of own raw materials base and capacities for its development [5].

Materials research methods, equipment and instruments

In carrying out the experimental studies, portland cement clinkers of JSC "Kizilkumcement" and JSC "Akhangarancement", gypsum stone, wastes of enrichment of tungsten ore tails from Inghichka deposit were used as initial materials. The investigations

were carried out using chemical, physical-chemical and physical-mechanical methods for analysis of raw materials and construction products in accordance with the requirements of relevant regulatory documents (GOST (State Standard) 5382–91, GOST 310.1–310.4, GOST 10178–85).

Results and its discussion. Products of secondary processing of tungsten ore tails are a loose, solid, fine-grained material of dark gray color with light inclusions of calcite and hydromica. The granulometric composition of the tungsten ore enrichment tailings is 98,75% represented by fractions less than 2,5 mm and does not require additional costs for crushing the material when using additional cement in the grinding process (Table 1).

The chemical composition of the waste is favorable for use in the production of additional cements due to low concentrations of harmful oxides (MgO; SO₃; alkalis), the content of which is regulated by regulatory documents for additives and filler additives. Mineralogical composition of wastes of enrichment of tungsten ores is represented by minerals, the list of which is given in (Table 2).

Table 1. – Granulometric composition of tailings enrichment tailings of tungsten ores

№	Name of sample	Private residues on sieves,%							
		10 mm	5 mm	2.5 mm	1.25 mm	0.63 mm	0.315 mm	0.16 mm	Bottom
1.	Waste from enrichment of tungsten	–	0.50	0.75	0.75	2.98	26.30	41.45	27.27

Chemical composition of tailings enrichment tailings of tungsten ores

№	Name of sample	Oxide content. %									
		loss on ignition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	Σ
1.	Waste from enrichment of tungsten	8.89	46.17	5.28	14.90	21.71	2.22	foot-prints	0.42	0.41	100.0

Table 2. – Mineralogical composition of tailings of enrichment of tungsten ores

№	Minerals	Diffraction reflections, nm
1	2	3
1.	Quartz	0,424; 0,334; 0,244; 0,227; 0,212; 0,197; 0,181; 0,166; 0,153 ...
2.	Calcite	0,385; 0,302; 0,254; 0,227; 0,208; 0,191; 0,181; 0,166; 0,153 ...

1	2	3
3.	Feldspars	0,421; 0,392; 0,375; 0,364; 0,347; 0,334; 0,322; 0,258; 0,323 ...
4.	Magnetite (FeFe_2O_4)	0,299; 0,232; 0,254; 0,245; 0,208 ...
5.	Pyrite (FeS_2)	0,318; 0,270; 0,244; 0,222; 0,191; 0,162; 0,150 ...
6.	Pyrrhotite FeS (magnetic pyrites)	0,299; 0,292; 0,270; 0,217; 0,214; 0,209; 0,191; 0,176 ...
7.	Hydromica	0,475; 0,451; 0,331; 0,258 ...
8.	Marcasite (FeS_2)	0,347; 0,270; 0,237; 0,234; 0,191; 0,176 ...
9.	Wollastonite	0,375; 0,352; 0,297; 0,249 ...

In accordance with the data in (Table 3), for compressive strength, additional cements with a waste content of enrichment of tungsten ores up to 15% of the mass correspond to cement grade M «400».

Table 3. – Physical and mechanical properties of additional cements using waste from the enrichment of tungsten ores

Notation cements	SO_3 , %	Fineness of cement grinding on the remainder on a sieve № 008, %	Normal density of cement paste, %	Setting time, h – min		Strength limit, $R_{\text{bending/com-pression}}$, MPa aged		
				Start	End	3d	7d	28 d
Cementless cement PC D0	2,15	10	24,3	2–15	3–30	$\frac{5,4}{20,1}$	$\frac{6,4}{28,0}$	$\frac{6,8}{40,2}$
Cementless cement PC D10	2,25	8	24,8	2–55	3–40	$\frac{5,4}{26,8}$	$\frac{6,6}{30,0}$	$\frac{7,6}{41,0}$
Cementless cement PC D15	2,50	9	25,4	2–45	3–35	$\frac{5,6}{27,0}$	$\frac{6,9}{36,0}$	$\frac{7,5}{41,8}$
Cementless cement PC D20	2,30	11	26,0	2–55	4–00	$\frac{4,3}{12,5}$	$\frac{4,8}{24,0}$	$\frac{5,9}{36,7}$

The efficiency of waste utilization of tungsten ore enrichment in the production of additional cements is significantly enhanced due to the territorial proximity of tailings to such large cement producers as JSC “Kizilkumcement” and Jizzakh cement plant. Consumers of this waste can become cement plants in Djizak, Surkhandarya, Bukhara and Samarkand regions.

Conclusion. The expediency of using wastes of enrichment of tungsten ores as a mineral additive for the production of general extrusion cements with the savings of an expensive clinker part, a reduction in the cost price and an increase in the output of the products is experimentally substantiated. The possibility of introducing it up to 15% as an additive-filler in the grinding of clinker for the production of general Portland cements without reducing their brand strength has been established. The investigat-

ed additive, according to GOST (State Standard) 24640–91 “Additives for cements. Classification”, by the nature of the main effect on the properties of cement, can be attributed to the components of the cement’s material composition, which contribute to the savings of the clinker component of cements. Due to the high dispersity, the use of the additive for the enrichment of tungsten ores contributes to the elimination of energy costs for the crushing of additives and the reduction of costs for clinker milling. In this case, the products are relatively low cost, while maintaining quality indicators that meet the requirements of GOST (State Standard) 101787–85 “Portland cement and slag Portland cement. Technical conditions”. Such an approach to the issue of secondary tailings enrichment utilization for tungsten ore tailings contributes to a reduction in costs

for the construction and maintenance of waste storage facilities, improves the ecological situation in the Ingichka mine management area, replaces natu-

ral filler additives, the extraction of which is related to the cost of quarrying and damage to fertile soils suitable to use in agriculture.

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INVESTIGATION OF THE PREPARATION METHOD OF GRAIN FOR MILLING IN THE FORMATION OF BAKING PROPERTIES OF FLOUR

Abstract: In this paper, the peeling of wheat grain, with the aim of improving the quality of flour have been studied. The proposed peeling equipment is distinguished by the main working units, which are used in the preparatory department of the mill, creates the prerequisites for obtaining high-quality products. The effectiveness of the proposed method of grain peeling in the shelling device developed by us has been proved, which will allow us to obtain bakery flour of consistently high quality and, as a result, products with high consumer values.

Keywords: wheat, peeling, ash content, flour, efficiency, bread.

Theoretical research and practice of bakery production show that the quality of bread and bakery products primarily depends on the indicators characterizing the baking properties of flour. The definition of these indicators allows us to predict the quality of finished products, predetermines the choice of the main parameters of the technological process and creates the prerequisites for obtaining high-quality products [1].

Analysis of general trends and directions in the solution of the problem of obtaining flour with consistently high baking properties showed the dependence of their values on the method of preliminary preparation of grain for milling. In order to study this dependence, some experiments were carried out using wheat grains of the varieties "Andijan 2R1", "Andijan 4R1" and "Polovchanka", from the Kashkadarya province of the Republic of Uzbekistan. A grinding mixture was prepared from the grain of these wheat varieties, which was divided into two parts. The grain of the first part of the grinding mixture was pretreated with the technology of peeling and hydrothermal processing currently in use at the milling enterprises. The grain of the second part of the grinding mixture was subjected to a three-stage process of grain peeling in

the peeling device (Fig. 1), developed jointly with the Applied Physics Laboratory of the Research Institute of Electronics of the Academy of Sciences of the Republic of Uzbekistan, with appropriate adjustment of the main technological parameters of hydrothermal processing [2].

The flow of the grain mass from the receiving pipeline is fed into the space between the brush drum and the outer mesh cylinder. Then the grain enters to the annular space between the saw cylinder and the mesh shell, where an additional tearing and sheath removal occurs from the grain surface. In the next stage, the mixture enters to the annular space between the cylinder and abrasive surface and a mesh shell, where the fruit shells are further removed and the grain surface is ground.

The milling of control and experimental lots of grain was carried out on a laboratory mill "BRANDAMER" (Germany).

The baking properties of flour were evaluated based on the results of a study of the protein-proteinase and carbohydrate-amylase complexes, trial laboratory baking, which characterizes the properties of the dough and the quality of the bread.

The comparison sample was flour from the grain of the grinding mixture subjected to peeling

and hydrothermal treatment according to the operating scheme, an experimental sample of flour

from grain, processed according to the proposed technology.

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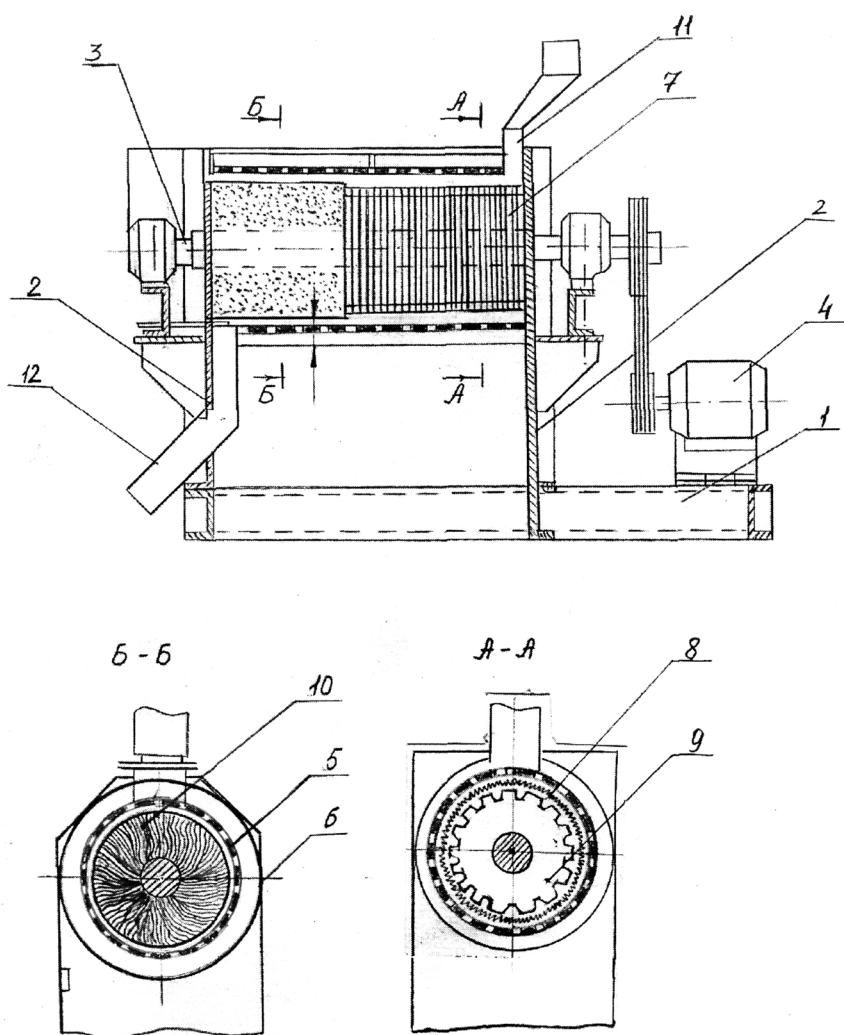


Figure 1. Equipment for peeling grain: 1 – frame; 2 – sidewalls; 3 – shaft; 4 – electric motor; 5 – perforated cylindrical body; 6 – cover; 7 – working drum; 8 – saws; 9 – disks with grooves; 10 – disks with brush; 11 – receiving pipeline; 12 – discharge tray

Comparative analysis of the experimental data showed that the preparation of the grain to grind according to the proposed method would allow to increase the yield of high-grade flour to 1.0%, reduce its ash content by 0.02–0.03%, increase the dispersion and homogeneity of the particles relative to the reference sample. Thus, the surface area of the particles of the experimental flour an average of 1.5–2.0 m² (1.3–1.7%) exceeded the control values, which to a

certain extent influenced the intensity of biochemical and colloid processes of the dough, and as a consequence, on the quality and the yield of bread.

It was established that the fractions of relatively smaller particles of flour are richer in protein, which is confirmed by the experimental data. Thus, in the experimental samples of flour, the mass fraction of the total protein exceeded the control value by an average of 1.3% (Table 1).

Table 1. Characteristics of protein-proteinase complex of the flour

Samples of flours	Mass fraction of proteins, %		Mass fraction of glutes, %		Ratio of gluten to protein	Gluten strain meter, units	Bonitet number, point	Quality group
	Total	Water-soluble	Moist.	Dry				
Control	10.6	1.53	30.2	11.0	2.85	84	45.7	II
Experiment	11.9	1.84	31.4	11.6	2.64	80	50.3	II

The ratio of water-soluble protein in percentage to total protein was 14.4 in the control, and 15.5% in the experiment. That is, the experimental flour was characterized by an increased content of water-soluble protein.

In experimental flour, as more finely dispersed, the yield of wet and dry gluten exceeded similar control values, respectively, by 1.2 and 0.6%. In the experimental variant, the coefficient characterizing the ratio of gluten to protein was 0.21 units lower than in the control.

It should be noted that, in the flour of the prototype there was also a strengthening of gluten, as evidenced by the values of its elasticity and bonitet number. According to the extensibility and elasticity of gluten, the flour of the test samples corresponded to the quality of Group II.

It was experimentally established that the increase in experimental flour samples relative to the

control of the sugar-forming ability on average by 1.6 mg maltose/g of flour (7.2%), the amount of carbon dioxide liberated by 170 cm³ of CO₂ (12.6%), the water-absorbing capacity of the dough by 6 cm³/100 g of flour (9.7%).

The increase in the sugar and gas-forming ability of flour is obviously due to an increase in the degree of attack of starch, since the activity of amylolytic enzymes of flour remained practically unchanged.

However, the main criterion for assessing the baking properties of flour is the quality of the bread of the laboratory baking test. Therefore, we conducted a series of laboratory bread baking from experimental and control flour samples in accordance with the requirements of GOST 27669–88 “Wheat flour baking. Method of trial laboratory bread baking”.

The values of the main indices determining the rheological properties of the dough and the processes of its maturation are determined (Table 2).

Table 2. – Indicators of the dough quality

Indicators	Option	
	control	experiment
Acidity, degree	3.5	4.0
pH	5.26	5.18
Lifting force, min	14	12
Gas-forming ability, sm ³ CO ₂ /100 g	1460	1520
The spreadability of the dough ball at the end of fermentation (H: D ratio)	0.40	0.48

It has been established that the acid-accumulation processes are more intensive in semifinished products from experimental flour samples, as evidenced by the values of titrated and active acidity. Thus, for an equal duration of dough maturation, the values of the final titrated and active acidity in the experimental variant exceeded the control values by 0.50 (14.3%) and 0.08 degree (1.5%), respectively.

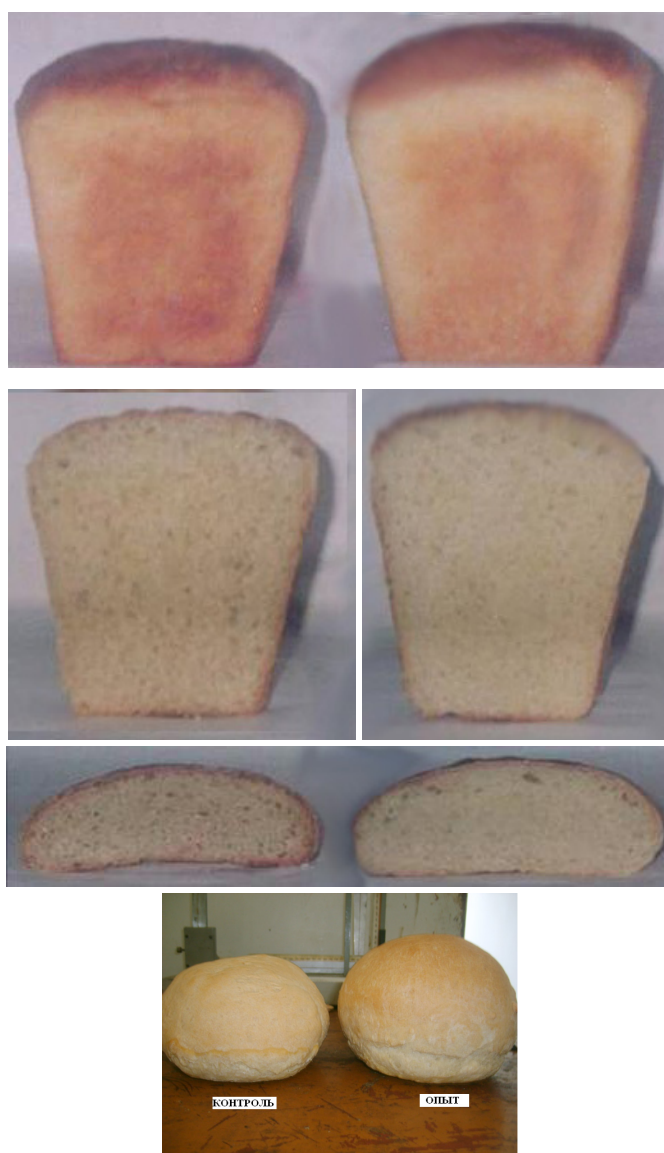
Improving the sugar-forming ability of flour promoted the activation of yeast, as a result, the lift strength of the dough improved by 2 minutes.

The value of spreadability of the test ball at the end of fermentation in the relation of H: D increased from 0.40 to 0.48. The prototype dough was lighter and more elastic.

The bread quality indicators of the laboratory baking are given in (Table 3) and Fig 2.

Table 3. – Results of the analysis of the laboratory baking bread quality

Indicators of the bread quality	Bread from flour	
	reference sample	experiment sample
Humidity,%	44.0	44.2
Acidity, degree	3.5	3.6
Specific volume of bread, $\text{sm}^3/100 \text{ g}$	306	320
Porosity,%	75	77
Form-stability of bread (H: D)	0.42	0.47
Organoleptic level, point	77.6	80.4



1

2

Figure 2. Type of bread from wheat flour, processed by the conventional (1) and proposed technology (2)

Due to the intensification of the processes of sugar and gas formation in the dough from experimental flour and improvement of its structural and mechanical properties, the specific volume of bread increased by 14 cm^3 (2.6%) compared to the control option, the structure of porosity of crumb improved by 2%. The H: D value of the bread increased from 0.42 to 0.47 (11.9%), providing products more characteristic form.

The quality of bread on the basis of organoleptically and objectively determined indicators was estimated at 80.4 points, which is 2.8 points (3.6%) higher than the same value in the control option.

It was established that the flour from the grain of the investigated wheat varieties, subjected to a three-stage peeling process in the proposed peeling device, has good baking properties. Bread, cooked from it, both in individual indicators, and in their totality, meets the requirements for good quality products.

Thus, according to the results of trial bread baking, the effectiveness of the proposed method of grain peeling in the shelling device developed by us has been proved, which will allow us to obtain bakery flour of consistently high quality and, as a result, products with high consumer values.

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PREREQUISITES FOR OPTIMAL DISTRIBUTION OF WATER IN IRRIGATION CANAL SYSTEMS

Abstract: The article presents the prerequisites for optimization water distribution in irrigation canal systems through a mathematical model for unsteady flow in canal sections of the full equations of Saint-Venant. The method of consecutive approach for optimal distribution of water, based on the explicit derivatives of the variation of the optimality criterion from variation control is offered.

Keywords: water, irrigation canal systems, mathematical model, optimality criterion.

1. Relevance

Canals of irrigation systems in the Republic of Uzbekistan are designed to supply water to various consumers. In this context, it is necessary to distribute the water through canals to each consumer in required quantities and in due time, while keeping minimum losses. This can be done with the optimal distribution of water to consumers.

To this end, it is necessary to create the prerequisite conditions for optimal distribution water along the canals of irrigation systems and develop an algorithm for optimal control of water distribution, which minimizes the difference between the actual and design level and discharges of water at structures of the canal sections. By studying them, we will ensure an optimal distribution of water in irrigation canals with minimum losses.

2. Introduction

We while consider an irrigation canal, consisting of two sections connected by a hydraulic engineering structure (Figure 1).

As a mathematical model of sections of the irrigation canal, we take the well-known full differential equations of Saint-Venant [1; 2; 3] that can be written in the following form

$$\frac{\partial z_i}{\partial t} = f_i^1 \left(z_i, \frac{\partial z_i}{\partial x_i}, q_i \right), \quad (1)$$

$$\frac{\partial Q_i}{\partial t} = f_i^2 \left(z_i, Q_i, \frac{\partial z_i}{\partial x_i}, \frac{\partial Q_i}{\partial x_i} \right) \quad i = 1, 2; \quad 0 < x_1 < l_1; l_1$$

$$< x_2 < l_2; \quad 0 < t < T.$$

here

$$f_i^1 \left(z_i, \frac{\partial z_i}{\partial x_i}, q_i \right) = -\frac{1}{B_i} \left(\frac{\partial Q_i}{\partial x_i} - q_i \right),$$

$$f_i^2 \left(z_i, Q_i, \frac{\partial z_i}{\partial x_i}, \frac{\partial Q_i}{\partial x_i} \right) = \frac{g \omega_i i_{i0} Q_i^2}{(\omega_i c_i)^2} - \frac{g \omega_i Q_i |Q_i|}{K^2} - \frac{2Q_i}{\omega_i} \frac{\partial Q_i}{\partial x_i} - g \omega_i \left[1 - \frac{Q_i^2}{(\omega_i c_i)^2} \right] \frac{\partial z_i}{\partial x_i}$$

Where $Q_i = Q_i(x_p, t)$, and $z_i = z_i(x_p, t)$, are the flow rate and the ordinate of the free flow surface of the i – canal section; respectively $B_i = B_i(z_i)$ is the

width of flow on the top; $\Omega_i = \omega_i(z_i)$ is the cross-sectional wet area $\omega_i = \omega_i(z_i)$; $c_i = c_i(z_i)$ is the small wave propagation velocity; $K_i = K_i(z_i)$ is the flow modulus. The last four parameters are determined by morphometric and hydraulic characteristics of the canal section. The path inflow (outflow) $q_i = q_i(x_p, t)$ calculated per unit length of the i -section of the canal is the distributed disturbance.

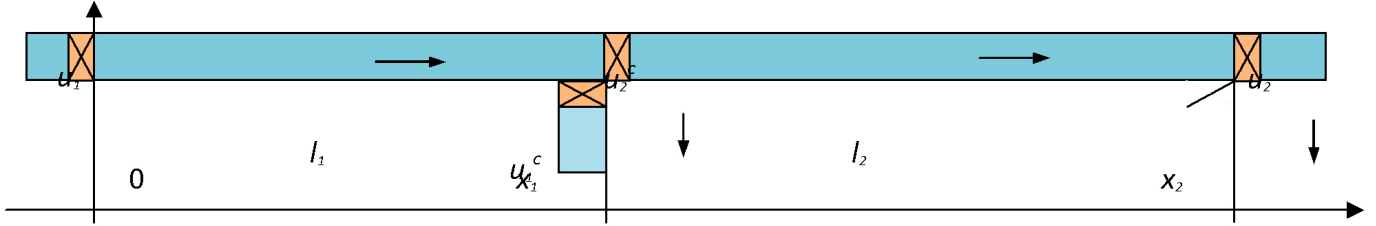


Figure 1. Scheme of irrigation canal

The initial conditions are

$$Q_i(x_i, 0) = Q_{i0}(x_i), \quad z_i(x_i, 0) = z_{i0}(x_i), \quad (2)$$

The boundary conditions at $x_1 = 0$ and $x_2 = l_2$ are written as follows

$$Q_1(0, t) = g_1(z_1(0, t), u_1(t)), \quad (3)$$

$$Q_2(l_2, t) = g_2(z_2(l_2, t), u_2(t), u_3(t)), \quad (4)$$

where, $g_1 = \mu_1 b_1 u_1(t) \sqrt{2g(z_1^h - z_1(0, t))}$,

$$g_2 = \mu_2 b_2 u_2(t) \sqrt{2g(z_2(l_2, t) - \varepsilon_2 u_2(t))},$$

Where $u_i = u_i(t)$ $i = 1, 2$ are the control functions applied at boundary points (the height of the gates open); b_i $i = 1, 2$ is width of the gate openings; z_1^h is the ordinate of free flow surface in the upstream tail of the first gate.

The conjugation conditions at point $x_1 = x_2 = l_1$ can be written as follows:

$$Q_1(l_1, t) = g_1^c(z_1(l_1, t), z_2(l_1, t), u_1^c(t), u_2^c(t)), \quad (5)$$

$$Q_2(l_1, t) = g_2^c(z_1(l_1, t), z_2(l_1, t), u_2^c(t)), \quad (6)$$

where, $g_1^c = \mu_1^c b_1^c u_1^c(t) \sqrt{2g(z_1(l_1, t) - \varepsilon_1^c u_1^c(t))} + g_2^c$,

$$g_2^c = \mu_2^c b_2^c u_2^c(t) \sqrt{2g(z_1(l_1, t) - z_2(l_1, t))},$$

Where, $u_i^c = u_i^c(t)$ $i = 1, 2$ are the control functions applied at the junction point of canal sections (height of gate open), b_i^c $i = 1, 2$ is the width of gate opening.

3. Methods and results

For an irrigation canal, a water distribution plan is set for a given period of time $[0, T]$. In the case under consideration, the planned water discharge $Q_i^*(t_i)$ is specified for the hydraulic structures of lateral and end off takes.

The problem of optimal distribution of water in the irrigation canal is formulated as follows: it is to define such controls in the time interval $[0, T]$,

$$u_{1*} \leq u_1(t) \leq u_{1*}^*, \quad u_{2*} \leq u_2(t) \leq u_{2*}^*,$$

$$u_{1*}^c \leq u_1^c(t) \leq u_{1*}^{c*}, \quad u_{2*}^c \leq u_2^c(t) \leq u_{2*}^{c*},$$

That minimize the linear combination of integral deviations of the actual water discharge through the lateral and end off takes.

The optimality criterion is written as follows (7)

$$I = k_1 \int_0^T G_c^1 [z_1(l_1, t), u_1^c(t)] dt + k_2 \int_0^T G_c^2 [z_2(l_2, t), u_2^c(t)] dt,$$

where,

$$G^1 = \left\{ \mu_1^c b_1^c u_1^c(t) \sqrt{2g(z_1(l_1, t) - \varepsilon_1^c u_1^c(t))} - Q_1^*(t) \right\}^2,$$

$$G^2 = \left\{ \mu_2^c b_2^c u_2^c(t) \sqrt{2g(z_2(l_2, t) - \varepsilon_2 u_2(t))} - Q_2^*(t) \right\}^2.$$

Let a set of programmed controls supposed to be optimal be known $u_{10}(t)$, $u_{20}(t)$, $u_{10}^c(t)$, $u_{20}^c(t)$. Then we can analyze the effect on the optimality of these

programmed controls by using relevant variations $\delta u_1(t)$, $\delta u_2(t)$, $\delta u_1^c(t)$, $\delta u_2^c(t)$.

By expanding (1) in a Taylor power series in the neighborhood of the optimal trajectory and dropping the terms of the expansion above the first order of infinitesimal, we derive an equation in variations:

$$\frac{\partial \delta z_i}{\partial t} = \left(\frac{\partial f_i}{\partial z_i} \right)_0 \delta z_i + \left(\frac{\partial f_i}{\partial Q_i'} \right)_0 \frac{\partial \delta Q_i}{\partial x_i} + \left(\frac{\partial f_i}{\partial q_i'} \right)_0 \delta q_i, \quad (8)$$

$$\frac{\partial \delta Q_i}{\partial t} = \left(\frac{\partial f_i^2}{\partial z_i} \right)_0 \delta z_i + \left(\frac{\partial f_i^2}{\partial Q_i'} \right)_0 \delta Q_i + \left(\frac{\partial f_i^2}{\partial z_i'} \right)_0 \frac{\partial \delta z_i}{\partial x_i} + \left(\frac{\partial f_i^2}{\partial Q_i'} \right)_0 \frac{\partial \delta Q_i}{\partial x_i}, \quad (9)$$

Where $(Q)_0$ means that the corresponding value is calculated along the optimal trajectory, $Q_i' = \partial Q_i / \partial x_i$

$$\frac{\partial f_i^1}{\partial z_i} = \frac{B_i'}{B_i^2} \cdot \frac{\partial Q_i}{\partial x_i}, \quad \frac{\partial f_i^1}{\partial Q_i'} = -\frac{1}{B_i}, \quad \frac{\partial f_i^1}{\partial q_i'} = \frac{1}{B_i},$$

$$\frac{\partial f_i^2}{\partial z_i} = -\frac{g_{i0} Q_i^2 (2\varpi_i c_i' + \varpi_i' c_i')}{\varpi_i^2 c_i^3} - \frac{g_{i0} |Q_i| (2\varpi_i K_i - \varpi_i' K_i)}{K_i^3} + \frac{2g\varpi_i' Q_i'}{\varpi_i^2} - g \left[\varpi_i' \left(1 - \frac{Q_i^2}{\varpi_i^2 c_i^2} \right) + \frac{2Q_i^2 (\varpi_i c_i' + \varpi_i' c_i')}{\varpi_i^2 c_i^3} \right] z_i', \quad (10)$$

$$\frac{\partial f_i^2}{\partial Q_i} = \frac{2g_{i0} Q_i}{\varpi_i^2 c_i^2} - \frac{2g\varpi_i |Q_i|}{K_i^2} - \frac{2}{\varpi_i} Q_i' + \frac{2gQ_i}{\varpi_i c_i^2} z_i,$$

$$\frac{\partial f_i^2}{\partial z_i'} = g\varpi_i \left(1 - \frac{Q_i^2}{\varpi_i^2 c_i^2} \right), \quad \frac{\partial f_i^2}{\partial Q_i'} = \frac{2Q_i}{\varpi_i},$$

$$Q_i' = \frac{\partial Q_i}{\partial x_i}, \quad z_i' = \frac{\partial z_i}{\partial x_i}, \quad B_i' = \frac{\partial B_i}{\partial z_i},$$

here

$$c_i' = \frac{\partial c_i}{\partial z_i}, \quad K_i' = \frac{\partial K_i}{\partial z_i}.$$

In a completely analogous manner for the variation of the optimality criterion (7), we obtain (11)

$$\delta I = \int_0^T \left\{ \left(\frac{\partial G_c}{\partial z_1(l_1, t)} \right)_0 \delta z_1(l_1, t) + \left(\frac{\partial G_c^1}{\partial u_1^c(t)} \right)_0 \delta u_1^c(t) \right\} - \int_0^T \left\{ \left(\frac{\partial G_2^2}{\partial z_2(l_2, t)} \right)_0 \delta z_2(l_2, t) + \left(\frac{\partial G_2^2}{\partial u_2(t)} \right)_0 \delta u_2(t) \right\} dt$$

Let introduce the conjugate variables or Lagrange multipliers by through the expressions

$$\int_0^T \int_0^{l_1} \left[\frac{\partial \delta z_1}{\partial t} - \left(\frac{\partial f_1^1}{\partial z_1} \right)_0 \delta z_1 - \left(\frac{\partial f_1^1}{\partial Q_1'} \right)_0 \frac{\partial \delta Q_1}{\partial x_1} - \left(\frac{\partial f_1^1}{\partial q_1'} \right)_0 \delta q_1 \right] \lambda_1^1 dx_1 dt = 0, \quad (12)$$

$$\int_0^T \int_0^{l_1} \left[\frac{\partial \delta Q_1}{\partial t} - \left(\frac{\partial f_1^2}{\partial z_1} \right)_0 \delta z_1 - \left(\frac{\partial f_1^2}{\partial Q_1'} \right)_0 \delta Q_1 - \left(\frac{\partial f_1^2}{\partial q_1'} \right)_0 \frac{\partial \delta z_1}{\partial x_1} - \left(\frac{\partial f_1^2}{\partial Q_1'} \right)_0 \frac{\partial \delta Q_1}{\partial x_1} \right] \lambda_1^2 dx_1 dt = 0, \quad (13)$$

$$\int_0^T \int_0^{l_2} \left[\frac{\partial \delta z_2}{\partial t} - \left(\frac{\partial f_2^1}{\partial z_2} \right)_0 \delta z_2 - \left(\frac{\partial f_2^1}{\partial Q_2'} \right)_0 \frac{\partial \delta Q_2}{\partial x_2} - \left(\frac{\partial f_2^1}{\partial q_2} \right)_0 \delta q_2 \right] \lambda_2^1 dx_2 dt = 0, \quad (14)$$

$$\int_0^T \int_0^{l_2} \left[\frac{\partial \delta Q_2}{\partial t} - \left(\frac{\partial f_2^2}{\partial z_2} \right)_0 \delta z_2 - \left(\frac{\partial f_2^2}{\partial Q_2'} \right)_0 \delta Q_2 - \left(\frac{\partial f_2^2}{\partial z_2'} \right)_0 \frac{\partial \delta z_2}{\partial x_2} - \left(\frac{\partial f_2^2}{\partial Q_2'} \right)_0 \frac{\partial \delta Q_2}{\partial x_2} \right] \lambda_2^2 dx_2 dt = 0, \quad (15)$$

Subtracting (12) – (15) from (11) results in for the variation of the functional a new form

$$\delta I = \int_0^T \left\{ \left(\frac{\partial G_c}{\partial z_1(l_1, t)} \right)_0 \delta z_1(l_1, t) + \left(\frac{\partial G_c^1}{\partial u_1^c(t)} \right)_0 \delta u_1^c(t) \right\} dt - \int_0^T \left\{ \left(\frac{\partial G_2^2}{\partial z_2(l_2, t)} \right)_0 \delta z_2(l_2, t) + \left(\frac{\partial G_2^2}{\partial u_2(t)} \right)_0 \delta u_2(t) \right\} dt +$$

$$\begin{aligned}
 & + \int_0^T \int_0^{l_1} \left[\left(\frac{\partial H_1}{\partial z_1} \right)_0 \delta z_1 + \left(\frac{\partial H_1}{\partial Q_1} \right)_0 \delta Q_1 + \left(\frac{\partial H_1}{\partial z_1} \right)_0 \frac{\partial \delta z_1}{\partial x'_1} + \left(\frac{\partial H_1}{\partial Q_1} \right)_0 \frac{\partial \delta Q_1}{\partial x_1} - \lambda_1^1 \frac{\partial \delta z_1}{\partial t} - \lambda_1^2 \frac{\partial \delta Q_1}{\partial t} \right] dx_1 dt + \\
 & + \int_0^T \int_{l_1}^{l_2} \left[\left(\frac{\partial H_2}{\partial z_2} \right)_0 \delta z_2 + \left(\frac{\partial H_2}{\partial Q_2} \right)_0 \delta Q_2 + \left(\frac{\partial H_2}{\partial z_2} \right)_0 \frac{\partial \delta z_2}{\partial x_2} + \right. \\
 & \left. + \left(\frac{\partial H_2}{\partial Q_2} \right)_0 \frac{\partial \delta Q_2}{\partial x'_2} - \lambda_2^1 \frac{\partial \delta z_2}{\partial t} - \lambda_2^2 \frac{\partial \delta Q_2}{\partial t} \right] dx_2 dt,
 \end{aligned} \tag{16}$$

where H_1 and H_2 are Hamiltonians defined as follows

$$H_i = \lambda_i^1 f_i^1 + \lambda_i^2 f_i^2, \quad i=1,2 \tag{17}$$

When differentiating the Hamiltonian H_i , it is necessary to take into account that f_i^1 does not depend on Q_i and z_i and f_i^2 does not depend on q_i , as follows from the basic equation.

We integrate by parts the following expressions

$$\int_0^T \int_0^{l_1} \left[\left(\frac{\partial H_1}{\partial z_1} \right)_0 \frac{\partial \delta z_1}{\partial x'_1} \right] dx_1 dt = \int_0^T \left\{ \left(\frac{\partial H_1}{\partial z_1} \right)_0 \delta z_1 \Big|_0^{l_1} - \int_0^{l_1} \frac{\partial}{\partial x_1} \left(\frac{\partial H_1}{\partial z_1} \right)_0 \delta z_1 dx_1 \right\} dt \tag{18}$$

$$\int_0^T \int_{l_1}^{l_2} \left[\left(\frac{\partial H_1}{\partial Q_1} \right)_0 \frac{\partial \delta Q_1}{\partial x_1} \right] dx_1 dt = \int_0^T \left\{ \left[\left(\frac{\partial H_1}{\partial Q_1} \right)_0 \delta Q_1 \right]_{l_1}^{l_2} - \int_{l_1}^{l_2} \frac{\partial}{\partial x_1} \left(\frac{\partial H_1}{\partial Q_1} \right)_0 \delta Q_1 dx_1 \right\} dt, \tag{19}$$

$$\int_0^T \int_{l_1}^{l_2} \left[\left(\frac{\partial H_2}{\partial z'_2} \right)_0 \frac{\partial \delta z_2}{\partial x'_2} \right] dx_2 dt = \int_0^T \left\{ \left[\left(\frac{\partial H_2}{\partial z'_2} \right)_0 \delta z_2 \right]_{l_1}^{l_2} - \int_{l_1}^{l_2} \frac{\partial}{\partial x_2} \left(\frac{\partial H_2}{\partial z'_2} \right)_0 \delta z_2 dx_2 \right\} dt, \tag{20}$$

$$\int_0^T \int_{l_1}^{l_2} \left[\left(\frac{\partial H_2}{\partial Q'_2} \right)_0 \frac{\partial \delta Q_2}{\partial x'_2} \right] dx_2 dt = \int_0^T \left\{ \left[\left(\frac{\partial H_2}{\partial Q'_2} \right)_0 \delta Q_2 \right]_{l_1}^{l_2} - \int_{l_1}^{l_2} \frac{\partial}{\partial x_2} \left(\frac{\partial H_2}{\partial Q'_2} \right)_0 \delta Q_2 dx_2 \right\} dt, \tag{21}$$

$$\int_0^T \int_0^{l_1} \left[\lambda_1^1 \frac{\partial \delta z_1}{\partial x'_1} \right] dx_1 dt = \int_{l_1}^{l_2} \left\{ \left[\lambda_1^1 \delta z_1 \right]_0^T - \int_0^T \left[\frac{\partial \lambda_1^1}{\partial t} \delta z_1 \right] dt \right\} dx_1, \tag{22}$$

$$\int_0^T \int_0^{l_1} \left[\lambda_1^1 \frac{\partial \delta Q_1}{\partial x'_1} \right] dx_1 dt = \int_{l_1}^{l_2} \left\{ \left[\lambda_1^1 \delta Q_1 \right]_0^T - \int_0^T \left[\frac{\partial \lambda_1^1}{\partial t} \delta Q_1 \right] dt \right\} dx_1, \tag{23}$$

$$\int_0^T \int_{l_1}^{l_2} \left[\lambda_2^1 \frac{\partial \delta z_2}{\partial x'_2} \right] dx_2 dt = \int_{l_1}^{l_2} \left\{ \left[\lambda_2^1 \delta z_2 \right]_0^T - \int_0^T \left[\frac{\partial \lambda_2^1}{\partial t} \delta z_2 \right] dt \right\} dx_2, \tag{24}$$

$$\int_0^T \int_{l_1}^{l_2} \left[\lambda_2^1 \frac{\partial \delta Q_2}{\partial x'_2} \right] dx_2 dt = \int_{l_1}^{l_2} \left\{ \left[\lambda_2^1 \delta Q_2 \right]_0^T - \int_0^T \left[\frac{\partial \lambda_2^1}{\partial t} \delta Q_2 \right] dt \right\} dx_2, \tag{25}$$

Substituting (18) – (25) in (16), gives

$$\delta I = \int_0^T \int_0^{l_1} \left\{ \left[\left(\frac{\partial H_1}{\partial z_1} \right)_0 - \frac{\partial}{\partial x_1} \left(\frac{\partial H_1}{\partial z_1} \right)_0 + \frac{\partial \lambda_1^1}{\partial x'_1} \right] \delta z_1 + \left[\left(\frac{\partial H_1}{\partial Q_1} \right)_0 - \frac{\partial}{\partial x_1} \left(\frac{\partial H_1}{\partial Q_1} \right)_0 + \frac{\partial \lambda_1^2}{\partial x'_1} \right] \delta Q_1 + \left(\frac{\partial H_1}{\partial q_1} \right)_0 \delta q_1 \right\} dx_1 dt +$$

$$\begin{aligned}
 & + \int_0^T \int_{l_1}^{l_2} \left\{ \left[\left(\frac{\partial H_2}{\partial Q_2} \right)_0 - \frac{\partial}{\partial x_2'} \left(\frac{\partial H_2}{\partial z_2'} \right)_0 + \frac{\partial \lambda_2^1}{\partial x_2'} \right] \delta z_2 + \left[\left(\frac{\partial H_2}{\partial Q_2} \right)_0 - \frac{\partial}{\partial x_2} \left(\frac{\partial H_2}{\partial Q_2} \right)_0 + \frac{\partial \lambda_2^2}{\partial x_2'} \right] \delta Q_2 \left(\frac{\partial H_2}{\partial q_2} \right)_0 \delta q_2 \right\} dx_2 dt + \quad (26) \\
 & + \int_0^T \left\{ \left[\left(\frac{\partial G_c}{\partial z_1(l_1, t)} \right)_0 + \left(\frac{\partial H_1}{\partial z_1'} \right)_0(l_1, t) \right] \delta z_1(l_1, t) + \left[\left(\frac{\partial G_2^c}{\partial z_2(l_2, t)} \right)_0 + \left(\frac{\partial H_2}{\partial z_2'} \right)_0(l_2, t) \right] \delta z_2(l_2, t) + \right. \\
 & \quad + \left(\frac{\partial G_2^2}{\partial u_2} \right)_0 \delta u_2(t) + \left(\frac{\partial G_c}{\partial u_c} \right)_0 \delta u_c(t) + \left(\frac{\partial H_2}{\partial Q_2'}(l_2, t) \right)_0 \delta Q_2(l_2, t) + \\
 & \quad \left. + \int_0^T \left\{ \left[\left(\frac{\partial H_2}{\partial Q_2} \right)_0 - \frac{\partial}{\partial x_2} \left(\frac{\partial H_2}{\partial Q_2} \right)_0 \right]_{x_2=l_2} \delta Q_2(l_2, t) \right\} dt + \right. \\
 & \quad \left(\frac{\partial H_1}{\partial Q_1'}(l_1, t) \right)_0 \delta Q_1(l_1, t) - \left(\frac{\partial H_1}{\partial Q_1}(0, t) \right)_0 \delta Q_1(0, t) - \left(\frac{\partial H_1}{\partial Q_1}(0, t) \right)_0 \delta z_1(l_1, t) - \\
 & \quad - \left(\frac{\partial H_2}{\partial Q_2'}(l_1, t) \right)_0 \delta Q_2(l_1, t) - \left(\frac{\partial H_2}{\partial z_2'}(l_1, t) \right)_0 \delta z_2(l_1, t) \left. \right\} dt - \\
 & \quad \int_0^{l_1} [\lambda_1^1(x_1, T) \delta z_1(x_1, T) + \lambda_1^2(x_1, T) \delta Q_1(x_1, T)] dx_1 + \\
 & \quad + \int_0^{l_2} [\lambda_2^1(x_2, T) \delta z_2(x_2, T) + \lambda_2^2(x_2, T) \delta Q_2(x_2, T)] dx_2
 \end{aligned}$$

Now in (26) the effect of variations δu_1 , δu_2 , δQ_1 , δQ_2 on the variation δI is expressed explicitly. Since it was assumed that these variations were arbitrary, the remaining prerequisite conditions for optimal control u_1 and u_2 and their derivatives Q_1, Q_2 with respect to are derived by reducing the coefficients of these variations to zero [4; 5].

It is clear from the expression (26) that the explicit dependence of the variation of the functional on $\delta z_1(x_1, t)$, $\delta z_2(x_2, t)$, $\delta Q_1(x_1, t)$, $\delta Q_2(x_2, t)$ is no more valid if $\lambda_i^j(x_i, t)$ meets the condition

$$\begin{aligned}
 \frac{\partial \lambda_i^1}{\partial x_i} &= \left(\frac{\partial H_i}{\partial z_i} \right)_0 - \frac{\partial}{\partial x_i} \left(\frac{\partial H_i}{\partial z_i} \right)_0, \\
 \frac{\partial \lambda_i^2}{\partial x_i} &= \left(\frac{\partial H_i}{\partial z_i} \right)_0 - \frac{\partial}{\partial x_i} \left(\frac{\partial H_i}{\partial z_i} \right)_0, \quad i=1,2 \quad (27)
 \end{aligned}$$

Since here with the expressions in the square brackets of the double integrals equal zero. Now, if at the end of the process the conjugate variables meet the conditions

$$\lambda_i^1(x_i, T) = 0, \lambda_i^2(x_i, T) = 0, \quad i=1,2 \quad (28)$$

then the last two integrals in (26) are always zero.

For variation of the conjugation conditions (5) – (6), we get expressions

$$\delta Q_1(l_1, t) = \left(\frac{\partial g_1^c}{\partial z_1(l_1, t)} \right)_0 \delta z_1(l_1, t) + \left(\frac{\partial g_1^c}{\partial z_2(l_1, t)} \right)_0 \delta z_2(l_1, t) + \left(\frac{\partial g_1^c}{\partial u_1^c(t)} \right)_0 \delta u_1^c(t) + \left(\frac{\partial g_1^c}{\partial u_2^c(t)} \right)_0 \delta u_2^c(t) \quad (29)$$

$$\delta Q_2(l_1, t) = \left(\frac{\partial g_2^c}{\partial z_1(l_1, t)} \right)_0 \delta z_1(l_1, t) + \left(\frac{\partial g_2^c}{\partial z_2(l_1, t)} \right)_0 \delta z_2(l_1, t) + \left(\frac{\partial g_2^c}{\partial u_2^c(t)} \right)_0 \delta u_2^c(t) \quad (30)$$

Similarly, for a variation of the boundary conditions

$$\delta Q_1(0,t) = \left(\frac{\partial g_1}{\partial z_1(0,t)} \right)_0 \delta z_1(0,t) + \left(\frac{\partial g_1}{\partial u_1(l,t)} \right)_0 \delta u_1(t), \quad (31)$$

$$\delta Q_2(0,t) = \left(\frac{\partial g_2}{\partial z_2(0,t)} \right)_0 \delta z_2(0,t) + \left(\frac{\partial g_2}{\partial u_2(t)} \right)_0 \delta u_2(t), \quad (32)$$

It is clear from (26) for the variation of the functional that the conjugate variables satisfy the following conjugation conditions

$$\left(\frac{\partial G_c}{\partial z_2(l_1,t)} \right)_0 + \left(\frac{\partial H_1}{\partial z_1'}(l_1,t) \right)_0 + \left(\frac{\partial H_1}{\partial Q_1}(l_1,t) \right)_0 \left(\frac{\partial g_1^c}{\partial z_1(l_1,t)} \right)_0 - \left(\frac{\partial H_2}{\partial Q_2'}(l_1,t) \right)_0 \left(\frac{\partial g_2^c}{\partial z_2(l_1,t)} \right)_0 = 0 \quad (33)$$

$$\left(\frac{\partial H_2}{\partial z_2'}(l_1,t) \right)_0 + \left(\frac{\partial H_2}{\partial Q_2}(l_1,t) \right)_0 \left(\frac{\partial g_2^c}{\partial z_2(l_1,t)} \right)_0 - \left(\frac{\partial H_1}{\partial Q_1'}(l_1,t) \right)_0 \left(\frac{\partial g_2^c}{\partial z_2(l_1,t)} \right)_0 = 0 \quad (34)$$

The boundary conditions are

$$\begin{aligned} \left(\frac{\partial H_1}{\partial Q_1'}(0,t) \right)_0 \left(\frac{\partial g_1}{\partial z_1(0,t)} \right)_0 + \left(\frac{\partial H_1}{\partial z_1'}(0,t) \right)_0 &= 0 \\ \left(\frac{\partial G_2^2}{\partial z_2(l_2,t)} \right)_0 + \left(\frac{\partial H_2}{\partial z_2'}(l_2,t) \right)_0 + \left(\frac{\partial H_2}{\partial Q_2'}(l_2,t) \right)_0 \left(\frac{\partial g_2}{\partial z_2(l_2,t)} \right)_0 &= 0 \end{aligned} \quad (35)$$

Taking into account certain equations for conjugate variables, the conjugation conditions and boundary conditions, we get an expression for the variation of the functional (36)

$$\begin{aligned} \delta I = \int_0^T \left\{ \left[\left(\frac{\partial H_2}{\partial Q_2'}(l_2,t) \right)_0 \left(\frac{\partial g_2}{\partial u_2(t)} \right)_0 + \left(\frac{\partial G_2^2}{\partial u_2(t)} \right)_0 \right] \delta u_2(t) - \left(\frac{\partial H_1}{\partial Q_1'}(0,t) \right)_0 \left(\frac{\partial g_1}{\partial u_1(t)} \right)_0 \delta u_1(t) + \left(\frac{\partial G_c}{\partial u_1^c(t)} \right)_0 \delta u_1^c(t) + \right. \\ \left. + \left(\frac{\partial H_1}{\partial Q_1'}(l_1,t) \right)_0 \left[\left(\frac{\partial g_1^c}{\partial u_1^c(t)} \right)_0 \delta u_1^c(t) + \left(\frac{\partial g_1^c}{\partial u_2^c(t)} \right)_0 \delta u_2^c(t) \right] \right\} dt. \end{aligned}$$

We have defined explicit expressions for the variation of the functional from the variation of controls $\delta u_1(t)$, $\delta u_2(t)$, $\delta u_1^c(t)$, $\delta u_2^c(t)$. Since it was assumed that these variations were arbitrary, the prerequisite condition for optimality is that these expressions for these variations are zero.

Thus, the maximum principle for the optimal control problem under consideration is formulated as follows: in order for the controls $u_1(t)$, $u_2(t)$, $u_1^c(t)$, $u_2^c(t)$ to be optimal taking into account the constraints, it is necessary to satisfy the following conditions must be met:

$$-\left(\frac{\partial H_1}{\partial Q_1'}(0,t) \right)_0 \left(\frac{\partial g_1}{\partial u_1(t)} \right)_0 = 0 \quad (37)$$

$$\left(\frac{\partial H_2}{\partial Q_2'}(l_2,t) \right)_0 \left(\frac{\partial g_2}{\partial u_2(t)} \right)_0 + \left(\frac{\partial G_2^2}{\partial u_2(t)} \right)_0 = 0 \quad (38)$$

$$\left(\frac{\partial G_c}{\partial u_1^c(t)} \right)_0 + \left(\frac{\partial H_1}{\partial Q_1'}(l_1,t) \right)_0 \left(\frac{\partial g_1^c}{\partial u_1^c(t)} \right)_0 = 0 \quad (39)$$

$$\left(\frac{\partial H_2}{\partial Q_2'}(l_1,t) \right)_0 \left(\frac{\partial g_2^c}{\partial u_2^c(t)} \right)_0 + \left(\frac{\partial G_c}{\partial u_2^c(t)} \right)_0 = 0 \quad (40)$$

When operating within the constraint zone, the corresponding values in the left hand sides of equations (37) – (40) must be negative, if they are reached in the upper limits.

The control action has the following ran

$$\begin{aligned} u_1^{\min} \leq u_1(x,t) \leq u_1^{\max}, \\ u_2^{\min} \leq u_2(x,t) \leq u_2^{\max} \end{aligned} \quad (41)$$

Limitations on the modes of operation of canal sections have the form

$$\begin{aligned} z^{\min} & \leq z(x,t) \leq z^{\max}, \\ Q^{\min} & \leq Q(x,t) \leq Q^{\max} \end{aligned} \quad (42)$$

The problem of minimization (1) under condition (2) with the help of the control interaction (3) – (4) and under constraints (5) – (6) represents a control problem for quasilinear systems with distributed parameters with constraints on the states.

$$\begin{aligned} \delta I = & \int_0^l [z(x,T) - z^*] \delta z(x,T) dx + \sum_{j=1}^N \int_0^T 2(q_j(t) - q_j^*) \delta q_j(t) dt - \\ & - \int_0^T \left\{ \left[\left(\frac{\partial H}{\partial Q} \right)_0(l,t) \right] \left(\frac{\partial g_2}{\partial u_2(t)} \right)_0 \delta u_2(t) + \left(\frac{\partial H}{\partial Q} \right)_0(0,t) \left(\frac{\partial g_1}{\partial u_1(t)} \right)_0 \delta u_1(t) \right\}, \end{aligned} \quad (43)$$

where

$$H = \lambda^1 f^1 + \lambda^2 f^2. \quad (44)$$

By calculating the derived Hamiltonian with respect to Q , we obtain

$$\frac{\partial H}{\partial Q} = -\frac{1}{B} \lambda^1 - \frac{2Q}{\omega} \lambda^2 \quad (45)$$

Now we have defined explicit expressions for the variation of the functional from the variation of controls $\delta u_1(t)$, $\delta u_2(t)$. Since it was assumed that these variations were arbitrary, the prerequisite condition for optimality is the equality of the expressions for these variations.

Thus, the final optimality prerequisites for the full Saint-Venant equations, under control in the constraint zone, have the form

$$\left[\left(\frac{1}{B} \right)_0 \lambda^1 - \left(\frac{2Q}{\omega} \right)_0 \lambda^2 \right]_{x=0} \left(\frac{\partial g_1}{\partial u_1(t)} \right)_0 = 0, \quad (46)$$

$$\left[\left(\frac{1}{B} \right)_0 \lambda^1 - \left(\frac{2Q}{\omega} \right)_0 \lambda^2 \right]_{x=l} \left(\frac{\partial g_1}{\partial u_1(t)} \right)_0 = 0, \quad (47)$$

If the upper (lower) boundaries are to be controlled, the respective values in the left sides of expressions (46) – (47) must not be positive (non-negative).

Taking into account expressions for the coefficients of the basic equation and calculating corresponding derivatives, we will get expressions for conjugate variables λ^1 , λ^2 that satisfy the following differential equations

$$\begin{aligned} \frac{\partial \lambda_i^1}{\partial t} = & - \left\{ \left(\frac{B_i}{B^2} \frac{\partial Q}{\partial x} \right)_0 \lambda^1 + \left(\frac{2Q \omega'}{\omega^2} \frac{\partial Q}{\partial x} - \frac{g_{i0} Q^2 (2\omega c' + c \omega')}{\omega_i^2 c_i^3} \right) \right. \\ & \left. - \frac{g |Q| \left[Q (2\omega K' + K \omega) \right]}{K^3} \right\} \lambda^2 - \left(g \omega \left[1 - \frac{Q^2}{\omega^2 c^2} \right] \right)_0 \frac{\partial \lambda_i^2}{\partial x}, \end{aligned} \quad (48)$$

The complete model of unsteady flow in the canal section considers all the main hydraulic properties of water flow.

Taking into account the prerequisite optimality conditions derived in (37) – (40), we obtain the final ones for the full system of Saint-Venant equations. Under control within the constraint zone for the problem (1) – (7) considered above, the variation of the optimality criterion has the form

$$\frac{\partial \lambda_i^1}{\partial t} = - \left\{ \left(\frac{B_i}{B_i^2} \frac{\partial z_i}{\partial x_i} \right)_0 \lambda_i^1 + \left(\frac{2g i_0 Q_i}{\omega_i c_i^2} - \frac{2g \omega_i |Q_i|}{K_i^2} + \left(\frac{2g Q_i}{\omega_i c_i^2} + \frac{2Q_i \omega_i}{\omega_i^2} \right) \frac{\partial z_i}{\partial x_i} \right)_0 \lambda_i^2 - \left(\frac{1}{B_i} \right)_0 \frac{\partial \lambda_i^1}{\partial x_i} + \left(\frac{2Q_i}{\omega_i} \right)_0 \frac{\partial \lambda_i^2}{\partial x_i} \right\}, \quad i = 1, 2 \quad (49)$$

Similarly, we define boundary conditions

$$\left[\left(\frac{1}{B} \right)_0 \lambda^1 + \left(\frac{2Q}{\omega} \right)_0 \lambda^2 \right]_{x=0} \left(\frac{\partial g_1}{\partial z(0, t)} \right)_0 + \left[g \omega \left(1 - \frac{Q^2}{\omega^2 c^2} \right)_0 \lambda^2 \right]_{x=0} = 0 \quad (50)$$

$$- \left[g \omega_2 \left(1 - \frac{Q^2}{\omega^2 c^2} \right)_0 \lambda_2^2 \right]_{x=l} - \left[\left(\frac{1}{B} \right)_0 \lambda^1 + \left(\frac{2Q}{\omega} \right)_0 \lambda^2 \right]_{x=l} \left(\frac{\partial g_2}{\partial z(l, t)} \right)_0 = 0, \quad (51)$$

with conditions at the end of the control process

$$\lambda^1(x, T) = 2 [z(x, T) - z^*], \quad \lambda^2(x^2, T) = 0 \quad (52)$$

In this case, the conditions for the main variables are determined by expressions (1) – (4), and for the conjugate variables by expressions (5) – (6).

For the full mathematical model of unsteady flow in canals, one recommends the successive approximation approval, which is that based on the gradient projection method for optimal water distribution between consumers. The sequence of controls is the following:

$$u_1^{m+1}(t) = \begin{cases} u_{1\min} & \text{under } u_1^m(t) - \alpha_m \delta u_1^m(t) < u_{1\min}, \\ u_1^m(t) - \alpha_m \delta u_1^m(t) & \text{under } u_{1\min} \leq u_1^m(t) - \alpha_m \delta u_1^m(t) \leq u_{1\max}, \\ u_{1\max} & \text{under } u_1^m(t) - \alpha_m \delta u_1^m(t) > u_{1\max}. \end{cases} \quad (53)$$

$$u_2^{m+1}(t) = \begin{cases} u_{2\min} & \text{under } u_2^m(t) - \alpha_m \delta u_2^m(t) < u_{2\min}, \\ u_2^m(t) - \alpha_m \delta u_2^m(t) & \text{under } u_{2\min} \leq u_2^m(t) - \alpha_m \delta u_2^m(t) \leq u_{2\max}, \\ u_{2\max} & \text{under } u_2^m(t) - \alpha_m \delta u_2^m(t) > u_{2\max}. \end{cases} \quad (54)$$

$$u_1^{cm+1}(t) = \begin{cases} u_{1c\min} & \text{under } u_1^{cm}(t) - \alpha_m \delta u_1^{cm}(t) < u_{1c\min}, \\ u_1^{cm}(t) - \alpha_m \delta u_1^{cm}(t) & \text{under } u_{1c\min} \leq u_1^{cm}(t) - \alpha_m \delta u_1^{cm}(t) \leq u_{1c\max}, \\ u_{1c\max} & \text{under } u_1^{cm}(t) - \alpha_m \delta u_1^{cm}(t) > u_{1c\max}. \end{cases} \quad (55)$$

$$u_2^{cm+1}(t) = \begin{cases} u_{2c\min} & \text{under } u_2^{cm}(t) - \alpha_m \delta u_2^{cm}(t) < u_{2c\min}, \\ u_2^{cm}(t) - \alpha_m \delta u_2^{cm}(t) & \text{under } u_{2c\min} \leq u_2^{cm}(t) - \alpha_m \delta u_2^{cm}(t) \leq u_{2c\max}, \\ u_{2c\max} & \text{under } u_2^{cm}(t) - \alpha_m \delta u_2^{cm}(t) > u_{2c\max}. \end{cases} \quad (56)$$

The essence of the method for the problem considered is that if $u_1^k(t)$, $u_2^k(t)$, $u_1^{ck}(t)$ and $u_2^{ck}(t)$ are not optimal, then the control increments are chosen

so as to ensure the motion of the system in the direction opposite to the variation gradient Functional.

The algorithm for finding optimal controls consists of the following steps:

1. Set the initial values $u_1^0(t), u_2^0(t), u_1^{c0}(t), u_2^{c0}(t)$ of the controls for $0 \leq t \leq T, 0 \leq x_1 \leq l_1, 0 \leq x_2 \leq l_2$ and the initial conditions.

$$z_1^0(x_1), Q_1^0(x_1), z_2^0(x_2), Q_2^0(x_2), \\ 0 \leq x_1 \leq l_1, 0 \leq x_2 \leq l_2.$$

2. Calculate the value of the criterion I (12) by solving the equations of dynamics (1) with the initial and boundary conditions (2) – (4) together with the conjugation conditions (5) – (6).

3. Solve the system of equations for conjugate variables (53) – (56) under conditions (46) – (47).

4. Make local improvement of control $u_1^{k+1}(t), u_2^{k+1}(t), u_1^{ck+1}(t), u_2^{ck+1}(t)$ in accordance with (11) by minimizing I^{k+1} and selecting ε_i (this can be done by any method of multidimensional search).

5. Check the stopping condition $|I^{k+1} - I^k| \leq \delta_0$, δ_0 is accuracy and k is – calculation-step.

6. If the break conditions are not met, then go back to step 2.

It should be noted that the boundary value problem for the basic variables for a complete mathematical model is solved in direct time, and

the boundary value problem for conjugate variables is the reverse one. These boundary-value problems are solved by numerical methods, for example, by finite-difference or finite elements [6; 7; 8]. With a good choice of the initial condition and the initial controls, the proposed algorithm quickly converges. The initial controls are selected from the solution of the problem of optimal distribution of water between consumers, obtained using simplified mathematical models of unsteady water movement in the canal sections [1; 9], and the initial conditions are determined from the solution of the steady water movement in the canal sections.

4. Conclusions

On the basis of the research, the necessary conditions for the optimality of the distribution of water in the canals of irrigation systems are obtained using the complete system of differential equations of the unsteady water movement of Saint-Venant.

On the basis of the necessary optimality conditions, an algorithm for optimal control of water distribution in the canals of irrigation systems was developed using the method of successive approximations, based on the gradient projection method. This algorithm can be used in the calculation of transient processes in sections of the canal to determine the specified water level in the obstructing structures and lateral branches of the canal sections, which will ensure the optimal distribution of water in the canals of irrigation systems.

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THE RESULTS OF AN EXPERIMENTAL STUDY OF THE ACCUMULATION OF ENERGY IN A SOLAR DRYING PLANT

Abstract: The paper considers the classification of heat-accumulating materials. The results of experimental studies of various heat-accumulating materials in an energy-saving helio-drying plant are conducted.

Keywords: drying, energy saving, accumulation, solar drying installation.

Today, the bulk of the world's energy balance is covered by traditional fossil fuels – 78% (coal, gas, oil) and nuclear power about 3%. The contribution of all types of renewable energy source to the world production of electricity is about 22%, of which 17% for hydropower, while for other renewable sources of energy, slightly more than 5% [1]. Estimates of hydrocarbon reserves showed that the period of the world oil supply at the beginning of 2012 is 54 years, for natural gas – 64 years, coal for 112 years [2]. But the problems of energy supply to the world's population have not been fully resolved to date. Today, another 20% of the world's population (1.4 billion people) do not have access to electricity at all, and 40% traditionally use biomass for cooking [3]. According to the International Monetary Fund, the annual increase in global energy consumption is about 2.5%. Considering such rates of energy consumption, it can be assumed that in the coming decades, hydrocarbon raw materials are no longer able to meet the basic needs of the world economy in electricity.

One of the possible measures that allows for the more efficient use of thermal energy in various sectors of the economy is the accumulation of heat through the use of different heat-accumulating materials and heat accumulators of various designs [4–9].

Classification of heat-accumulating materials. The most important characteristics of the thermal energy storage system are [8]:

- capacity per unit volume or weight;
- operating temperature range, i. e., the temperature of the coolant at the inlet and outlet of the system;
- methods for supplying and taking heat and corresponding temperature differences;
- temperature stratification in the battery;
- power required for supply and removal of heat;
- volumes of containers, tanks or other structural elements associated with the storage system;
- means for regulating thermal losses of a battery;
- cost of manufacture and operation.

The creation of heat accumulators depends on the temperature level, the scale of the installation and the duration of heat accumulation.

According to the accumulation temperature, the heat accumulators are divided into three groups: low-temperature ($35\text{ }^{\circ}\text{C} < t < 100\text{ }^{\circ}\text{C}$); medium temperature ($100\text{ }^{\circ}\text{C} < t < 500\text{ }^{\circ}\text{C}$); high-temperature ($t > 500\text{ }^{\circ}\text{C}$). In terms of the use of heat, they can be classified as small-scale (for decentralized consumers) and large-scale (for large centralized systems). In terms of storage time, heat accumulators are divided into short-term (1–2 days), medium-term (up

to 1 month), off-season (up to six months) [10].

The level of temperature, the scale of the storage unit and the necessary duration of heat storage determine the requirements for the design of batteries, the choice of heat storage substances.

Moreover, the higher the accumulation temperature, the more difficult it is to ensure a long accumulation time due to existing heat loss. But the improvement of thermal insulation reduces the intensity of heat losses, and therefore increases the possible duration of storage of stored energy. Therefore, the type, design and cost of heat accumulators depend on the desired duration of heat storage.

At present, the main problem of drying agricultural products is high energy consumption, which can be reduced under the following conditions:

- process optimization;
- development of more progressive methods of drying and technical means for their implementation;
- the replacement of expensive energy sources with alternative cheap types, in particular solar energy;
- optimization of constructive schemes of solar drying.

The analysis of literature sources on the helio-drying of agricultural products does not allow us to determine the optimal options for using solar energy for drying the material, give precise recommendations on the methods and techniques of helio drying of various types of products. The majority of operating installations are experimental with a small ray-receiving surface, they are constructed on the basis of single experimental data. Unfortunately, at the present time there are no existing industrial plants that have been approved, which is explained by the absence of standard methods for the complex analysis of solar dryers [11].

Thus, in the future, all efforts should be directed to improving the process technology to simplify and reduce the cost of the design of solar dryers, which will allow their wide implementation in the agro-in-

dustrial complex. The successful solution of this not only important economic, but also complex scientific and technical problem is inconceivable without systematization of a great variety of existing methods of helio drying and various designs.

To analyze the processes of mass and heat transfer, it is advisable to compile a model of a capillary-porous body. As an example, consider one of the simplest models of a body with a rigid skeleton, in which there are pores in the form of a set of cylindrical capillaries of the same diameter [12–13].

During the warming up of the material above the surface of the porous body, a diffusion zone δ_{r} . Then, during the period of constant drying rate (I period), the liquid evaporates from the surface of the diffusion layer. The loss of water is compensated by its inflow from the column of liquid in the capillary. The motion of the liquid in the capillary is mainly due to capillary forces. During drying, a gradual decrease in the height of the liquid in the capillary is observed. When the meniscus reaches the bottom of the capillary, the evaporation rate. At this moment, the period of constant drying speed is completed and the period of the falling drying speed (II period) begins. The transition from the first drying regime to the second is associated with a change in the mechanism of internal mass transfer. In this case, a transition occurs from evaporation of the capillary liquid to the evaporation of the remaining film moisture. During this period, the contribution of surface diffusion, of the vapor and film currents increases [12].

The temperature of the material also changes during the drying process. During the warm-up period, the temperature of the material rises from the initial temperature to the temperature of the wet medium thermometer. In the first period, the temperature of the surface and the entire volume of wet material is the same, constant and equal to the temperature of the wet thermometer. In the second period, the temperature of the material gradually increases, approaching the ambient temperature [14].

The ideal model of fluid motion in pores is the Stokes law for the flow of a liquid in a cylindrical capillary [15]. The application of this law for practical calculations is difficult, because real porous bodies have pores and capillaries of different diameters, different tortuosity, shape and roughness. A particularly strong deviation from the Stokes law is observed in the flow of liquid in micropores whose radii are commensurable with the radius of surface molecular forces.

In the process of drying wet materials, there are interrelated processes of heat and mass transfer between the material and the drying agent. External processes are characterized by external mass-exchange – evaporation of moisture, i. e. the movement of steam from the surface of the material to the surrounding airspace and external heat exchange between the heated gas and the surface of the material. When the moisture evaporates, the equilibrium is disturbed from the surface. The internal parts of the

product have a higher humidity and, correspondingly, a lower temperature in comparison with the surface layers. Due to the difference in the moisture content of the surface and inner layers, a gradient of moisture content. This leads to processes of internal heat and mass transfer, in which moisture is transferred from the inner, more humid layers, to the surface ones and its evaporation is already taking place there. Due to the presence of a moisture content gradient, a continuous decrease in moisture throughout the entire volume of the dried product [16].

For carrying out experimental studies in the laboratory of the Tashkent state technical university, an installation was made – an energy-saving mini-infrared helio drying plant with accumulation of solar energy [17–20].

Experimental studies of various materials in an energy-saving solar drying plant have been carried out. Based on the results of the experiments, the following results were obtained (table 1–2).

Table 1. – The heating process using different materials up to 2 cm layer

Heating time, minutes	Temperature of material with high heat capacity, ° C			
	Paraffin	Sand	Salt	Brick
10	25.4	24.5	24.0	23.0
20	27.6	25.0	25.7	24.1
30	29.0	27.2	27.8	25.4
40	31.0	29.0	29.6	26.2
50	34.7	30.8	33.0	29.7
60	39.5	32.1	35.3	31.1
70	43.6	35.6	39.0	35.0
80	47.5	36.0	41.8	38.9
90	51.2	38.3	45.0	42.0
100	53.4	41.0	48.0	45.3
110	58.0	42.6	51.0	47.0
120	62.7	43.4	53.2	48.7

Table 2. – The cooling process when using different materials up to 2 cm layer

Cooling time, minutes	Temperature of material with high heat capacity, ° C			
	Paraffin	Paraffin	Paraffin	Paraffin
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
10	59.8	41.2	50.6	46.0
20	59.4	38.6	47.2	45.1
30	58.7	35.3	44.7	44.2

1	2	3	4	5
40	56.4	31.5	41.3	42.5
50	54.6	28.6	38.6	40.3
60	52.5	24.4	34.9	38.2
70	50.1	22.1	31.4	35.7
80	47.8	20.8	28.1	33.6
90	44.5	19.0	25.6	31.9
100	42.9	18.6	24.0	30.1
110	41.3	17.9	23.1	28.4
120	40.6	17.1	22.5	27.0

Thus, the solar dryer is designed for drying medicinal herbs and root vegetables, as well as vegetables and fruits. The developed technology is recommended for use in forestry and agricultural

enterprises of all forms of ownership, which are engaged in growing and storing products and are interested in increasing the profitability of production.

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THE CONTACT ANGLE MEASUREMENT ON A POROUS MONTMORILLONITE CLAY BEFORE AND AFTER ITS SULFURIC ACID TREATMENT

Abstract: The main aim of this study is determining the change in wettability of the Prrenjas clay of the montmorillonite type, after its sulfuric acid activation by determining the contact angle of clays with water. Prrenjas clay samples were activated with three different H_2SO_4 concentration 184%, 491% and 1113% calculated against the clay dry mass. The contact angles between clay samples and water were determined by Thin Layer Adhesive Tape Wicking (TLATW) technique using methanol as total spreading liquid. Washburn equation is used to calculate the contact angle out of the rate of wicking on the adhesive tape. The Differential Light Scattering (DLS) technique was used to determine the particle size distribution of clay samples. The most present particle size results to be similar with the effective radiuses calculated using the methanol wicking rate in the Washburn equation, around 170 nm for the untreated Prrenjas clay and 240 nm for the Prrenjas clay treated with 1113% sulfuric acid. Fourier Transformed Infrared Spectroscopy (FTIR), used to determine the chemical changes after the acid treatment of the Prrenjas clay shows that the hydroxyl groups bounded in the clay metals Fe, Al and Mg almost disappears. It leads to a hydrophobization of the clay surface since its water contact angle changes from 70° for the untreated clay to similar values of 84° for the clays treated with 184%, 491% and 1113% H_2SO_4 .

Keywords: acid activation, contact angle, surface energy.

Introduction

For many naturally occurring or artificially obtained solids which are of great interest of study or

uses, such as soil, clays, pigments, pharmaceuticals and others the contact angle cannot be measured directly and, consequently indirect methods such as the

adhesive tape method must be used. This method has been so far quite popular in studying the porous structure of several inorganic materials and synthetic polymers (e.g. [1–6]). In this study was investigated the change in the wettability of Prrenjas clay, an iron and magnesium rich montmorillonite type mineral, before and after the activation with sulfuric acid in 3 different concentrations. These clays have a high specific surface area in natural form which increases up to 4 times after the acid activation due to the leaching of metals and hydroxyl groups from the clay structure. The wicking technique, consist in using a packed column or film (thin layer wicking) of the particles, the capillarity rise measurement of a liquid in that column/film can yield the contact angle of that liquid with respect to the particles' surface. Wicking is the measurement of the contact angle which liquids forms with particulate solids, by determining the rate of the capillarity rise of these liquids. In the thin layer adhesive tape wicking used in this study, the film of the clay material is created on an inert adhesive tape enabling to assess the contact angle of the powdered solid clay samples.

Washburn describes the rate of the penetration, ν of liquid into small cylindrical capillaries as:

$$\nu = \frac{R_D^2 \Delta P}{8\eta l} \quad (1)$$

In the Washburn equation, ν is the kinetics of flow, R_D the mean hydrodynamic radius of the capillary, η the viscosity of the liquid, l the length of the capillary and ΔP the pressure difference. ΔP can be expressed as the capillary pressure. Thus equation can be written in a simpler form:

$$h^2 = \frac{r\gamma_l \cos\theta}{2\eta} t \quad (2)$$

Where h is the height to which liquid has risen in time t . One fundamental difficulty of this approach is the fact the equation uses two unknowns (R_D and $\cos\theta$). This difficulty has been avoided by using a liquid which is expected to spread over the solid material in which case it is held that $\cos\theta = 1$, for this we use methanol, which have the ability to wet completely the solid surface, without forming a

finite contact angle. Consequently, the value of R_D is obtained, which can then be used to define the $\cos\theta$ value of the same particle for non-spreading liquids.

Experiment

Materials:

TLC vessel, methanol, hexane, natural Prrenjas clay, Prrenjas clay treated with sulfuric acid 187%, 491% and 1113%, SiO_2 , adhesive tape, stopwatch.

Infrared analysis of the Prrenjas clay samples were performed in a Nicolet 6700 FTIR of the producer Thermo Scientific equipped with an Attenuated Total Reflectance (ATR) device. The samples were analyzed as dried powder form by applying them on the ATR crystal. The measurements were performed in the Institute of Applied Nuclear Physics, University of Tirana.

The particle characterization was carried out using the Dynamic Light Scattering (DLS) using a Zetasizer-Nano ZS from Malvern Instruments operating with a 4 mW He-Ne laser (633 nm), Peltier element. The instrument measures hydrodynamic size by dynamic light scattering DLS through phase analysis light scattering. DLS measurements were performed in backscattering at fixed detector.

Preliminary work start:

Beforehand, the work begins with the washing of the glassware, initially with tap water, then left for 24 hours in dilute HCl acid solution. After everything is done, a white test is performed, which will serve as a comparative test using SiO_2 in methanol.

The sulfuric acid activation is done using three different acid concentrations 187%, 491% and 1113% calculated against the dry mass of the clay, second a procedure described in detail elsewhere [7].

Wicking Experiment

The clay particles were sprinkled over a double-sided adhesive tape and pressurized in order to obtain a flat surface. On the other side the adhesive tape was bonded on a stainless steel ruler which enables to read the liquid rise. The adhesive tape was cut 12 mm over the ruler edge and the ruler was than in-

troduced to a TLC glass chamber and placed vertically over the end of that chamber. It was firstly filled up to 10 mm with the testing liquid (methanol or water) using a glass pipette so that the liquid did not touches the powder. The cup of the chamber was closed and let so for 24 hours in order to allow the liquid vapors to saturate the atmosphere inside the chamber and get adsorbed on the powder as well. Than the cup was reopened and half of the firstly poured liquid volume was added. Beginning from that moment the time and the rising height of the liquid were registered for up to one hour.

This procedure was carried out for the untreated Prrenjas clay, the Prrenjas clay treated with 184%, 491% and 1113% sulfuric acid and powdered fumed silica SiO₂. The liquids used were methanol and water with the physical properties as given in Table 1.

Results and Discussions

The first wicking measurements consist in using the SiO₂ as a blank test and methanol as a liquid which is considered to fully wet the powder surface and demonstrate a $\cos \theta = 1$. The measurements are carried out for the four different Perrenjas clays, untreated and treated with three different concentrations of sulfuric acid. The results are shown in figure 1. A good linearity, shown in table 2, is demonstrated in the relationship of the square wicking height against time, which speaks for the validity of the equation 2.

Table 1. – Surface tension values of some common test liquids for surface energy analysis

Name	Surface tension @ 20 °C (mN/m)	Viscosity (mPa*sec)
Methanol	22.70	0.594
Water	72.80	1.003

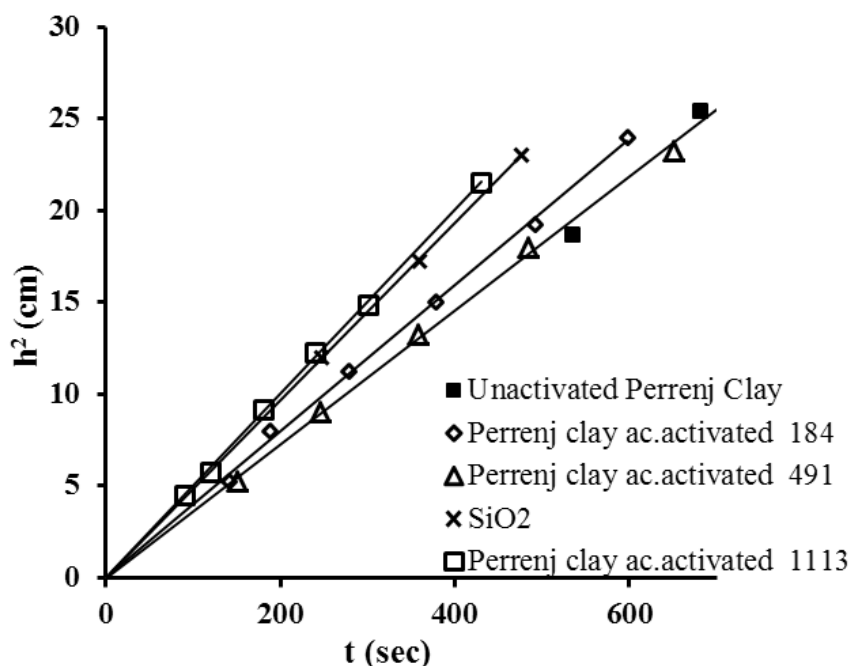


Figure 1. Variation of the height of methanol capillary rise with the time for Prrenjas clay samples and fumed silica measured by thin layer adhesive tape wicking technique

By using the equation no.2 where h is the height where methanol rises in time t , the difficulty of this approach is the fact the one uses one equation with two unknowns (R_D^2 and $\cos \theta$), but by using methanol with a known contact angle of zero ($\cos \theta = 1$),

and knowing its surface tension and viscosity, the mean capillary radius R_D of the different solids can be determined.

After transforming the equation 2 and substituting the values; η the viscosity of the

liquid = 0.545 mPa×s (at 25 °C), γ – surface tension = 22.70 mN/m; $\cos \theta = 1$, one can obtain the values of mean capillary radiuses R_D of the adhesive bounded clay samples.

$R_D = h^2 * 2\eta / \gamma * \cos \theta * t$ – where h^2/t is graphically determined as the slope of the best linear line fitting with the experimental points.

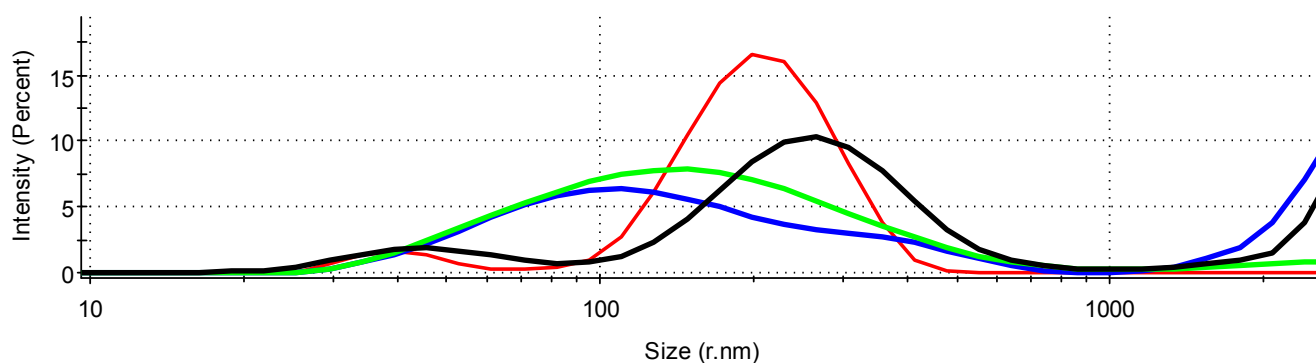
For two of the clay samples (Perrenjas untreated and treated with 1113% sulfuric acid) the particle size distribution were determined by Differential Light Scattering technique. The particle size is a good

estimation of the mean capillary radius R_D resulting after the bonding of the clay samples on the adhesive tape. As shown in the figure 3 the maximum in the untreated clay line (green line), representing the most frequent size of the clay particle, is around 170 nm matching well with the radius calculated by equation 2 when using methanol as wicking liquid. Same results confirms for the 1113% acid treated clay sample as well where the black line shows a maximum in around 240 nm, nearing so the mean capillary radius calculated by equation 2.

Table 2. R_D – values of the solids measure in methanol and the θ angle measured in hexane and distilled water

Material	Methanol			Distillated Water		
	Slope	Linearity	R_D (nm)	Slope	Linearity	θ (degree)
Unactivated clay	0.0364	0.997	174.78	0.0176	0.9938	76
Activated clay 184	0.0399	0.997	191.59	0.0072	0.9937	85
Activated clay 491	0.0364	0.998	174.78	0.0073	0.9872	84
Activated clay 1113	0.0501	0.999	240.57	0.0086	0.9939	85
SiO ₂ crystal	0.0482	0.999	231.44	0.0266	0.9973	74

Size Distribution by Intensity



—	Record 71: avg POS 21.6 mg PO in 5 mL Na ₂ SO ₄ 0.01 M SVN 1
—	Record 72: avg P1113S_supernatant 2
—	Record 73: avg POW_supernatant 2
—	Record 91: AVG P1113W_supernatant 1

Figure 3. Particle size distribution of Prrenjas clay unactivated and activated with 1113% sulfuric acid dispersed in water or in 0.01 M solution of Na₂SO₄

In figure 4 is shown how the square wicking height changes with the time when using as liquid distilled water. Transforming equation 2 in $\cos \theta = h^2 * 2\eta / R_D * t$, and determining the h^2/t as

the slope of the best linear fit of the experimental points for every clay sample the water contact angle with the clay samples can be obtained. Those calculated θ values are given in the table 2 and

characterize the wettability of the Perrenjas clay samples. It is clearly shown that the acid treatment causes a significant decrease in water wettability of the Perrenjas clay. The water contact angle changes from 76° for the untreated Perrenjas clay sample to

$84^\circ - 85^\circ$ for the acid treated clay samples. In the range of sulfuric acid concentrations from 184% to 1113% the treatment seems to cause nearly the same changes on the clay surface regarding hydrophobicity.

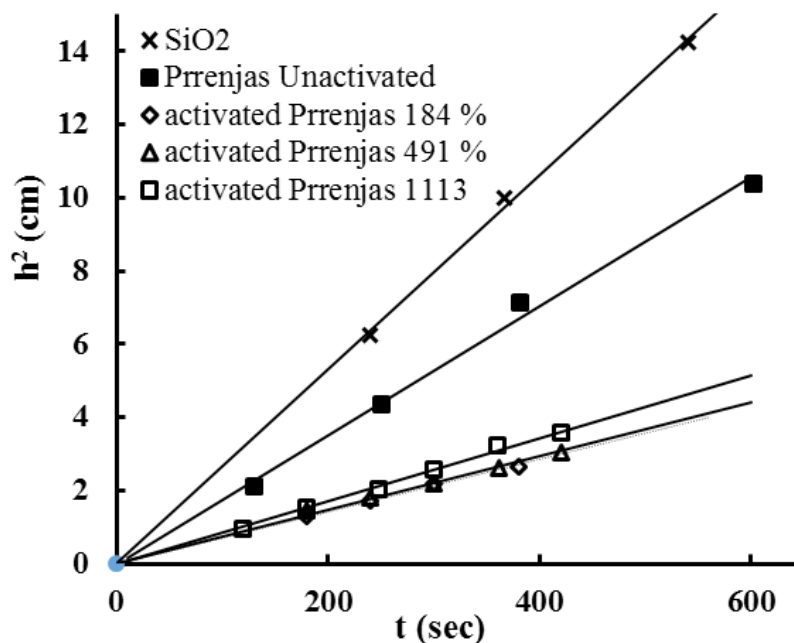


Figure 4. Variation of the height of water capillary rise with the time for Prrenjas clay samples and fumed silica measured by thin layer adhesive tape wicking technique.

In the figure 5 are shown the IR spectra for the untreated and H_2SO_4 treated clays in different concentrations. These spectra shows some changes that occur in the range from $4000-500\text{ cm}^{-1}$. The green color spectrum belongs to untreated clay and continues in the order shown in the graph with increasing acid concentration. The band displayed at 3354 and 1631 cm^{-1} is caused by the vibrations of water molecules present in the clay and is wide due to hydrogen bonds. The most intense band is the $977-1056\text{ cm}^{-1}$ zone attributed to the vibrations of the Si-O bond of the tetrahedral layers. The Si-O-Al Band ($500-520\text{ cm}^{-1}$) represents the most sensitive band playing the role of the indicator in the octahedron layers [8; 9]. The band of $600-700\text{ cm}^{-1}$ links to the octahedron (R-O-Si) perpendicular vibrations, where (R = Mg, Al, Fe) three groups of hydroxyl groups associated with these cations (near 976 cm^{-1} Al- Al-OH) and (796 cm^{-1}

Al - Mg - OH) confirm substitution in the octane layer. From the graph we see that acid-activated clays show a peak at 798 cm^{-1} , which indicates the presence of quartz. Also from the above spectrum IR we see that by increasing the concentration of sulfuric acid band at $500-520\text{ cm}^{-1}$ comes decreasing until it disappears in the concentration over 1000%. At 3620 cm^{-1} for Al-OH-O oscillations, where O is oxygen from the inner layer; 3360 to 3590 cm^{-1} belong to the hydroxyl groups whose oxygen atom has undergone the influence of the cations that are not related to them. Absorption at 3660 cm^{-1} refers to the shaking of poorly bound water-based molecules of hydrogen bonded to surface oxygen [10]. With increasing acid concentration it is noted that peak (520 cm^{-1}) disappears at concentrations above 491% H_2SO_4 , which indicates the removal of Al^{3+} from the octahedron layers. Peaks from the $600-700\text{ cm}^{-1}$ peak almost lose.

This is related to the fact that in these concentrations, the oxides of Al, Fe, Mg are greatly reduced. The band which remains unchanged from acid attack is 977–1056 cm^{-1} , belonging to vibrations of Si – O bonds of tetrahedral layers that have not been affected during acid attack. The intensity of the 3354 cm^{-1} band and 1632 cm^{-1} is reduced by increasing the concentration of acid as a result of the reduction of OH groups. The broadest band with a maximum at 3354 cm^{-1} is connected to the intermolecular water vibrations;

3690 cm^{-1} for bonds Al-OH-O, where O is the oxygen of the neighboring layer; 3765 cm^{-1} corresponds to the OH group in Si-OH; 3550 cm^{-1} twisted vibrations of the silanol group. Adsorption bands from 3720 to 3680 cm^{-1} belong to Al-OH groups. In the area of 3550 to 3695 cm^{-1} , these peaks appear and with acid activation they disappear: 3550 cm^{-1} (Fe-Mg-OH), 3564 cm^{-1} (Al-Fe-OH), 3592 cm^{-1} (Al-Al-OH), 3653 cm^{-1} (Al-Al-OH), 3695 cm^{-1} (AL-Mg-OH) [10].

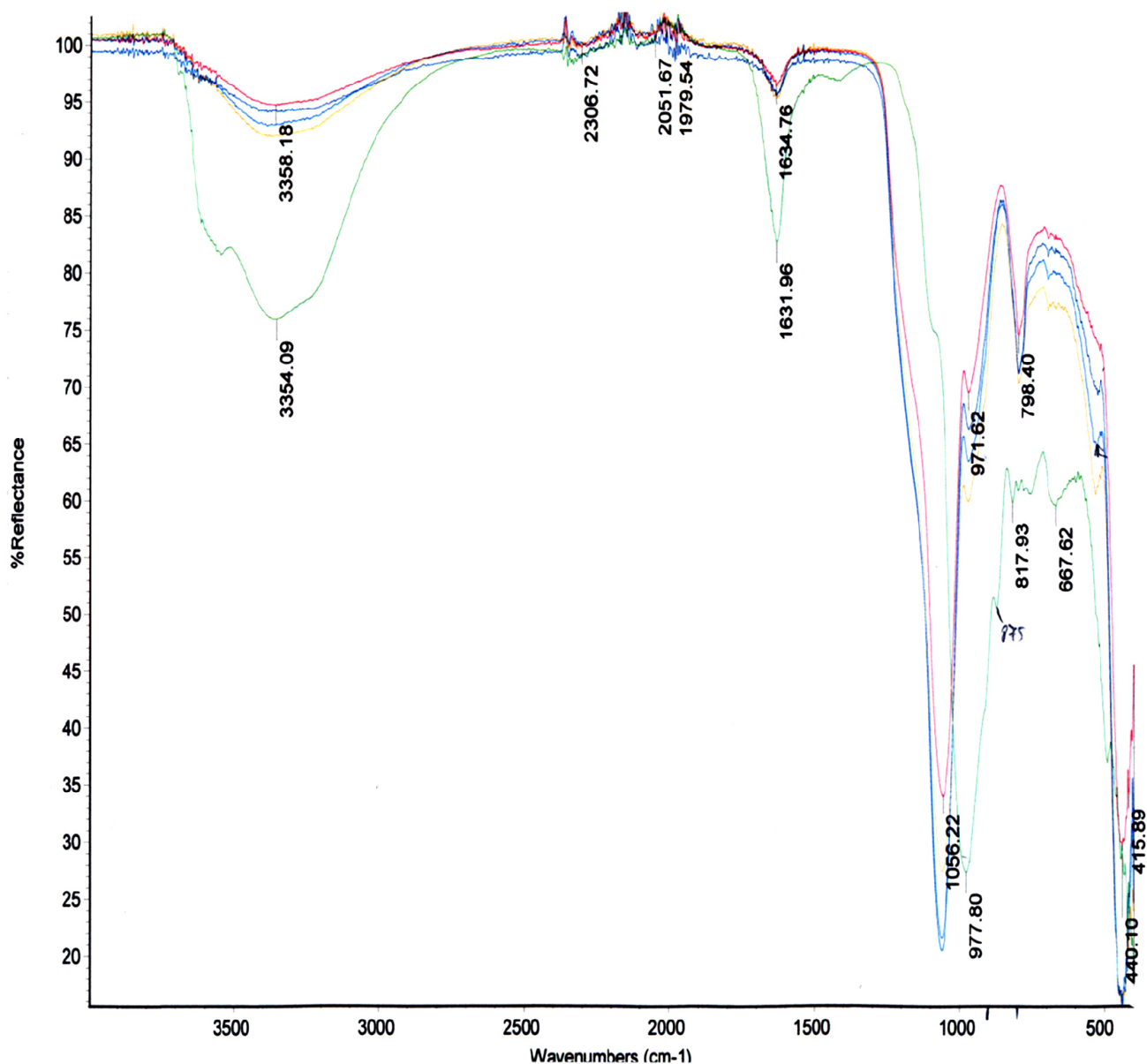


Figure 5. FT – IR spectroscopy for the untreated and H_2SO_4 acid treated Perrenjas clays in the concentrations 184%, 491%, and 1113%

Conclusion

Wicking technique on adhesive tape is shown to be an effective technique in determining the mean capillary radius of bonded porous clay samples using methanol as completely spreading liquid. The sulfuric acid treatment changes the surface of the

clay samples in the same way in the range between 184% and 1113% regarding its interaction with water resulting in the same hydrophobicity of the samples. From the IR spectra of the clay samples the main reason of the developing hydrophobicity during the acid treatment is the dehydroxylation of the clay.

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CONDUCTOMETRICAL DETERMINATION OF SCANDIUM BY SOLUTION OF β -HYDROXYETHYLIMIDE

National university of Uzbekistan after named M. Ulugbek, Tashkent

Abstract: Methods of conductometrical determination of scandium by solution of β -hydroxyethylimide on different by acid-baseal properties phone electrolytes and buffer mixtures are considered. Obtained experimental results treated by methods of mathematical statistics have allowed to determine of scandium by solution of β -hydroxyethylimide.

Keywords: conductometric titration, scandium, β -hydroxyethylimide.

Conductometrical methods of analysis in comparison with others possessed by following advantages: they give possibility without great difficulties to determine ions of different metals not only in transparent but also in coloured and turbid solutions and also in presence of oxidants and restorers; to carried out investigations not only in water but also in not-water and mixed water-organical mediums; lightly to carried out avtomatization of process of titration; in many cases it is possible to avoid separation of impurities preventiny to determination at using of others methods; to carried out differential titration of mixtures of electrolytes what is impossible at using of others method of titration or analysis [1].

Scandium and it's compounds are used in different branches of technics and industry what is caused by it's increasing role and mashtabs of it's production. The wide using of scandium in indus-

try, medicine and also direct contact with him of man have determined some interest to investigation of it's biological action [2].

By this reason intensive development of science technics and industry on modern stage has put forward before chemist-analytcs aim by elaboration of new and moderation of existed methods of analysis with improvement metrological characteristics and possibility of their using in wide interval of determined concentrations of scandium in different by nature industrial and biological materials and also in some other objects.

One of the direction of decision of above-mentional tasks is conductometry possessing high rightness, reproducing, expression, reliability wide diapason of determined concentrations of ions of different metals and simplicity of apparatous and methodological mounting.

In connection with this determination of macro-and micro-grammal quantities of scandium in

different by nature model mixtures, real objects and natural materials is very important and timely.

Experimental part

Method of determination of Sc (III).

For experiments 0,1M solution of scandium obtained from its salt- ScCl_3 was used. Then this salt was dissolved in bidistalate in measured flask by volume 100ml; also 0,1M solution of β -hydroxyethylimide was prepared by dissolution of its 5,0g in 1,0 l of bidistalate. Then experiments by titration of Sc (III) by β -hydroxyethylimide have been carried out.

Used apparatuses, metals, reagent and solutions.

At titration scandium by solution of β -hydroxyethylimide with aim of determination of optimal interval of pH medium the universal ionomer ЭВ-74 and pH-meter pH/mV/TEMP Meter P25 EcoMet were used. In experiments conductometer КЭЛ-1 М2, cell $C_1 - 0,1009$ by capacity 20,0ml, magnetic stirrer MM-3 M-5065 and microburette of first class of precision also were used.

All used reagents have qualification "c. p.", "ch. p." and "p.ch. a." Standard solution of scandium and some other metals used in this investigation with concentration $1,0\text{mg}/\text{dm}^3$ were obtained by dissolution of their nitrates in bidistalate. Working solutions of used metals were obtained by following dilution of their concentrated solutions before beginning of carrying out experiments [3].

Results and their discussion

At conductometrical titration change of common concentration of electrolytes has carried out and correspondingly electroconductivity of solution. On the base of obtained at titration data graph has constructed where by abscissa axis volume (ml) of working solution of reagent depended on titration has been marked and by ordinate axis electroconductivity of investigated system. Initial solution was titrated by equaled portion of titrant and every time its electroconductivity was

marked. Obtained results were marked on graph as points and then they were connected by lines. By this method two curves were obtained crossing of which was corresponded to end point of titration. Also there is other method of determination of the point of equivalence where device for measuring of electroconductivity of investigated solution is bonded with registering apparatus (registrator) with aim of obtaining of more reproducible and continuous recording of titration curve at determination of concentration of component in analysed probe in process of carrying out of conductometrical titration [4].

At preparation of analysed solution in it different by nature and concentration phone electrolytes and buffer mixture were introduced which have caused high electroconductivity of investigated system, extinguishing of migrational currents, the best mass-transfer and some other factors influencing on results and some other physico-chemical parameters of conductometrical titration.

Carrying out investigations have shown that character and form of curves of conductometrical titration of scandium by β -hydroxyethylimide in analysed solutions containing different by nature and concentration buffer mixtures or phone electrolytes have depended in great degree on pH medium.

Obtained at carrying out experiments values of pH of medium were characterized for reaction of complex-formation of scandium by β -hydroxyethylimide carrying out practically qualitatively, quickly and in great degree. At values lower of optimal values of pH the reversibility reaction has increased and at more high values reaction has carried out in more higher degree.

It was determined that at optimizational value of pH (2,5) of medium scandium (III) forming the most stable complex with β -hydroxyethylimide is determined in high degree and at this ending point of titration was observed at molar ratio of components of reaction equaled 1:1. Some from obtained results are presented on figure 1 and in (table 1).

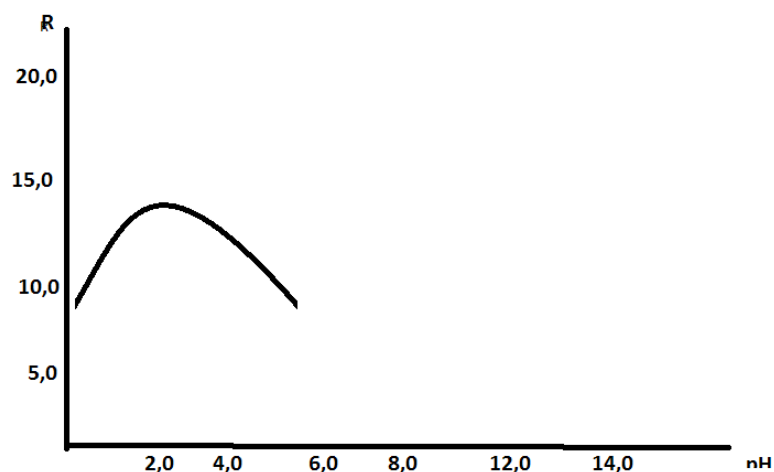


Figure 1. Results of conductometrical titration of 4,5mg of scandium by solution of β -hydroxyethylimide in presence of buffer mixture Britton-Robinson having pH in range 1,81–13,86

It is necessary to note that in acid medium complex-formation of scandium with β -hydroxyethylimide has increased but in weak base medium formation of its base complexes was worsen and correspondenly conditions of conductometrical titration are changed and correspondenly type of titration curves was worsen and results of scandium determination became less persion.

Data of table 1 have shown that finded concentrations of scandium at its conductoimetrical titration by solution of β -hydroxyethylimide are in strong correspondence with it's introduced quantities. Also it was determined that acid medium buffer solution Briton-Robinson was the best at scandium determination by β -hydroxyethylimide and at this the relative standart deviation (S_r) wasn't more than 0019.

Table 1. – Results of conductometrical determination of 4,5 mg of scandium by solution of β – hydroxyethylimide in presence of different quantities of buffer mixture Briton-Robinson ($P = 0.95$; $x \pm \Delta x$; $n = 5$)

Volume of buffer system, ml	pH of medium	Finded of scandium, mg	Reproducing	Relative standart deviation (S_r)
2.0	2.5	4.51 ± 0.12	0.08	0.017
3.2		4.54 ± 0.17	0.11	0.024
3.6		4.61 ± 0.11	0.09	0.019
4.0		4.65 ± 0.08	0.07	0.015
4.4		4.63 ± 0.09	0.09	0.019
4.8		4.58 ± 0.08	0.11	0.024
5.2		4.61 ± 0.14	0.12	0.026

At conductometrical titration of scandium by β -hydroxyethylimide high- stable complexes in accordance with theoretical preconditions have formed and correspondingly curvers of titration posessed the best by form breaks in point of equivalency at pH 1,81–3,83.

For determination of rightness and reproducung of conductometrical titration of scandium by β -hydroxyethylimide the titration of it's different quantities with parallel repetition of every determination (4 times and more) was carried out results of which are presented in (table 2).

It is shown from data of tables that titration of milligramme quantities of scandium by solution of β -hydroxyethylimide enough right and reproducible results have been obtained and in all cases finding

quantities of scandium were corresponded to it's quantities with the relative standart deviation (S_r) didn't exceeded 0,169 what is witnessed about high precision of elaborated conductometrical method.

Table 2. – Results of conductometrical titration of different quantities of scandium by standart solution of β -hydroxyethylimide ($P = 0.95$; $x = \Delta x$; $V_{\text{common}} = 20,0\text{ml}$)

Introduced of Sc, mg	Finded of Sc, mg	Number of parallel determinations	Reproducing	Relative standart deviation (S_r)
0.56	0.53 ± 0.11	5	0.09	0.169
1.12	1.15 ± 0.09	5	0.11	0.073
2.24	2.25 ± 0.09	4	0.16	0.064
2.80	2.79 ± 0.08	5	0.17	0.061
3.92	3.96 ± 0.08	5	0.18	0.045
5.60	5.62 ± 0.07	5	0.22	0.039
9.52	9.54 ± 0.06	5	0.25	0.026

With aim of determination of the selective degree the influence of some cations on determination of scandium has been investigated. It was shown that Th (IV), Fe (III), Zn, In and U (IV) in any ratios have influenced on Sc determination but Na^+ , K^+ (1:500) Mn^{2+} (1:100); Cd (1:50), Bi^{3+} (1:25), Zn^{2+} , Ti^{4+} (1:1), Ni^{2+} , Al^{3+} , (1:5) didn't influenced on it's determination.

Conclusion

The conductometrical method of determination Sc (III) with using of new organic reagent β -hydroxyethylimide was elaborated. It was shown

that titration of milligramme quantities of Sc (III) by solution of β -hydroxyethylimide an enough right and reproducible results have been obtained and in all cases finding quantities of Sc (III) at analysis different objects were corresponded to it's introduced quantities and at this the relative standart deviation (S_r) didn't exceeded 0.169 what is witnessed about high precision of the elaborated conductometrical method and elaborated method by it's metrological parameter don't yield to known conductometrical methods of determination ions of different metals.

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SENSOR FOR MORITORING OF CARBON II IN COMPOSITION GASES OF AVTOTRANSPORT MEANS

Abstract: In this article results of elobaration of selection sensor for mortitoring of Co in erhawust gases of transport means are present. Programm of sensor testing was incheded carring of special experiments connecting with determination of time, dynamical and gramatal characteristics and also readiness determination of degree of it`s selecting and stability of it`s work. Tests were carried and in general and explatational regime.

Keywords: sensor, selectivity, catalost, exhaust gase, carbon monoxide, sensor`s feeding, gramatal characheristics.

In constructive plane the thermoctaytical sensor for selective determination of cocontent in exhaust gases of transport means consists from two sensible elements and resistors inchding in noctobal sh-eme. Both sensible elements are in reactor cell. The analysch gaseans mixture is fetched up on sensible element and heated before corresponding temperature containing catalyst (1–3).

At fetching up of analysed on catalyst of measuring element the full oxidation of mixture consisting from CO and H₂ has carried out: but only H₂ is oxy-dired on catalyst of compensating sensible element. In result of this appering signal of sensible measuring element proportionate to total consentration CO and H₂, but signal of sensible compensating element was proportionate to hydrogen content. In optimal conditions on both sensible elements hydrocarbons practically didn`t oxidized. In result difference of signals of measuring and compensating element is proportionate to precise concentration of CO in mixture.

To tests were undergone samples of thermocntalytical sensors working in composition of tressfered avtomatical analyzators using for control of CO

contant in exhaust. Programm of sensor testing has conchected the carring and special experiment connecting with determination of time; dynamical and gradnatcharecteristics and also exponsure of degree of it`s selectivity and stability hring of work. Tests were carried and in usual and operational regimes.

Value of signal and selectivity of thermonotalotical sensor have been temperature of catalyst surface of sensible elements of sensor. Increasing of temperature pd sensible elements canded to oxidation of CO on the surface of catalyst of compensating element what canded to decreasing of usefull signal of sensor by determinate component. Decreasing of catalyst temperature correspondely has decreased it`s activity in measureing sensible element of sensor. This increasing or decreasing of temsion feeding is accompanied by decreasing of value of positive analytical signal of sensor. IN fluence of temsion feeding on the sensor`s signal has been investigated in following conditions: temperature –20+20 c; pressure of gase phase 730+10 mmm, c.; humidity of environment 60–70%. In tests standart mixture with content of CO 25 val% was used. The obtained results are present in table 1.

Table 1. – Dependence of analytical signal TKS-CO from feeding tension of sensor (content of CO-2,5 vol% n=5; P=0,95)

Tenzion, V	Signal of Sensor mV		
	$X \pm \Delta x$	S	$S_r * 10^2$
1,5	12,6±0,4	0,21	2,2
1,8	29,7±0,6	0,32	1,1
2,0	44,4±0,5	0,40	1,1
2,2	38,5±0,6	0,21	0,9
2,4	33,1±0,5	0,40	1,4
2,5	25,4±0,5	0,30	1,3

From data of table 1 it is shown that the highest signal of sensor (37,7 mV) was observes at feeding tension 2, OV and this reason all following test were carried and at 2.0 V.

Experiments by determination of dinamical band of registering device. Results of determinati-

nation of dynamical characteristics of thermocatalytical sensor have been carried and at continnous whroting of diagram band of registering device. Results of determination of dynamical characteristics of thermocataltical sensor at CO concentration 5,0% are presented in table 2.

Table 2. – Dinamical characteristics of sensor on Carbon oxide (D)

$T_{0,1}$ – time of beginning of registratio	$T_{0,65}$ – time, s	$T_{0,9}$ – time of readings fixing	T_p – full summary time of readings
1	4	7	9
1	5	7	9
2	4	7	9

As shown from data of taller at elaboratch sensor ($t_{0,1}$ 1–2s $t_{0,65}$)– didn `t more than 5s; $t_{0,9}$ =7,5 md lower and at dis 9s.

The presented data have shown the possibility of expressal determination of CO by elaborated sensor.

Dependence of useful analytical signal sensor from concentration of determined component in

mixture was investigated in interval of CO concentration 0.10–10.00v%. Experments were carried and by diaposone of measure was characterized by 10 values:5 at direct and 5 at zeverse cyeks of concentration measures.

It was determined that in investigated interval of values the dependence of signal TKS-CO from CO concentration has anrectilines character (talls).

Table 3. – Results of determination dependence of signal TKS-CO from CO concentration in mixture (n=5; p=0.95)

№	Concentration of CO in mixture, v%	Signal of sensor m V		
		$X \pm \Delta x$	S	$S_r * 10^2$
1	2	3	4	5
1	0,1	2,2±0,1	0,08	3,6
2	0,5	11,1±0,2	0,16	1,4
3	1,0	22,2±0,2	0,16	0,7
4	1,5	33,3±0,3	0,24	0,7
5	2,0	44,4±0,3	0,24	0,5
6	2,5	55,5±0,3	0,24	0,4
7	3,0	66,6±0,4	0,32	0,5

1	2	3	4	5
8	4,0	88,8±0,6	0,48	0,5
9	5,0	111,7±0,5	0,40	0,4
10	6,0	133,2±0,8	0,64	0,5
11	7,0	155,4±0,9	0,72	0,5
12	8,0	177,6±0,8	0,64	0,4
13	9,0	199,8±0,8	0,64	0,3
14	10,0	222,5±0,8	0,64	0,3

It is known that one of important characteristics of sensors is stability of signal in time. Control of stability of TKS-CO working was carried and at usual conditions of testing and continuous working as sen-

sor during 30 by passing analysed mixture consisting from CO (1.0 v%) and air.

Results by determination of stability of termocatalytical sensor working at determination of CO are presented in table 4.

Table 4. – Results by determination of stability of work termocatalytical sensor TKS-CO at determination of CO (n=5; p=0,95)

Time, h	Values of parameters of gas medium		Signal of sensor.nV.		
	Temperature, C	P, mm.ms	X±Δx	S	Sr*10 ²
1	20,5	735	22,3±0,3	0,24	1,1
24	20,5	730	21,7±0,4	0,32	1,5
96	20,0	735	21,9±0,4	0,32	1,5
120	20,5	735	22,5±0,5	0,40	1,8
240	20,0	735	22,8±0,3	0,24	1,1
480	20,0	730	21,6±0,5	0,40	1,9
960	20,5	735	22,5±0,4	0,32	1,4
1000	20,5	735	21,3±0,4	0,32	1,5
1500	21,0	735	21,9±0,3	0,24	1,1
2000	21,0	730	21,5±0,6	0,48	2,2
2500	20,0	730	22,6±0,5	0,40	1,8
3000	20,5	735	21,8±0,6	0,48	2,2

As shown from data of table 4 the value of signal from sensor during reglamentatch interval of time was stability retained change of value of antsihe signal during reglamentated interval of time (s tg) was valid according to GOS713320–81. The limit value of this parameter determined by relation (1)

$$\Delta tg = (U_{p_{max}} - U_{p_{min}}) 100 / U_{sk} \quad (1)$$

Where stg-limit of admitted changing of outside signal during reglamentated interval of time: U_{max} – maximal and minimal of signal divergence. U_{min} – scale of derive (KSP 0–50mV). According to GOST 13320–81 sensor is considered of tests if at this inequality $st < is$ observed.

Results of calculations have shown that value stg during of reglamentated interval of time was equal 1,5% what is satisfied to demands to gaso-analyses on excust gases what has allowed to suppose that elaborated sensor on CO concentration is considered as sustained of tests.

Selectivity of work of elaborated by CO was determined in the presence of hydrogen, vapors of benzene, methane, diesel fuel, vapors of water and carbon dioxide which are presented with CO in composition smoke, exhaust and technological gases of motors of inner combustion. Results are presented in table 5.

Table 5. – Results of selectivity, determinate of work sensor
TKS-CO at determination of carbon oxide (II) (n=5; p=0,95)

Introducent of gas mixture, V%	Determinend Carbon oxide (II) V%		
	$X \pm \Delta x$	S	$Sr * 10^2$
CO(1,60)+air	1,64±0,01	0,01	0,5
CO(1,60)+H ₂ (2,00)+air	1,68±0,03	0,02	1,4
CO(1,60)+ C ₄ H (2,00)+air	1,62±0,02	0,02	1,0
CO(1,60)+ disel fennel's (2,00)+air	1,65±0,04	0,03	1,9
CO(1,60)+ benz.(2,00)+air	1,61±0,03	0,02	1,5
CO(1,60)+ H ₂ O(2,00)+air	1,63±0,01	0,01	0,5
CO(1,60)+ CO ₂ (2,00)+air	1,62±0,02	0,02	1,0

As shown from data of table elaborated sensor has allowed selectively to determine CO in multgeompacent gas-air mixture where simultanconsly with CO there are hydrogen teams of hydrocarbonsb benzenes and, carbon dioxide, steams of water and methane (natural gas). Also to such mixture gaseons heating systems, exhanst gases fengines of internal combustion; atmospherical air of gas-refuel stations.

On the baze of carring and ivvestigation it is os- sible to conchide that elabroted sensor is settable for continous avtomatical controle of CO content in wide intervals of it`s concentrations in exhaust and technological gases. This sensor can towork continous regine in complect with avtomatical gas-analyzer on exhaust gases.

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USING THE POSSIBILITY OF THE SYNCHRONOUS MOTOR COMPENSATION IN THE PRODUCTION PROCESSES WITH SYNCHRONOUS AND INDUCTION MOTORS

Abstract: The peculiarity of using the possibilities of possibilities synchronous power compensation by high-power synchronous and induction motors in production processes has been substantiated. The observations have been carried out for the case of n induction and m synchronous motors connected to the same busbar of the high-voltage substation. An algorithm to determine the reactive power required for the operation of induction motors and, in case of generating that power, a method for studying the operation modes of synchronous motors have been developed. An algorithm for the optimal distribution of the reactive load between the synchronous motors has been proposed. The method proposed gives an opportunity to ensure such a value on the substation busbar, at which $\cos\varphi = 1$ is independent of the load of synchronous and induction motors.

Keywords: compensation, reactive power, optimal distribution, synchronous motor, power factor, loading.

Introduction. The structure of electric loading in power-intensive productions is multi-character which conditions the application of powerful synchronous

electric drives and mechanisms with induction motors. The combined usage of synchronous and induction electric drives in the same technological process

gives an opportunity to economize on power consumption due to the reduction of losses in transmitting the reactive power and developing an automated system for regulating the excitation system of synchronous motors which will allow to ensure a maximum of the power factor and efficiency coefficient (EC) of the whole power system of the enterprise.

Synchronous motors have two main advantages as compared with the induction ones: they operate in the mode $\cos\varphi = 1$ and even supply reactive power to the net, as well as ensure a larger loading capacity as the moment value depends on the voltage value in the first degree ($M \equiv U$) [2]. At high powers it predetermined their application as a drive of reciprocating compressors, air blowers, hydraulic pumps, crushers, ball mills, etc. High-power synchronous motors (0.5 ... 2 MWt) are usually made to be salient-pole, high-voltage (higher than 1kV) and slow-speed ($p > 1$), allowing to use them in complex and labour-consuming production processes.

High-power induction motors have a low price, are simple and reliable in maintenance. The main disadvantage is that $\cos\varphi < 1$ all the time and they develop a moment, depending on the network voltage in the second degree ($M \equiv U^2$) [2]. At present, the power system is rather powerful and the voltage change in the network does not exceed the permissible values, therefore the main disadvantage of induction motors is conditioned by the consumption of reactive power ($\cos\varphi$).

The investigation of different power-intensive production processes using synchronous and induction electric drives simultaneously has shown that the statement of the problem on the rationalization of using on them electric power by applying the compensating ability of synchronous motors is completely relevant [2; 3].

However, at changing the loadings, the reactive power of the compensating devices changes, leading to the violation of the assigned degree of the power factor on the busbar of the supply network. Taking into account that in power-intensive production enterprises different types of synchronous

and induction motors are used, it becomes possible to compensate the reactive power. At that, it is expedient to consider the operation modes of each motor and, only depending on them, regulate the excitation of synchronous motors aimed at determining the required power factor.

At present, there are a number of scientific works devoted to the issues of developing methods for regulating the excitation of synchronous motors [4–6]. However, there is no sufficient technical and economic substantiation, ensuring the improvement of power indices. Based on this, the goal of the work is formulated.

The goal of the present work is to develop a calculation method for ensuring the compensation of the reactive power of production mechanisms, containing synchronous and induction motors.

The method substantiation. Let us consider a case when the induction and synchronous motors are connected to the same busbar of high-voltage substation (Figure 1).

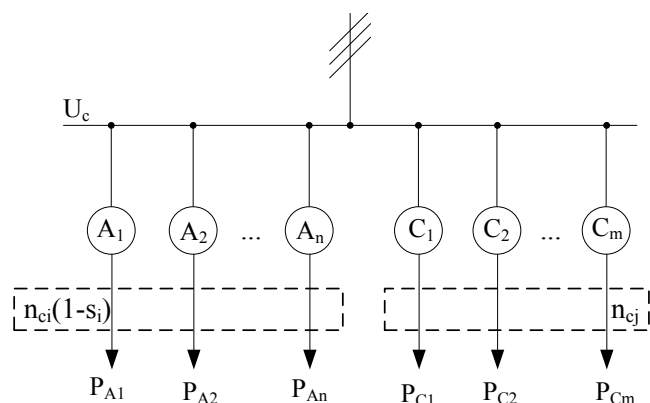


Figure 1. Induction and synchronous motors connected to the same network

In (Fig. 1), the induction and synchronous motors are introduced which are connected to the supply line and have a different degree of loading. It should be noted that at the given moment, the motors have different values of the power factor and EC, depending on the loading of all motors and the excitation currents of synchronous motors. Under such conditions, the problem is reduced to determining the mode of synchronous motors at which a

complete compensation of the reactive power takes place regardless of the loading values of all motors.

Determining the required value of the reactive power for induction motors. To determine the value of the required reactive power $\sum_{i=1}^m Q_{Ai}$, it is necessary to determine the dependences of the EC (η_{Ai}) and the power factor ($\cos\varphi_{Ai}$) of all induction motors, depending on the power at the output end of the given induction motor shaft P_{Ai} .

The reactive power of the i -th induction motor at the given loading is:

$$Q_{Ai} = m_1 U_c I_{A1i} \sqrt{1 - \cos^2 \varphi_{Ai}},$$

where m_1 is the number of phases; $\cos\varphi_{Ai}$ – the power factor at the given loading:

$$\cos\varphi_{Ai} = \frac{P_{Aoi}}{m_1 U_c I_{A1i}}.$$

The efficiency coefficient is:

$$\eta_{Ai} = \frac{P_{Ai}}{P_{Aoi}} = \frac{P_{Ai}}{P_{Ai} + P_{ACi} + P_{AE1i} + P_{AE2i} + P_{Amexi} + P_{Adopi}},$$

where P_{Aoi} is the power on the stator terminals of the i -th induction motor; P_{Ai} – the useful power on the shaft of the i -th motor; P_{ACi} – the magnetic losses in the stator steel of the i -th motor; P_{AE1i} , P_{AE2i} – the losses in the stator and the rotor windings of the i -th motor respectively; P_{Amexi} – the mechanical losses of the i -th induction motor; P_{Adopi} – the additional losses of the i -th induction motor.

The values P_{ACi} , P_{Amexi} , P_{Adopi} are determined by to the recommendations [7]. In accordance with the energy diagram and T-form equivalent scheme of the induction motor, a system for equations of the electromagnetic moment of the induction motor M_{AEMi} can be made up (1):

$$\left\{ \begin{array}{l} M_{AEMi} = \frac{pm_1 U_c^2 \frac{r'_{2i}}{s_i}}{2\pi f_c \left(r_{1i} + c_{1i} \frac{r'_{2i}}{s_i} \right)^2 + (x_{1i} + c_{1i} x'_{2i})^2}, \text{ where } n_{ci} \\ M_{AEMi} = \frac{P_{AMXi}}{2\pi(1-s_i)n_{ci}} \end{array} \right.$$

is the synchronous velocity of the i -th motor; r'_{2i} , x'_{2i} – the reduced active and inductive resistances of the

rotor winding of the i -th induction motor; $c_{1i} = 1 - \frac{x_{1i}}{x_{mi}}$ – the coefficient of reducing the T-form equivalent scheme to the Γ -form equivalent scheme of the induction motor; P_{AMXi} – the full mechanical power of the i -th motor.

$$P_{AMXi} = P_{Ai} + P_{Amexi} + P_{Adopi}$$

The solution of the system (1) is carried out by the iteration method in the range $(0,05...1,2)s_{Ni}$ and M_{AEMi} and s_{Ni} are defined, allowing to determine the currents of the stator I_{A1i} , the rotor I_{A2i} and the losses in these windings by using the equivalent scheme of the induction motor.

By plotting the characteristics $\cos\varphi_{Ai} = f(P_{Ai})$, $\eta_{Ai} = f(P_{Ai})$, these functions for each motor can be obtained by interpolation which will allow to determine the power factor and the EC at different loadings of the i -th induction motor without further additional calculations.

The required total reactive power at the given loading of all induction motors will be:

$$Q_{A\text{e}} = \sum_{i=1}^n Q_{Ai}.$$

Determining the operation modes of synchronous motors, at which the required value of the reactive power is ensured.

The required value $Q_{C\text{e}}$ should be distributed among all the loaded synchronous motors proportionally to the rated reactive power of each synchronous motor.

The reactive power which can be generated by each synchronous motor at a rated load is determined as follows:

$$Q_{CNj} = m_1 U_{cj} I_{CNj} \sqrt{1 - \cos^2 \varphi_{CNj}}.$$

The reactive power which should be ensured by the given synchronous motor will be:

$$Q_{Cj} = \frac{\sum_{i=1}^n Q_{Ai}}{\sum_{j=1}^m Q_{CNj}} Q_{CNj},$$

To generate the required reactive power Q_{Cj} by each of the synchronous motors, it is necessary to determine the value of the excitation current at

which both the reactive and active powers for the given motor is ensured. Based on this, first of all, it is necessary to determine the consumed active power, the EC, and the power factor of each synchronous motor according to its energy diagram.

The efficiency coefficient is:

$$\eta_{Cj} = \frac{P_{Cj}}{P_{Coj}} = \frac{P_{CEMj} - P_{Cmexj} - P_{Cdoj} \left(\frac{I_{C1j}}{I_{C1Nj}} \right)^2}{m_1 U_{Cj} I_{C1j} \cos \varphi_{Cj}},$$

where P_{Coj} is the active consumed power; P_{Cj} – the useful active power on the shaft; P_{Cmexj} – the mechanical and ventilation losses; P_{Cdoj} – the additional losses at the rated load; I_{C1j}, I_{C1Nj} – the running and rated current of the stator winding; P_{CEMj} and $\cos \varphi_{Cj}$ – the electromagnetic power and the power factor of the j -th synchronous motor respectively determined by the solution of the equation system (2) by iteration in the range $\cos \varphi = 0,78 \dots 0,99$. We determine P_{CEMj} and $\cos \varphi_{Cj}$.

$$\left\{ \begin{array}{l} P_{CEMj} = Q_{Cj} \frac{\cos \varphi_{Cj}}{\sqrt{1 - \cos^2 \varphi_{Cj}}} - \frac{(m_1 r_{aj} I_{C1pj})^2}{1 - \cos^2 \varphi_{Cj}} - P_{Ccj} \\ P_{CEMj} = P_{Cj} + P_{Cmexj} + \frac{P_{Cdoj} (I_{C1pj})^2}{(1 - \cos^2 \varphi_{Cj}) (I_{C1Nj})^2} \end{array} \right\}, \quad (2)$$

where P_{Ccj} is the losses of the steel determined according to [1], preliminarily calculating the losses P_{Cmexj} , P_{Cdoj} , as well as the power losses in the stator winding P_{CENj} and the losses on excitation P_{CfNj} at rated load of the j -th synchronous motor. The stator current I_{C1j} , its reactive I_{C1pj} and active I_{C1aj} components are determined according to the vector diagram of the synchronous motor.

The active consumed power of the j -th synchronous motor is determined:

$$P_{Cj} = \frac{Q_{Cj}}{\operatorname{tg} \varphi_{Cj}}.$$

Determining the optimal excitation modes of synchronous motor.

To determine the optimal excitation modes, first of all, it is necessary to establish the economically most expedient distribution of the reactive power

among m synchronous motors. Economical distribution of the reactive power is ensured based on the following considerations:

– The reactive power Q_{Ae} required for compensating the reactive power of the induction motors and the own needs of synchronous motors should be distributed among the motors so that the total losses of active power (depending on the generation and distribution of the reactive power) should be minimal;

– For the systems, consisting of n induction and m synchronous motors, the most beneficial distribution of the reactive load among the synchronous motors will be in the case of the minimum sum of relative active losses, at generating the reactive power $\Delta_1, \Delta_2, \dots, \Delta_j, \dots, \Delta_m$,

$$\Delta_j = \frac{\Delta P_{Cj}}{Q_{Cj}}.$$

ΔP_{Cj} is the losses of the active power of the j -th synchronous motor for generating reactive power.

The required value Q_{Cj} of each motor is determined by solving the problem of optimization whose mathematical formulation has the following form:

$$\left\{ \begin{array}{l} \sum_{j=1}^m \Delta_j = \Delta_1 + \Delta_2 + \dots + \Delta_m \rightarrow \min \\ Q_{Ae} = Q_{C1} + Q_{C2} + \dots + Q_{Cj} + \dots + Q_{Cm}, \\ \eta_{C1} \geq \eta_{CN1}, \dots, \eta_{Cj} \geq \eta_{CNj}, \dots, \eta_{Cm} \geq \eta_{CNm} \end{array} \right\} \quad (3)$$

By determining the optimal value of the reactive power of each motor, the excitation current at the given load can be determined [8]:

$$I_{fj} = \sqrt{\frac{1 + \beta_j^2 x_{dsj}^2 \cos^2 \varphi_{Cj} + \gamma_j^2 x_{dsj}^2 \sin^2 \varphi_{Cj} + 2\gamma_j x_{dsj} \sin \varphi_{Cj}}{1 + x_{dsj}^2 + 2x_{dsj} \sin \varphi_{Cj}}},$$

where $\beta_j = \frac{P_{Cj}}{P_{CNj}}$, $\gamma_j = \frac{Q_{Cj}}{Q_{CNj}}$ are the load coefficients of synchronous motors; x_{dsj} – the saturated value of the synchronous inductive impedance along the axis d of the j -th synchronous motor.

To determine the synchronous inductive impedance, considering the saturation, it is necessary to make use of the vector diagram of the synchronous

motor [7] – the “normal” characteristics of the idle run [1].

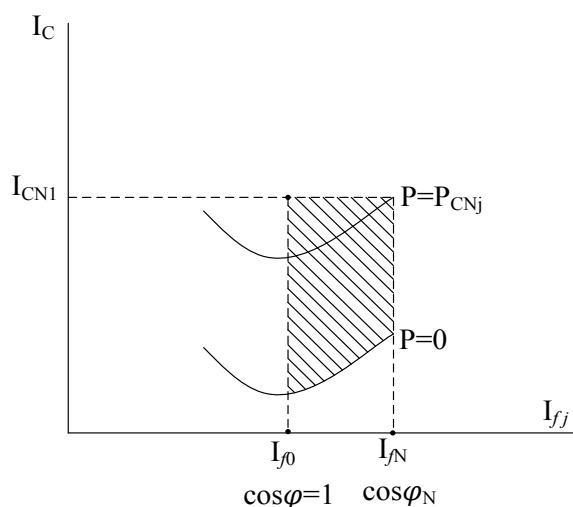


Figure 2. Operation area of the synchronous motor

It should be mentioned that the range of the change in the active and reactive powers is predetermined by the nominal data of the motor which are to be considered at developing an automated regulation system.

(Fig. 2) introduces the range of the change in the excitation current and the stator current of the given synchronous motor.

Conclusions

The method proposed allows to ensure the total compensation of the reactive power at the given enterprise, i. e. a value of the total current on the substation busbar is ensured at which $\cos\varphi = 1$, regardless of the load value on the induction and synchronous motors.

The method allows to determine the value of overloading (increasing the load) of the synchronous motor at the expense of underloading of the given motor by reactive power.

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