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COMPREHENSIVE HOMOGENIZATION OF LIQUID FUEL. (Dynamic Mixing and Homogenization of Liquid Fuel and Complex Fuel Blends, as well as the Formation of Gasified (Compressible) Fuel Mixtures According to the Methodology of Hryhorii Baranovskyi)

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Abstract

The article examines the technology of dynamic mixing and homogenization of liquid fuels and complex fuel blends developed according to the methodology of Hryhorii Baranovskyi. It presents an original device for sequential dynamic homogenization directly within the fuel pipeline, enabling the formation of homogeneous micro and nanoscale fuel emulsions as well as gasified (compressible) fuel mixtures. Particular attention is given to the creation of special turbulent hydrodynamic conditions that ensure homogenization without disturbing the chemical and physical equilibrium of the fuel components.

The paper describes the structural features of the device, including an accelerating hydrodynamic section, a vortex generator, and a turbulence amplification section, as well as the principles of sequential fuel-flow homogenization under high pressure. The versatility of the technology is emphasized through its applicability to a wide range of fuels, including diesel fuel, biofuels, ethanol and methanol-based blends, and synthetic fuels produced from recycled plastic waste and used tires.

Special attention is devoted to the thermodynamic and environmental effects of homogenized fuel, including faster and more efficient combustion, reduction of soot and nitrogen oxide emissions, and lower energy consumption of high-pressure fuel systems. The article also highlights the compact design, industrial applicability, and ease of integration of the device into existing internal combustion engines and other thermodynamic systems without significant modifications.
Keywords: *Dynamic mixing; Compressible fuel mixture; Homogenization; Dynamic homogenization process; Sequential in-flow homogenization; In-line pipeline homogenization process; Homogenization by turbulence level; Special turbulent hydrodynamic conditions; Original device for dynamic homogenization*

The Necessity of the Homogenization Process.

Any type of liquid hydrocarbon fuel, and especially fuel compositions based on liquid hydrocarbon fuels, loses its homogeneity during storage, resulting in the formation of clots and sediment, primarily at the bottom of storage tanks containing the fuel or fuel blend.

Figure 1. *Device for Dynamic Mixing and Homogenization of Liquid Fuel and Fuel Blends, as well as for the Formation of Gasified (Compressible) Fuel Mixtures. The image shows a device with a working diameter of 40 mm and a capacity of 1000 liters per hour*

Figure 2. *Device for Dynamic Mixing and Homogenization of Liquid Fuel and Fuel Blends, as well as for the Formation of Gasified (Compressible) Fuel Mixtures*

Figure 3. *Industrial installation for the homogenization of liquid fuels ranging from Diesel Fuel No. 6 (heavy fuel oil) to Diesel Fuel No. 2, as well as for the micro-miniaturization and optimization of spray dispersion of biofuels, methanol, ethanol, and kerosene produced from the recycling of plastic waste and automotive tires. Despite its compact dimensions, the installation has a processing capacity of 1000 liters per hour*

Ensuring homogeneity is even more problematic for various types of synthetic liquid fuels, especially those produced from the recycling of plastic waste or used automotive tires. Such fuels contain numerous additional contaminants uncommon in conventional fuels, such as formaldehyde, which further increases the necessity of homogenization, at least before injection into the combustion chamber or during the combustion process itself.

The described non-uniformity can be eliminated most effectively and conveniently through the application of a homogenization process using an innovative dynamic homogenization device that performs homogenization directly within the pipeline through which the fuel or fuel blend flows.

The author of this publication also emphasizes the exceptionally important role of continuous interaction with end users of these technologies, carried out by innovation specialist Hryhorii Baranovskyi, as well as the software-based methods and mobile applications developed by him for coordinating, in real time, the proportional interaction between technological capabilities and the increasingly complex demands of the consumer market.

Such an original coordination system makes it possible to accurately determine the required operational characteristics and significantly reduce the time necessary for implementing innovative technologies in the modernization of premium automobiles, including modern PORSCHE vehicle models.

Dynamic Homogenization Process

At the outset, a brief overview should be given of the proposed technology, its features, and the novelty of this integrated technological approach developed according to the principles of Hryhorii Baranovskyi.

The device for the dynamic homogenization of liquid fuels and fuel blends consists of an accelerating hydrodynamic section connected coaxially to a second hydrodynamic section with an integrated vortex generator, which in turn transitions into a hydrodynamic turbulence amplification section connected to the inlet of the high-pressure pump of an internal combustion engine.

Within the device, the liquid fuel or fuel blend undergoing homogenization is divided into two flows. The first flow (60% of the total flow), under a pressure of at least 3 bar (45 psi), enters the accelerating hydrodynamic section, where acceleration occurs through systems that initiate coaxial Bernoulli effects. The second flow (40% of the total flow), also under a pressure of at least 3 bar (45 psi), enters the second hydrodynamic section coaxial to the first.

The device performs a dynamic process of sequential homogenization of the liquid fuel or fuel blend flow. At the first stage, homogenization is achieved through turbulence-level homogenization within the pipeline. Such a process is absent in all previously known homogenization devices and technologies and represents one of the key innovative aspects of the technology, confirmed in the fundamental intellectual property documents of Hryhorii Baranovskyi, the developer of the technological elements.

After this stage, the homogenized flow of liquid fuel or fuel blend is transformed into a hydrodynamic vortex tube by means of the integrated vortex generator and directed toward the high-pressure pump of a diesel or other internal combustion engine operating at pressures from 2000 to 3000 bar (29,000––43,500 psi). There, the second stage of dynamic in-flow homogenization takes place, reducing the particle size in the homogenized flow to less than one micron. According to the key parameters of the flow, the resulting liquid becomes equivalent in properties to a homogeneous nanoscale fuel emulsion.

A similar system can also operate in the fuel lines of boilers, burners, turbines, and other thermodynamic devices and equipment.

The homogenization process occurs in less than one second and does not disturb the natural interactions within the homogenized liquid fuel or fuel blend. The process takes place at a stable temperature or, under certain ratios, with a reduction in the temperature of the combustible liquid or fuel mixture.

The entire dynamic homogenization process is achieved through the creation of special turbulent hydrodynamic conditions within the fuel or fuel blend flow, without disrupting the chemical and physical equilibrium between its components.

Advantages of the dynamic homogenization process proposed by Hryhorii Baranovskyi compared to existing technologies:

- Existing technologies do not include a turbulence-level dynamic homogenization stage, which means they cannot perform homogenization directly within the fuel pipeline of an internal combustion engine;
- The second stage of the homogenization process takes place under pressure at least twice as high as that required for homogenization at the nanoscale particle level;
- The particle sizes (globules) in the liquid fuel or fuel blend homogenized using the proposed technology are uniform within the range of 70–120 nanometers and do not tend to agglomerate, whereas existing technologies produce particle size variations exceeding a factor of ten, ranging from 0.2 to 2 microns;
- All stages of dynamic homogenization can be carried out directly in the fuel pipeline of an internal combustion engine, for example between the fuel pump and the high-pressure pump, without requiring special modifications to the engine design (the same applies to other types of thermodynamic equipment);
- During the dynamic homogenization process, the temperature of the homogenized liquid fuel or fuel blend does not increase;
- The dynamic homogenization device allows additional components to be introduced simultaneously during homogenization, such as water, methanol, ethanol, or synthetic kerosene;
- The dynamic homogenization device has minimal dimensions, is more convenient to operate than existing systems, and provides optimal conditions for installation and maintenance;
- The device for dynamic homogenization of liquid fuels and fuel blends is significantly less expensive than existing equipment designed for the same purpose.
- The device can also be used for technological homogenization before introducing fuel or fuel blends into industrial equipment for the production of other hydrocarbon products.

As can be seen from the presented photographs, the dimensions of the device are extremely compact in relation to its performance capacity (the images show devices with a throughput of 1000 liters per hour).

Figure 4.

Original Device for Dynamic Homogenization

Based on the concept developed by Hryhorii Baranovskyi, a device for the dynamic homogenization of liquid fuels and fuel blends has been designed, manufactured, and repeatedly tested.

All elements and components of the device are produced using standard CNC machining equipment without the use of specialized technologies or special cutting tools.

Stainless steel is used as the structural material, allowing the installation of the device and associated systems in environments with increased corrosion exposure, such as marine vessels.

The device is extremely compact, with dimensions that allow it to be integrated into virtually any internal combustion engine, including both stationary engines (such as marine engines) and engines installed in vehicles of all types.

Figure 5.

Figure 6.

The device does not require any additional elements or components for operation and can be installed directly in the fuel pipeline of an internal combustion engine, between the fuel pump and the high-pressure pump.

All inlet and outlet connection elements of the device are standardized. Installation of the device on an internal combustion engine does not require special training, tools, or equipment.

The device contains no moving parts and can be manufactured in any required dimensional scale.

The device can be produced using standard CNC manufacturing equipment, and its production, assembly, and quality control do not require specialized technologies, materials, or tools.

Figure 7.

Thermodynamic Effect of Using Homogenized Fuel (Produced by the Dynamic Homogenization Device).

After homogenization, the fuel burns uniformly, without the formation of local zones containing larger dispersion fractions after injection.

As a result, the combustion process proceeds 35–40% faster, and efficient heat extraction is accelerated in the same proportion (the results were confirmed in more than 300 test cycles using a modern production diesel engine with a displacement of 2.5 liters).

The homogenization technology operates equally effectively in both standard engines and engines equipped with exhaust gas recirculation systems.

In the event of unintended water contamination in the fuel tank, dynamic homogenization forms a micro-emulsion within milliseconds before the fuel enters the high-pressure pump, completely eliminating any harmful effects of water contained in the fuel emulsion on engine operation (confirmed in more than 60 test cycles on a modern 2.5-liter production diesel engine).

While maintaining effective engine power, the micro-emulsion significantly reduces soot emissions in exhaust gases (up to 97%) and nitrogen oxide emissions (up to 35%), shortens the complete combustion cycle, and accelerates heat extraction (confirmed in more than 300 full reverse-cycle tests on a modern 2.5-liter production diesel engine).

The use of the homogenization system also makes it possible to achieve the same spray dispersion quality at pressures 35–45% lower than the conventional 1600–2000 bar injection pressure range.

This effect reduces the power consumption required for operating the high-pressure pump and also demonstrates potential energy savings for turbines and turbo-generators operating at injection pressures of 30 bar and above.

Environmental Effect of Using Homogenized Fuel

The use of a dynamic liquid fuel homogenization device in the fuel systems of internal combustion engines significantly reduces the toxicity of exhaust gases and may enable previously manufactured vehicles, including those that have been in long-term operation, to meet modern environmental standards.

Sequential Dynamic Homogenization Process in a Modern Diesel Engine

The device for dynamic homogenization of fuel and fuel blends in a modern diesel engine is installed in the fuel line between the fuel pump and the high-pressure pump.

In this configuration, the fuel flow leaving the fuel pump is divided into two streams. One stream, representing 60% of the total fuel flow, is directed into the central axial inlet of the dynamic fuel homogenization device, while the second stream, representing 40% of the total flow, enters the integrated inlet consisting of four radial channels.

After homogenization, the fuel burns uniformly, without the formation of local zones containing larger dispersion fractions after injection.

As a result, the combustion process proceeds 35–40% faster, and efficient heat extraction is accelerated in the same proportion (confirmed in more than 60 test cycles on a modern production diesel engine with a displacement of 2.5 liters).

The homogenization technology operates equally effectively in both standard engine configurations and engines equipped with exhaust gas recirculation systems.

Sequential Dynamic Homogenization Process in a Modern Gasoline Engine

The device for dynamic homogenization of fuel and fuel blends in a modern gasoline engine is installed in the fuel line between the fuel pump and the high-pressure pump.

In this configuration, the fuel flow leaving the fuel pump is divided into two streams. One stream, representing 60% of the total fuel flow, is directed into the central axial inlet of the dynamic fuel homogenization device, while the second stream, representing 40% of the total flow, enters the integrated inlet consisting of four radial channels.

The homogenization technology operates equally effectively in both standard engine configurations and engines equipped with exhaust gas recirculation systems.

Application of the Dynamic Homogenization Process in Internal Combustion Engines Using Ethanol–Gasoline Fuel Blends

Ethanol, even of high quality, contains a certain amount of water. Before mixing with gasoline, ethanol is a relatively stable substance in which separation of water and alcohol does not occur.

However, an ethanol–gasoline blend is not completely stable, and under certain conditions, such as low temperatures, water may separate from the gasoline–ethanol mixture.

If a dynamic homogenization device is integrated into the engine system, the water separated in the fuel tank from the primary hydrocarbon fraction of the fuel blend is dynamically remixed with the hydrocarbon fractions within the device, transforming the resulting mixture into a micro- or nanoscale emulsion.

The combustion of such an emulsion generally occurs in a stable thermodynamic regime, without detonation and with reduced soot and nitrogen oxide emissions in the exhaust gases.

Application of the Dynamic Homogenization Process in Internal Combustion Engines Using Methanol–Gasoline Fuel Blends

Methanol, even of standard quality, contains virtually no water. Before mixing with gasoline, methanol is a relatively stable substance and, after mixing, generally does not separate from gasoline.

However, methanol–gasoline blends are not completely stable and, under certain conditions such as low temperatures, may tend to form clots or agglomerates.

The combustion of homogenized fuel generally occurs in a stable thermodynamic regime, without detonation and with reduced soot and nitrogen oxide emissions in the exhaust gases.

Application of the Dynamic Homogenization Process in Internal Combustion Engines Using Gasoline and Biofuel Blends (Currently the Most Important and Relevant Application)

Since these thermodynamic systems use fuel blends containing gasoline together with heavier biofuels and various types of viscous combustible biological materials, the formation of clots and agglomerates in such composite fuels occurs more intensively.

If a dynamic homogenization device is integrated into the thermodynamic system, the clots formed under certain conditions in the fuel tanks and consisting of the primary hydrocarbon fraction of the fuel blend are dynamically mixed with the remaining hydrocarbon fractions inside the device, transforming the clotted mixture into a homogeneous system of micro- or nanoscale particles.

The combustion of homogenized fuel generally occurs in a stable thermodynamic regime, without detonation and with reduced soot and nitrogen oxide emissions in the exhaust gases.

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