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GREEN AVIATION FUEL. (Applied developments of fully "green" aviation fuel, the publisher reports. Scientists and engineers have created fuel from "green" hydrogen and captured CO_2)

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Abstract

The article discusses approaches to the development of environmentally friendly aviation fuel based on "green" hydrogen and captured carbon dioxide, as well as the prospects for implementing Sustainable Aviation Fuel (SAF) in the context of aviation decarbonization. Special attention is given to cyclic carbon utilization technologies that enable the production of fuel chemically identical to conventional aviation kerosene without increasing atmospheric carbon concentration.

The article presents the design features and advantages of complex dynamic homogenization technology for hydrocarbon fuel mixtures and emulsions, enabling efficient mixing of components directly within the flow process. Applications of the system in various internal combustion engines, oil refining facilities, and fuel stations are considered.

The study demonstrates that this technology improves fuel mixture uniformity, reduces soot emissions, enhances combustion efficiency, and increases fuel performance while allowing integration without significant modifications to existing engines and industrial equipment.

Keywords: *Aviation fuel; Emulsion of green hydrogen and captured carbon dioxide; Applied developments of environmentally friendly aviation fuel; Fuel that is chemically identical to kerosene but does not increase carbon concentration in the atmosphere; Aviation is one of the most difficult industries to decarbonize; Renewable fuel; A product of a fully circular carbon use cycle; Hydrocarbon fuel mixtures*

Possible Applications of Complex Dynamic Homogenization Technology for Hydrocarbon Fuel Mixtures in Internal Combustion Engines

Design Advantages of the Device for Dynamic Homogenization and Dynamic Formation of a Mixture or Emulsion in the Flow of Its Components.

The device for dynamic online homogenization and dynamic formation of a mixture or emulsion within the flow of its components has minimal dimensions and a simple geometric shape in the form of a regular cylinder (for example, a device with a capacity of 50 gallons of emulsion per hour has a diameter of only 37 millimeters and a total length of only 150 millimeters).

The device can be manufactured in any required scale factor.

Figure 1. *Device for Fuel Mixture Homogenization*

Types of Internal Combustion Engines in Which Complex Dynamic Homogenization Technology for Fuel and Fuel Mixtures Can Be Applied.

The dynamic homogenization system has minimal dimensions and an optimal geometric shape.

The liquid inlets to the system and the outlets for the homogenized liquid are completely standardized; therefore, the dynamic fuel mixture homogenization system can be installed on any internal combustion engine.

Modern engines equipped with a high-pressure pump can be fitted with a dynamic fuel mixture homogenization system without requiring any modifications to the fuel system.

The dynamic homogenization system can be installed both on stationary internal combustion engines and on internal combustion engines used in vehicles.

The dynamic homogenization system may be equipped with an additional system for the formation of two types of fuel emulsions: compressible emulsions and incompressible emulsions.

The dynamic homogenization system enables the efficient introduction of up to eight additional components into the emulsion.

Without modification, the dynamic homogenization system can effectively dissolve combustible gases in the flow of liquid hydrocarbon fuel before injection into the combustion chamber, both in stationary internal combustion engines and in engines installed in vehicles.

Types of Liquid Hydrocarbon Fuels That Can Be Subjected to Dynamic Homogenization.

Any type of liquid hydrocarbon fuel can be processed using dynamic homogenization technology.

Any types of fuel mixtures based on gasoline, all types of diesel fuel, and fuel oil can be processed using dynamic homogenization technology.

Any types of liquid biofuels can be processed using dynamic homogenization technology.

Any types of biological fuel compositions can be processed using dynamic homogenization technology**.**

Dynamic homogenization of fuel without impurities

In liquid hydrocarbon fuels, fuel clumps may form during storage, which can subsequently cause problems with fuel injection and uniform combustion.

The higher the fuel viscosity, the greater the probability of the formation of clumps and other types of fuel non-uniformities.

The dynamic fuel homogenization system is installed in the engine fuel system on the fuel pipeline between the engine fuel pump and the engine high-pressure pump.

As the fuel passes through the dynamic homogenization system, homogenization occurs within the flow according to the turbulence level, after which the process of dynamic homogenization is completed

in the high-pressure pump in terms of volume and dimensional scale within a three-dimensional coordinate system.

The operation of the dynamic fuel homogenization system does not require any additional energy sources or additional structural elements.

The dynamic fuel homogenization system can also be used in homogenization processes and equipment in parallel with fuel recirculation in storage tanks during fuel production and fuel storage at filling stations.

Dynamic homogenization of gasoline-based fuel mixtures

Fuel mixtures based on gasoline, such as gasoline-ethanol mixtures and gasoline-methanol mixtures, may experience the effect of gravitational separation of water from the hydrocarbon portion of the fuel mixture during long-term storage.

The dynamic homogenization system in gasoline engines using a mixture of gasoline and ethanol or a mixture of gasoline and methanol as fuel is installed between the fuel pump and the engine high-pressure pump.

As the fuel mixture, in which water has separated from gasoline, passes through the dynamic homogenization system, homogenization occurs within the flow according to the turbulence level, after which the process of dynamic homogenization is completed in the high-pressure pump in terms of volume and dimensional scale within a three-dimensional coordinate system.

During the homogenization process, water in the form of microdroplets is uniformly distributed throughout the volume of the hydrocarbon fuel mixture, after which the specified mixture is transformed into a micro- or nanoscale emulsion.

According to the test results of the emulsion obtained using the dynamic homogenization system, the soot concentration in exhaust gases is reduced by 97%, while the level and rate of heat release increase by at least 35%.

The installation of the dynamic homogenization system on a gasoline engine does not require any additional original components, and no structural modifications to the engine are required.

Dynamic homogenization of diesel fuel-based mixtures

The preparation of fuel mixtures consisting of diesel fuel and ethanol or methanol is extremely difficult due to the large difference in viscosity between these materials.

The dynamic fuel mixture homogenization system can prepare a high-quality and homogeneous mixture of diesel fuel and ethanol or methanol within fractions of a second, directly in the pipeline and in any required proportion.

The dynamic homogenization system in diesel engines using a mixture of diesel fuel and ethanol or a mixture of diesel fuel and methanol as fuel is installed between the fuel pump and the diesel engine high-pressure pump.

As the fuel mixture, in which water has separated from the fuel, passes through the dynamic homogenization system, homogenization occurs within the flow according to the turbulence level, after which the process of dynamic homogenization is completed in the high-pressure pump in terms of volume and dimensional scale within a three-dimensional coordinate system.

During the homogenization process, water in the form of microdroplets is uniformly distributed throughout the volume of the hydrocarbon fuel mixture, after which the specified mixture is transformed into a micro or nanoscale emulsion.

According to the test results of the emulsion obtained using the dynamic homogenization system, the soot concentration in exhaust gases is reduced by 97%, while the level and rate of heat release increase by at least 35%.

The installation of the dynamic homogenization system on a diesel engine does not require any additional original components, and no structural modifications to the engine are required.

Dynamic homogenization of heavy diesel fuel-based mixtures

The preparation of fuel mixtures consisting of heavy diesel fuel and ethanol or methanol is extremely difficult due to the large difference in viscosity between these materials.

The dynamic fuel mixture homogenization system can prepare a high-quality and

homogeneous mixture of heavy diesel fuel and ethanol or methanol within fractions of a second, directly in the pipeline and in any required proportion.

The dynamic homogenization system in heavy diesel engines using a mixture of heavy diesel fuel and ethanol or a mixture of heavy diesel fuel and methanol as fuel is installed between the fuel pump and the engine high-pressure pump (if such a pump is included in the engine design). If a high-pressure pump is not part of the engine, the dynamic homogenization system is installed on the fuel pipeline after the fuel pump.

As the fuel mixture, in which either water has separated from the heavy diesel fuel or clumps of heavy diesel fuel have formed, passes through the dynamic homogenization system, homogenization occurs within the flow according to the turbulence level, after which the process of dynamic homogenization is completed in the high-pressure pump or in the injectors in terms of volume and dimensional scale within a three-dimensional coordinate system.

During the homogenization process, water in the form of microdroplets is uniformly distributed throughout the volume of the hydrocarbon fuel mixture, after which the specified mixture is transformed into a micro- or nanoscale emulsion.

According to the test results of the emulsion obtained using the dynamic homogenization system, the soot concentration in exhaust gases is reduced by 97%, while the level and rate of heat release increase by at least 35%.

The installation of the dynamic homogenization system on an engine using heavy diesel fuel does not require any additional original components, and no structural modifications to the engine are required.

Dynamic homogenization of fuel oil-based fuel mixtures

The preparation of fuel mixtures consisting of fuel oil and ethanol or methanol is extremely difficult due to the large difference in viscosity between these materials and because of the non-uniformity of fuel oil.

The dynamic fuel mixture homogenization system can prepare a high-quality and homogeneous mixture of fuel oil and ethanol or methanol within fractions of a second, directly in the pipeline and in any required proportion.

In cases of an especially high level of fuel oil non-uniformity, the structural simplicity of the system allows its staged use with the formation of a gradual (step-by-step) sequential process for preparing a fuel oil-based fuel mixture.

The dynamic homogenization system in large engines using a mixture of fuel oil and ethanol or a mixture of fuel oil and methanol as fuel is installed between the fuel pump and the subsequent element of the engine fuel system.

As the fuel mixture, in which water has separated from the fuel oil or in which clumps and lumps have formed within the fuel oil flow, passes through the dynamic homogenization system, homogenization occurs within the flow according to the turbulence level, after which the process of dynamic homogenization is completed in the nozzle or injector in terms of volume and dimensional scale within a three-dimensional coordinate system.

During the homogenization process, water in the form of microdroplets is uniformly distributed throughout the volume of the hydrocarbon fuel mixture, after which the specified mixture is transformed into a micro- or nanoscale emulsion.

According to the test results of the emulsion obtained using the dynamic homogenization system, the soot concentration in exhaust gases is reduced by 97%, while the level and rate of heat release increase by at least 35%.

The installation of the dynamic homogenization system on the specified engine does not require any additional original components, and no structural modifications to the engine are required.

Preparation of fuel mixtures at oil refining facilities

At oil refining facilities, the system for dynamic homogenization of hydrocarbon liquids must include a high-pressure pump operating on the principle of a diesel engine high-pressure pump.

The specified integrated system can be used as a pump for mixing fuel mixture components or as a system ensuring fuel mixture recirculation in storage tanks.

The installation of such systems can be carried out on existing equipment without redesign or modernization; however, in this case, the system must include pumps for supplying mixture components into the system.

One of the possible applications of the dynamic homogenization system at oil refining facilities is the formation of a fuel mixture during the supply of fuel mixture components into a transport tank. Since the preparation time of the fuel mixture within the system is only fractions of a second, preparing the mixture during transfer into a transport tank eliminates the need for special storage tanks for fuel mixtures at the facility.

Preparation of fuel mixtures at fuel stations

At fuel stations, the system for dynamic homogenization of hydrocarbon liquids must include a high-pressure pump operating on the principle of a diesel engine high-pressure pump.

The specified integrated system can be used as a pump for mixing fuel mixture components or as a system ensuring fuel mixture recirculation in storage tanks.

The installation of such systems can be carried out on existing equipment without redesign or modernization; however, in this case, the system must include pumps for supplying mixture components into the system.

One of the possible applications of the dynamic homogenization system at fuel stations is the formation of a fuel mixture during the supply of fuel mixture components directly into the fuel tank of a vehicle or other transport unit. Since the preparation time of the fuel mixture within the system is only fractions of a second, preparing the mixture during transfer into the vehicle fuel tank eliminates the need for special fuel mixture storage tanks at the facility.

Preparation of fuel mixtures directly within the internal combustion engine system

If a vehicle can be equipped with an additional tank for the second component of the fuel mixture, the preparation of the fuel mixture can be carried out by the dynamic homogenization system directly within the fuel pipeline.

The feasibility of this approach was tested on a production diesel engine, and during this test a water-in-oil fuel emulsion was produced, i.e., diesel fuel was emulsified using ordinary tap water.

As a result of using such an emulsion, the soot concentration in exhaust gases was reduced by 97% (mixing proportions in the emulsion: 20% water and 80% diesel fuel).

Installation of the dynamic homogenization system on a newly manufactured internal combustion engine

The installation of the dynamic homogenization system on a newly manufactured internal combustion engine does not require any new elements in the engine design.

The system is installed into the fuel pipeline after the fuel pump, and its outlet is connected to the inlet of the high-pressure pump or, in the absence of such a pump, to the inlet of the structural element following the fuel pump.

Installation of the dynamic homogenization system on a retrofitted internal combustion engine

The installation of the dynamic homogenization system on a repaired or modified internal combustion engine does not require any new elements in the engine design.

The system is installed into the fuel pipeline after the fuel pump, and its outlet is connected to the inlet of the high-pressure pump or, in the absence of such a pump, to the inlet of the structural element following the fuel pump.

Installation of the dynamic homogenization system on industrial facilities for fuel mixture production

The system can be supplied by the manufacturer in a modular configuration.

The system composition and its functions can be modified by the manufacturing company without additional design work.

The system has no limitations or elements that would prevent its installation on any industrial equipment.

Installation of the dynamic homogenization system on fuel mixture tanks at fuel stations

The system can be supplied by the manufacturer in a modular configuration and can be manufactured in any required scale factor.

The system composition and its functions can be modified by the manufacturing company without additional design work.

Figure 2. *Device for Dynamic Emulsion Preparation*

The system has no limitations or elements that would prevent its installation on any industrial equipment.

The device for dynamic homogenization of liquid fuel and fuel mixtures can be used to perform technological homogenization before introducing the fuel or fuel mixture flow into processing equipment for the production of other hydrocarbon products.

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

Original Device for Dynamic Homogenization

A device for the dynamic homogenization of liquid fuels and fuel mixtures has been developed, manufactured, and repeatedly tested.

All elements and components of the device are manufactured using standard computer numerical control (CNC) machines without the use of special technologies or specialized cutting tools.

Stainless steel is used as the structural material, which allows the installation of the device and systems incorporating it in more corrosion-aggressive environments, such as marine vessels.

Figures 3, 4, and 5. Device for Dynamic Preparation of Fuel Emulsion in Disassembled Form

a)

b)

c)

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

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

All input and output connection elements of the device are standardized. No special preparation, tools, or equipment are required for installing the device on an internal combustion engine.

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

The device can be manufactured using standard serial production equipment with computer numerical control (CNC); no special technologies, materials, or tools are required for the manufacturing, assembly, or quality control of the device.

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