Mechanical Activation of Hydrocarbon Motor Fuels

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Abstract. Solving the problems of energy saving and reducing the load on the environment during the operation of internal combustion engines develops in different directions. One of the ways to reduce fuel consumption and reduce the amount of harmful emissions can be the use of an activator of liquid hydrocarbon fuel. Activator of motor hydrocarbon fuel (gasoline, diesel fuel, aviation kerosene, fuel oil) carries out processing of fuel, changing its composition and performance properties and is a highly efficient mechanical device. As a result of the action of the activator, the composition and properties of the hydrocarbon fuel change, the content of heavy fractions decreases, lighter and branched molecules appear, the sulfur and tar content decrease, and fuel consumption decreases. The decrease in the content of harmful emissions of CO, CH, CO₂ in exhaust gases was experimentally established. Activated (structured) motor fuel, in addition to these advantages, increases the life of the engine by improving the organization of the working process in the engine cylinders, provides easier start-up at low temperatures and approaches the requirements of the Euro-5 certificate, regardless of the initial quality. This development provides solution of actual problems of energy saving and reduction of environmental pollution during operation of internal combustion engines.

1. Introduction

The problem of fuel economy of vehicles and reduction of toxicity of exhaust gases of motor thermal motors is still very relevant in the world, due to high fuel prices and low efficiency of car engines. Therefore, all the new cars that allow to solve these tasks, namely: to save gasoline, improve the ecology of the car and at the same time increase the engine's power, are still relevant and in demand by the market.

Magnetic fuel activators have been known for a long time and are very effective and therefore are produced in the world in rapidly increasing volumes and are already sold in many countries of the world and are gradually gaining the entire world car market.

Development of technologies for mechanical activation of hydrocarbon motor fuel (gasoline, diesel fuel, aviation kerosene, fuel oil) allows performing highly efficient fuel processing, changing its composition and performance properties.

To date, numerous studies have been carried out on the effect of cavitation and mechanoactivation of liquid media [1-10]. A number of works show a change in the structure and properties of liquids [11-14].

The scientific and technical novelty of the solution lies in the fact that the mechanical action on the medium to be treated is carried out consistently in three or four sections in order to create a highly developed interfacial surface and a high specific energy intensity. In the first section, quasi-impact and vortex processes are performed, in the second section - cavitation processes, and in the third section -...
high level of jet turbulence is created. These sections are basic. The fourth section transforms the turbulent flow regime into a laminar flow and promotes further self-organization of the new structure of the treated medium. The main difference from analogs is the creation of locally large energy densities necessary for breaking intermolecular bonds. Activated (mechanically structured) motor fuel, in addition to these advantages, increases the life of the engine by improving the organization of the working process in the engine cylinders, provides easier start-up at low temperatures and approaches the requirements of the EURO-5 certificate regardless of the initial quality. The direct-flow type activator is easily integrated into any fuel system, does not require a drive, does not contain chemicals, and does not lead to a change in the fuel parameters regulated by the relevant requirements.

![Diagram of the activator of mechanical action](image)

**Figure 1.** Scheme of the activator of mechanical action (mechanical activator): 1 - housing; 2-4 - vortex formers; 5-7 - cavitator; 8 - the chamber of dubbing; 9 - jet flow divider of the labyrinth type [15].

The underlying factors of mechanical activation are direct force effects on molecular formations, irreversible changes in the properties and composition of the liquid medium, and the initiation of a self-activation process with the release of internal energy.

In accordance with these components of mechanical activation, a mechanical effect on the liquid medium is realized, leading to a disordered state called "quantum chaos", weakening and breaking of intermolecular bonds and self-organization at the molecular level until the energy equilibrium state is reached.

With mechanical activation, the energy expended is compensated and supplemented by the formation of new molecular chains that restore the energy balance. For this, it is necessary to create local large energy densities. Concentrated at the nodal points of molecular chains, the constantly incoming energy is capable of breaking down molecular chains into pieces or free radicals. Nodal points are formed by the bifurcation of molecular chains, the coalescence of two molecular chains, the introduction of oxygen atoms, the presence of defects such as double bond and nonlinearity.

The activator of motor hydrocarbon fuel (gasoline, diesel fuel, aviation kerosene, fuel oil) [15] carries out fuel structuring, changing its composition and operational properties, as a result of which it allows to obtain:

- economy of any kind of fuel from 15 to 27%;
- reduction of CO content in exhaust gases from 20 to 50%;
- reduction of noise of the internal combustion engine up to 15%;
- reduction of the mass fraction of sulfur by 25-50%;
- a decrease in the concentration of actual resins in 7-9 times.

The activator is a highly efficient mechanical device that uses models of phenomenological thermodynamics and molecular physics, and has three successive stages of action on the fuel medium, leading to the self-organization of the energy state by the principle of increasing the mass fraction of light hydrocarbons.
The goal of the development is to increase the efficiency of mixing and structuring, as a result of which molecules and molecular chains acquire such a spatial configuration that provides more complete oxidation with oxygen.

Typically, the achievement of this goal by means of one type of static mixer requires the development of its design and process parameters in relation to specific miscible or activated liquid phase systems, which is often a long and time-consuming process. Therefore, the consistent use of several static mixers of different designs located in a single-flow case allows a universal static mixer-activator.

The technical task is to obtain a high degree of homogeneity when mixing the dispersion medium and the dispersed phase, and for a separately processed liquid medium, activation and recombination leading to rupture, both intermolecular bonds caused by van der Waals forces, and P-bonds, using mechanical action on liquid-phase systems.

To solve this technical problem, it is necessary to carry out a mechanical action with a high specific energy intensity and create a highly developed interfacial surface.

With respect to static mixers, the solution can be obtained by passing the streams of liquid-phase systems being mixed or an individual liquid medium through mixers with various methods of action, reproducing the complex motion of elementary volumes, accompanied by the distribution of colliding molecules at relative energies.

In addition, mechanical activation facilitates the purification of liquid fuels used in internal combustion engines from heavy and hardly flammable impurities. This problem has special significance for hydrocarbon fuel, which can be attributed to colloidal systems consisting of complex structural units distributed in a liquid hydrocarbon medium. Therefore, the properties of liquid fuels are controlled through a change in their fractional and component composition.

The liberation of liquid fuels from heavy fractions containing, for example, carbon (C16 - C21), sulfur, lead, possibly chemically, by recombination, that is, a process in which ions of opposing signs form a neutral molecule. This method is effective for small volumes.

A mechanical method is possible—precipitation of heavy impurities in centrifuges, but it is effective only in the case of weak interaction of impurities with molecules of liquid fuels.

The most effective way is to provide a pulsating effect on molecular chains. The energy of bond dissociation in this case can be enhanced by cavitation of the medium to be treated. To implement this method, rotor pulsation apparatuses (RPA) are most suitable, which initiate such parameters as the formation rate of cumulative bubbles and temperature.

The method of cleaning is that liquid fuel is processed in a rotary pulsation apparatus in a multi-cycle pulsation regime, supplemented, if necessary, by cavitation action. In this case, long molecular chains containing molecules of heavy fractions break up into shorter ones at the sites of crosslinks with the separation of molecules of heavy fractions. The process of cleaning liquid fuel is intensified by adding some water to it and mixing it. In this case, water molecules bind heavy fractions, which tend to have a higher density than the medium to be treated, but less than water. As a result, a three-component liquid medium is obtained: the light fractions form the upper layer, the impurities form the middle layer and the water-the lower layer. This layered distribution makes it easy to remove each of them.

2. Results and Discussion
A series of experiments was carried out using a developed and patented mechanical activator on motor fuels: diesel and gasoline with an octane number of 92.

The results of the experiments were evaluated by means of chromatograms, fuel consumption indicators, environmental performance of fuel and exhaust gases.

The analysis of the activated motor fuel is made in the Test laboratory of petroleum products of LLC "Tambov-Terminal". The purpose of the tests: to determine the hourly fuel consumption, ignition timing, air excess ratio, the content of harmful emissions of CO, CH, CO2.
The tests were carried out on the bench injection gasoline engine ZMZ-406 with the help of the CAD-400-02 auto diagnostics complex complete with the AVG-4-201 gas analyzer under the following conditions:
- Ambient air temperature + 20 °C;
- Relative air humidity of 36% ≤ φ ≤ 50%
- Atmospheric pressure 750 mm Hg. ≤ Pa ≤ 760 mm Hg;
- The fuel temperature at the inlet to the fuel system was maintained within 20-25 °C;
- The coolant temperature was maintained within the limits specified in the technical conditions for the engine 75-90 °C;
- The oil temperature is 80-100 °C.
Used fuel gasoline with octane number 92 brand «Lukoil».

Chromatographic analysis was carried out for mechanically activated diesel fuel. Several grades of diesel fuel were used. Based on the obtained chromatograms, the following conclusions were made.

Diesel fuel of Rosneft. Activation occurred due to a decrease in the concentration of nonane hydrocarbons and especially decane, phytane and pristane. The greatest decrease corresponds to the decane. The contents of octane are unchanged.

Diesel fuel of the company EURO. Activation occurred due to approximately the same decrease in the concentration of phytane and pristane. The content of octane, nonane and decane remained almost unchanged.

Diesel fuel of the company Lukoil. Activation occurred due to a strong decrease in the concentration of nonane and decane and a slight decrease in octane. The content of phytane and pristane increased.

Diesel fuel of Rosneft, TEXACO, EURO, Lukoil - the fuel activation was due to a significant reduction in the concentration of (C11- C18) hydrocarbons and a gradual lowering of the reduction of (C19 - C25).
Analysis of the graphs showing the percentage of hydrocarbons N (octane, nonane, decane, phytane, pristane), obtained from the results of chromatograms is shown in Figure 3 to 5.

**Figure 3.** Chart of results of chromatographic analysis of Rosneft diesel fuel.

**Figure 4.** Chart of results of chromatographic analysis of EURO diesel fuel.

**Figure 5.** Chart of results of chromatographic analysis of Lukoil diesel fuel.

With the help of chromatography, the composition and properties change after mechanical activation:

a) in diesel fuel - the appearance of new components (mainly hexane, heptane, pentane) to 37%;

b) gasoline - an increase in the concentration of octane-determining components (mainly toluene) by 16%;

**Figure 6.** Combined IR spectrum of the nomenclature (upper) and activated (lower) diesel fuel.
Confirmation of the cleavage of the molecular chain can serve as (IR spectrum) shown in Figure 6. The top image corresponds to the nomenclature diesel fuel [16], the lower image corresponds to the diesel fuel subjected to mechanical activation.

The appearance of additional peaks on the lower spectrum indicates a change in the composition of diesel fuel after mechanical activation, it is clear that new complexes appear. The mechanism of splitting of molecular chains of hydrocarbons was considered in [17].

3. Conclusion
When assessing the properties of mechanically activated gasoline with octane number 92, an increase in the concentration of octane-determining components (mainly toluene) by 16%, as well as a decrease in the hourly fuel consumption by 27.7%. Examination of exhaust gases showed a significant reduction in CO, CH, CO₂ (up to 30%). When evaluating diesel fuels, chromatographic analysis revealed the appearance of new components (mainly hexane, heptane, pentane) to 37%. In this case, a decrease in the concentration of other compounds (octane, nonane, decane) is observed.

An important fact should be considered that after the termination of mechanical activation autonomously for some time the processes of activation and self-organization continue, leading to a further change in the properties of the liquid medium.

In addition, this method of mechanical activation is expediently used for cleaning fuels. In this case, long molecular chains containing molecules of heavy fractions decompose into shorter ones at the cross-links with the separation of molecules of heavy fractions, after the removal of which the quality of fuel is markedly improved.

4. References
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