Investigation of Oil – Water Ultrasound Emulsifier

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Abstract. Diesel fuel and water emulsifier designed for diesel fuel contaminated with water mixing to improve fuel combustion properties, it could also be used as mixing device for water and diesel fuel mixture. Examined literature describing the oil and water mixture emulsifiers. Analyzed the experiments related to diesel fuel and water emulsion combustion and distribution of its water volume. It has been developed and described principle emulsifier scheme. Calculated and modeled piezoelectric ultrasonic vibration actuator, which causes cavitations in mixing chamber. Ultrasonic vibration actuator is designed for the cavitation emulsion processing. Comparing experimental data with calculations obtained less than 10% deviation from the theoretical resonance frequency values. Performed experimental testing of ultrasonic vibration actuator to determine its resonance values. It also performed test of the distribution of water drops in diesel fuel using a microscope. Diesel fuel combustion effluents is one of the major problems stopping air pollution, especially in more populated areas.

1. Introduction

During the storage of a diesel fuel in large containers, a diesel fuel with contaminated water layer are formed at the bottom of the containers, which is unfit for consumption because of the poor combustion process. Therefore, the fuel can be mixed before use by means of ultrasound. During this process, water is exposed to cavitation, split into small droplets and forms the diesel fuel-water emulsion that suitable for the combustion process. As the water evaporation temperature is lower than the diesel combustion temperature, water broken up into small drops evaporation decomposes diesel fuel into the droplets, which increases the surface area for interaction with the oxygen that is maintained or improving the combustion properties of the emulsion and also significantly reduces the combustion process emissions. It is also possible to produce a diesel fuel-water emulsion to achieve the same goals.

The aim of research is to design and investigate an ultrasonic vibration actuator for diesel fuel emulsification to ensure proper fuel combustion, as well as perform the diesel fuel-water emulsion research.

2. Water and diesel fuel mixed emulsion

Water and diesel fuel emulsion is usually made up of 10-20 percent water, 80-90 percent of the diesel fuel and 1 percent of the fuel additive [1], allowing the emulsion to remain stable for a longer period of time as the emulsion of two immiscible liquids significantly reduces ability to form the layer of water at the bottom of the tanks, since the density of water higher than density of diesel fuel.

The emulsion formed by splitting water into the nano or micro consecutive droplets, which are surrounded by diesel [2]. The emulsion manufacturing process is a continuous process whereby the dispersing medium is continuously fed with the dispersing and dispersed phases by adjustable flow rate pumps. Cavitation is excited in dispersing medium by means of ultrasonic vibration actuator has a direct effect on emulsion fineness, the size and distribution of the water droplets in diesel fuel

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medium.

The emulsion combustion process turns water droplets to steam as the water evaporation temperature is lower than the temperature of the combustion of diesel fuel. Water evaporation causes the micro-explosion of water droplets in emulsion volume. These explosions affect the oxygen and fuel oil interfacial area by increasing it, producing a better combustion process. The cavitation fuel processing leads to a number of positive changes, influencing on fuel caloricity and combustion quality [1].

3. Water in fuel emulsification system

In line water in fuel emulsification system is presented in Figure 1. Before the cavitation fuel processing, the rough mixing procedure of the water- fuel in tank 2 with rough mixing fuel pump 1 is performed. After rough mixing procedure fuel is delivered into the emulsification chamber 5 via a fuel pump 4, where the cavitation is excited in dispersing medium by means of ultrasonic vibration actuators 6. In line water in fuel emulsion is diverted back to the fuel tank 2, from which it can be diverted to the other storage tank via valve 3.

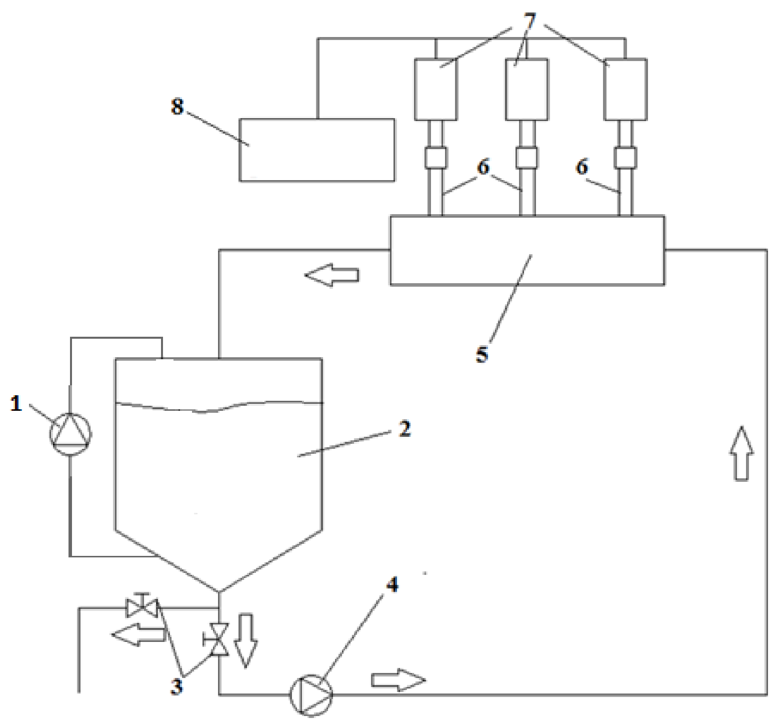


Figure 1. Fuel emulsification scheme:
1 – rough mixing pump,
2 – diesel fuel tank,
3 – valves,
4 – fuel pump,
5 – emulsification chamber,
6 – actuators hubs,
7 – ultrasonic vibration actuator,
8 – ultrasonic vibration controller.

In the emulsification chamber water in diesel fuel mixture is agitated by the ultrasonic vibrations which produces strong cavitation in the mixture. Water in diesel fuel mixture exposed to high-intensity ultrasound undergo ultrasonic cavitation, which produces violently and asymmetrically imploding bubbles and causes micro-jets that create extreme mechanical shear forces. These forces are responsible for the emulsification processes [3]. Ultrasonic amplitudes order of 100 microns peak-to-peak are necessary in order to take full advantage of this effect. At low amplitudes (below about 50 microns), the intensity of ultrasonic cavitation is insufficient for emulsification processes. In order to produce sufficient cavitation intensity, ultrasonic transducer (converter) is equipped with high-gain acoustic horn, which amplify the vibration amplitude generated by the transducer and deliver the ultrasonic energy to working liquid (Figure 2). Ultrasonic horns can be classified into exponential, catenoidal, conical, parabolic, hyperbolic and stepped forms according to the decreasing rate of their cross sectional area. For the prototype in this work, a stepped horn shape was employed.

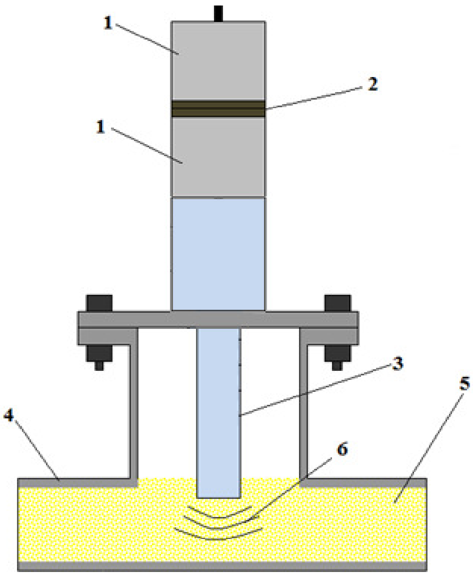


Figure 2. Emulsification chamber with a piezoelectric transducer:
1 – back and front elements,
2 – piezoelectric elements,
3 – ultrasonic vibrations transformer- acoustic horn,
4 – fuel flow tube,
5 – in line fuel emulsification chamber,
6 – zone of cavitation.

Horn tip longitudinal oscillations amplitude frequency response (Figure 3a) was measured using a laser Doppler vibrometer OFV 5000 (Polytec GmbH, Germany), which was connected to a personal computer through analog-digital converter Picoscope 3424 (Pico Technology, United Kingdom). Dependence of amplitude of the oscillations at the resonate frequency of 16.75kHz on piezoelectric transducer voltage is presented in Figure 3b.

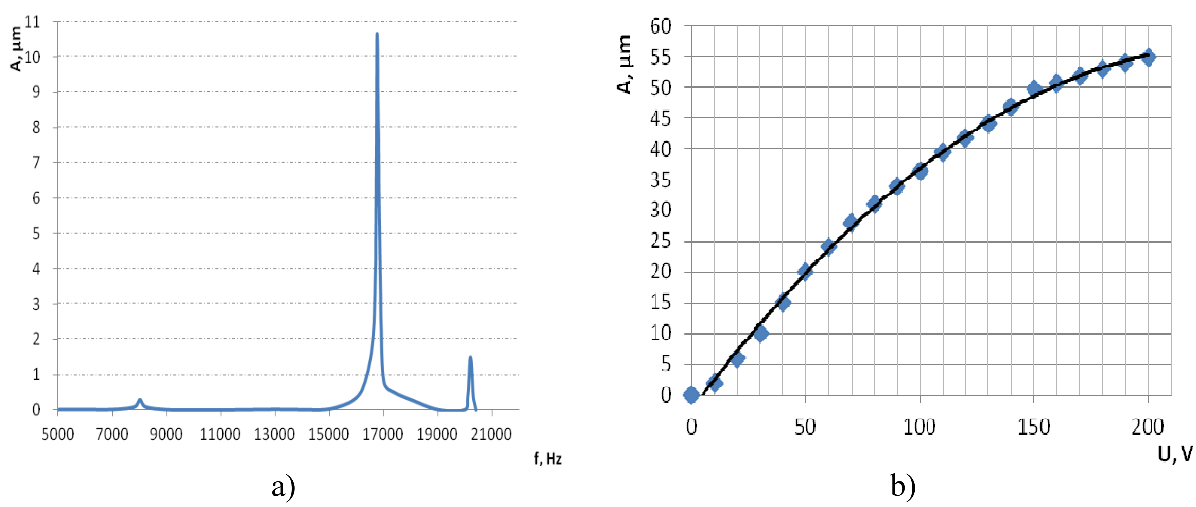


Figure 3. Dynamic characteristics of the piezoelectric transducer:
a – horn tip longitudinal oscillation amplitude frequency response,
b – horn tip longitudinal oscillation amplitude dependence on the excitation signal.

4. Experimental research of the diesel-water emulsions

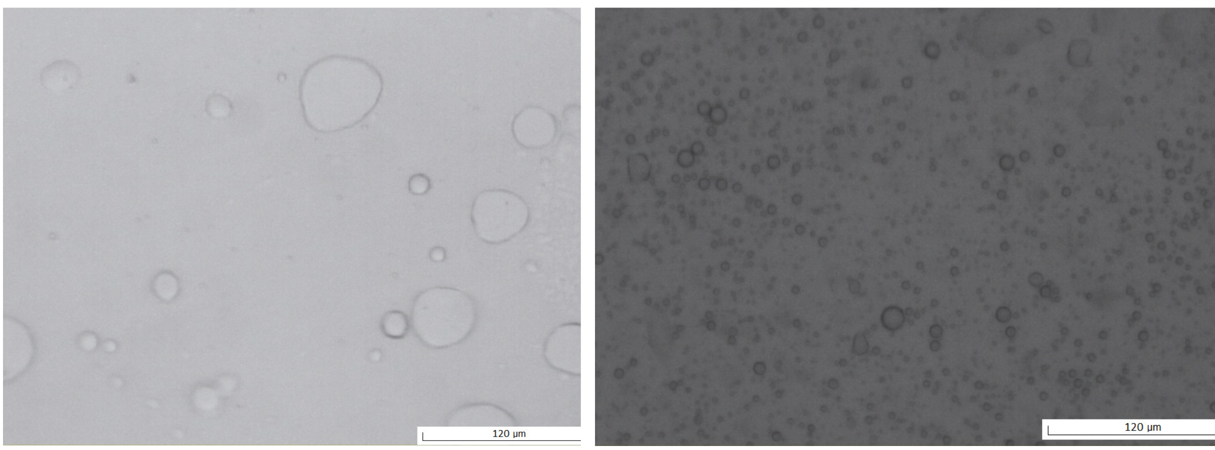
In order to find out size of water droplets in fuel mixture after cavitation treatment the experiment was carried out. As a fuel mixing tank and emulsification chamber was used for small capacity plastic bottle and medical 20-ml syringes for dosing the ingredients of mixture.

An optical microscope with a digital camera NIKON L-IM is used to observe the distribution of the dispersed phase of the water in emulsion, the droplet-size variations, and the emulsion formation process after emulsification process. A water in diesel fuel mixture with 15% of volume water content is exposed to ultrasonic cavitation excited by a piezoelectric transducer for 20s.

Emulsion analysis was carried out in two cases, when the emulsion is mixed mechanically, and when it was affected by the ultrasonic irradiation and cavitation for 20s. The results are displayed in Figure 4a (mechanically mixed) and Figure 4b (after ultrasonic irradiation).

As we can see in the photo of water/fuel emulsion before ultrasonic irradiation the diameters of water droplets are about 60μm. It is too large in size in order to maintain a stable combustion process. To be considered effective, an emulsifier should distribute at least 90% of water in the 1 to 10μm range [4].

The photograph of the emulsion affected by the piezoelectric transducer vibrations is shown in Figure 4b. As we can see the maximum size of emulsion droplets of water is less than 15μm diameter. This suggests that the emulsion is mixed properly, and the combustion parameters are met.



a) b)

Figure 4. Photo of a – water/fuel emulsion before ultrasonic irradiation at a magnification of 200, b – water/fuel emulsion after ultrasonic irradiation at a magnification of 200.

5. Conclusion

A piezoelectric transducer with resonance excitation signal frequency of 16.75kHz and the maximum amplitude of 55μm at 200V excitation voltage was developed and experimentally investigated. After ultrasonic treatment fuel emulsion was observed through a microscope. It have a more even distribution and smaller size of dispersed-phase of water. The distribution of water in diesel fuel and maximum diameters of water droplets is less than 15μm. To achieve the best possible combustion with diesel fuel oil, water droplets with a size of 10 to 15μm have to be thoroughly mixed with the fuel. Water droplets with particle size of more than 15μm will atomize too slowly which will result in an unstable combustion.

References

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