UDK 532.528:665.753(045)

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APPLICATION OF HYDRODYNAMIC CAVITATION FOR DIAGNOSING FUELS AND LUBRICANTS WATERING

The paper provides the research results of the changes in the properties of fuels and lubricants depending on water content in them. A fundamentally new dependence has been discovered. The analysis of the acoustic spectrum of aviation fuels hydrodynamic cavitations shows the influence of water concentration in petroleum products on the increase in the total signal power. The obtained dependencies can be used when developing new diagnosing cavitations technologies.

Keywords: hydrodynamic cavitations, throttle nozzles, fuels and lubricants, acoustic spectrum.

The problem and its connection with scientific and practical tasks. Condition of fuels and lubricants greatly affects the performance of machines, mechanisms and even entire systems. One of the criteria for evaluating the fitness of petroleum products for use is the water content in them. For aviation fuel, for example, fraction of its total mass should not exceed 0,003 %. Fuels are examined for compliance with the standards in laboratories of tank farms and fuel complexes. Quantitative analysis of water content with the use of laboratory methods was carried out by ISO 9030 (ASTM D 4007, ASTM D 1796) through the use of centrifugal forces; by GOST 2477 by heating the sample with insoluble in water solvent and measuring the volume of condensed water in the receiver-trap; by ASTM D 4006 with a similar procedure for diagnosing; by GOST 14870 using the three methods of visual Fisher reagent titration based on the interaction of iodine and sulfuric anhydride with water and the formation of hydroiodic acid and sulfuric anhydride in the medium of methanol and pyridine; by ASTM D 4377 by potentiometric Fisher titration; by ASTM D 1744 by electrometric Fisher titration [1]. The mentioned methods have significant cost of consumables and require certain qualifications of the researcher. The only certified according to [2, Application 30 to paragraph 4.3.12] device for the quantitative water detection in fuel samples is “Aqua-Glo”, the principle of its action coincides with ASTM D 3240 “Standard Test Method for Undissolved Water In Aviation Turbine Fuels”. This method is described in the international standard, it can define the concentration of water from 1 to 60 parts per million (ppm) or from 0,0001 to 0,006 % by comparing etalons and samples after translucence with ultraviolet comparator. However, according to the instruction [3], even this method does not respond to dissolved water and depends on the degree of solubility and temperature of fuel.

In view of the above, we can conclude that the study of new dependencies between the water content in the fuel and its properties is important and promising for the development of new diagnosing methods, and therefore for the prevention of failures and damage of mechanisms and machines.

Analysis of research and publications. Some of the new attempts to solve the problem of methodological complexity of laboratory diagnosing of fuels and lubricants (including water content of fuel) are given in [4, 5]. At the same time the problem of significant cost of reagents and equipment is not solved. [6] is an attempt to show an alternative approach to solving this problem by using cavitation technologies that are practically realized in [7]. But the unsatisfactory sensitivity of the method led to widening the field of research [8].

Statement of the problem. Theoretic precondition to find the dependence between the water content in the fuel and its acoustic spectrum is the well known difference in densities of this liquids, which, in accordance with [9], must have a significant impact on the rate of spread perturbations in the cavitation area (and therefore on pulsation pressure). As, in obedience to [10], actual transition from liquid state to gaseous and vice versa, is associated with splitting the original homogeneous substance in two different coexisting phases, we can assume that the acoustic spectrum of aviation fuel will vary, due to variations of saturated vapor pressure in the cavitation zone which in its turn will change with the increase or decrease in the total water concentration at any condition. Practical prerequisites for the presented research are the results of the analysis of the acoustic spectrum of ultrasonic cavitation [11].

In view of the pendency of the formation of new advanced methods of diagnosing petroleum products watering, which use modern advances in science, the authors faced the task of experimental investigation of the effect of water content in the fuel on the value of total power of acoustic spectrum of hydrodynamic cavitation generated by throttle cavitation units. This article is a continuation of previous publications by the authors on presented topics.

Presentation of the material and the results. For the research of acoustic spectrum of hydrodynamic cavitation generated at the outlet of throttle device, an experimental stand was designed and manufactured (Figure 1).

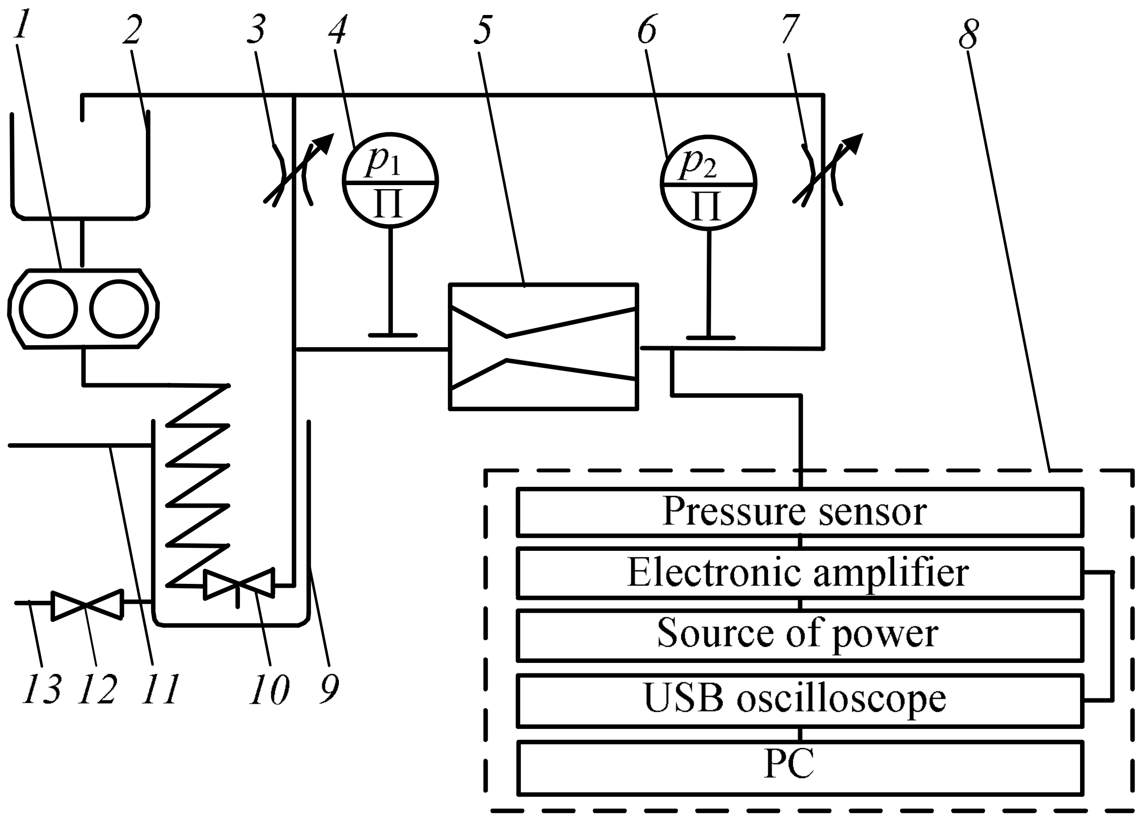

Figure 1 – Principle scheme of experimental stand for the research of the acoustic spectrum of fuels and lubricants hydrodynamic cavitation:
1 – gear pump; *2* – tank; *3,7* – throttle valves; *4,6* – manometers; *5* – cavitation generator of pulsations; *8* – measuring unit; *9* – cooling tank; *10* – drain valve; *11* – cold water feed line; *12* – overlapping crane; *13* – drain line

The source of power in the stand is gear pump *1*, which transfers working fluid from tank *2* into the coil located in tank *9*, where by line *11* continuously goes and from which by line *13* through valve *12* drains water. Heat exchange, which effectively cools the fluid in installation during the experiment, helps to maitain a stable temperature. Then fluid enters the cavitation generator of pulsations *5*, the inlet and outlet pressures of which are controlled by manometers *4*, *6* and regulated by throttle valves *3*, *7*, and returned to tank *1*. Valve *10* is used for draining residual fluid after the experiments. Research of the acoustic spectrum is carried out with measurement unit *7*. Piezoelectric sensor in it perceives pulsations and transforms them into electrical signal. USB oscilloscope allows observing the signal in time and frequency areas by making Fourier transform.

Research is conducted by three procedures. The first procedure (procedure 1) is to use prepared samples of fuels with known water content in random order and to clean the stand after each; the second procedure (procedure 2) is to add certain amount of water into fuel in series but with stand turning off for equal period of time; the third procedure (procedure 3) is to add definite quantity of water into fuel continuously. Fuel temperature was maimtained stable for all procedures. Preparing samples for procedure 1 was performed by ultrasonic or hydrodynamic cavitation mixing, for procedures 2 and 3 – immediately after adding water to the tank, cavitation generator was used as a mixer.

As the experimental hydraulic stand allows working with different pressure in the system, the tests employing the most difficult method 1 were held in the three operation modes, the parameters of which were definied using the results of [12, 13]. Thus, each of the modes was with the same pressure drop and contributed to the developed cavitation. For further work mode 2 is selected as optimal in terms of resulting signal informativity.

Analysis of the array data was carried out qualitatively and quantitatively. For qualitative assessment we built acoustic spectrums of fuel with different water content, compared the value of harmonics over the entire range and the most informative in terms of variations in the signal bandwidth of frequencies (Figure 2).

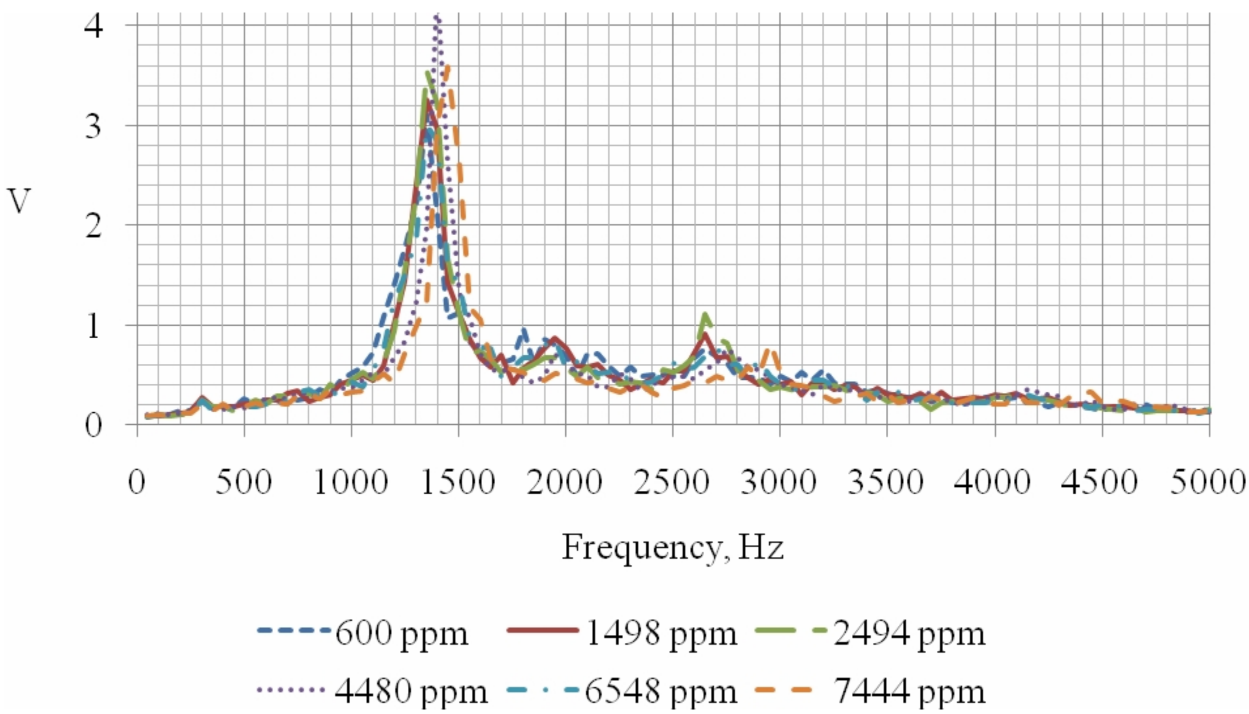

Figure 2 – Acoustic spectrum of hydrodynamic cavitation of fuel with varying water content (bandwidth 50-5000 Hz)

Difference between spectrums has chaotic character.

For quantitative analysis we applied various methods, including determination of the total power magnitude signal of acoustic spectrum of fuel with varying water content for the entire range of studied and selected bandwidths (Figure 3).

Forming an array of information took place by recording 10-50 realizations of each measurement using all the techniques and modes of operation. Two methods of calculating the primary data were used. The first method (method 1) includes averaging results of realizations and calculating the total power of spectrum. The second method (method 2) involves defining the value of the signal at all frequencies of each of the implementations, summation and averaging.

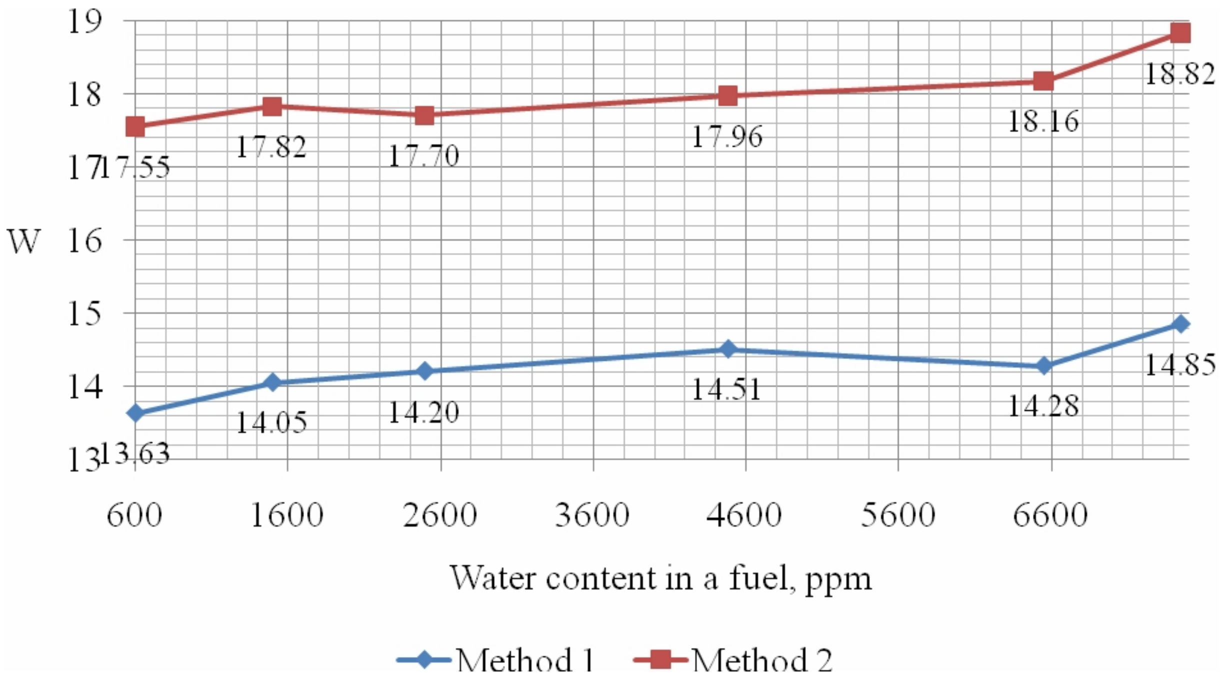

Figure 3 – The dependence of the acoustic spectrum power on the concentration of water in aviation fuel

All researches were performed alternately with aviation fuel TS-1 and JET-A1.

Conclusions and directions for further research. The results of experimental studies indicate that the total power of acoustic spectrum of hydrodynamic cavitation of aviation fuel increases with rising concentration of water in the fuel.

Application of different procedures for experiments provides similar results, with other conditions being equal, therefore, for further research it is inexpedient to use procedure 1 as it takes to much of resources.

Calculation (with the use of different methods) of primary data processing only changes quantitatively the value of power for each of the concentrations of water in the fuel, not significantly changing the character of the dependencies.

Further research should focus on identifying the limits of water content in the fuel, in which the growth of the total acoustic power spectrum is so small, that it does not allow applying the procedure using the obtained dependencies.

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Стаття надійшла до редакції 04.04.2013

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Застосування гідродинамічної кавітації для діагностування обводнення пально-мастильних матеріалів

Наведено результати експериментальних досліджень зміни властивостей пально-мастильних матеріалів від вмісту води в них. На прикладі аналізу акустичного спектру гідродинамічної кавітації авіаційних палив показано вплив концентрації води в нафтопродукті на величину сумарної потужності акустичного сигналу. Запропоновано отримані залежності використовувати для формування нових кавітаційних технологій діагностування.

Ключові слова: гідродинамічна кавітація, дросельний насадок, пально-мастильні-матеріали, акустичний спектр.

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Применение гидродинамической кавитации для диагностирования обводнения горюче-смазочных материалов

Приведены результаты экспериментальных исследований изменения свойств горюче-смазочных материалов от содержания воды в них. На примере анализа акустического спектра гидродинамической кавитации авиационных топлив показано влияние концентрации воды в нефтепродукте на увеличение суммарной мощности акустического сигнала. Предложено полученные зависимости использовать в процессе формирования новых кавитационных технологий диагностирования.

Ключевые слова: гидродинамическая кавитация, дроссельный насадок, горюче-смазочные материалы, акустический спектр.