

UDC 62-82:532(045)

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## ACCELERATION OF TESTS ON OIL BY APPLYING CAVITATION

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**Abstract.** *The method of acceleration of tests on oil is examined. Application of hydrodynamic cavitation when experimenting on oil decreases the time of tests, energy and material costs. The description of this method is given. The hydraulic scheme of device for accelerated testing of oil and graphs of experimental dependence are presented.*

**Keywords:** hydrodynamic cavitation; hydraulic stand; oil tests.

### 1. Introduction

There are laboratory, stand and exploitation tests of oils. Laboratory tests on oil of industrial-use are conducted according to methodical recommendations, which are regulated by DSTU (National Standards of Ukraine), GOST (State Standard), ISO, ASTM, CEC and other normative documents. In methodical recommendations the terms and exactness of measurements, equipment and testing order are noted. Type of equipment which is used during tests determines the method of test – mechanical, optical, thermal, reagent and so on. The use of laboratory methods in creating lubricants gives a possibility to estimate the impact of compositions of basic oils and additives on general physical and chemical characteristics of a developed product on the basis of experience to predict their behavior in the process of exploitation. On the base of results of laboratory tests decision on the necessity of further testing is taken.

Stand tests are conducted on oil installations which simulate conditions of a particular mechanism or aggregate. In some cases, for more reliable test results used both stands with nodes and aggregates of real machines and mechanisms are used.

Exploitation tests are carried directly on the machines. During these tests not only service properties of oils, but other indicators, such as oil consumption, number of repairs, the need for spare parts, etc. are assessed.

The disadvantage of methods in laboratory, stand and exploitation tests are high time consumption for their holding, and therefore increase of energy and material consumption, which affect the expense of

testing. The time, for tests can last from one week to several months.

### 2. Analysis of the latest research and publications

Analysis of publications is shown that cavitation in worked fluids is accompanied by change of its exploitation properties [1].

Ours previous research was fixed that cavitation in worked fluids of hydraulic system is leaded to change of fluid viscosity and acidity. This fact we used for creation of given method.

### 3. Aim of the article

The purpose of the proposed method of testing oil and appliance for its implementation is a significant reduction of the time required to test oil, which is achieved by applying hydrodynamic cavitation.

### 4. The main body of article

The method is based on the fact that the effects which accompany the hydrodynamic cavitation are accelerating research:

– Mechanical – high stretching force in oil and local pressure oscillations which arise directly during collapse of cavities and pressure oscillations in the fluid stream which are generated by cavitation zone;

– Sound – a wide range of hydrodynamic sound and ultrasonic sound emitting, generated by oscillations in fluid of cavitation jet;

– Heat – local increase in temperature to values of plasmas` temperature, and a general rise in temperature of fluid flow;

– Evaporative – the presence of oils' vapor in the cavitation caverns;

– Oxidation – the formation of oxidation products due to the presence of molecular oxygen (up to 40% of total emissions [1]) and atomic oxygen, formed as a result of the collapse of cavities, in cavitation caverns;

– Dissociative – the presence of positively charged hydrogen atoms, negatively charged oxygen atoms and free radicals oil;

– Vented – the allocation of undissolved into stream in the cavitation zone;

– Cindery – combustion of oil as a result of high temperatures and high oxygen saturation;

– Mixing – mixing of various components in oil as a result of high turbulence in cavitation zone.

The above mentioned effects also occur both during stand and exploitation testing, but much less during laboratory ones.

The advantage of the cavitation method is to increase the intensity of processes, which affect the physical and chemical properties of oils. Intensification of tests is achieved through complex simultaneous action of the above mentioned effects. This makes it possible to significantly reduce research time.

The essence of the proposed method of testing oils is in the following. Oil, which is to be tested, is exposed to hydrodynamic cavitation. It leads to the emergence of a number of effects, which occur in real systems while operating in different modes. Physical and chemical characteristics of the oils change thanks to the simultaneous action of these effects. The dynamic of change is fixed depending on the time  $t$  of tests or on a certain number  $n$  of passes of investigated volume of liquid  $Q$  through cavitation zone, which is created with a special device, called cavitator [1]. The parameter  $n$  is calculated according to the formula:

$$n = \frac{tQ}{V},$$

where  $Q$  – the volume of fluid passing through cavitator per minute (costs);

$t$  – time of test;

$V$  – total volume of liquid.

The value of  $Q$  depends on the geometric design parameters cavitator. As the simplest cavitator throttle element can be used.

Number fluid passes through cavitator is fixed at a certain number of cavitation  $\chi$  :

$$\chi = \frac{2(p_{out} - p_{cav})}{\rho v^2},$$

where  $p_{out}$  - output pressure of cavitator;

$p_{cav}$  - pressure at which cavitation occurs;

$v$  - velocity of fluid leaks;

$\rho$  – density of the liquid.

The formula for determining the number  $\chi$  of cavitation for practical use is not very convenient, especially when assessing high-pressure cavitation leakage. So let's consider another approach.

During cavitation (for throttle channel) dynamic pressure relative to the pressure at the inlet of cavitator  $p_{in}$  can be written as:

$$\frac{\rho v^2}{2} = p_{in} - p_{cav}.$$

Then the number of cavitation:

$$\chi = \frac{p_{out} - p_{cav}}{p_{in} - p_{cav}}.$$

Considering the fact that  $p_{out} \gg p_{cav}$  &  $p_{in} \gg p_{cav}$  we get:

$$\chi = \frac{p_{out}}{p_{in}} = \bar{p}.$$

So  $\bar{p}$  represents a dimensionless similarity factor for modeling fluid leakage through the throttle device.

For the pressure drop on the throttle cavitation number  $\chi_1$  will look like:

$$\chi_1 = \frac{p_{in} - p_{out}}{\rho \frac{v^2}{2}} = \frac{p_{in} - p_{out}}{p_{in} - p_{cav}} \approx \frac{\Delta p}{p_{in}} = \Delta \bar{p}.$$

Pressure drop  $\Delta \bar{p}$  and backpressure  $\bar{p}$  are interconnected by ratio:

$$\Delta \bar{p} + \bar{p} = 1.$$

The value of pressure drop and backpressure are considered critical if they correspond to origin point of cavitation stabilization of fluid outgo and are denoted as  $\Delta \bar{p}_{cr}$  and  $\bar{p}_{cr}$  respectively.

Intensity of cavitation will depend on the number and thus so does the test time  $t$ .

The proposed method for assessing formulas for  $\Delta \bar{p}$  and  $\bar{p}$  is suitable for practical use because you only need to measure the  $p_{in}$ ,  $p_{out}$  and there is no need to define  $p_{cav}$ ,  $\rho$ ,  $v$ . The pressure  $p_{cav}$  at

which cavitation occurs can change its value from tabular and gets higher depending on working fluid saturation with dissolved air and on increasing of the operating temperature.

In the way of comparing and analyzing of received by cavitation method, physicochemical characteristics of oils, the result can be introduced according to hour kilometers, hours of flight tests and other parameters.

Based on data obtained during testing of one type of oil, cavitation method allows to make simulations on the results of studies on other oils both for separated physicochemical parameters such as viscosity, acid number, and for complex parameters.

Installation for accelerated testing of oil. In the simplest case, oil cavitation test method may be implemented using a standard hydraulic stand. As a working fluid it uses tested oil. The main components of the stand are the source of pressure and cavitator. Test procedure is following: at the beginning cavitator is set to constant entering pressure  $p_{in}=const$ , and the output pressure  $p_{out}$  is changed upwards till cavitation process begins. Fixed output pressure  $p_{out,cr}$ , is considered to be critical if it will respond to the beginning of cavitation stabilization of liquid loss. Using  $p_{out}$ ,  $\Delta\bar{p}_{cr}$  and  $\bar{p}_{cr}$  can be found.

$$\bar{p}_{cr} = \frac{p_{out,cr}}{p_{in}};$$

$$\Delta\bar{p}_{cr} = 1 - \bar{p}_{cr}.$$

Further changes in the output pressure during cavitation stabilization of liquid loss, set pressure drop that corresponds to the value given by cavitation number  $\chi = \bar{p}$ .

Tests are made at a constant temperature of the working fluid and cavitation stabilized by its loss. Measurement of loss Q is made by a standard procedure. Cavitation mode, during which loss are stabilized, determined by the presence of cavitation self-oscillations in the flow of fluid behind cavitator, that fix using sensor for pressure fluctuations. The whole process of testing is divided into stages corresponding to a certain number of hours or cycles. Each stage ends with the measurement of physicochemical parameters of tested oil. After the tests, experimental dependences with further analysis are received.

In order to eliminate the influence of the pump to the results of research, authors proposed special

device (figure 1). It consists of two isolated from each other systems. The first of these systems is driven and consists of adjustable supply pump 1 and safety valve 3 and spread-regulating control equipment, which includes two-position servo valve 4, controlled by two solenoid valves (pressure switch) 5 and 6.

The second test hydraulic system consists of hydrodynamic cavitation generator (confusion-diffuser nozzle) 10 and two spherical tanks 7 and 8. Their upper and lower cavities are hermetically separated by a rubber diaphragm. Spherical hydroaccumulators were used as containers. Fluid supply by pump 1 in the upper cavity of one of the tanks (7 or 8) leads to the fact that the bottom cavity of the tank, separated from the upper reservoirs rubber diaphragm, test liquid is pushed out through the generator 10 to the bottom of the second cavity capacity.

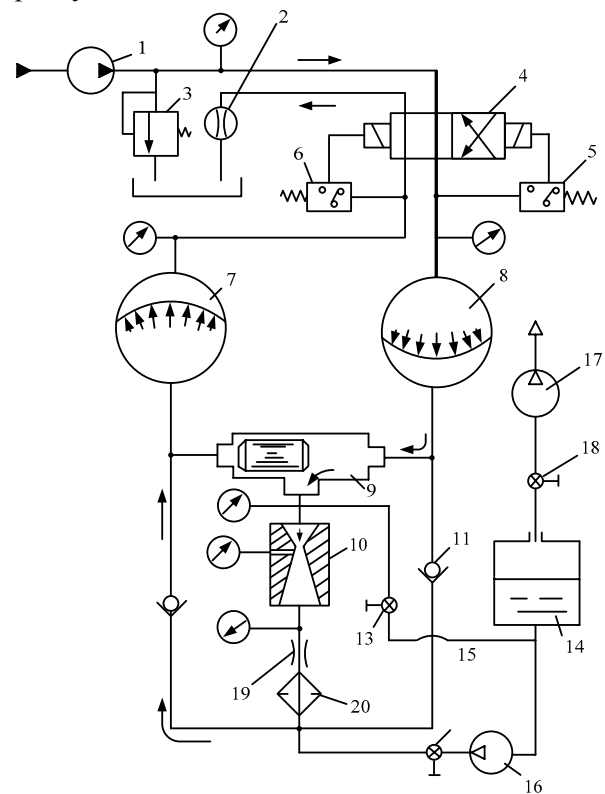


Fig. 1. Device for accelerated testing of oil

At the end of the run, the bended diaphragm of first capacitance will be on the walls of case. As a result, in the upper cavity pressure will abruptly rise to a value of setting of corresponding relay pressure (5 or 6), which automatically switches the valve 4 to the power capacity of the second pump 1. Further process repeated.

To provide one-sided flow through cavitation generator 10, nine automatic shuttle valve and check valves 11 and 12 are used.

With the help of a hand pump 16, system is filled with testing fluid (lower cavity volume 7 and 8). It is powered from the reservoir 14. The vacuum pump 17 is used to remove air from the test system. When system is filled with liquid shut-off air valves 13, 15, 18 are used. The back pressure on the outlet of cavitation is created by throttle nozzle 19. The cooling system is provided by means of the refrigerator 20.

### 5. The results of experimental research.

At the Figure 2 the dependence between viscosity fluid AMГ-10 (ГОСТ 6794-75) and time of cavitation work stand with confusion-diffuser nozzle when  $p_{in} = 21 \text{ MPa}$ ,  $\bar{p}_{cr} = 0,74 : 1 - \bar{p} = 0,0047$ ,  $p_{out} = 0,1 \text{ MPa}$ ; 2 -  $\bar{p} = 0,2381$ ,  $p_{out} = 5 \text{ MPa}$ ; 3 -  $\bar{p} = 0,4761$ ,  $p_{out} = 10 \text{ MPa}$ .

Changes in viscosity fluid AMГ-10 during cavitation tests depends on the pressure at the inlet of cavitator and back pressure. Degradation of the viscosity of the fluid increases with these parameters. Thus, initially the degradation process is intense, and at the end - slow. It happens due to the fact that initially cavitation destruction effected by high-fractions thickening polymer additives vinipol ББ-2Б, and then others. The higher entering into cavitator pressure, the lower level of slowing degradation is.

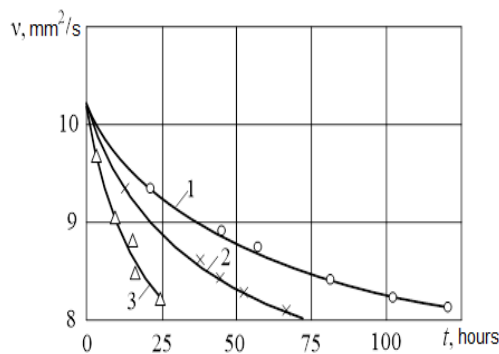


Fig. 2. Dependence between viscosity fluid AMГ-10 and time of cavitation device work

At Figure 3 the dependence between acid number of fluid AMГ-10 and the number of cycles  $n$  cavitation device of confusion-diffuser nozzle is presented, with  $p_{in} = 20 \text{ MPa}$ ,  $\bar{p}_{cr} = 0,68$ ,

$\bar{p} = 0,025$ ,  $p_{out} = 0,5 \text{ MPa}$ . According to test results, the acidity of the liquid changes upward depending on prolongation of cavitation processing. The process of growing of acid number is due to the formation of reactive-capable micro radicals and hydrocarbon radicals, which is spent on decontamination antioxidant additive.

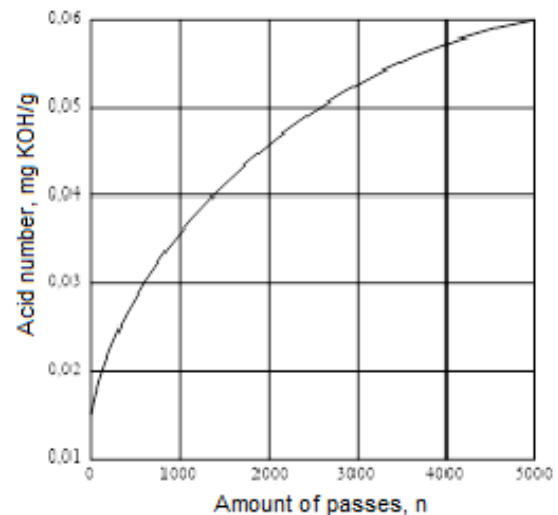


Fig. 3. Dependence between acid number of fluid AMГ-10 and the number of cycles cavitation device work

The presented graphs (fig. 2, 3) show that operational testing of oils using cavitation can be carried out for 25 hours. It is known, that such kinds of testing without cavitation are carried out during one or two months.

### 6. Conclusions.

The method, which is useful for practical application, was proposed in this work. The special testing plant, where fluid flows through cavitation generator and doesn't flow through the pump, was introduced. This plant gives opportunity to avoid the affecting of pump on the results of held tests. The use of hydrodynamic cavitation during oils testing reduces the time of implementation. The more intense cavitation the less time trial is.

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Received 03 October 2015

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Розглянуто спосіб прискореного випробування масел. Наведено описання способу. Наведено схему гідравлічного стенду для його реалізації і графіки експериментальних залежностей. Завдяки гідродинамічній кавітації значно скорочується час для проведення випробувань, зменшуються енергетичні та матеріальні затрати.

**Ключові слова:** випробування масел; гідродинамічна кавітація; гідравлічний стенд.

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Рассмотрен способ ускоренного испытаний масел. Приведено описание способа. Представлена схема гидравлического стенда для его реализации и графики экспериментальных зависимостей. Благодаря гидродинамической кавитации значительно сокращается время для проведения испытаний, уменьшаются энергетические и материальные затраты.

**Ключевые слова:** гидродинамическая кавитация; гидравлический стенд; испытания масел.

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