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RESEARCHES OF FRICTION FORCE OF INJECTOR NEEDLE IN INJECTOR BODIES OF MARINE DIESEL ENGINES IN THE PRESENCE OF LUBRICATING COMPOUND

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Abstract

In article have been presented the results of researches of friction force between injection needle and body of marine diesel engines. There were injector nozzles of piston engines, which were feeding diesel oils or residual fuels. For investigations injector nozzles were chosen amongst sprayers operated in natural conditions, in which excess resistances of the spire were stated at the movement of needles in injector nozzles. There were disabilities, which importantly disturbed performance. There has been used, so passive experiment.

The investigations have been carried on two stands for measurement of friction forces in dependence on its largeness. First of they have been raised in personal range for maximum friction force appointment witch utilization of weighting of gravity forces. For investigated of course of friction forces in injector nozzles about greatest resistances to motion, has been utilisation of stand for investigations of samples of tensile strength.

An influence of angle putting the injector needle was being examined with regard to the body of the sprayer and kind of the greasing middle. They were greasing factors: fuel, applied oil it of conservation and oil applied for attempts at the stage of the production. There has been measurement of diameter clearance between frictional couple precise and researched him influence on the values of maximum friction force.

To value of the maximum friction force among the body and needle of the injector nozzle has influence the amount and the quality of the lubricating compound, the state cooperating surfaces and their mutual location.

Keywords: marine diesel engines, injector nozzles, friction force

1. Introduction

The wrong operation active of injection apparatus of marine diesel engines in the result of wear in the fundamental way influence fall in the legal validity, fuel consumption, pollutant of the exhaust fumes and the like. The scope of the correct exploitation of injectors depends on the permanence and the most precise reliabilities of assembles, which injector nozzles are.

Injector nozzles marine diesel engines are being operated in very disadvantageous conditions, at high pressures of fuel as well as they are surrendered to thermal and mechanical loads [1]. As a result of the influence of different extrinsic factors, is achieving the intense friction, the wear and tear and failures and the passage from the state of the applicability to the acceptable profession or the state unfit nesses [6, 8].

However till the here and now a sufficient knowledge about factors having the influence on correct action of the injection sub-assembles, referring to such problems is missing, as: the influence of the wear, friction and lubricating on precise steam, the influence of the turnover of the needle in the body of the injector nozzle for increasing wearing out. He exists so are needed, being influenced by scientific as well as economic accounts, of carrying examinations of life of injection apparatus and seeking different ways for increasing it.

At work one presented results of the own research on the maximum friction force, needed for moving the injector needle from the body of the injector nozzle, as well as measurements of times

of coming out were described of needle from bodies of injector nozzles for different angles of the turnover of the injector needle in the body of the nozzle. The carried researches aren't aimed at checking the dependence of the storage friction force on the angle of the turnover of injector needle in the bodies of injector nozzle, spreading the injector needle, the kind on the time of coming out and mass of the injector needle.

2. Friction of solid bodies

An outside friction is accompanying the internal friction on micro- coming into existence and the disappearance of friction bonds, are being located in outer layer regions [3]. From a point of view of the kinetics of the move an outside friction is being distinguished static and outside friction kinetic. In fig. 1 a disintegration of forces working on the body on the inclined plane is shown.

The friction measure is resistance balanced by resultant power is tangent during transferring one body towards second. At relative transferring two bodies a kinetic friction is appearing (moving), in addition, if the relative speed of areas of the friction of two bodies is equal of the naught, then a static (rest) friction is appearing.

Kinetic friction, on account of the kind of the move, it is possible to divide in the sliding, rolling and fluid friction [9]. From a technical point of view, a division of the friction is most important for dry, border and liquid. For reducing the outside friction they were trying to divide surfaces rubbing with the layer of lubricating substance that is to replace the dry friction of solid bodies with the fluid friction.

If on account of great individual pressures is layer subject to liquid “for squeezing "from the space between friction surfaces, then between them a poor thin layer of liquids remains staying there only as a result of the interaction of liquids with solid bodies, called the boundary layer. It protects against the appearance of the dry friction. In the operation of machines only are making advances a mitigated solid friction and fluid friction. On account of the fact that cooperating surfaces aren't perfectly smooth, can be found of dry or mitigated solid friction in tops of these irregularities, and in hollows fluid friction [3].

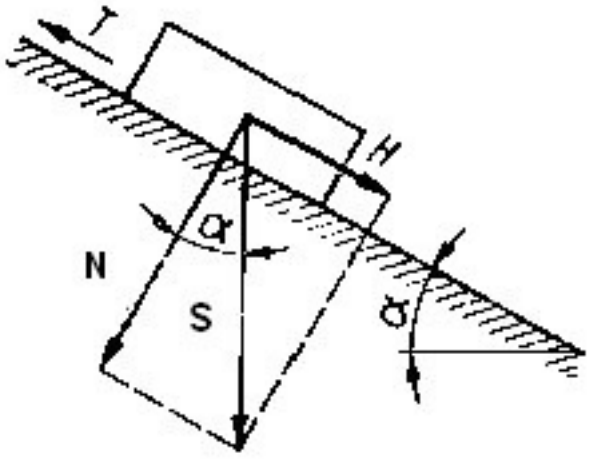

Fig. 1. Distribution of forces working on the solid body on the inclined plane: T – friction force [N], H – power transferring the body [N], N – power of the pressure [N], G – weight [N], α – indication angle of body [°]

The solid body put on the inclined plane has the weight *G*. Itself strength of the friction of the *T* is preventing of displacement from two bodies tangent to the surface and on the contrary directed as for the move and direction of power transferring the body phenomena of appearing of the joint

are *H*. The friction force *T* exists thanks of appearing of the joint of two surfaces. For the body being in a rest on the inclined plane (fig. 1) about the pitch ah, it is possible to elaborate the triangle of strength of the *G*, *N*, the *T* (*T* = *H*) [3]. Then the following dependences are appearing:

$$T = G \cdot \sin \alpha, \tag{1}$$

$$N = G \cdot \cos \alpha, \tag{2}$$

The friction force determined is formula:

$$T = \mu \cdot N, \tag{3}$$

The last relation is Amontonsa theory (law of the dry friction), which sounds: “the friction is a result of climbing of one body by irregularities second, at moving them towards oneself under the effect of the normal pressure”. There is power of the normal pressure, which is counteracting climbing in his format of friction with the deciding factor by irregularities. The border friction is appearing in the period of dawning on, when irregularities weren't still removed and they are breaking the oil wedge. Such a phenomenon can turn up at injector nozzles.

From most often kind of friction in elements of machines is a mixed friction, called the semifluid friction. It is next kind of the friction, being able to turn up at injector nozzles. It relies on the fact that in areas of the immediate joint of tops of two rubbing bodies dry or border rubbing is coming into existence, however in areas of hollows so-called spreadable microwedges are formed. The mixed friction is appearing at the swinging-turning move that is in the injector nozzle it is taking place during the movement of the injector needle in the corps. The mixed friction up is appearing in injector nozzles while reaching. At the relative move spreadable substance is filling hollows of the inequality up.

At mixed friction single areas of the metallic joint exist, where the surface is small compared with the nominal surface of the friction. There is substance greasing with air between areas of metallic joints as well as there products of the wear and tear are coming in.

At limiting friction of frictional resistance and wear of cooperating surfaces in conditions of limiting friction from coarseness of the surface and spreadable substance. In injector nozzles surfaces of the friction are lubricated by fuel [5]. Therefore a sliding, fluid or mixed friction up can here appears, if they appear great side pressures. Friction force and so will be addicted to the property of fuel, the speed slide at mixed friction up, of pressures and the coefficient of the friction.

3. The methods of friction and wear investigations of injector nozzles

With most often applied method there was a based method for measuring the storage friction force on the principle of setting power in motion under force of gravity of fixed sample from which he results, the transfer is directly proportional to needed power for transferring the sample. Applied methods of examining the wear enable the assessment of the relative resistance of materials to the wear. Value of the wear and tear, and in some cases and intensity of using up, it is possible to judge with the help of quantitative methods: of a scale, metric, of clocks, optical, of flow measurements [4, 7].

The metric method consists in the measurement of using up linear dimensions of the element checked before wearing him out and after the determined stage. The accuracy of the measurement is made conditional on measuring tools. Applying digital devices it is possible to get the accuracy of the measurement even up to 0.0001 mm [6]. To flaws in the metric method one should rank problems in measurements of the inequality on the entire examined surface. So in this method it is

possible to make the measurement of diameters of leading parts of the injector needle, diameters of the part of the body, which is piloting of the injector needle, of maximum stroke of the needle and apex angles of cones of the needle [6].

In the article research findings of the friction force were presented between the injector needle and the body of nozzles of ship's engines [5]. They were these are injector nozzles of piston internal-combustion engines, fed with diesels or residual fuels. For investigations injector nozzles were chosen around amongst exploited in natural conditions, at which immobilizing the needle was stated. In conditions of the vetting of the part constructing corps and pins of nozzles, after washing in diesel, one undergone blowing through with compressed air, i.e. for practically removing fuel.

Reliability of precise pairs of fuel apparatus, particularly injector nozzles, includes the wide range of problems of the design, production and exploitation nature. Increasing the reliability is possible through a penetrating analysis of behaving parts in all stages of making them, the assembly and the operation [4].

4. The aims of investigations

The investigations one carried in Laboratories of Institute of Power Plant Operation of Maritime University of Szczecin on several investigation stands. The aim of researches was qualified of values determining parameters essential to appoint was an aim of examinations of components of friction forces needed for moving needles from bodies of injector nozzles for different lubricating means and of all sorts of people of angles of turning the needle in the body of the injector nozzle with applying the numerical method, as well as getting of measurements of diameters leading parts the corps and the needle, what it will be possible to appoint medium ease of manner thanks to in three plains, and next to appoint its influence on value of power of rubbing for every of plains.

The tribological investigations of precise pairs should take the liberty of determining value of storage friction forces at the change of angles of needles in bodies of injector nozzles for all sorts of people of lubricating means.

5. The destinations of researches

They were an object of investigations withdrawn from operation the injector nozzles of combustion diesel engines (fig. 2). Choice of injector nozzles used to examinations was random. During the operation, the part from them was powered with residual fuel, and part with distillation fuel. These injector nozzles dated from bulk carriers of the fleet, but the part from the magazine of the shipowner.

Fig. 2. Body and needle of injector nozzle tacked in investigations

A position was the first research position for the measurement of the component of power frictions. Experiment consisted in the fact that one should check, what additional mass m_a the needle will come out from the body of the injector nozzle by [5].

On the inclined plane under angle 45° a put corpus stayed together with the pin of the injector nozzle, confirmed with the help of the fixing handle. Next, holding the bung of the needle they were checking, whether the needle would come out spontaneously, whether additional m_a mass is needed. When the injector needle didn't come out from the body of the injector nozzle, they used for burdening the weight, of which the handle was screwed with the help of the screw to the bung of needle, was put in the laboratory room of the Maritime Academy in Szczecin.

If was it is insufficient mass needed for moving the needle from the body of the injector nozzle, a string was being tied to the extender, to which a container was on an end. In order to increase mass waters were applied pouring into the container, all the way to beginning the moment and total moving the needle. Next they used scales, about different measuring scopes, in order to determine mass of injection needle and additional mass.

At very great additional masses needed for moving the needle from the body of the injector nozzle positions, were used for examinations of durability of samples to stretching.

6. Method of examinations

Measurement of the component of the friction force the position for the measurement of the storage friction force was compound of the inclined plane under the angle 45°, on which the fastened heap was for. With the help of the fixing handle of injector was put on it, directed with bung of the needle into the bottom. Before installing additionally substance was added to precise lubricating steam or they didn't add, of examinations depending on the kind carried out.

These examinations consisted on testing, whether the injector needle will come out alone from the corps under angle 45°, if this way it was, precise steam could farther be exploited, because, if the needle is coming out from the body of injector nozzle it means that he is fit for a further exploitation. Carrying out an experiment, the injector needle not always has come out under the own weight, then one should attach to the bung of the injector needle with the help especially of the made extender and the cord additional m_a mass.

In this experiment water which was gradually was additional mass titrate into the container fastened at the end of the cord, all the way to the moment, in which moving the needle from the corps followed. Next additional mass, by which the needle came out, was weighed on the scale. There were two used electronic scales depending on value of additional mass, from which one weighed with the accuracy to 1 g, and second with the accuracy till 0.001 g next after weighing additional mass, the needle was taken out of the body of the injector nozzle and weighed on the electronic scale with the accuracy till 0.0001 g.

In first experiment leading parts of injector needles were greased with vaseline-oil low setting about the following properties:

- cinematic viscosity in temperature 50°C – (6,3÷8,5) mm^2/s,
- temperature of setting – not higher than – 60 °C,
- flashpoint in the melting pot opened – not higher than 130°C,
- acid number – not higher than 0.05 mg.

White mineral oil is destined for laboratory tests on account of good properties in temperatures of surrounding the row + 20°C. Next leading parts of injector needles were greased with distillation fuel and Calibration Shell oil.

The first part of examinations focused on the relation of power of rubbing with T_{max} from greasing the kind. The second part of experiment ran similarly to first. At first injector nozzles were fixed on the heap with the presence of Calibration oil Shell after spraying, carried out investigations of using the stream of the flow to the assessment of spray holes 2 years earlier [6].

Next, when the injector needle came out, additional m_a mass was weighed, and then needle. The same injector nozzle was examined after for adding lubricating oil of needle leading parts and by analogy additional mass m_a and the needle were weighed.

The consecutive stage of examinations was aimed at checking the relation of maximum power of T_{max}, needed for moving the needle, from the angle of the turnover of the needle in the body of the injector nozzles and the time, needed for moving the needle. There were a needed stopwatch and a round made template in experiment around, which the angle scale was made of cardboard on (0÷360) °. In the initial phase of investigations the needle was turned in the body of the injector nozzle as 90°. Also a marked point of reference became the felt-tip pen on every bung of the needle.

This part of examinations was left connected with the second part of experiment, where the leading part of the needle was preserved after flow after flow investigations made is flying earlier with using Calibration Shell oil, and one make of oil at leading part of the injector needle with Calibration Shell oil. So every injector needle, in this part of examinations, was examined eight times, at the 0° angle, 90°, 180° and 270°. For each of given angles he was timed needed for moving the needle from the body of the injector nozzle. As this way as in previous experiment, additional m_a mass and the needle were weighed before and after for adding lubricating oil.

After examinations carried out stayed for the measurement of the component two injectors nozzles, in which were secured the precise pairs and in spite of trials even for hanging additional mass for value m_a = 68.137 kg, didn't manage to take needles out of bodies of injector nozzles. In order to disconnect seizured of precise steam was made a success to the position of the endurance machine, where needles were taken out of bodies of injector nozzles [5].

After installing injector nozzles in the tester gradual increasing power working on the needle followed which was put with bung of the needle vertically into the bottom. First from studied the injector needle came out at strength 1490 taking out of N (injector nozzle number 9). Second whereas, at 2200 N (injector nozzle number 43). After the outside examination of one of injector needles a distinct influence of the corrosion wear and tear was stated.

7. Research results

In experiment 46 chosen randomly injector nozzles which, were withdrawn from use, were examined. On the basis of collected results they calculated; with applying a computer program Microsoft the Excel, the maximum T_{max} friction force. Get value enabled to make the graph of maximum values of friction forces for next numbers of injector nozzles by all sorts of lubricating kinds. Fig. 8 is presenting powers needed for moving needles from bodies of injector nozzles to value.

Injector nozzles were investigated at first for lubricating from investigations made in 2 years ago, and then one make at precise pairs with Calibration Shell oil, what was every needle turned with regard to the bodies fourfold for angle 90°. Investigations were supposed to show, what value of the maximum friction force will be for lubricating from 2004 year and for spreading the from 2006 year by different locations on the needle with account of the body.

On the basis of get scores they stated, that after for adding lubricating oil of injector needle leading parts, additional mass wasn't needed for moving the needle from the body of the injector nozzle that is for adding lubricating oil reduced the surface maximum friction force.

On the attitude of collected put results graphs were made out. The 3 picture is showing value of maximum T_{max} friction forces for next numbers of injector nozzles, apart from numbers of nozzles 2, 9 and 43, by all sorts of kinds lubricating compound.

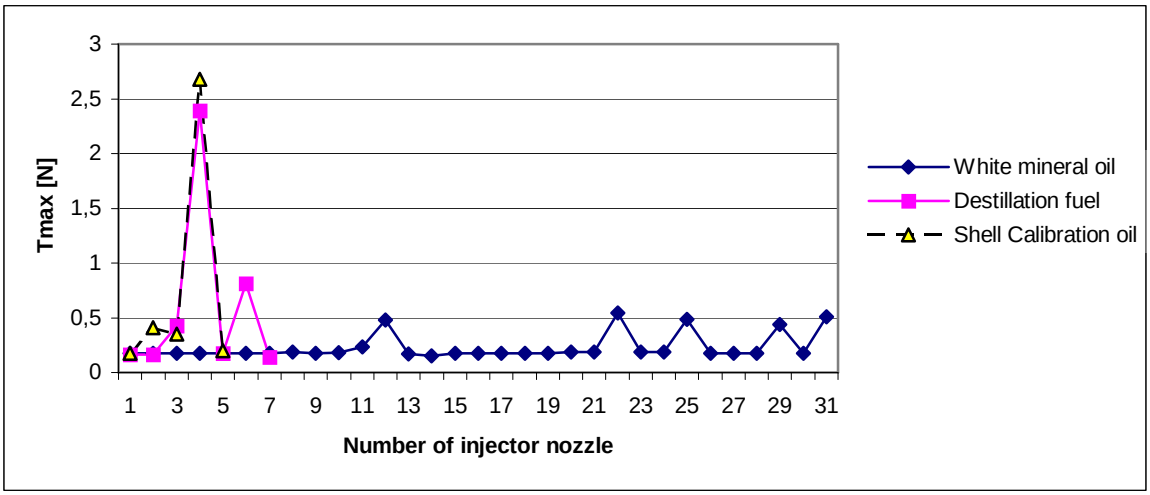

Fig. 3. The values of maximum forces of rubbing with T_{max} for next numbers of injector nozzles by all sorts o of lubricating kinds

How results from the presented fig. 3, the kind of greasing an essential influence on the maximum friction force has. For white mineral oil the maximum friction force is smallest in comparing to distillation fuel and for Calibration Shell oil, since white mineral oil is abiding for greasing devices cooperating in low temperatures. Of maximum value of strength of rubbing for distillation fuel and Calibration Shell oil are even five times bigger than for white mineral oil because of the lower viscosity in the 50°C temperature.

Next figures 4, 5 and 7 are showing the influence of "old" greasing and of adding oil of precise pairs to maximum power of rubbing for three injector nozzles.

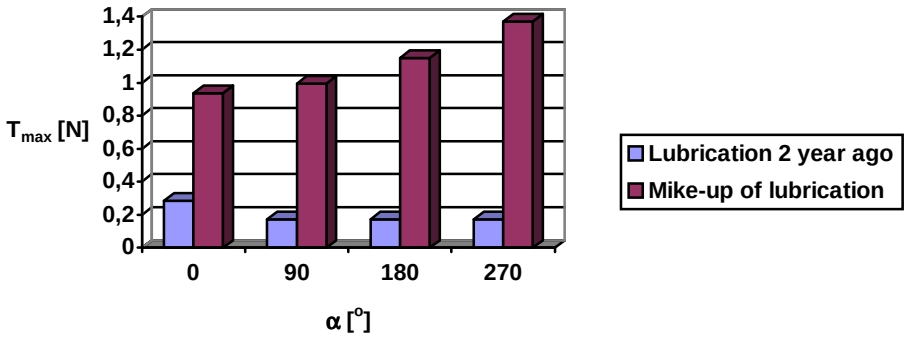

Fig. 4. The maximum values of friction power with T_{max} for the location of injector needle with account of the body of the nozzle α at spreading the from 2 year ago on precise steam and of adding oil in during investigations

He results from the presented picture 3, that "old" greasing causes increasing the maximum friction force, hence using precise steam up are increasing. After for adding oil the maximum friction force has much smaller values for the same precise steam. Examining the influence of the time of leaving the fuel or oil in the injector nozzle is pointing out to effects of leaving fuel or preservative to the technical state of precise steam.

The next 5 graph is showing maximum friction forces T_{max} from the time of coming out of needle from bodies of injector nozzles.

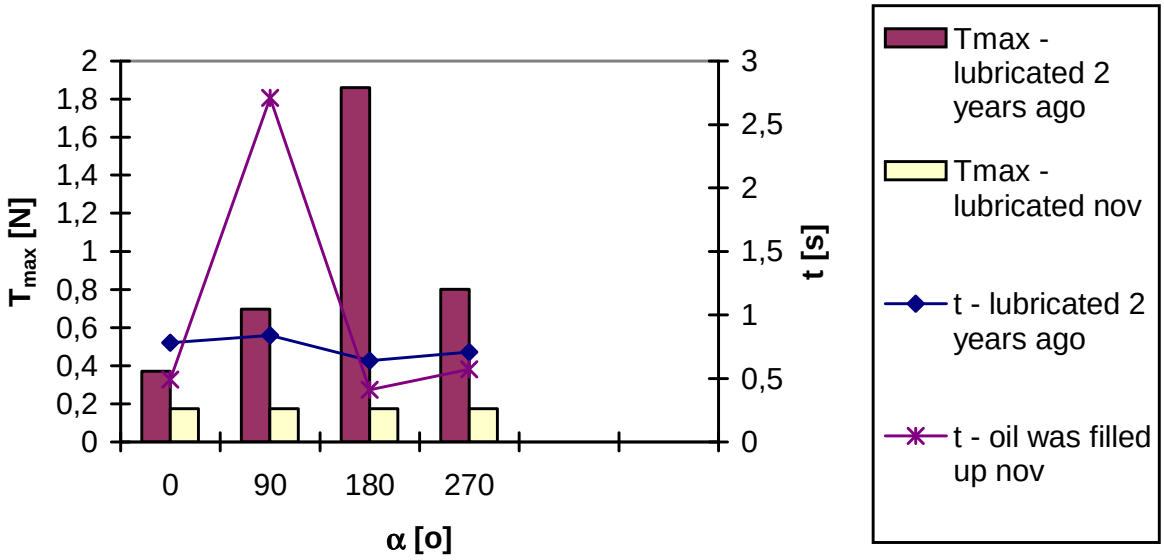

*Fig. 5. The values of maximum friction power of with T_{max} for putting the needle with account of the body of the injector nozzle **α** at spreading 2 year ago on precise steam and of adding oil in during investigations from considering times of moving needles*

Of relations on the base presented (fig. 5) it is possible to state, that time of coming out of needles from bodies of the injector nozzle largely by locations 0° and 180° is similar, as this way as for locations 90° and 270° what is providing about errors of shape of the injector needle.

The 6 picture is presenting maximum friction forces T_{max} to the relation from putting needles with account of corps for six examined injector nozzles with spreading on precise pairs with white mineral oil. The graph was made on the basis of data from the measurement table.

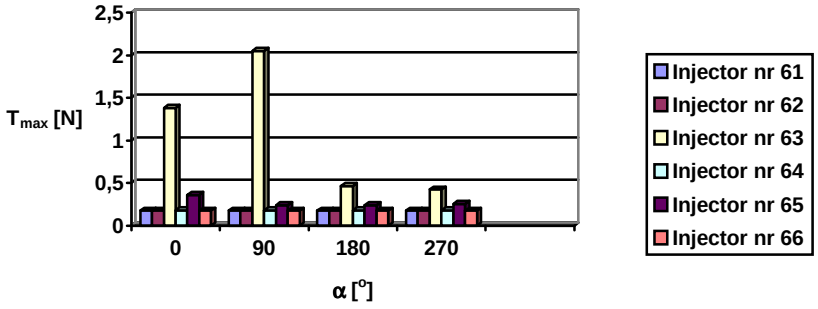

Fig. 6. Value of maximum friction power of rubbing with T_{max} from putting the needle with account of the body of the injector nozzle α

The 7 picture is presenting maximum values of T_{max} friction forces for the angle of the turnover to the needle at greasing with white mineral oil and make for the same injector nozzle. How he results from the fig. 7, new lubricated of precise steam that is increasing masses of the spread able middle, causes reducing the friction force.

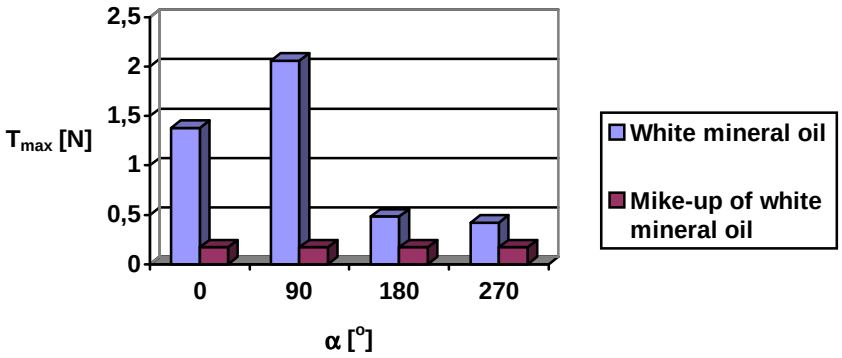

Fig. 7. The values of maximum friction power with T_{max} from putting the needle with account of the body of the injection nozzle

In the picture 8 a relation of times of moving needles from bodies of injector nozzles was presented. On the basis of the fig. 8 it is possible to state that the majority of times of coming out didn't cross needles more how for 5 s. Arranging it is biggest for the range of additional mass m_a from 0 up to 0.05 kg.

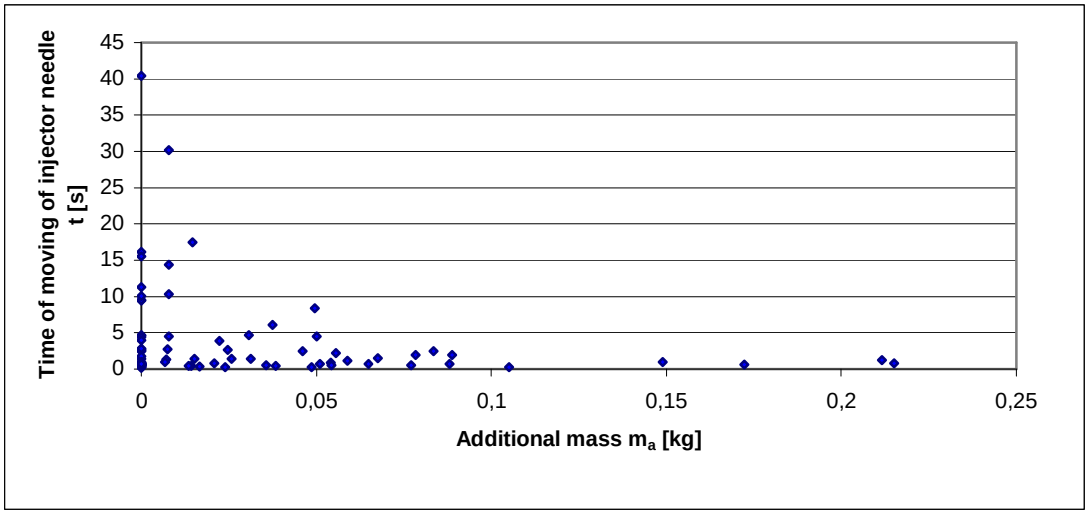

Fig. 8. Disintegration of times of coming out of inector needles t for different value of additional mass m_a

Picture 9 is showing the graph made out during the research on the course of maximum friction power on the stand for investigation of tensile strength for the injector number 43, where the position and the method of investigations were described at work [5].

On the course of the friction force at of moving the of the needle from the body of the injector nozzle at first the friction force is increasing gradually, and then a resistance, which is introduced in the picture, follows as dips and increases in the force of friction. Next moving into the right side of the picture a fall and an increase in power, by which the needle is left protruding from the body of the injector nozzle follow. Oscillations of the friction force are caused with uneven nesses of leading surfaces and randomly put pollutants.

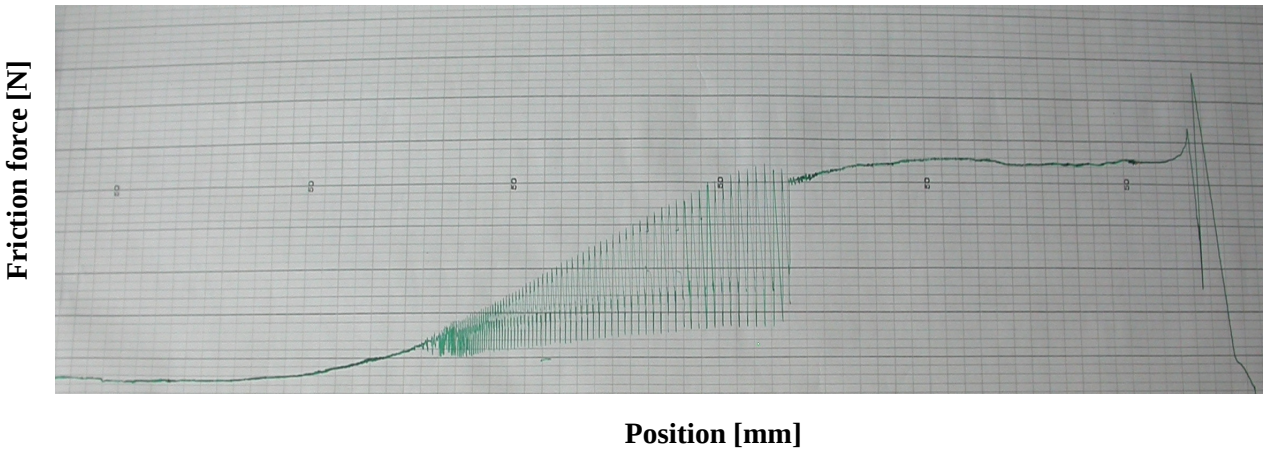

Fig. 9. Course of the friction force at of moving then needle from the body of the injector needle, made out on the machine for examining the resistance to stretching

7. Conclusions

The carried out tribological investigations of injector nozzles they allowed for checking dependences of the maximum friction force on greasing the lubricating kind, of angle of the turnover of the needle in the body of injector body and the time of coming out of needle from the body of the nozzle, as well as at the performance of geometrical measurements precise pairs of minimal and maximum diameter clearance by different angles of the turnover of the needle.

For carrying all measurements out needed using a few positions was, in addition carrying examinations out was time-consuming and it required the great accuracy. The repetitiveness of measurements was impossible on account of low ease of manner among the precise pair, as well as influence of mistakes of the shape of the needling injector nozzle and corps and being pollutants inside in lubricating.

Examinations showed that an essential influence on value of the friction force had the kind of greasing by different angles of the turnover of the injector needle. Amount of the lubricating oil influences for reducing the friction force [10]. Great value of the maximum friction force are informing about increasing using precise steam up. On the basis of turning the needle in the body of the injector nozzle uneven using up needles was stated.

On the basis of turning the needle in the body of the injector nozzle uneven using up cooperating precise couples was stated. Research findings concerning of research on friction forces in four plains they showed that the influence of the measuring plain was essential.

Get results of tribological research findings pointed to the usefulness of the research on the maximum friction force, at the assessment of the technical state of injector nozzles.

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