DAMAGES OF DISTRIBUTOR INJECTION PUMPS OF DIESEL ENGINES

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SUMMARY
In fuel injection pumps of diesel engines the damages of pressure injection systems can occur. The typical form of damages are the material losses in the surface layers of cams and meshing rollers as well as the cracks of distributor plungers. It was stated that the reason of material losses are the excessive stresses in the surface layers of cams which are causing the fatigue of surface called pitting. The damages of distributor plungers are caused by the bending moments and torque's generated by the dimensional deviations of elements of pressure injection and driving systems as well as the pump housing.

Keywords: diesel engines, high pressure fuel injection

1 INTRODUCTION
The automotive diesel engines of cars and delivery trucks are equipped among others in the distributor plunger high pressure injection pumps [1-3]. In both new and repaired pumps the damages of pumping systems occur. Characteristic form of these damages are the material losses of the surface layer of cams, rollers and the cracks of distributor plungers [3]. The grounds for explaining the reasons of damages are the loads acting on the cam plate; these loads have to be calculated using cam acceleration and fuel injection pressures as functions of time. The damages of injection system elements are due to the excessive stresses in the cam surface layer, which result in the surface fatigue.

The distributor pumps of some engines operate at the fuel injection pressure which is increased in relation to the assumed one. An increase in fuel injection pressure causes, first of all, an increase in load acting on the cams and distributor plungers; it accelerates wear and causes the decrease in durability of these elements [3]. Furthermore, it comes to the worsening of lubrication conditions of mating elements by generating the mixed friction conditions of lubrication. The lubrication is not satisfied at low supply pressures because the diesel oil, particularly its new modifications [5], are not good lubricants. In the injection pump's high pressure stage which generates the high fuel pressure needed for fuel injection, above mentioned damages more often occurs.

As long as the reasons of wear in the form of seized mating surfaces of elements or pitting type damages are generally known [3], the determination of reasons of these damages of cams and distributor plungers is more complicated.

The task of paper is the investigation of wear occurring on the elements of distribution injection pumps. The knowledge and analysis of calculated, by means of FEM, stresses in the pumping system elements, can give more grounds for the design of reliable high pressure fuel injection systems. In order to determine the reasons of wear, the load acting on the meshing elements has been calculated using cam acceleration and fuel injection pressures as functions of time. Based on the calculated load and the results of metallographic tests of elements, it has been found, that the wear is due to the excessive stresses in the elements surface layers [3], which result in the surface fatigue called pitting.

The papers gives some explanations concerning the reasons of these damages.

2 THE LOAD OF PUMPING SYSTEM
The load of pumping system by the pressure force of rollers, has been described in [3]. The physical, one degree of freedom model (Fig. 1) was applied for analysis of pumping system The model of the system consists: the mass \( m \) representing inertial properties, massless springs of elastic forces and viscous damper of the damping properties of system. Mass \( m \) is the sum of following masses: piston-distributor, cam plate, spring bridge.

It was assumed that this force acts along the axis of distributor plunger \( r \) what causes the same load is applied to all of cams, and distributor plunger has the best condition of meshing with cylindrical bore of the head. The load of pumping system changes when this force acts parallel to the axis of distributor plunger at the distance \( \epsilon \), as shown in Fig. 1. This orientation of force can be caused by non-perpendicular position of cam plate with regard to the axis of distributor plunger. This as a sequence can result of unequal strokes of cams as well as unequal diameters of rollers. The strict sense, an effect of unequal strokes of cams and rollers diameters is caused by inconvenient adding of dimensions deviations of elements included in the pumping and driving systems as well as the housing of injection pump. In the first case the bending moment \( R \epsilon \) occurs each 90 degree rotation of disc with four cams. It can be said that it is the moment rotating together with the cam plate. Distributor plunger at the time of one rotation undergoes two sides bending in two planes, i.e. in the
plane of the Fig. 1 and the perpendicular plane. The cam having the largest stroke will undergo the largest load.

In the second case the force R occurs always on the side of roller of larger diameter and distributor plunger will undergo the one side bending in the same plane four times during one revolution.

Fig. 1 Scheme of pumping system fuel injection pump; R – pressure force of rollers, e – the distance of action line of force R from the axis of distributor plunger, A-A – cross-section at the inlet plane of distributor head, 1 – cam plate, 2 – rollers, 3 – distributor plunger, 4 – distributor head, 5 – the spring of distributor plunger, 6 – spring bridge, 7 – control bore

The distributor plunger undergoes the action of bending moment at the cross-section A-A, which is placed close to the control bore 7, having the connection to the inner bore of distributor plunger. These bores are the reason of stress concentration. The bending moment causes that the distributor plunger is pressed to the edge of head at the cross-section A-A, and as results of this action it arises the friction force giving the resistance torque causing the periodical, cyclic twisting of distributor plunger.

It seems that the most dangerous case is the one with the rotating bending moment.

Discussed elements of pumping system are shown in Fig. 2.

3 THE FORM OF CAM AND DISTRIBUTOR PLUNGER DAMAGES

An example of damaged elements of pumping system of distributor pump are introduced in Fig. 3. The cam plate shown in Fig. 3 has one cam damaged by the pitting (Fig. 3a) and the face surface of distributor head with the loss of material (Fig. 3b), as well as the cracked part of distributor plunger with welded piece of head material (Fig. 3c).

Based on the scheme introduced in Fig. 1 and considering only one cam, it can be assumed that the inclination of cam plate has been caused, first of all, by larger dimension deviation of damaged cam what has generated larger force than the other cams.

These clear microcracks and material loss in the surface layer of cam are shown in Fig. 4.

Rotating bending moment and generated by this moment the torque at the cross-section A-A (Fig. 1) has caused the friction of distributor plunger at the edge of bore in the considered cross-section what is confirmed by the peripheral seizures on the distributor plunger. Fatigue fracture of head surface placed around the half of bore certifies the larger stress concentration of distributor plunger on this side of head what probably has been caused by additional effect of dimension deviations of driving system and the pump housing.
Distributor plungers of injection pumps are particularly under the risk of damages in case of load by cyclic action of bending and torsion moments because of stress concentration caused by the notch having the shape of control bore 7 which exists in the neighbourhood of cross-section A-A (Fig. 1). Typical crack of distributor plunger which is caused by the joint action of bending and torsion loads, and going exactly through this bore, is introduced in Fig. 5. On this fracture the front lines which are characteristic for the fatigue process are visible. The next crack having the form of helix line going along the cylindrical surface of distributor plunger can also be observed. The values of forces and pressures can explain the wear phenomena occurring in the elements of high pressure fuel injection system. With the force of 2594 N acting on the rollers (648,5 N for one roller) the value of existing pressure is of order 420 MPa.

The distributor plunger stroke and delivery phases show the metering of fuel to an engine cylinder. For a 4-cylinder engine the distributor plunger rotates through 90° for a stroke from BDC to TDC and back again. In the case of a 6-cylinder engine, the plunger must have completed these movements within 60° of plunger rotation. This type of plunger operation means that this pumping system is heavy duty, dynamically loaded one.

4 FINAL REMARKS

It results from the analysis of damaged elements of pumping systems of injection distributing pumps, that the main reason of cam wear is an excessive contact pressure generated in the cam surface layer. This contact pressure causes the surface fatigue called pitting. The decrease in these contact pressures by variation of pumping system parameters in not possible considering the fact of increase in fuel supply pressure which mostly effects in the increase of contact pressures. It remains therefore adequate adaptation of surface layer strength to the existing load conditions [3, 6].
The reasons of cracks of distributor plunger are excessive bending moments and torque’s caused by inconvenient adding of dimensional deviations of pumping system elements, driving systems and the housings of pumps. The distributor plunger, the distributor head bushing and the control collar are so precisely fitted (lapped) into the distributor head that they seal even at very high pressures. Small leakage’s losses are nevertheless unavoidable, as well as being desirable for plunger lubrication. For this reason, the distributor head is only to be replaced as a complete assembly, and never the plunger, control collar, or distributor flange alone. The dimensional deviations cannot be too large considering the diametrical clearance of 3 µm which exists between the distributor plunger and the cylinder placed in the housing. Any deviation of dimensions will result in additional thermal and dynamic loads affecting the operation and increasing the wear of system.

Additionally the tribological problem of contact load and friction force between the cam and roller should be investigated more exactly to allow for explanation of operating conditions of high pressure stage of injection pumps. These problems are strictly connected to the cam plate contour influencing the fuel injection pressure and the injection duration. The contact and friction forces of cam and roller can be precisely measured by detecting the forces acting on the cam by application of three component force sensors [5].

More attention should be also put to the quality of roller and cam surface layer as well as to the special heat [6] or another treatment to increase the durability of these elements.

All these suggested investigations can give the progress in development of high pressure fuel injection system thus improving the quality of engines from the environmental point of view.

In all considered cases the thermal and dynamic load of real high pressure injection system, the heterogeneity of material, accelerating the damage of element, can not be neglected. In not so far future, the application of high pressure fuel injection pumps can be limited because of extreme high loads resulting from continuous increase in fuel injection pressure at insufficient lubrication of cams by diesel fuel. Their place take presumably the accumulating injection systems and the systems consisting the pump injectors [1].

5 REFERENCES