WEAR OF INTERNAL COMBUSTION ENGINE PARTS WITH POSSIBILITIES FOR THEIR REGENERATION

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1 INTRODUCTION

For the purpose of classifying the tribological components, the motor vehicle can be divided into engine, transmission, traction drive, continuously variable transmission (CVT), drive train, joints, and ancillaries. Engine friction losses including piston skirt friction, piston rings and bearings are 66% of the total friction losses, and in the valve train, crankshaft, transmission and gears they are approximately 34%. Concerning the powertrain friction loss only, sliding of the piston rings and piston skirt against the cylinder wall is undoubtedly the largest contribution to friction in a powertrain system [1]. Frictional losses arising from the rotating engine bearings (notably the crankshaft and camshaft journal bearings) are the next most significant, followed by the valve train (principally at the cam and follower interface) and the auxiliaries, such as the oil pump, water pump and alternator. The friction between piston skirt and cylinder, considered as hydrodynamic in the past, can be also mixed. The lubrication between the piston and the cylinder bore reaches the boundary lubrication condition at around top or bottom dead centre [2]. The sections below present some typical damages of engine parts and assembly with proposed methods aimed to regenerate and make them ready for further exploitation.

2 DAMAGES

2.1 Engine body damages

The crankcase consists of a block, which is closed at the top by the cylinder's head, and at the bottom by the oil sump. The cylinder block is a very responsible and the most expensive part on an IC engine. During exploitation, the following damages can appear on the engine body (Figure): wear of cylinder or cylinder liner working surfaces (A), wear of the crankshaft bearing pocket (B), wear of the camshaft bush pockets (C), cracks and punches on the water chamber walls (D), cracks and punches on cylinders' partition walls (E), deformation of the cylinder liners surfaces (F), wear of a hole for the valve tappet bush (G), nicks and scratches on the block's bottom surface (H), where the oil sump collects, irregularities of the block's upper surface (I), where the cylinder head is located, wear and shearing of threads in threaded holes (J) [3].

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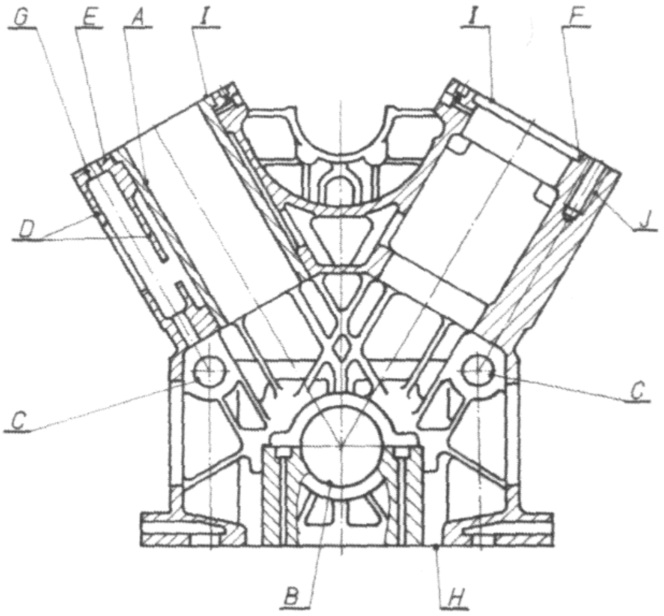

Figure 1:
Engine body damages

Cylinders' and cylinder liners' working surfaces are subjected to extremely high loads, so they wear faster than the other engine parts. On the other hand, relatively low wear of cylinders surfaces leads to significant deterioration of effective indicators of engine running (decrease of engine power and increase of fuel and oil consumption).

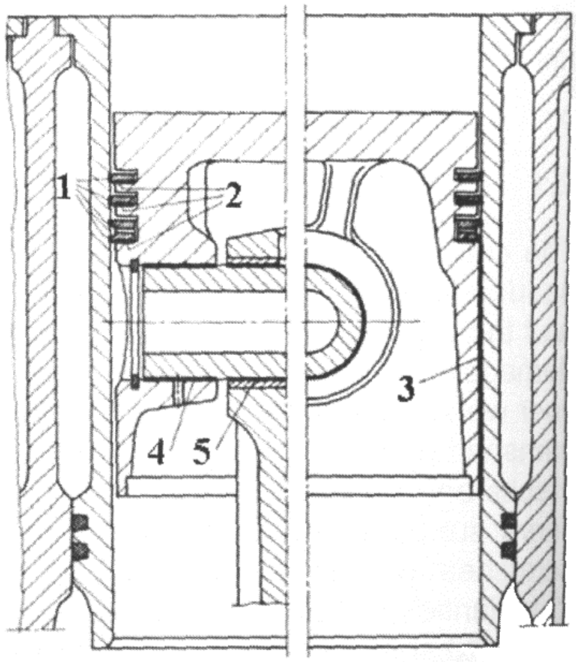

Figure 2:
Tribo-mechanical couples of piston-cylinder assembly:
1. Piston rings – cylinder,
2. Piston rings – grooves of piston rings in piston,
3. Outer surface of piston – cylinder,
4. Pin – piston,
5. Pin – piston rod

Cylinders are worn in the area of the piston rings motion. Cylinder working surface wears into an oval cross-section, with a larger ellipse axis in the plane of the piston rod oscillations, and along the height it gets the conical shape, with the tip pointed downwards. Irregularity in the cylinder wear is explained by the action of the piston rings, especially the first one, due to high pressure of gases, high temperature, gas corrosion, poor lubrication conditions, action of abrasive particles – dust particles entering into the cylinder together with air, and formation of coke during fuel combustion. Cylinder and cylinder liner wear characteristics, as presented in Figure 3, point to the irregularity of wear in the height direction (the upper and the bottom dashed-line represent positions of the upper edge of the first piston ring, when the piston is at the upper dead point and the bottom dead point, respectively).

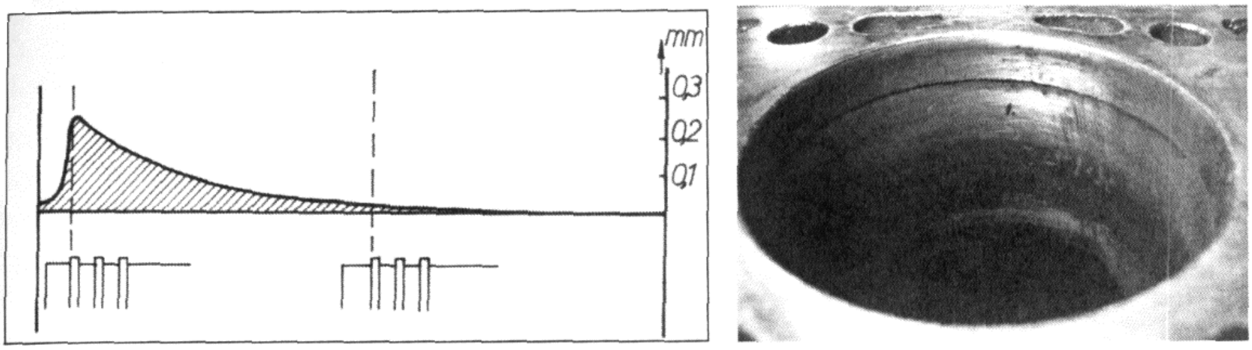

Figure 3: Cylinder wear characteristics and typical damages

2.2 Damage of the piston mechanism elements

Tough exploitation conditions in which the IC engine piston mechanism elements operate assume high requirements for their production and regeneration. Operation of the engine with the worn piston mechanism elements leads to decrease of the engine power, increase of the oil and fuel consumption, appearance of smoke and soot, impacts, increased noise, and other irregularities. Crankshaft necks usually suffer wear due to the inertia force interaction of the moving elements. They cause wear on the surfaces of the crankshaft bearing and flying necks. The first consequence of unequal wear of the rod is that it becomes conical and oval. Wear intensity depends on the axle's end points of crankshafts on oil quality, efficacy and condition of the oil filtration system and many other factors. The crankshaft bearing and flying necks get oval and conical during exploitation.

The most frequent damages of the crankshafts and typical locations [4] of their likely occurrence are presented in Figure 4:

- Wear of the supporting (bearing) necks,
- Wear of the flying necks,
- Shaft flexure,
- Wear of necks to which the seals and distributing gear are fitted,
- Wear and damages of grooves, threaded and other holes,
- Occurrence of cracks on the shaft,
- Plastic deformation of the cranked portions, namely different distances between the single cranked portion walls.

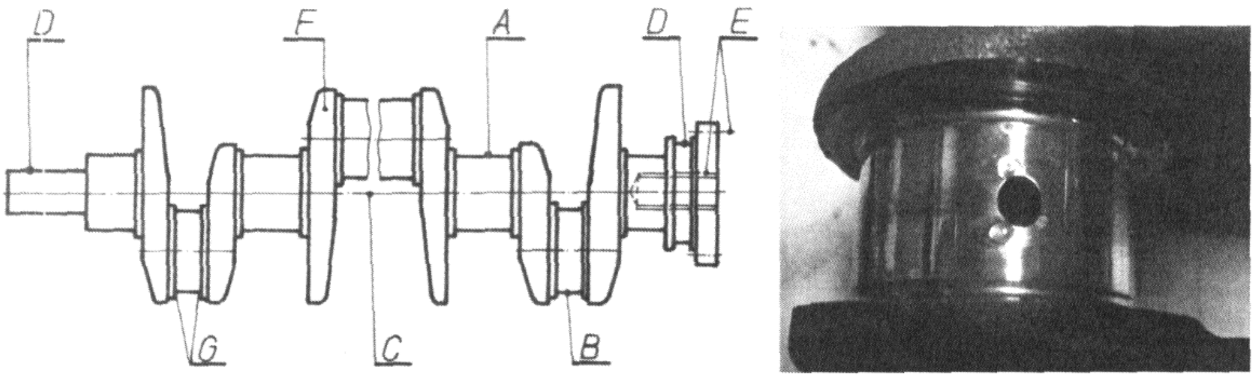

Figure 4: Positions of the IC engine crankshafts damages and worn neck

3 DIAGNOSTICS

In the diagnostics of engine body damages due to wear and piston elements, the following methods could be applied:

- The visual method is used to identify larger damages of cylinders, larger surface cracks, punches, threaded holes damages, deformation of cylinder liners surfaces, as well as nicks and scratches on the bottom surface of the body.
- The technical measurements method is used to check the magnitude of wear of the cylinders, bearing pockets, bushing pockets, cylinder liners surfaces, holes for valve guides, and unevenness of the body upper surface.
- The hydraulic method is used to detect the passing-through cracks, and to check the hermeticity. These tests are usually done using water at 0.2-0.4 MPa pressure, for 5 min [5].
- Hidden cracks are the most difficult to detect, so for that purpose different methods of defectoscopy are applied such as: magnetic, penetrating, rarely radioscopy and ultrasonic.

3.1 Engine body diagnostics

In cylinder diagnostics, one observes with the naked eye or flexible endoscopes the interior surface, on which no damages are permitted (holes, scratches, jams). The IC engine cylinders, due to wear, become oval and conical, and non-symmetrical relative to the cylinder axis. Determination of ovality and conicity is done using a comparator to perform measurements. Depending on the degree of wear, the extent of repair is defined to which the cylinder has to be drilled. The coaxiality of crankshaft basic bearings pockets is checked using the shaft and inspection masters or rulers with a small comparator. The permissible non-coaxiality of basic bearings pockets is 0.03 mm for passenger car engines, and 0.07 mm for tractor engines. Non-coaxiality of crankshaft basic bearings holes, in the assembly with caps, is checked by a special mandrel.

Evenness of the body's upper surface is checked by the ruler and inspection masters in two perpendicular directions. Unevenness of the surface must not exceed 0.15 mm. If it were larger, the cylinder head could not be evenly fastened to the body's surface, which would lead to seals damages, water penetration and fuel leak.

3.2 Diagnostics of the piston mechanism elements

Before regeneration the crank shaft should be disassembled and thoroughly washed. With special care, the canals for oiling and holes for oil drainage should be cleaned. Clearances are determined for each type of engine, and for each crankshaft regeneration measure, according to corresponding technical conditions. In crankshafts diagnostics, special attention should be devoted to the working surfaces of bearing and flying necks and bearings, clearances in bearings, distances between the cranked portion walls, and radial eccentricity of flying necks. If the crankshaft eccentricity does not exceed 0.1 mm for automobile engines, and 0.2 mm for heavy engines, they are not subjected to straightening. Damage is removed by grinding. Checking of the shaft flexure can be done also for the frontal eccentricity of the flange for fixing the flywheel. Maximum allowed eccentricity is 0.05 mm. Eccentricity located on the crankshaft flying necks is determined by the clock-type comparator that is fixed to the holder. The value of eccentricity is established as a difference between the smallest and the highest reading from the comparator's arrow, for the shaft full rotation, at two sections of 0.4 neck length distance from the middle point of the neck, to both sides. The distance between the crank portion walls is measured using special equipment with the clock-type indicator. The device is placed between the walls of the cranked portion, the arrow is brought to the zero position, and then the shaft is rotating slowly [5].

4 REGENERATION

4.1 Engine body regeneration

All above described irregularities can be successfully regenerated. However, if the internal partition walls fracture occurred, if there are more than two cracks 800 mm long, the cracks that are passing through the threaded holes, or if they exit on the body machined surfaces, or if there are more than two fractures of the complex form, the body is not regenerated [6]. Cuts, nicks and scratches of the body bottom surface are removed by manual processing or machining. Worn cylinders are drilled out, honed to the next repair size, and completed by the pistons of corresponding dimensions. Repair sizes are usually increased by 0.5 mm. The number of repair sizes is 2-4, most frequently three. Cylinders are drilled out on special vertical drilling machines. Drilled out cylinder liners and cylinders are then honed. Honing is done on special, vertical honing machines by abrasive grindstone of rectangular cross-section, fixed in heads aimed for this operation (Figure 5). Head has simultaneous rotational and translational (up and down) motions. It is possible to check grindstones pressure on the cylinder walls. After honing, the cylinder surface must not have any traces of wear, and conicity and ovality greater than 0.02 - 0.03 mm. After exhausting all allowed repair measures, worn wet cylinder liners are removed and replaced by new ones. In engines which do not have the cylinder liners, after the limiting wear, cylinders are drilled out, and then the dry liners are pressed into them and drilled out to the nominal size. The cylinder liners are pressed into the cylinder with an overlap of 0.08 - 0.12 mm, so it is frequently necessary to heat the body or cool the liners [7].

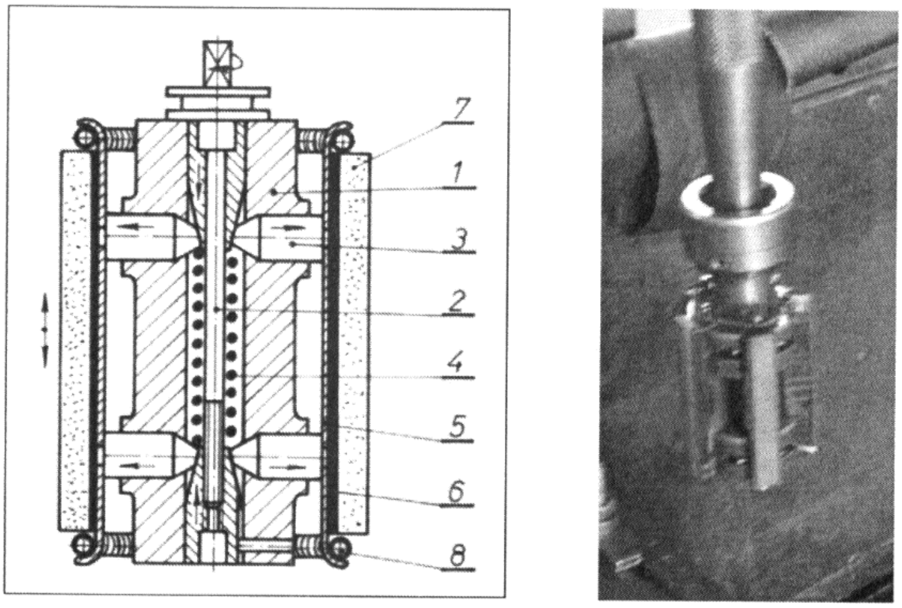

Figure 5: Honing head (1 – body, 2 – spindle, 3 – fasteners, 4 – spring, 5 – grindstone holder, 6 – grindstone neck, 7 – grindstone, 8 – springs)

Instead of honing, the rolling can be performed, using a head with small rollers fixed to the drilling machine spindle. Such machining, besides removing the roughness, also provides for higher surface quality and increases its resistance to wear. The damaged pockets of cylinder liners are hard faced, and then machined to nominal sizes. Regeneration of the crankshaft basic bearings pockets is done by drilling out to repair sizes on a special horizontal drilling machine. Into the machined pockets are placed bearing's halves of increased sizes. Cracks can be welded directly, or reinforced by fastening the screws, and then welded. Damaged upper surface of the body is regenerated by even grinding. If the body is made of aluminium alloy, then the milling is applied. Worn and sheared threaded holes are regenerated by drilling out and threading in the larger size thread, into which is then screwed the threaded bushing that has the interior thread of a nominal size. It is possible to drill out the threaded hole, thread the new thread of the repair sizes, and produce the step bolting screws. Step bolts have the thread with increased nominal sizes on one end, which is screwed into the body, and the remaining portion of the bolt is of the nominal size. In some engines there also appears wear of holes for valves bushes and valve tappets in the body. If wear is greater than 0.7 mm, the wholes are regenerated by drilling out to a repair size. In such prepared holes are placed bushings with adequate dimensions.

4.2 Regeneration methods for piston mechanism elements

The piston regeneration is reduced to reaming of the hole for the piston axle with the manual reamer. The diameter of the hole must correspond to the piston axle. If the damage remained within the allowed limits, the channels must be cleaned, and soot, scale and resin must be removed. The piston axle is regenerated by grinding to the repair size, and by polishing or hard chroming, and then grinding. Worn and damaged inside surfaces of the small and large crossheads, as well as damaged separation surface of the piston rod and the large crosshead cap can be regenerated by hard facing and subsequent mechanical machining of surfaces to the nominal sizes. The basic operation of the crankshaft regeneration represents grinding of the bearing (Figure 6) and flying neck to the repair sizes. Crankshaft basic necks grinding is done on special grinding machines, with necessary application of devices that enable correct placing and control of that placing of the shaft, prior to grinding. Flying necks are ground during placing the crankshaft in fixtures eccentrically, where it is fixed by its end bearing necks. Eccentricity enables moving of the shaft for a crank radius, and bringing the flying necks axes to coincide with the grinding machine spindle [7]. The flying neck's axes must be parallel to the bearing neck's axes. Flying and bearing necks must be ground to the same repair size, with differences in diameters less than 0.05 mm. During grinding special attention should be paid to transition from the neck working surface to the cranked portion wall. This transition must be smooth, so the inside stresses would be removed and the crankshaft fracture prevented.

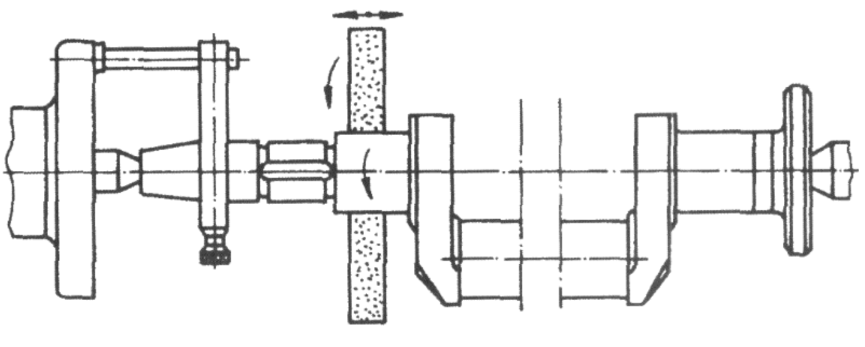

Figure 6: Grinding of the basic (bearing) necks

The crankshaft, after regeneration, must be subjected to dynamic balancing. Imbalance of the shaft is removed by drilling of the holes in necks or by counter weights placed on the shaft. The allowed magnitude of imbalance for the agricultural machines' crankshafts is 120 gcm, for trucks' shafts it is 100 - 150 gcm, and for light vehicles 10-50 gcm [7]. Bearing and flying bearings of contemporary engines represent mutually changeable steel or bronze inserts, soldered by the anti-frictional layer of 0.2 - 1 mm thickness. Worn inserts of bearing and flying bearings of all the engines, as a rule, are replaced by new ones, with smaller repair sizes, according to measures of crankshaft necks after their grinding, or they can be regenerated by deposition of polymer materials. During the piston mechanism elements regeneration the control of lubricating channels is mandatory, both on crankshaft and on piston rods, and their rinsing on special devices.

5 CONCLUSION

There have been many studies leading to an elucidation of friction in engine components. It is revealing to examine where the energy of the fuel that is burnt actually goes. Only 12% of the available energy in the fuel finds its way to the driving wheels, with some 15% being dissipated as mechanical, mainly frictional, losses [8]. Those implications underline the significance of reparation and regeneration methods applied for engine parts and assemblies. This paper intended to present just a part of those methods based on the experience of diesel engines regeneration in a specialized company in mid Serbia. Presented regeneration methodology of the severely damaged parts and surfaces of the diesel engine enable fast return of the engine and the whole machine system into exploitation. Those procedures lead to a significant exploitation cost reduction, especially if one needs to buy and import new engine parts. Exact and more detailed economical effects of engine parts regeneration used to be done in some further analysis but it exceeds this paper's volume and topic. Besides, those regeneration possibilities could extend the working life of the engine assembly with doubtless reliability protection during the vehicle operation.

6 LITERATURE

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