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CONSIDERATIONS REGARDING THE COMPARATIVE DETERMINATION OF MATERIALS HARDNESS SUBMITTED TO HEAT TREATMENTS

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Abstract: *Present paper aims to determine a comparative analysis of mechanical part hardness, used in automotive field, by highlighting values measured in different functional surfaces. Therefore, it was used a Fervi D08 hardness tester and it was applied the Rockwell scale in order to enunciate several conclusions regarding the influence of heat treatments on materials, as well as hardness value distribution on the entire surface of a mechanical part. At the same time, it was used a coordinate measuring machine to determine depth of imprinted indentation on tested surfaces. Such an analysis allows evaluating the behaviour of a mechanical part in case of different stresses which occur during functioning.*

Key-Words: *Hardness, Heat treatment, Coordinate measuring.*

1. INTRODUCTION

Hardness testing has the aim to determine physical properties of materials with the purpose to evaluate behavior under the influence of mechanical actions, as well as a quantifiable assertion of results, in order to evaluate whether a metal part meets stress demands that occur during functioning [1].

Main scope of the paper was to determine by measuring the tappet hardness of an internal combustion engine. Tappets (or cam followers) are constituent parts of the distribution system of a motor vehicle, with function to actuate the valves of internal combustion engines [2].

For the experimental tests it was used a mechanical tappet, of cylindrical shape, with a plate at the inferior part which comes in contact with the valves.

The part used for testing was made of alloyed steel and was submitted to tempering (heat treatment) on the entire surface so that it complies with requirements assessed by the operating conditions.

Considering the wearing process of a tappet during functioning, it was performed a comparative analysis of hardness, at the middle point of the cam follower (tappet) and in several points on the exterior circular line of the tappet's plate.

Also, in order to highlight variation of hardness values on the entire longitudinal axis of the tappet, there were performed tests at both ends, in the middle point of the surface (one at the plate end and the other at the tappet's rear, also known as its tail) [2].

There have been processed and analyzed all results obtained from experimental tests, in order to highlight differences regarding mechanical properties determined on multiple surfaces of the same part which was prior submitted to tempering (heat treatment).

2. DEVELOPMENT OF EXPERIMENTAL TESTS

Experimental tests consisted in applying a static method to determine hardness, with the use of a Fervi D018 hardness tester.

The practical part was preceded by a functional checkup of the tester, realized with the use of a reference sample, with inscribed values for Rockwell hardness validation.

Several examples of calibration references are presented in figure 1a).

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Figure 1.a) Reference sample HRC b) Conical diamond indenter

After verifying the proper functioning of the tester (calibration process) it was selected an appropriate type of indenter based on the analyzed material and taking into account all specifications from specialty literature, as well as the indications provided by the manufacturer of hardness tester [1][3].
Therefore, the tester was equipped with a conical diamond indenter, presented in figure 1b), which is specific to the Rockwell hardness test.
This method is used in case of hardened materials such as tempered alloyed steel (HRC - conical diamond indenter), tools made of hardened alloys (HRA – conical diamond indenter) and soft, malleable or untreated metals (HRB).
In this case, considering the material of the analyzed tappet, it was used the HRC scale [1][3].
The procedure to determine material hardness consisted in [3]:

- cleaning of the tappet's surface, followed by grinding operation (the abrasion was realized with a grinding machine) so that the analyzed surface is polished, without scratch, rust stains or other defects;
- proper display of the tappet, on a V (Vee) anvil which is used for cylindrical shaped rods or tubing, so that there are eliminated errors specific to testing and reading the imprint made by the indenter. This stage ensures an orthogonal position between the tip of the indenter and the tested surface, but also a fixed position of the tappet under the influence of the indentation force;
- verifying minimal thickness of the tappet so that the material is 10 times higher that the depth of indentation;
- realising the contact between tested surface and indenter, by applying an intial charging force of 10 kgf (10 daN);
- the pressing lever was set to 100 kg (980.7 N);
- pressing the start button of hardness tester, the charging force was automatically loaded so that in the moment of maximum load, the main force was instantly applied. The force is maintained for 5 seconds.
- follow-up, hardness value was read from the tester's screen;
- for result validation there have been performed 5 measurements (one for each middle point at both ends where are the functional surfaces of the tappet and three indentations near the exterior diameter of the tappet's plate).

Testing procedure is depicted in figure 2.

Figure 2. Hardness testing in the middle of tappet's plate

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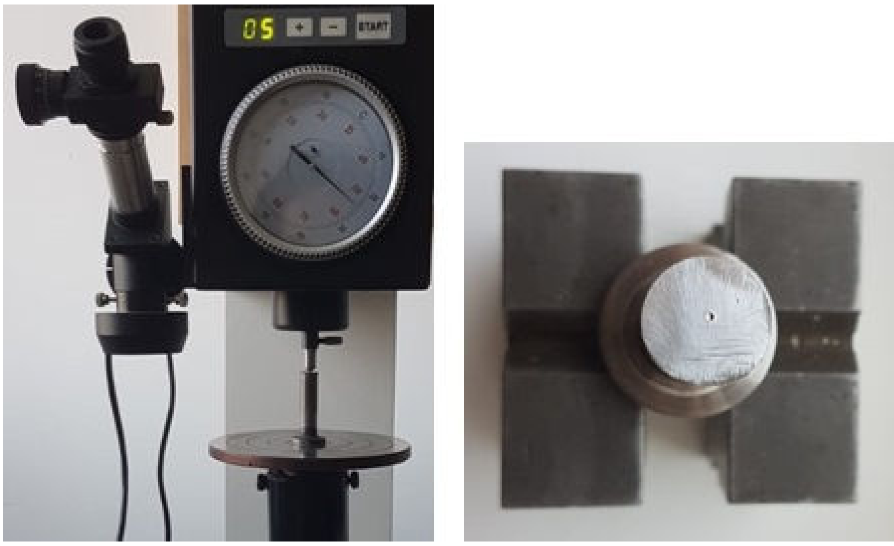

Figure 3. Hardness testing in the middle of tappet's rear (tail)

As it can be observed from figure 2 and figure 3, hardness value in the middle of tappet's plate is 32 HRC. Likewise, the value measured in the middle of tappet's rear was 24 HRC.
Regarding the values obtained from measurements near the exterior diameter of the plate, and considering that the mechanical part reached the end of its life cycle, hardness values obtained in various points on the diameter were different, resulting an average hardness of 38 HRC.

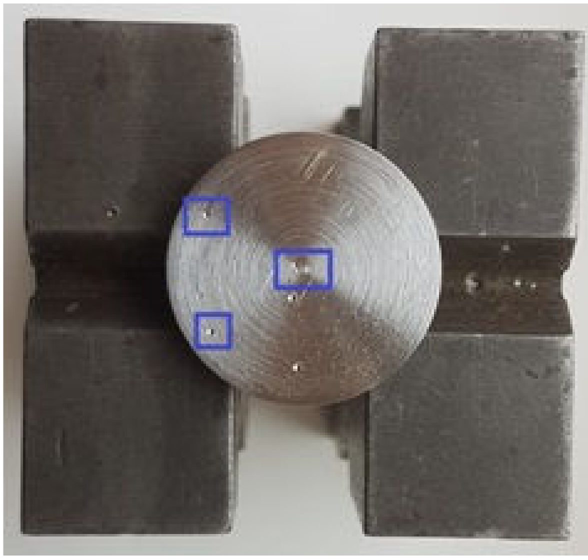

Figure 4. Areas from tappet's plate where hardness was tested

Analysis of results has highlighted that hardness values in superficial layer of tappet is higher than the value measured in the middle of material.
Differences obtained can be attributed to the tempering process, namely:
- holding period for temperature equalization on the entire section of the mechanical part,
- duration of the heating process,
- carbon concentration within the alloy,
- tempering environments, which must be chosen based on the mechanical part diameter and cooling speed etc.

Results obtained with the hardness tester can be validated with the use of a coordinate measuring machine, which allows determining hardness by mathematical computing [1]:

$$HRC=E-e \quad (1)$$

where E is a suitable chosen value, and e is the depth of residual indentation.

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In present paper it was used the coordinate measuring machine, presented in figure 5, for determining the indentation depth in order to compare values obtained on different areas of the tappet.

Figure 5. Coordinate measuring machine

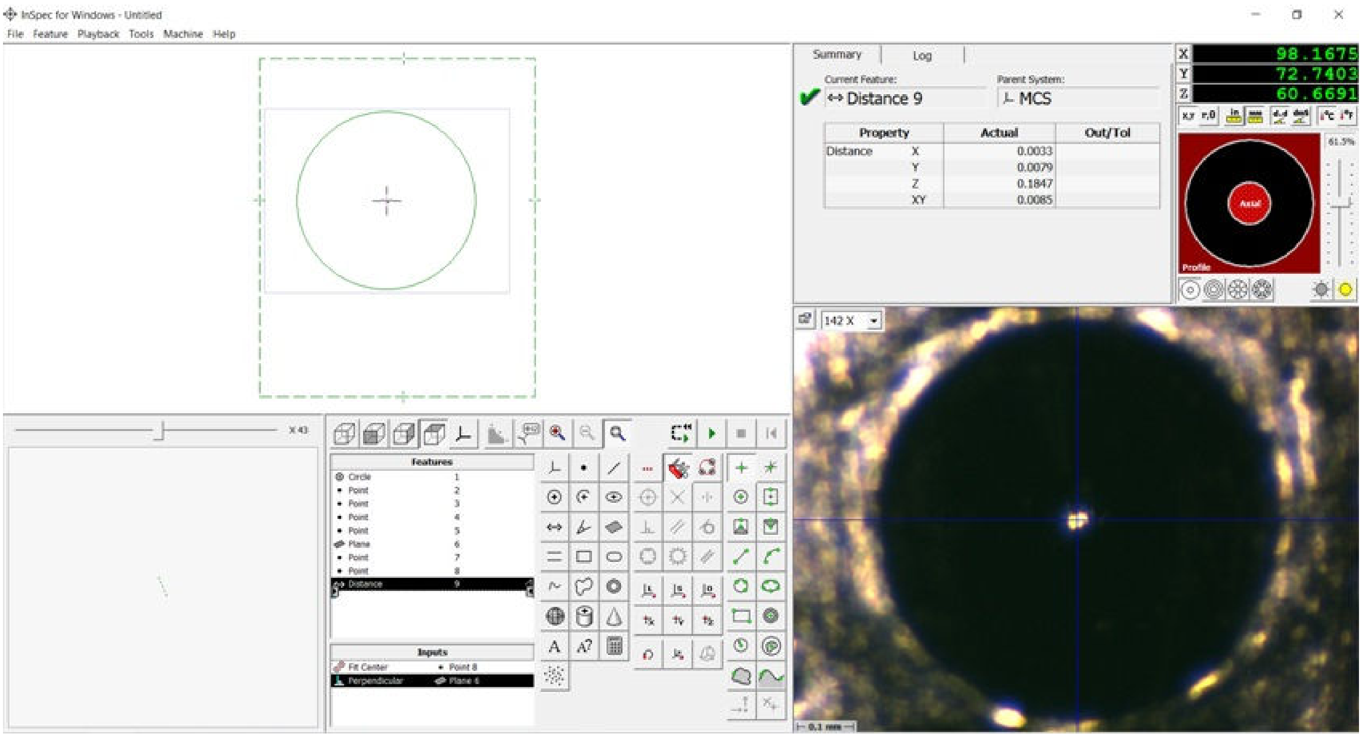

Figure 6. Indentation depth measured in the middle of the tappet's plate

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Several examples of results provided by the coordinate measuring device are presented in figures 6 and figure 7. In the upper-left quadrant of figure 6 is indicated the position of indentation made in material and in the upper-right quadrant are illustrated values of coordinate points of the indentation, as well as the depth of residual mark of 0.184 mm. At the same time, from figure 7, in the upper-left quadrant it can be observed the depth value of each imprint made by the conical diamond indenter, namely 0.139 mm, which is measured on Z axis.

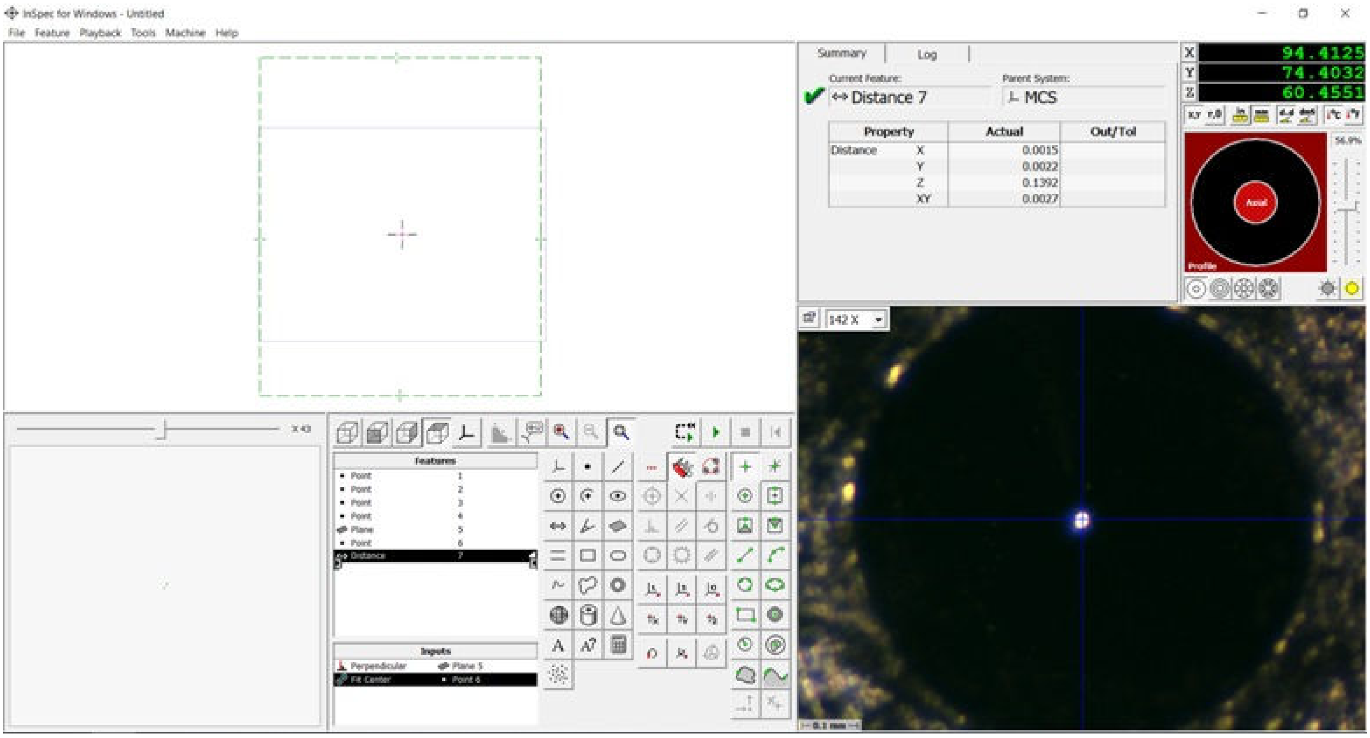

Figure 7. Indentation depth in one point on the exterior diameter of tappet's plate

3. CONCLUSIONS

Present paper had the purpose to list and elaborate phases made for a comparative analysis of mechanical part hardness, in different points on the transverse sectioning plane.

Methodology of experimental research must be applied considering all conventions from specialty literature, as well as the instructions recommended in the hardness tester workbook.

All characteristic stages must be passed through in order to eliminate errors while measuring and reading values.

From the analysis of hardness values, obtained both in the middle of tappet's plate and in several other points near the exterior diameter, it was observed that the heat treatment of tempering which was applied for improved mechanical properties, had different influences on the entire section.

Therefore, in the middle area there have been obtained lower hardness values than on the exterior circular line of the tappet's plate. Possible explanations have been detailed in chapter 2, regarding the procedure of experimental tests.

At the same time, following the analysis of results obtained by using the coordinate measuring machine, it was observed that the imprinted depth of indentation on the surface with 38 HRC hardness was 0.139 mm, whereas the value of indentation depth with 32 HRC hardness value was 0.184 mm, as was to be expected.

Therefore, it is a compulsory request to determine hardness materials in order to certify that a mechanical part can face stress, wearing process etc., depending on its functional usage.

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