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APPLICATION OF "BLOCK ON DISC" TRIBOMETER IN RESEARCHING MATERIALS WORKABILITY

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Abstract

Constant development of new materials, tools cutting fluids, etc. impose need for permanent experimental research in machining in order to estimate cutting workability of new materials and tribological propetries of new tool materials, as well as properties of cutting fluids.
There is a need for development of rapid research in model conditions, and one of posible ways is development of research methods by simulations of tribological process on tribometer. Research work, in Laboratory for machine tooling and tribology at Faculty of Mechanical Engineering in Kragujevac, has been making up significant results in development of tribometrics methods and measurement equipments for tribological investigation on "Block on Disk" tribometer. Researching of materials workability is at the very beginning. Regarding this, begun investigations are based on research of tribological occurrence into region of contact of two body, block and disc, where one body is sliding over other in present of cutting fluid as third element. A block is made of material for cutting tool, a disc is made of material for work pice, while achieved contact conditions (normal loading and sliding speed) are meeting real working conditions. Realized investigations on tribometer "Block on Disc" have had an aim to establish opportunity of investigation of materials workability by tribological parameters (coefficient of friction and width of wear scar on the block). Comparing analysis of experimental results in real cutting condition and tribological investigations, it is shown that simulation of cutting process by tribometer "Block on Disk" can replace experimental investigation, which is related to the determination of tribological characteristics of cutting tools and workpieces, and also describes the machinability of materials in real condition of cutting. In the specific conditions, related to the material comparison, it is possible with sufficient accuracy to apply material indexes with respect to the friction coefficients and wear scar on the block obtained by corresponded measurements on tribometer.

***Key words**: friction, wearing, tribometer, cutting workability, simulation*

1. Introduction

Development of new materials and improving of present materials are consequence of permanent striving to reduce losses of materials and energy produced by friction and wear into tribomechanical systems. Rapid grow of automotive and airplane industry, rocket technique, energetic and processing industry and etc., cause a wide application of numerous types of new materials which satisfy specific exploitation conditions by its properties. These materials are high-alloy steels and stainless fireproof steels, carbon and alloy tool steels, special alloys on the base of nickel and cobalt, multilayer and ceramics materials, and etc. Majority of these new materials possess improved mechanical characteristics and specific physical properties which reduce their technology characteristics from the standpoint of forming and cutting process. That means that new materials are not hard workable only in machining, but almost in every type of processing efficiency are still the subject of numerous research regarding continuous introduction of new materials, new procedures of its processing, new specialized cutting machines and new cutting tool materials.

To fit hard work conditions, new materials have to be highly strength, heatproof and wear resistant. It is not necessary to particular point out that in domestic industry tools made of high-speed cutting steel are still in use: HSS for low-speed cutting of easily workable materials and HSS.E with increased contents of alloys elements (W, Co, Mo) for hard-workable materials. Between hard metals (TM), TMs with coating and tungstenless TMs (cermet), which are distinguish with good ductility and strength of cutting edge, are in use.

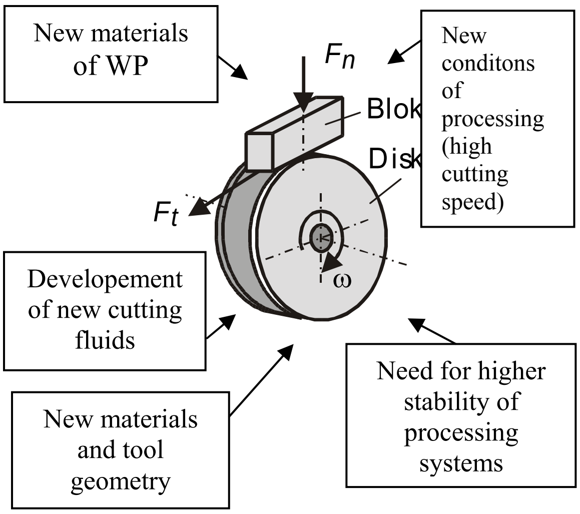

Figure 1: *Requirements for rapid models investigations on tribometer*

The focus of this paper is the most used difficult to cut materials: high alloy tool steels, high alloy Cr-Ni steels and improved steels. Processing of these materials are specific regarding tool materials and geometry, cutting regime, cutting fluids, demands for raise machine stiffness, etc.

Unavoidable need for rapid tribological models investigation is imposed by analyzing specific, variable processing conditions of difficult to cut materials, which require new types of tool materials and adapted tool geometry.

Development of tribological measurement systems and methodology for models investigation enable simulation of cutting process on tribometer "Block on Disk" as well processing. Problems of hard workable materials as identification of tribological processes into both of basic tribomechanics systems of this kind. That is concern on simulation of process happening into contact zone of tool insert rake face and chip, and tool clearing face and machining surface of work piece. Investigations, begun with this aim and presented in this paper, are based on research of tribologicl phenomenon appearing in contact of two bodies (Block and Disk), while one body slides over another in presence of cutting fluid. Block is made of materials of cutting tool and disk is made of materials of machining work piece.

2. Programs and conditions of experimental investigations

With the aim to investigate workability of different materials in concrete cutting process conditions, an experimental investigations were performed on lathe, with high-speed steels tools (HSS.E) and hard metal tools (TM), with and without cutting fluids. Values of each of three resulting cutting resistant components are measured for different cutting regimes during investigations, and curves of tools wear are formed too.

Investigation on tribometer "Block on Disk" are performed after investigation on the lathe. Blocks are made of high-speed steels (HSS.E) and hard metal (TM) for cutting tools, and disks are made of materials for work piece used in investigation conducted on lathe. During investigation conducted on tribometer, the data of coefficient of friction and wear of contact surface between block and disk are obtained.

These investigation were conducted with aim to establish possible relationship between results obtained in machine cutting process and results obtained in tribolocigal investigation on "Block on Disk" tribometer.

Conditions of lathe turning investigation

Investigated materials: group of difficult to cut materials: Č3840 (Merilo) 248 HB; Č4150 (OCR 12) 277 HB; Č5430 improved 40 HRC; Č5742 (Utop extra 1) 258 HB; Č7680 (HSS) 299 HB.

Cutting tools:

- high-speed tool steel - Č9780 (HSS.E): cutting tool JUS ISO 10 (16x25x250 E18 Co10) wit geometry: $\gamma=6^0$; $\alpha=8^0$; $\lambda=0^0$; $\chi=45^0$; $\chi_1=45^0$; r=1 mm.

- carbide tipped tool: tip:SPGR 120308 PGP-135 (P35), PP CORUN; tool support: CSDRP 2516 M12, KENAMETAL.

Machine: Prvomajska's universal turning lathe, 10 kW.

Cutting fluid: cutting oil ISO 22

Investigation regimes with HSS.E tool: cutting depth 0.5 mm; feed 0.112 and 0.14 mm/rev; cutting speed 20 and 40 m/min.

Investigation regimes with hard metal tool (TM): cutting depth 0.5 and 1 mm; feed 0.14, 0.18 and 0.25 mm/rev; cutting speed 60 and 100 m/min.

Measurement equipment: three-component dynamometer KISTLER, amplifier KISTLER, AD converter Burb Brown and computer.

Conditions of tribometer investigations

Materials of block: high-speed steel Č9780 (HSS.E) of hardeness 66 HRC; carbon tip without coating (TM) – SNUN 120412 in quality P30.

Materials of disc: group of difficult to cut materials investigated on lathe.

Sliding speed: 0.74 m/s and 1.143 m/s.

Normal loading: 200 N, 300N.

Lubrication: boundary, realized by passing lower part of disc through oil bath, cutting oil ISO 22.

Contact duration: 60 min, 120 min.

Measurement equipment:

- Tribometer TPD-93 for measurement of normal loading, force and coefficient of friction.
- Talysurf 6- for measurement of parametars of contact body sourface topografy
- Universal tools microscope UIM 21- for measurement of wear of contact surfaces.

Results of tribological investigation contain information about: coefficient of friction, width and depth of wear scar, wear shape of contact surface on block, change of friction coefficient during contact time, topography of block and disc surfaces before and after investigation, wear scar on block and disc, etc.

3. Results of investigation

On the basis of the measurement results for each of three components of cutting resistance, workability indexes are defined from aspects of main cutting resistance F_1, resistance of penetrating F_2, resistance of feeding F_3, resulting cutting resistance F_R, resultant of penetrating and feeding resistance $F_{R2,3}$, and from the aspect of relation coefficient φ between resultant $F_{R2,3}$ and main cutting resistance F_1. Those indexes are defined with the goal to improve quality of analysis and enable comparison of different difficult to cut materials. Steel Č5741 (Utop extra 1) is chosen as referential material, and workability indexes are defined as follows:

$$I(F_i) = \frac{F_{iref}}{F_{iinv}} \cdot 100$$

Histograms of workability indexes are formed on the basis of results obtained on that way. Figure 2. shows an example of workability index according main cutting resistance for group of investigated materials at processing by high-speed tool HSS.E.

Values of tool durability are defined for concrete process conditions at adopted criterion of tool wear of $h_k=0.2$ *mm* for the tool of HSS.E material and $h_k=0.3$ *mm* for the tool of TM material. Those values are defined on the basis of experimental defined curves of wear for the group of investigated materials.

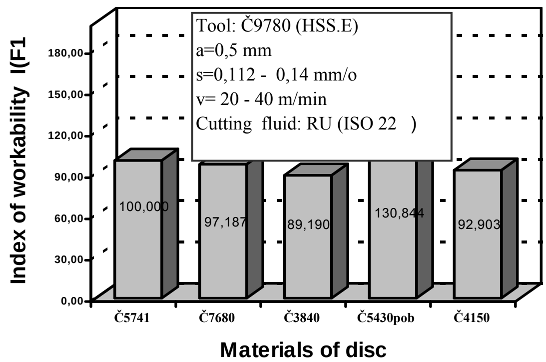

Figure 2: *Workability indexes from aspect of average value of main cutting resistance F_1*

Analysis of results originated from investigation on tribometer and comparison of materials are done from two different aspects: from the aspect of friction coefficient measured on tribometer and from the aspect of wear scar width on block at the end of experiment. Indexes of materials are formed from the aspect of friction coefficient measured on tribometer and from the aspect of wear scar width measured on block, and comparison of materials are done on the basis of that indexes.

Steel Č5741 (Utop extra 1) is choosen as referential material, as well as been chosen at previous processing on lathe. Index of material, from the aspect of friction coefficient obtained on tribometer, is determined as follows:

$$I_{isp} = \frac{\mu_{ref}}{\mu_{isp}} \cdot 100$$

#Figure 3. shows an example of comparison of investigated materials according these index.

Indexes of materials are formed from the aspect of wear scar width on the block, obtained on tribometer, and comparison of investigated materials is done from this aspect. It was done on the basis of measured results of average width of wear scar.

Indexes of materials from the aspect of wear scar width on block *b* obtained on tribometer are determined according to:

$$I_{inv} = \frac{b_{ref}}{b_{inv}} \cdot 100$$

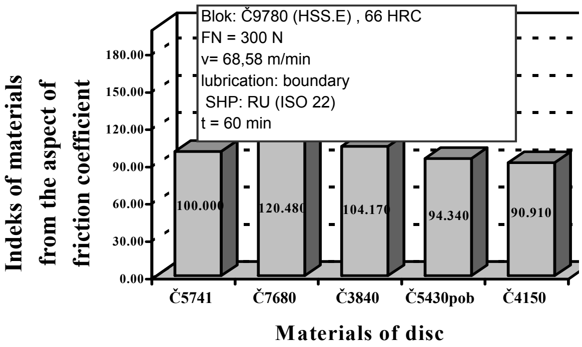

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Figure 3: *Indexes of materials from the aspect of friction coefficient obtained on tribometer.*

4. Comparative analysis of investigation results at lathe and on the tribometer "Block on Disc"

Analysing results of measurement of cutting resistance at lathe and indexes of workability determined according different parameters (F_1, F_2, F_3, F_R, $F_{R2,3}$ and φ), and results of measurement of friction coefficient on tribometer "Block on Disc" and indexes of materials from the aspect of friction coefficient obtained on tribometer, it can be concluded that there is an appropriate coincidence, that is analogy between obtained results. Also, results of measurement of tool wear and wear scar width on block, that is indexes of workability determined from the aspect of tool durability and indexes of materials from the aspect of wear scar width, point to existing of coincidence between obtained results.

Conditions of investigation on tribometer correspond to conditions of contact between tool clearing face and machining surface, that is sliding speed is approximately equal to cutting speed, and normal loading is approximately equal to radial component of cutting resistance.

By comparison of results of investigation on lathe and on tribometer (figures 4 and 5), it can be seen that the best comparison between materials is that done by indexes of workability, which are defined from the aspect of main cutting resistance F_1 and resulting cutting resistance F_R, and indexes of materials defined from aspect of the friction coefficient measured on tribometer "Block on Disc".

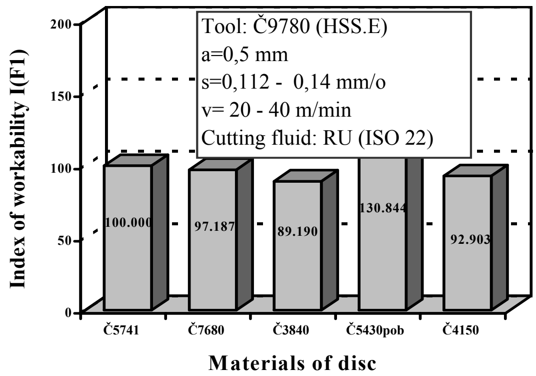

Figure 4: *Indexes of workability from the aspect of average value of main cutting resistance F_1*

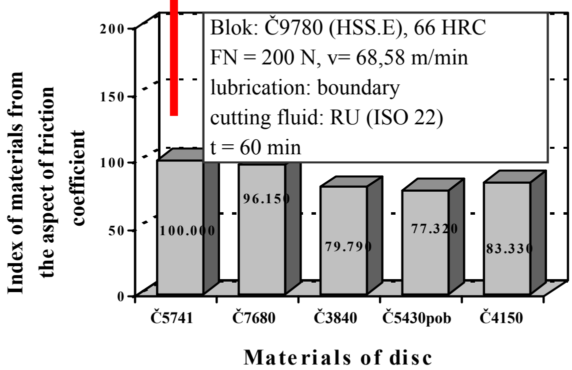

Figure 5: *Indexes of materials from the aspect of friction coefficient measured on tribometer*

By analyzing results of comparison it can be noticed that there is some coincidence at comparison of materials on the basis of workability on lathe from the aspect of main cutting resistance and indexes of materials on the basis of friction coefficient obtained by investigation on tribometer. #

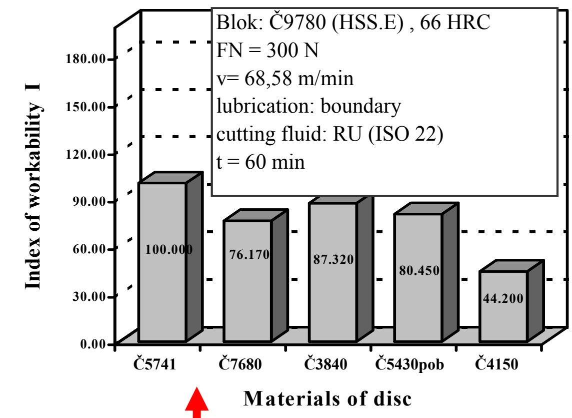

Figure 6: *Indexes of materials from the aspect of wear scat width on block made of HSS.E*

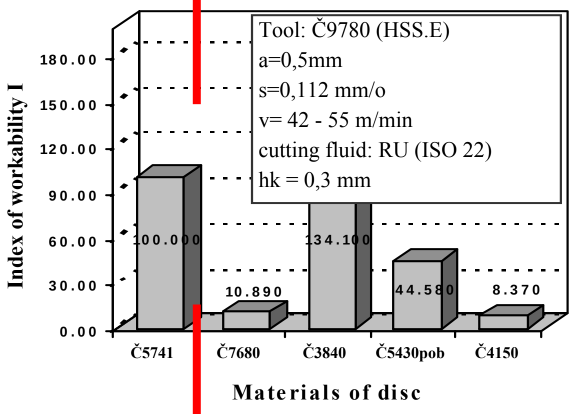

Figure 7: *Indexes of workability from the aspect of durability of tool made of HSS.E*

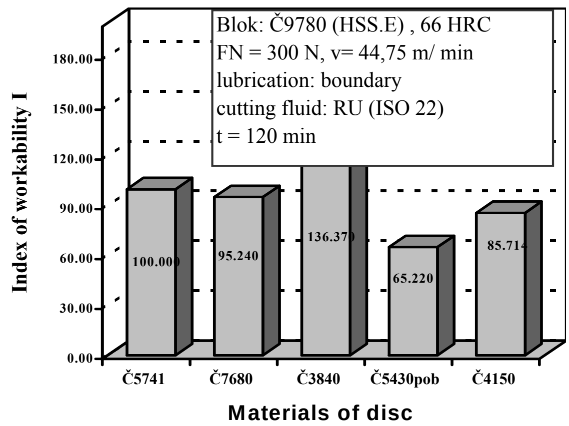

Figure 8: *Indexes of materials from the aspect of wear scat width on block made of HSS.E*

This coincidence is related to all investigated materials except for steel Č5430 in improved state, where is certain deviation happen and can be explained by the fact that this steel is of high hardness (40 HRC) and changed structure (improved state). That certainly point to need for investigation of heat treatment influence, that is structure and hardness of materials, to workability of materials from the aspect of machining in concrete condition of machining as well as from the aspect of tribological investigation.

Results of comparison of investigation done on the lathe and on tribometer are shown on figures 6, 7 and 8.

Analyzing results of investigation of tool wear at machining on lathe with tool made of HSS.E and indexes of workability of group of investigated materials formed on the basis of that results, it can be shown that there is exceptionally high coincidence with results of investigation on tribometer, where wear scar width on block were measured and indexes of workability from the aspect of wear scar width on tribometer were formed.

Relations of materials to workability from aspect of tool wear and from aspect of wear scar width on block are almost the same.

Comparison of investigated results regarding to group of investigated materials machined on lathe with hard metal tool and results of tribological investigation shows strong coincidence too.

5. Conclusion

Proposed model in this paper includes investigation on tribometer 'Block on Disc" where contact is realized by line, which corresponds to conditions of contact between tool insert clearing face and machining surface of work piece. Depending on width and depth of cutting, contact between tool insert rack face and chip can be modelled (simulated) too, by means of line contact between block and disc on tribometer for low cutting depth or feeds, that is small cross-sections of chip (fine machining conditions).For investigation conditions related to rough machining (greater width and depth of cutting, that is greater cross-section of chip) contact is realized by surface , so more realistic conditions of investigation could be obtained by surface contact between block and disc ("Pin on Disc" or "Ring on Disc" tribometer).

In this paper, with relatively simplified model, satisfying results are obtained and imply that investigation of workability could be preformed by means of tribological investigation on tribometer "Block on Disc'. Certainly that beginning idea, about changing long-term and costly investigations of different materials workability with rapid models investigations on tribometer, is confirmed by presented experimental investigation.

Next step in investigation should point to approaching of conditions of investigations on tribometer and conditions of investigation on tool insert, which means accurate estimate of loadings and speeds on rack and clearing face of tool insert for each concrete case, that is for group of similar investigated materials.

On the basis of verified model for rapid models investigations of materials workability on tribometer, the need and the idea of forming the materials workability data base from the aspect of tribological investigation are imposed, which is one of necessary direction of investigation in future.

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