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# METHODOLOGY FOR THE WHITE LAYER FORMATION ON THE MACHINED SURFACE DURING LONGITUDINAL TURNING OF HARDENED STEELS

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## ABSTRACT
*Methodology of the white layer formation on the machined surface, during longitudinal turning of hardened steels, on the basis of experimental investigations is presented in this paper. All necessary steps for examination of possibilities for the white layer formation on machined surface, as well as order of their (steps) realisation is taken in to account. Also, all possible correction activities (inside any of mentioned steps), in the case when white layer formation is absent or if mechanical as well as geometrical properties of the white layer are not appropriate, is described in this methdology.*
**Key words:** turning of hardened steels, white layer, white layer characteristics, tribological prtoperties

## 1. INTRODUCTION
Machine parts made of hardened steels represent high performance components which are widely used in production of: cars, bearings, gears, tools etc. Customer's demands for prices reduction of these products as well as for upgrading their quality have caused a sudden development of machine tools and new cutting materials. At the same time new machining processes were developed as well. One of the most important among them is the process machining of very hard materials using tools with defined cutting geometry so called hard machining. The characteristic of hard machining process is using cutting speed in conventional and high speed areas as wel as using hardness range of work pieces 45-70 HRC. Complexity of conditions that arise during hard machining cause changes inside of thin layer on machined surface:

- white layer, which is supposed to be a result of temperature created on the surface of work piece and quick cooling afterwards [1,2],

- unwanted distribution of residual stress directly bellow the machined surface [3], causing occurrence of micro cracks [4].

In most of previous researches of hard machining process the white layer was treated as a damage of the machined surface, i.e. as a negative additional occurrence of the main machining process. It's just recently that white layer phenomenon has begun being observed in the context of using its undoubtedly potentials [5,6].

Methodology of the white layer formation on the machined surface, during longitudinal turning of hardened steels, on the basis of experimental investigations is presented in this paper. All necessary steps for examination of possibilities for the white layer formation on machined surface, as well as order of their (steps) realisation is taken in to account. Also, all possible correction activities (inside any of metioned steps), in the case when white layer formation is absent or if mechanical as well as geometrical properties of the white layer are not appropriate, is described in this methdology.

## 2. EXPERIMENTAL WORK

Generally speaking, there is a large number of factors, in the context of a possibility of controlling the white layer formation and its characteristics, which should be analysed and whose influence should be defined:

- input factors (cutting speed, feed rate, cutting depth, machine rigidity, power, vibrations, etc.),
- tool (material, geometry, wear parameters, wear shape, etc.),
- work piece (mechanical and physical characteristics, chemical composition, microstructure, etc.).

Within previous research activities, from the set of influencing machining factors, wokpiece material, cutting tool material, tool wear size and shape, machining conditions and machining system rigidity were taken into consideration with analysis of type and scale of their influence on white layer formation for the longitudinal turning of hardened steels [7,8].

The work pieces materials, used in tool wear experiments, were highly alloyed tool steels X210CrW12 and X155CrVMo12. Regarding cutting tool material two mostly used materials in this field were observed, black ceramic and cubic boron nitride. Experimental tool wear tests were carried out for longitudinal turning process of these materials for different values of machining regimes.

Experimental tests of cutting, from the aspect of white layer formation on a machined surface, included outer longitudinal turning on the CNC turning machine type INDEX, with previously worn cutting inserts. The work pieces materials low-carbon alloyed steel 16MnCr5 and low-alloy bearing steel 100Cr6 were used. Round bars with cross-sections $\phi$80x100 mm made of the mentioned materials, after drilling holes $\phi$50 mm, were cut to lengths of 15 mm. With such shape of work piece (ring shape) an attempt was made to enable larger rigidness of the work system clamping tool - work piece - cutting tool and in that way increasing the probability of white layer formation.

During experimental research activities, from the set of input parameters machining parameters are taken in to account while the set of output parameters included, except for average thickness of white layer, average arithmetic deviation of the machined surface profile, as an important characteristic of the final processing operations, which turning hardened steel operations mostly are.

An analysis was made on what influence cutting speed and tool flank wear width have of white layer formation process when turning hardened steel, from the aspect of analysing possibilities for its control. Control in this context means controlling the characteristics of white layer formation, its average thickness value and evenness of its thickness along the machined surface. Analysis of influences that is made only for cutting speed and tool flank wear width is due to their direct proportionality with white layer thickness.

All research activities were carried out in accordance with planned experiment methodology.

## 3. RESULTS AND DISCUSSION

Methodology which includs all necessary steps for examination of possibilities for the white layer formation on machined surface, as well as order of their realisation on the Figure 1. is presented. Also, correction activities inside any of mentioned steps, in the case when white layer formation is absent or if mechanical as well as geometrical properties of the white layer are not appropriate, on the same figure is described.

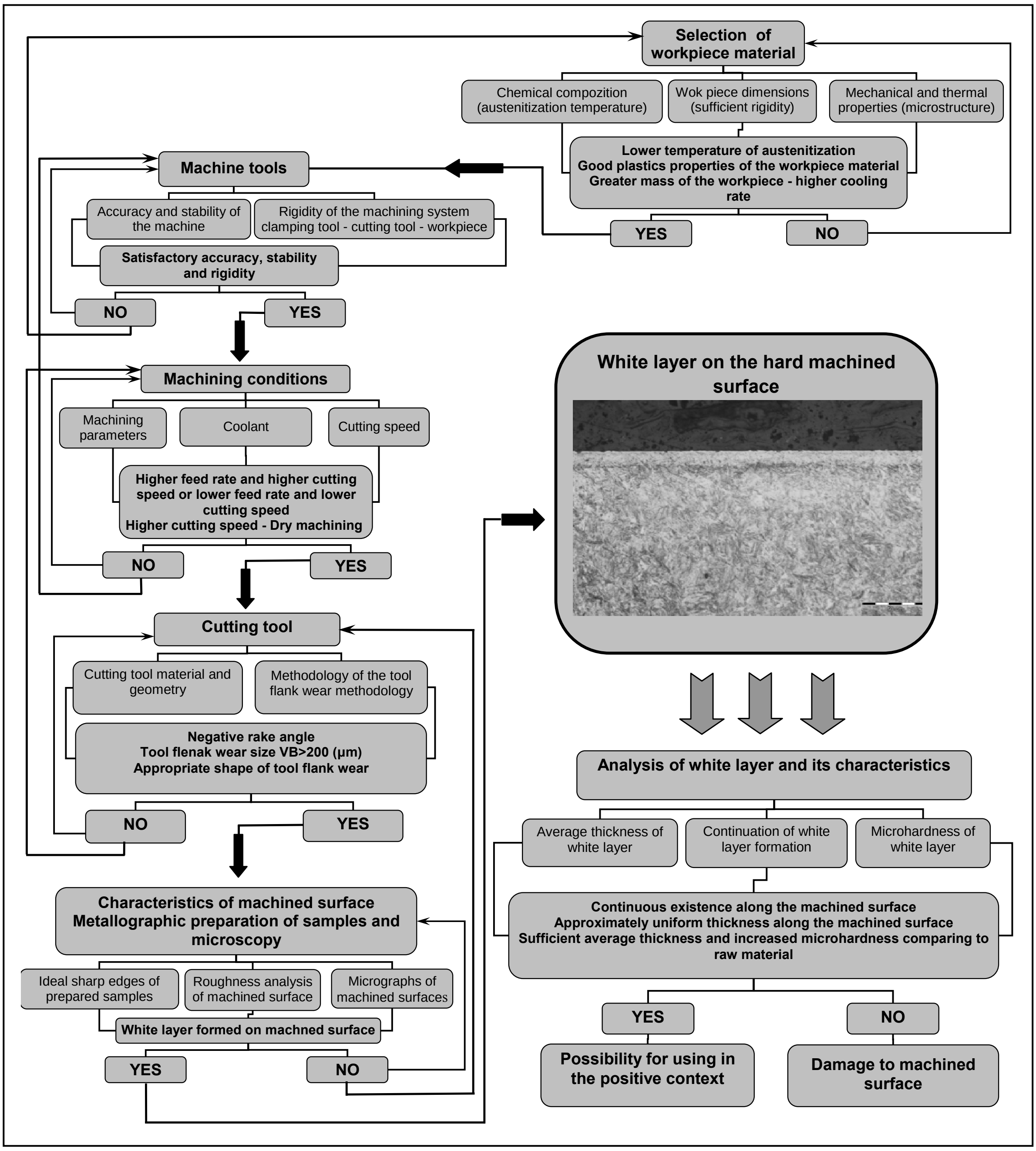


*Figure 1. Algorithm of the white layer formation on the machined surface during longitudinal turning of hardened steels*

Influence of work piece material on white layer formation can be observed indirectly via influence of mechanical and physical characteristics, chemical composition, microstructure, work piece geometry characteristics, etc.).

Influence of cutting tool material on white layer formation can be observed indirectly via influence of shape and size of tool flank wear. Since the influence of tool flank wear shape on white layer formation is significant then the influence of cutting tool material is significant as well because it determines, to a great extent, shape of tool flank wear, assuming other machining conditions are constant. When turning hardened steel, white layer is not formed on the machining surface if a new or not enough worn or worn with significant grooveson the flank surface cutting tool is used. Due to proved significance of tool flank wear shape on white layer formation, it is recommended that experiments of cutting processes with a goal of tool wear as well as white layer formation, should be carried out on the same work piece material.

Cutting speed and tool flank wear width, for all other machining conditions unchanged, can be used for control of white layer formation and its characteristics. Nature and level of influence of mentioned parameters are different for lower and higher values of feed rate and depth of cut. For lower values of feed rate and depth of cut influence of cutting speed is dominant comparing to toll flank wear width, while for machining processes with higher values of feed rate and depth of cut influence of tool flank wear width is dominant comparing to cutting speed.

During cutting processes of hardened materials, white layer formation can be accompanied by an effect of its additional plastic deformation, as a result of tool movement along the working piece axis, when mechanical load which occurs during the cutting process reaches acquired level.

If white layer formed on machined surface, evaluation of white layer quality must include evenness of its thickness along the machined surface (average thickness of white layer), evenness of the phenomenon along the machined surface (continuous or local type), as well as micro hardness value.

On the basis of ratio, average thickness of white layer and average arithmetic deviation of the machined surface profile, evaluation of the evenness of white layer can be made as well as continuation of its formation along a machined surface. Usually, larger values of mentioned ratio point to thicker and more even white layer along a machined surface and a better quality of machined surface.

## 4. CONCLUSIONS

- With a goal of identification of white layer on a machined surface it is very important to establish a procedure for its certain formation, at the same time enabling the procedure's repeatability. Also, it is necessary setting criteria, both geometrical and mechanical, for qualitative assessment of resulted white layer as well as their mutual comparison.
- Effect of white layer additional plastic deformation results in decrease of machined surface roughness compared to its expected value. In accordance with that there is a possibility for identification of white layer on a machined surface by measuring some of the roughness parameters without previous metallographic preparation of samples.
- On the basis of experimental work and presented methodology it is possible to generate white layer with followed properties: continuous existence along the machined surface, sufficient medium thickness, approximately uniform thickness along the machined surface, increased micro hardness compared to the raw material and sufficient bonding characteristics to the raw material. White layer with aformentioned characteristics can be use in the positive context and take over a role of tribology protection of the machined surface.

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