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AN APPROACH TO DETERMINE TRANSITION AREA FROM CONVENTIONAL TO HIGH-SPEED MACHINING BY MEANS OF CHIP SHAPE ANALYSIS

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ABSTRACT

High speed machining became a common machining solution for various machining applications. This fact is caused by many advantages that HSM can offer to manufacturers – good surface quality, shorter production cycles etc… Yet, the main problem producers faces here is increasing costs generated by high cutting tool price used in this application. This problem is common denominator most of the today high speed machining investigation. The paper shows an example of solving the problem by analyzing chip shape generated in this process in order to determine minimal cutting speed to be used in high speed area. In that sense it has been introduced new factor authors called "measure of segmentation", Ms, used to make clear distinction between conventional and high speed regions. Therefore, this cutting speed or cutting regime can contribute in increasing cutting tool life and improving economic benefits of HSM processes.

Keywords: High speed machining, chip shape, "measure of segmentation"

1. INTRODUCTION

First thoughts about machining materials applying high cutting speeds occurs almost 80 years ago, when dr. C. Salomon started with his experiments and patented this invention 1931 - *German Patent No. 523594.* [1] Yet, to become reality in practice, high speed machining ask for specific machine design, as well as tougher and more durable cutting tools. Since then, machine tools design has undergone significant development and improvements. Cutting tools has also undergone changes that together with new machine design have created preconditions for effective use of high speed machining in production practice.[2,3,4,5,6] These improvements confirmed most of advantages that HSC offers and put the technology amongst most usable machining practice. Today, main problems in HSC is connected to cutting tools performance, since high cutting speed used in this application deteriorates cutting edges fast, and in that way decrease many positive effects that this technologies bring. Hence, tool life is considered to be most frequently investigated topic and central issue of most researches dealing with HSC [7, 8]. Based on these facts an assumption has been made that a possible and logical way to preserve cutting edge, and at the same time use benefits of high speed cutting technology is to enter high speed region but keep the cutting speed as closer as possible to transition area from conventional to high speed machining.

2. TRANSITION AREA FROM CONVENTIONAL TO HSC

Existing of transition area has been investigated for a last decades. It has been proved that this area position depends of many other factors, not only of cutting speed value. Among those factors is material to be cut properties, figure 1. Question is how to define moment when machining process is transforming into high speed process - when benefits shown in figure 2 might be widely used. One possible approach to define that moment, used in this investigation, is related to chip generated in observed process. According to many researchers, chip shape generated in high speed machining is followed up and shaped by segmentation process.[9,10] Once segmentation process starts, there is no transition into another chip shape until cutting speed reach value of 30000 mpmin [11].

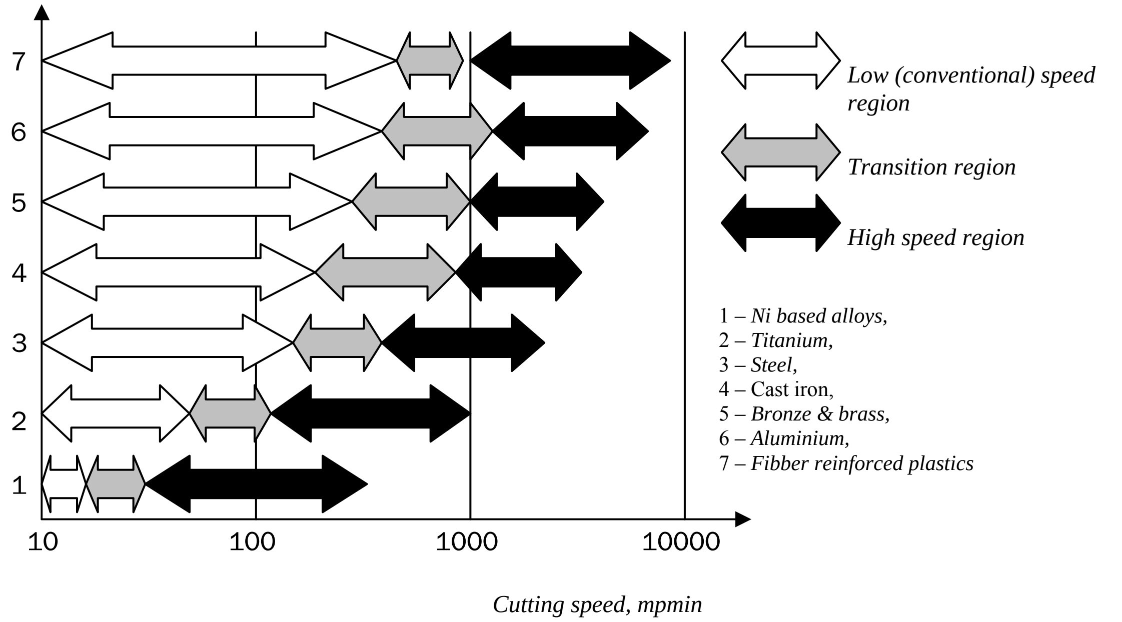


Figure 1. - Transition area from conventional to high speed area for different machined materials

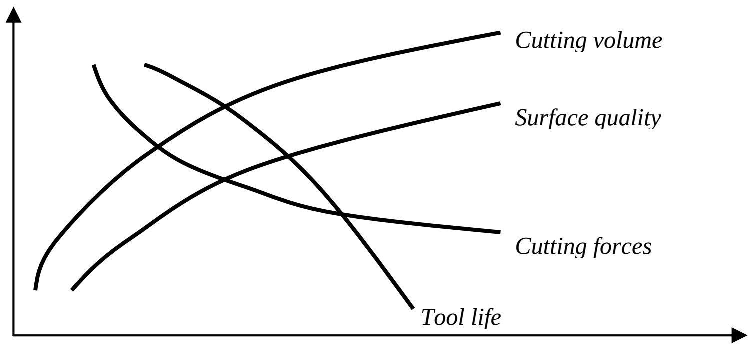


Figure 2. - Some advantages and main disadvantage (tool life shortening) of HSC

So, even if chip segmentation is define as a moment when high speed cutting characteristics starting to run, still there is another thing to be considered. That is, when the segmentation itself is starting? The question was how to define numerical values that can describe level of segmentation. A solution offered in this paper is related to newly introduced factors called "Measure of segmentation", Ms.

3. MEASURE OF SEGMENTATION

Figure 3 shows geometrical interpretation of a term "measure of segmentation". Based on this approach appropriate mathematical description is introduced, equation 1.:

$$M_s = \frac{\Delta}{A_2} = \frac{A_2 - A_1}{A_2} \rightarrow \boxed{M_s = 1 - \left(\frac{d}{D}\right)^2} \qquad \text{……(1)}$$

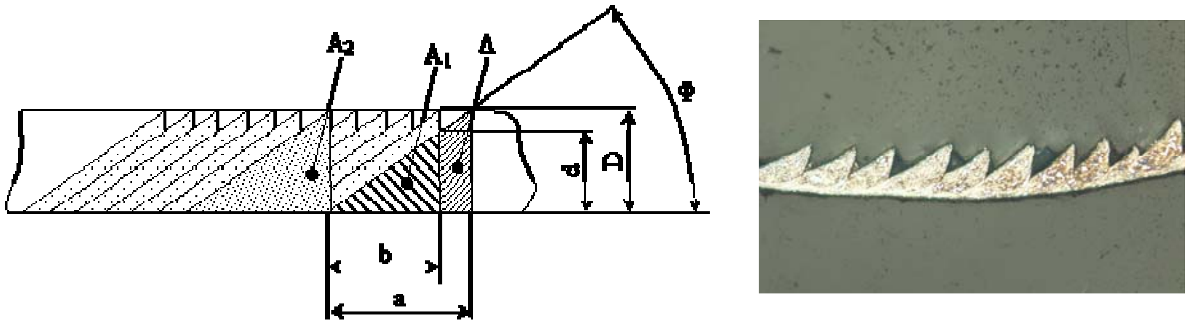


Figure 3. Geometrical interpretation of a "measure of segmentation

Metallographic preparations are performed on chip in order to obtain microscopic picture of generated chip – the one is shown on figure 3, right. From such a prepared chip necessary elements for calculating measure of segmentation – Ms, have been taken. Selected boundary values, the value for which it is certain to describe moment when machining process take all characteristics of high speed machining is **Ms=0.5.** Considering this value, that is, measure of segmentation as an output of a system, an experimental investigation has been conducted.

4. EXPERIMENTAL INVESTIGATION

To test established investigation hypothesis an experiment has been performed on 3 different steels in two different states, tempered and normalized. Selected materials are presented in Table 1.

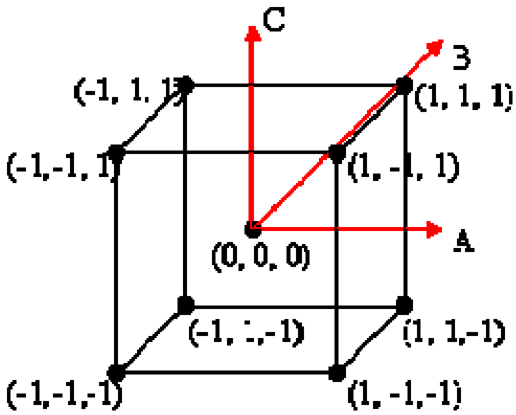
Table 1. Material used in experimental investigation properties

AIS/SAE	*DIN 17006*	*Normalized*		*Tempered*	
		Item	*Hardness*	*Item*	*Hardness*
*AISI 4340**	*30CrMoV9*	*1.1.*	*300 HB*	*1.2.*	*55 HRc*
D3	*X210Cr12*	*2.1.*	*340 HB*	*2.2.*	*54 HRc*
AISI 4340	*30CrNiMo8*	*3.1.*	*340 HB*	*3.2.*	*48 HRc*

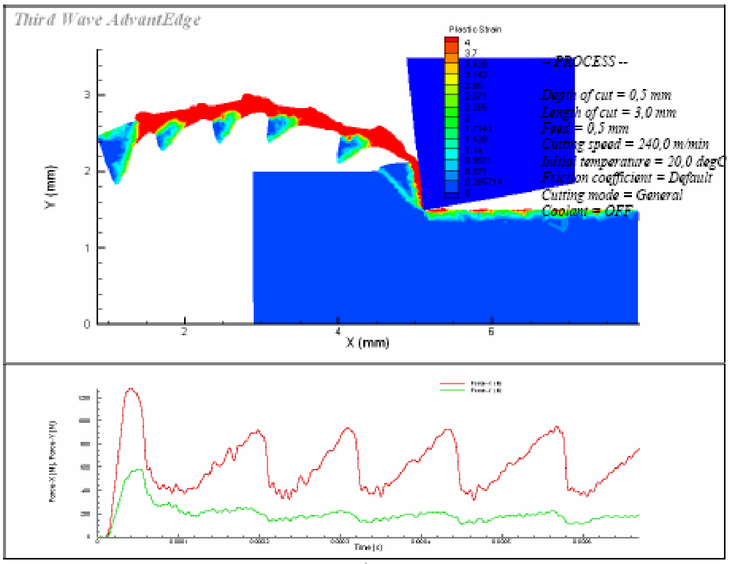
On each of selected materials experiment has been conducted according to 2^3 full factorial plans, with 3 repetitions in central point, table 2.

Table 2 – Plan matrix of experiment

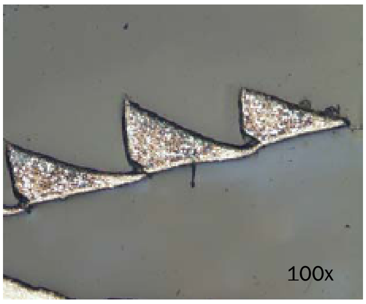
No.	*Factors*		
	A-cutting speed v, m/min	*B-feed f, mm/o*	*C-depth of cut d, mm*
1.	-1	-1	-1
2.	1	-1	-1
3.	-1	1	-1
4.	1	1	-1
5.	-1	-1	1
6.	1	-1	1
7.	-1	1	1
8.	1	1	1
9.	0	0	0
10.	0	0	0
11.	0	0	0



For all 6 materials appropriate factors level has been chosen based on literature source and tested by FEM simulation. Simulations are done in ThirdWave Advant Edge software for all 6x11=66 runs. For each run, chip is metallographic prepared, exported into AutoCAD in order to measure elements for calculation of Ms factor. These real chip models are then compared with virtual models generated in AdvantEdge software. An example of this comparison is shown in figure 3.



a)



b)

$$Ms = 1-(0.023/0.184)^2=0.98$$

Figure 3. An example of good correlation between virtual and real model of a generated chip

Standard statistical data processing has been performed based on these results. From this procedure appropriate regression models has been established. From these models it is possible to determine cutting regimes fro which Ms=0.5, that means moment of transition from conventional to high speed machining.

5. CONCLUSION

The paper describes a possible approach to determine cutting conditions in high speed machining aiming to increase tool life, hence, to improve efficiency of a HSC process. It has been developed and introduced new term, measure of segmentation, Ms, which can be effectively used in obtaining regression models that could be used to define more precisely, transition area and cutting speed to be used in order to make cutting tools last longer. Levels of controllable factors, cutting speed, feed and depth of cut are based on literature data but also checked with numerical simulation done in AdvantEdge software. Results reveal a significant level of agreement between real and virtual model.

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