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Determining the Workability of the New Metallurgical Materials

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Abstract**—**The aim of this paper is to experimentally discover the workability coefficient of the Inconel 718 material by using a slide turning machining. Two different types of cutting inserts, one made of carbide and the other one made of ceramic, are being used. The purpose is to compare measured results and recommend the appropriate materials and cutting parameters for a machining of the Inconel 718. Furthermore, the durability of inserts with the chosen wear criterion is being compared for different cutting speeds. Machinability of these materials is a crucial characteristic as it allows us to shorten the technological cycle time and increase the machining productivity. And this is of great importance from an economic point of view.

Keywords**—**Workability, Inconel 718, Turning Machining, Durability.

I. INTRODUCTION

A MATERIAL of workpiece is a key factor to achieve high performance and reliability of a component. Nowadays, highly rigid, hard and tough materials are desired. One of them is the chrome - nickel alloy Inconel 718, commonly used in aerospace and automotive industries. However, its disadvantage is a very poor machinability with a normal cutting operation.

II. WORKABILITY

Workability is the overall effect of physical properties and chemical composition of metal in course cutting process (economic and qualitative).

Workability is one of the most important material properties (in terms of machining technology). We can define workability as the ability of particular material to be processed by some of the methods of machining. Workability is a major factor in the choice of cutting conditions and tool's function in all methods of machining. Workability depends on many factors, the most important are:

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- method of production and heat-treating process of machined material,
- microstructure of the machined material,
- chemical composition of the machined material,
- physical and mechanical properties of the machined material,
- machining method,
- working environment,
- tool geometry,
- kind and properties of the tool material.

We evaluate the workability or cutting power in terms of intensity edge wear as well in terms of thermal, technology and qualitative. We often use intesity of edge wear.

Complex Taylor's relation is the most important criterion of this type. The other criterions are simply Taylor's relation and the value of cutting speed v_T which accordants with tool-life of cutting edge.

$$K_v = \frac{v_{T/VB} \ \ testing\ material}{v_{T/VB} \ \ etalon\ material} \quad (1)$$

possibly

$$K_v = \frac{c_{v_{ex.mat}}}{c_{v_{et.mat}}} . T^{\left(\frac{1}{m_{et}} - \frac{1}{m_{ex}}\right)}, \text{ where} \quad (2)$$

v_T / v_B tested material - corresponds v_{15ex} (m.min-l), which is the cutting speed vc at tool-life T_n = 15 minutes for tested (monitored) material,

v_T / v_B ethalon material - corresponds v_{15et} (m.min-1), which is the cutting speed vc at tool-life T_n = 15 minutes for referential (ethalon) material.

III. LONG-TERM TESTS MACHINABILITY

The long-term tool-life test is essentially only one. The value of cutting speed is a criterion here. It is performed by turning or milling - agreed constant cutting parameters, the type of cutting tool, geometry, more gradate cutting speeds up to optimal blunt of cutting edge [1].

This test is considered as essential. This test assesses the degree of objectivity for the other tests of workability. We can determine cutting power tools using this test. Large consumption of the machined material is a disadvantage and also demands on test time.

The long-term tool-life test has the following progress: 1) We have to measure time-course of tool-wear (on the clearance angle of tool VB_B) for several values of speeds at constant cutting parameters and then we can plot blunt curves (see Fig. 1).

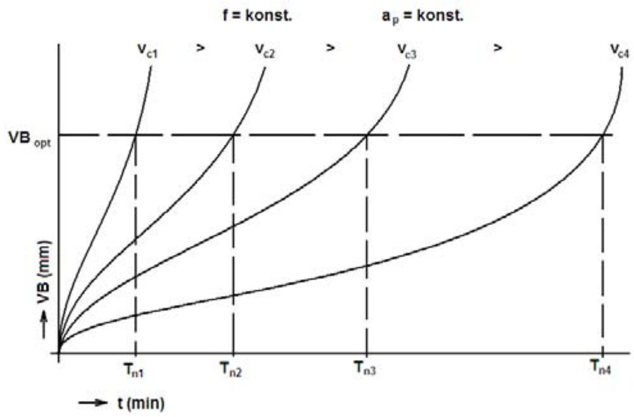

Fig. 1 Blunt curves at variable cutting speed, f = konst., a_p = konst. [1]

2) We set the criterion of wear VB_{opt} and with this we set the appropriate tool-life of the edge for each cutting speed (see Fig. 2).

3) We construct the dependence $T_n = f(v_c)$ in logarithmic coordinates. We can determine workability index for selected tool-life – a cutting speed (the testing material) compared with a cutting speed (etalon) - see Fig. 3.

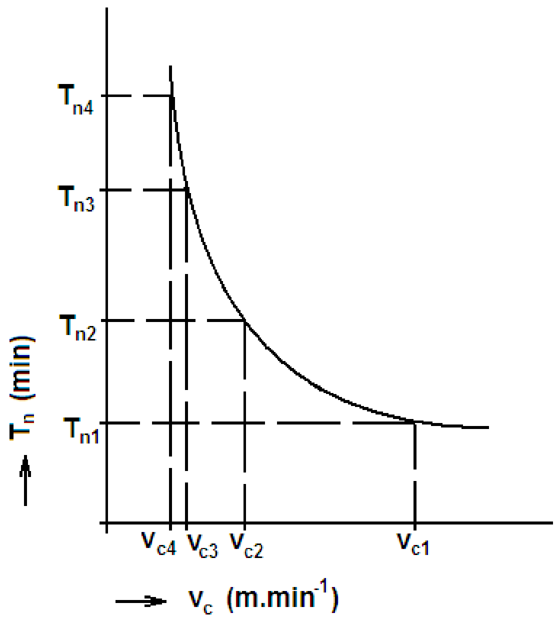

Fig. 2 Determination of tool-life (based on the criterion of wear) [1]

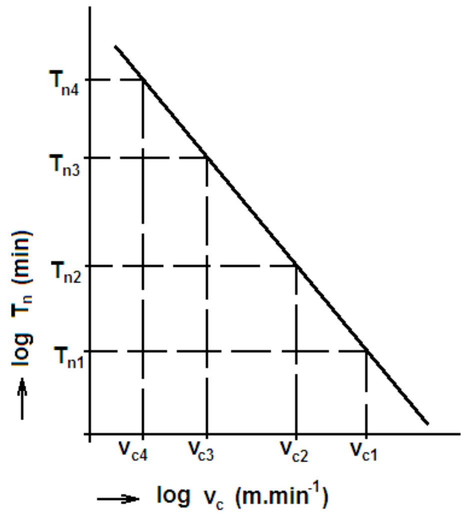

Fig. 3 Dependence – tool-life on cutting speed [1]

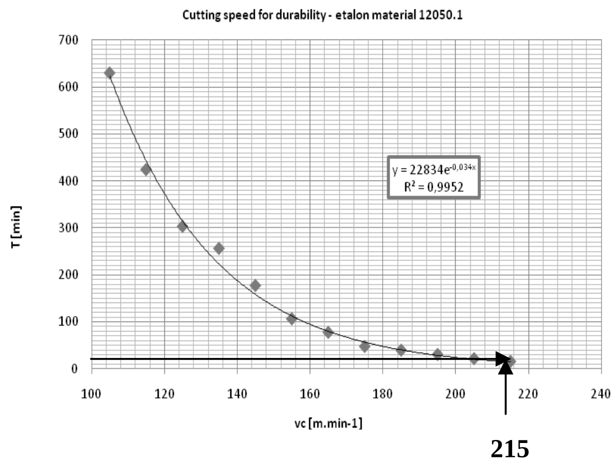

Fig. 4 Determination of tool-life (based on the criterion of wear) for etalon material

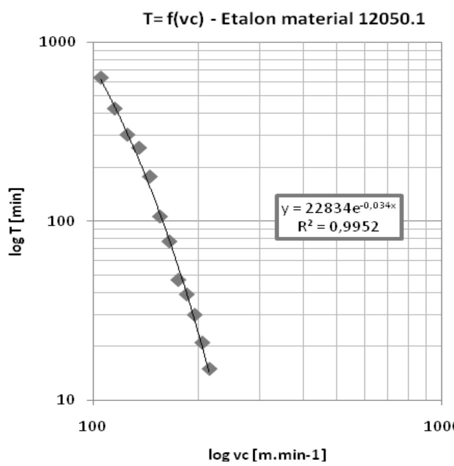

Fig. 5 Dependence – tool-life on cutting speed - for etalon material

IV. Machined Material

Inconel 718 is a precipitation-hardenable nickel-chromium alloy containing significant amounts of iron, niobium, and molybdenum along with lesser amounts of aluminum and titanium. It combines corrosion resistance and high strength with outstanding weldability, including resistance to postweld cracking. The alloy has excellent creep-rupture strength at temperatures up to $1300^{\circ}F$. Used in gas turbines, rocket motors, spacecraft, nuclear reactors, pumps, and tooling [3].

TABLE I
CHEMICAL COMPOSITION

Element	Percent by Weight	Element	Percent by Weight
Carbon	0.08 max.	Columbium	4.75 - 5.50
Manganese	0.35 max.	Titanium	0.65 - 1.15
Phosphorus	0.015 max.	Aluminum	0.20 - 0.80
Sulfur	0.015 max.	Cobalt	1.00 max.
Silicon	0.35 max.	Boron	0.006 max.
Chromium	17.00 - 21.00	Copper	0.30 max.
Nickel	50.00 - 55.00	Tantalum	0.05 max.
Molybdenum	2.80 - 3.30	Iron	Balance

V. Experiment

We used cermeted carbide P20 and cutting ceramic Greenleaf for slide turning machining of material Inconel 718. Furthermore, we chose the depth of cut a_p =2 mm, feed f = 0,3 mm.ot^{-1} and wear criterion VB = 0,8 mm. The size of wear was measured by digital microscope and the values are in tables.

TABLE II
READINGS

$v_c = 85$ m.min^{-1}			
Cemented carbide		Ceramic	
t [min]	VB [mm]	t [min]	VB [mm]
0	0	0	0
2	0,38	2	0,34
4	0,66	4	0,52
6	0,95	6	0,69
-	-	8	0,91

TABLE III
READINGS

$v_c = 105$ m.min^{-1}			
Cemented carbide		Ceramic	
t [min]	VB [mm]	t [min]	VB [mm]
0	0	0	0
1	0,68	1	0,57
2	1,06	2	0,95

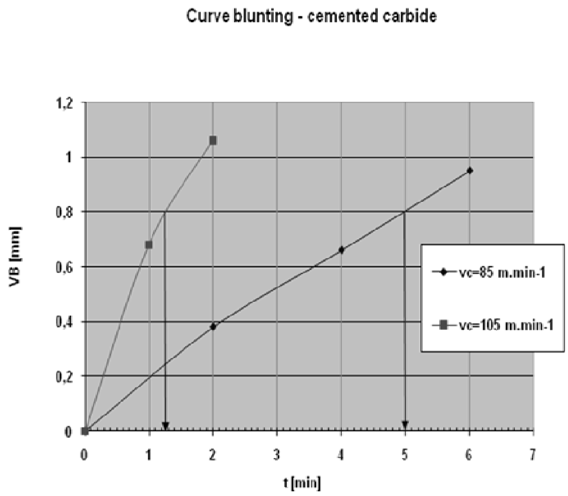

Fig. 4 Curve blunting – cemented carbide

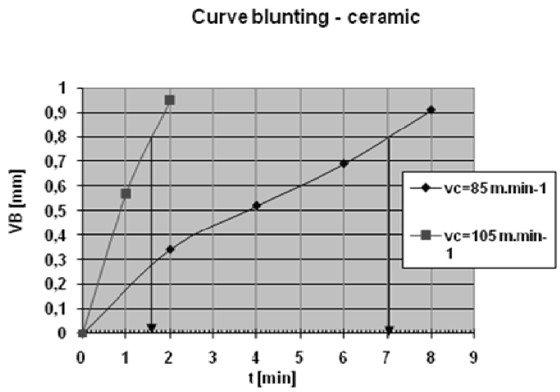

Fig. 5 Curve blunting - ceramic

From the graphs were deducted each value of time when we reach the wear criterion VB = 0.8 for the cutting speed (see Table 4).

TABLE IV
TIMES FOR WEAR CRITERION

Cemented carbide		Ceramic	
v_c [m.min^{-1}]	t [min]	v_c [m.min^{-1}]	t [min]
85	5	85	7,05
105	1,25	105	1,6

The table shows that the most durable has cutting ceramic in cutting speed v_c = 85m.min^{-1} and it is 7 minutes.

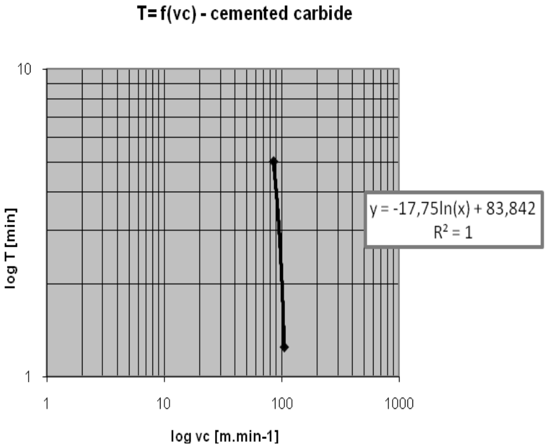

Fig. 7 Logarithmic dependence of durability on the cutting speed for cemented carbide

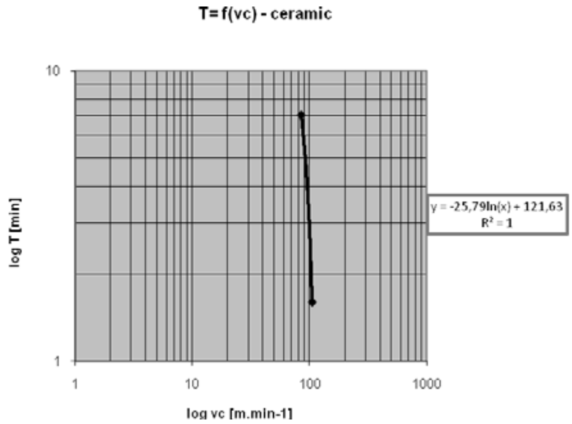

Fig. 8 Logarithmic dependence of durability on the cutting speed for ceramic

Cemented Carbide - calculation of cutting speed for tool-life T = 15 min:

$$y = -17,75\ln(x) + 83,842$$

$$\ln(x) = 3,8784225 \quad (3)$$

$$x = 48,35 = 48,4\text{m.min}^{-1}$$

Ceramic - calculation of cutting speed for tool - life T = 15 min:

$$y = -25,79\ln(x) + 121,63$$

$$\ln(x) = 4,1345483 \quad (4)$$

$$x = 62,46 = 62,5\text{m.min}^{-1}$$

Cemented Carbide – calculate the workability coefficient:

$$Kv = \frac{v_{c\,ex}}{v_{c\,et}} = \frac{48,4}{215} = 0,23 \quad (5)$$

Ceramic - calculate the workability coefficient:

$$Kv = \frac{v_{c\,ex}}{v_{c\,et}} = \frac{62,5}{215} = 0,29 \quad (6)$$

TABLE V
WORKABILITY COEFFICIENT FOR EACH CLASS OF STEALS

Class	Workability coefficient	Class	Workability coefficient
1b	0,045-0,054	11b	0,45-0,56
2b	0,055-0,069	12b	0,57-0,71
2b	0,070-0,089	13b	0, 72-0,89
4b	0,09-0,11	14b	0,90-1,12
5b	0,12-0,14	15b	1,13-1,41
6b	0,15-0,17	16b	1,42-1,78
7b	0,18-0,22	17b	1,79-2,24
8b	0,23-0,28	18b	2,25-2,82
9b	0,29-0,35	19b	2,83-3,55
10b	0,36-0,44	20b	3,56-4,47

According to the workability coefficient, we have identified a class 8b machinability in machining cemented carbide and class 9b machinability for cutting ceramics.

VI. Conclusion

The tested material Inconel 718 has a worse workability than the ethalon material 12050.1 which is in a 14b class. We determined a class of workability – 8b at machining sintered carbide P20 and at machining ceramic-cutting Greenleaf, we determine a class of workability – 9b. The difference in workability (of one class) is caused by coefficient workability – the results were on limit of the classes. The ceramic cutting Greenleaf is a more suitable for machining this hard machinable material. We measured (from graphs - blunt curves for selected criterion of wear) that we will achieve the greatest tool-life for ceramic cutting inserts at cutting speed $v_c = 85\text{m}\cdot\text{min}^{-1}$. We determined a cutting speed $v_c = 62{,}5\text{m}\cdot\text{min}^{-1}$ (for our chosen tool-life T=15minutes) at a depth $a_p = 2$ mm and a feed f = 0,3 mm.ot^{-1}. These are the optimal cutting conditions for machining Inconel 718 by ceramic cutting Greenleaf.

Acknowledgment

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