Serbian Tribology Society

# SERBIATRIB '09

11th International Conference on Tribology

University of Belgrade
Faculty of Mechanical Engineering

Belgrade, Serbia, 13 - 15 May 2009

# DEVELOPMENT OF APLICATION FOR ANALYSIS OF MACHINABILITY INDEX

**Gordana Globočki Lakić [1], Stevo Borojević[1], Đorđe Čiča[1], Branislav Sredanović[1]**
[1]Faculty of Mechanical Engineering, RS (B&H), gnm@urc.bl.ac.yu

***Abstract:*** *Rapid development of new materials, cutting tools and cutting fluids promote research of machinability for new materials and tribological characteristic of cutting tools and cutting fluids. Material machinability is very complex category and it must be considered from different points of view and with different machining requirements. It depends upon a number of influencing factors, primarily associated with mechanical, structural and thermal characteristic of working material and it is expressed through output parameters from machining process (tool wearing, cutting forces, quality of machining surface, etc.). This paper presents developed application, which gives results for machinability index for group of tough machined materials. Application is fundamentally developed on experiments, when measuring cutting force at turning operation for group of tough machining materials, and also experiments done on tribometer „Block on Disk". Application consists of several databases, developed modules for cutting forces calculation, experimental relations for evaluation of friction coefficient at clearance surface of cutting tool. Output indicators of application are comparative graphical and analytical results of machinability index for analyzed group of tough machining materials.*

***Keywords:*** *machinability index, machining process, Tribometer Block on Disk, cutting forces*

## 1. INTRODUCTION

Rapid development of new materials, cutting tools and cutting fluids promote research of machinability for new materials and tribological characteristic of cutting tools and cutting fluids. Material machinability is very complex category and it must be considered from different points of view and with different machining requirements. It depends upon a number of influencing factors, primarily associated with mechanical, structural and thermal characteristic of working material and it is expressed through output parameters from machining process (tool wearing, cutting forces, quality of machining surface, etc.). Results from testing of materials machinability allowing effective and reliability management of machining process for those materials and gives efficiently answers on high market and production demands.

In this paper definition of material machinability was made through machinability indexes for chosen group of tough materials.

## 2. MACHINABILITY INDEXES

Machinability indexes, as measurement of material's machinability, can be formed from tribological characteristics aspect based on:

- tool life,
- economical cutting speeds,
- process costs,

from energy characteristics aspect based on:

- cutting forces,
- cutting temperature, and

from surface finish aspect based on:

- surface finish parameter.

Machinability index of the i-th material in regard to r material is defined as ratio of parameter's values used for machinability evaluation, which is shown with formula (1):

$$I_i = \left(p_i / p_r\right)^{\pm 1} \cdot 100\% \quad (1)$$

where:

$I_i$ - machinability index of i-th material

$p_i$ - parameter value accepted for machinability evaluation of i-th material:

$p_r$ - parameter value accepted for machinability evaluation of r-th material:

Exponent of ratio $(p_i / p_r)$ has value of +1 in case that increase of chosen parameter has positive effect on "fluency" of *machining process* development, otherwise it is a -1 if effect is negative.

In this paper, establishing of the material machinability is done from energy aspect (main cutting force and tribological value) and based on tool life (trace width of wear).

According to that, relation (1) for machinability index determination is reduced to relations (2):

$$I_i = F_1^r / F_1^k \cdot 100\%; \quad I_i = \mu^r / \mu^k \cdot 100\%;$$

$$I_i = b_r / b_k \cdot 100\%; \qquad (2)$$

where:

$F_1^r$ i $F_1^k$ - correlation between main cutting force and cutting parameters for referent, that is k-th machined material

$\mu^r$ i $\mu^k$ - average value of tribological parameter, measured on tribometer "Block on Disk" for referent, that is k-th machined material

$b_r$ i $b_k$ - width of the wear trace on block for referent, that is k-th machined material, acquired by measurement on tribometer " Block on Disk".

## 3. EXPERIMENTAL ANALYSIS

Experimental analysis of chosen group of material machinability (table 1) were performed on universal lathe in real cutting conditions and at tribometer "Block on Disk", where block material is made from cutting tool material, and disk is made from analyzed materials.

The experiment encompassed manufacturing of mentioned materials by cutting tools with inserts (HM), with predefined conditions and parameters, recommended for manufacturing/cutting of tough materials [2]. During the process cutting forces $F_1$,$F_2$ and $F_3$ are measured.

**Table 1.** Group of tough materials

| Material | | Tensile Strength $R_m$ [MPa] | Hardness HB | Condition of the material |
|---|---|---|---|---|
| JUS | EN | | | |
| Č.5741 | 1.2713 | 850 | 258 | Soft Annealing |
| Č.7680 | 1.3343 | 900 | 299 | Soft Annealing |
| Č.3840 | 1.2842 | 720 | 248 | Soft Annealing |
| Č.5430 | 1.6511 | 950 | 388 | Tempered |
| Č.4150 | 1.2080 | 780 | 277 | Soft Annealing |

Tribological analysis are performed at tribometer „Block on Disk“ [1,3] ,where in broad spectrum of establishing of contacts conditions, measurements of average values of tribological parameter and block wear width were performed.

Based on measured values, material indexes are defined from coefficient of friction aspect, and wear width in block; based on this, material comparison is made.

All experimental analysis are carried out at Faculty of Mechanical Engineering in Kragujevac.

For experimental analysis cutting forces of measurement chain in Fig. 1 was used, while generation of recorded signals was made in programming package STATISTICA. Measurement chain for tribological analysis is shown in Fig. 2.

For measurement of nominal load, friction forces and calculating instantaneous values of tribological characteristic, user application LABTECH CONTROL is made.

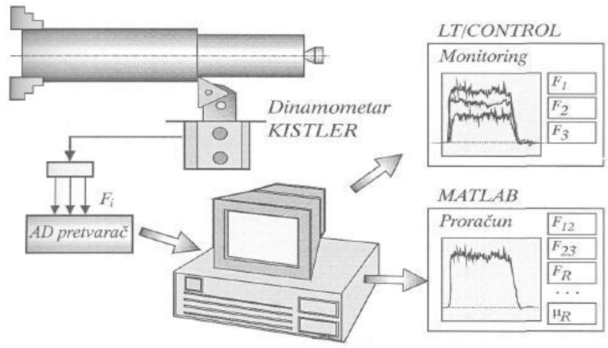


**Figure 1.** Measuring chain for cutting forces measurement

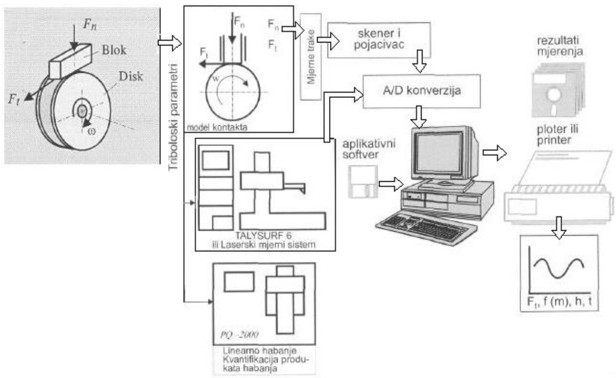


**Figure 2.** Measuring chain for tribological analysis

## 4. APLICATION DEVELOPMENT

Based on Experimental analysis in real cutting process environment at lathe and acquired correlative conditionality of cutting forces and cutting condition's parameters, average values of cutting forces are calculated using triple integral. In order to compare material's machinability for specific area of variable regimes, machinability indexes are defined from aspect of all three components of cutting forces. Reference material is steel. Č. 5741 (1.2713). Material comparison is also performed according to friction coefficient measured with tribometer, as well as by friction wear width on block and according that material indexes are formed and shown in relation (2). Material comparison and defining of machinability index is performed based on theoretic approaches for calculating all three components of resultant cutting forces [4,5]. At the time, following parameters are taken into consideration: cutting depth and width, radius of the tool tip, material strength of cutting material, coefficient of chips compression, cutting speed, tool geometry. Another theoretical approach [6] for determining of material machinability originates from known angle values at rake side, friction angle and normal force (N3) and friction force at rake tool side (T3), which are defined with function of cutting material strength and cutting angle.

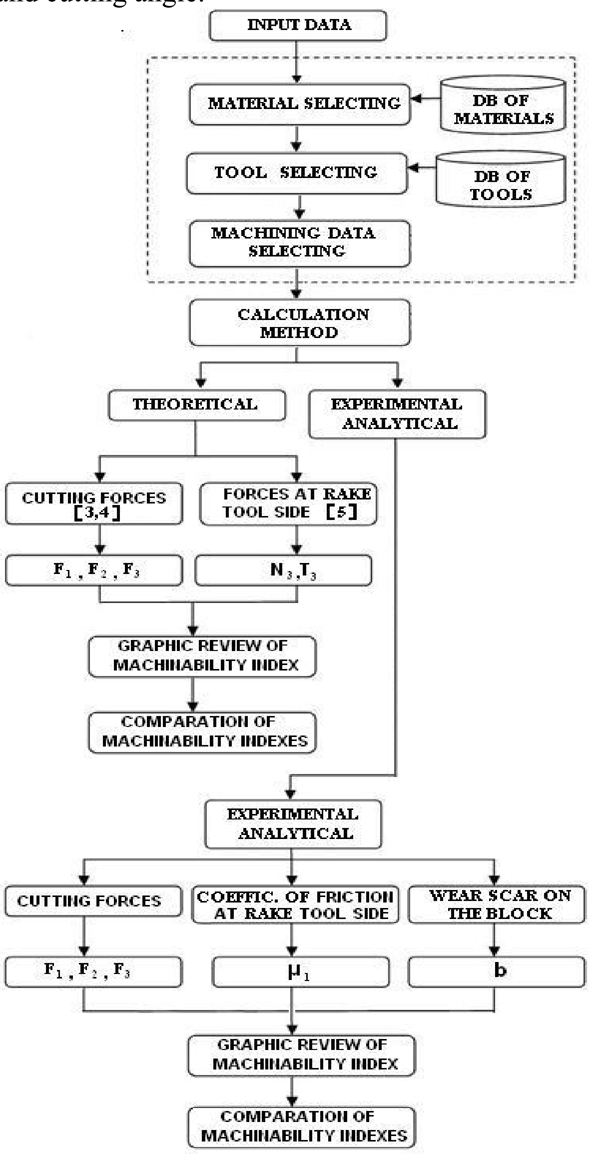


**Figure 3.** Flow-chart of application for machinability index calculation

Friction coefficient is determined from relation of forces at tool rake side, and machinability index is used for comparison of the analyzed materials (2). Developed application, presented in this paper, has a goal to determine machinability index for materials according to previously mentioned theoretic models and experimental analysis in real cutting conditions and tribological analysis. Applications consists of data base for analyzed materials, tool database with option to input corresponding tool geometry, database for selection of characteristic turning, for case of angled cutting and module for calculating of machinability index (Figure 3). Characteristic models for turning are important for finding chips depth and width and other parameters important for defining cutting forces according to theoretic model [4,5].

Aiming to get as realistic as possible theoretic values of cutting forces, which are compared with values of experimental-analytic model, cutting conditions for machining of tough materials are limited in application based on recommendations. Developed application further more allows determining of needed values according to above mentioned theoretical models (Fig 3).

In order to find machinability index from aspect of cutting forces by experimental analysis, regression equations for calculating cutting force are needed to be entered in application. Machinability indexes are shown in clear and simple way with comparative histograms.

This application is developed through object oriented programming with Visual Basic syntax. User interface of the application for analysis of machinability index is shown in Figure 4.

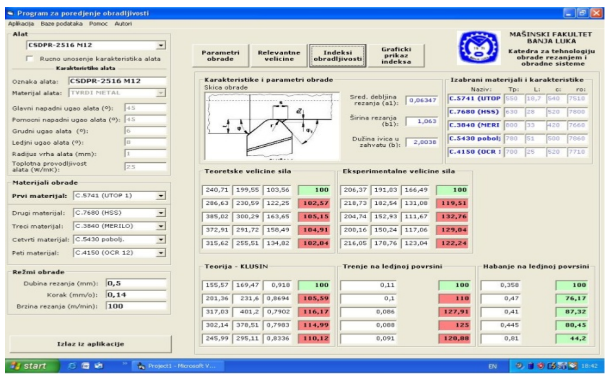

**Figure 4.** User interface of developed application

## 5. RESULTS

Advantage of the application is that it is possible to track single histograms of machinability indexes, which are determined by theoretic and experimental-analytic models.

With regard to importance of all three cutting forces components at machining of tough materials, one more advantage of the application is the possibility to track these indexes and compare by above mentioned models.

Results of the analysis of the machinability indexes by applying theoretic and experimental models are presented in Figure 5. Comparative analysis of machinability index, determined by various models, shows very high match of the results.

**Figure 5.** Histogram of machinability index for the group of tough materials

Figure 6 shows comparative analysis of machinability index determined by different models, encompassed in this developed application.

Curve 1 in figure 6 shows machinability indexes, which are determined applying regressive equations for calculation of cutting forces at machining of tough materials. Curve 2 shows material comparison which is done by friction coefficient, measured on tribometer "Block on Disk". Curve 3 shows machinability indexes which are determined using theoretic model approach for calculating friction forces and coefficient of friction at rake side of the tool [6], while curve 4 shows machinability indexes which are defined by theoretic model [4,5].

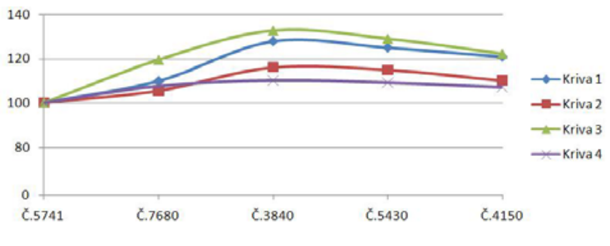


**Figure 6.** Comparative analysis of machinability indexes for analyzed group of the materials by various models.

Machinability indexes values which are determined by predefined models shows that there is no significant difference between theoretic and experimental approach. Machinability indexes determined based on experimental analysis correspond to real cutting conditions which take into consideration other relevant factors in machining process (coolant influence, vibrations, material condition, etc.), therefore material comparison from that aspect needs to be priority in regard to theoretic models.

Undoubtedly there is no need to lessen magnitude of theoretic models, because they open possibilities for wide variety of input values (cutting conditions, tool geometry, propriety of test materials, etc.) and tracking cutting force values which directly effect machinability indexes of materials. Thereby it is possible to encompass bigger number of analyzed materials and do comparison from machinability aspect.

## 6. CONCLUSION

Based on performed analysis of the machinability indexes, determined by theoretic and experimental-analytic model applying developed application, very high coincidence of results is noted. Advantage of the application is that allows wide area of comparison of analyzed materials from different aspects and at different levels.

Developed application allows increase of the number of the analyzed materials and their comparison by machinability with less number of experimental analyses. Experimental analysis need to allow as much as possible getting closer to realistic cutting conditions which are defined in theoretic models. New research directions are: application expansion for machinability index calculations of materials based on coefficient of friction at rake tool angle, development of theoretic models for calculation of tool wear, possibility of direct connection of application and software support in measurement chain.

## REFERENCES

[1] B. Ivković, Simulation of Tribological Processes in the Cutting Zone on Tribometer "Block on Disk", Journal"Tribology in industry", Vol..XX, N$^0$3, 1998

[2] G. Lakić-Globočki, B. Nedić, B. Ivković, V. Golubović Bugarski, Đ. Čiča, Possibility of Determination of Material Machinability Over Tribological Parameters by Use of Tribometer "Block on Disk", 9$^{th}$ CIRP International Workshop on Modelling of Machining Operations, Bled, Slovenia, 2006

[3] B. Nedić, G. Lakić-Globočki, Friction Coefficient for Al Alloys and Tool Materials Contact Pairs, Journal "Tribology in industry", Volume 27, No 3&4, str. 53-56. 2005

[4] С.С.Силин:Метод подобия при резании материалов МАШИНОСТРОЕНИЕ,Москва,1979

[5] В.Ф. Безъязычый, и др.: Оптимизация технологических условий механической обработки деталей авиационных двигателей, МАИ, Москва, 1993

[6] Вулф А.М. и др. Резание металов, Машгиз, Москва-Лењинград,1963