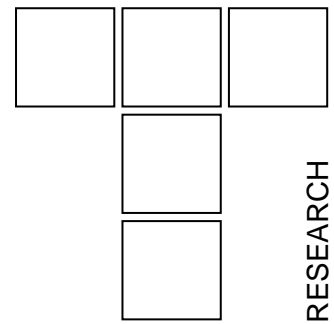*B. NEDIĆ, G. LAKIĆ GLOBOČKI*

Friction Coefficient for Al Alloys and Tool Materials Contact Pairs

RESEARCH

Development and application of new materials and increased application of calculations, simulations and modeling in area of metal cutting asks for the knowledge of friction coefficient for pairs made of these materials and cutting tool materials.

Part of results of friction coefficient measurement at "Block on disc" tribometer, for pairs made of Al alloy on one side and of different tool materials on the other side like HSS and HSE.E with and without coatings, hard metals with and without coatings and cutting tool ceramics are presented in this paper.

Keywords: *Al alloys, friction coefficient, cutting inserts, tribometer*

1. INTRODUCTION

The cutting process is done with high pressure between contact surfaces, large amount of heat generated in the cutting zone and intensive tool wear.

Management of the cutting process demands good knowledge of cutting tools tribological characteristics as well as arability of workpiece. Development and application of new tool materials lead to appearance of new generation materials resistant to vibrations, wear, high temperatures and which enable machining without agents for cooling and lubrication. Application of high speed technology is also enabled for them (machining with extremely high cutting speed).

In recent times, aluminium and its alloys have been broadly applied in various fields (car production, airplane industry and civil engineering) due to the fact that aluminium has smaller density than steel, good resistance to corrosion and good mechanical and recycling properties.

This application is especially prominent within car and airplane industries because the application of aluminium parts provides smaller fuel consumption and at the same time it reduces production costs. Aluminium and its alloys are used for production of engine heads, engine

blocks, cases for gearbox and differentials, carrying frame, car body panel etc. The following aluminium alloys are most widely applied for the previously mentioned purposes: *Al-Mg-Si* alloys which are heat hardening, weldable *Al-Zn-Mg* alloys, cold formed sheet metals based on *Al-Mg* and *Al-Mg-Mn*. (e.g. Audi A2 has 37% *Al*, Audi A4 16% *Al*, Mercedes Benz C - class 11%). According to some predictions, the share of light alloys in passenger car production will reach 80% by the year 2010. It is believed that the current aluminium alloys used in car industry will be replaced by Al-Mg-Li and Al-Cu-Li-Mg alloys in the following years, because these alloys have smaller density and higher elasticity module, what is very important for good welding properties.

The best known *Al* alloy is *AlSi12* with excellent mechanical properties and relatively high corrosion resistance. It is applied for medium stressed thin-wall castings for general purposes in car and aircraft industries. It is not thermally-hardening. *Al-Si* alloys which are most widely applied in car and aircraft industries are:

- *AlSi12Cu2Fe* - for car engine parts,

- *AlSi5Mg* - for castings of engines and vehicles exposed to impact load in the course of operation,

- *AlSi10Mg* - for tense thin-walled castings resistant to vibrations,

- *AlSi12CuMgNi* - multi-component alloy for cylinders of internal combustion engines,

- *AlSiCu4* - for castings of higher hardness,

Dr Bogdan NEDIĆ
Faculty of Mechanical Engineering,
Kragujevac, Serbia
Dr Gordana LAKIĆ GLOBOČKI
Faculty of Mechanical Engineering,
Banja Luka

- *AlSi6Cu2* - for the most loaded parts of internal combustion engines.

Development of new tool materials lately is evident, which especially refers to ceramic materials and coatings on hard metals, it brings the need for fast investigations of tool material influence on tribological characteristics of contact pair tool – workpiece. With that purpose investigations of tribological characteristics of tribological contact pair block on disc, where disc is made of workpiece material, and block of tool material are welcome.

2. TRIBOMECHANICAL SYSTEM OF THE CUTTING ZONE

It takes long time to develop the new tool material and to find its application in industry and to obtain first results of application. We must develop fast and light, but also reliable methods for determination of tribological characteristics of tools. That way, the time needed for development of tool materials would be significantly shortened. Tribological investigations in development phases of new tool have the main purpose to determine the influence on cutting wear intensity of tool material, cutting contact temperature, cutting fluid and cutting friction between elements in contact.

For many years, in the Laboratory for metal forming and tribology at Faculty of Mechanical Engineering in Kragujevac efforts have been made and significant results accomplished in developing tribological methods and modern equipment for tribological investigations. With that purpose, several tribometers have been designed and developed. The main measuring chain for tribometrical investigations at Faculty of Mechanical Engineering consists of tribometer TPD-93 for measuring load, force and friction coefficient, thermo-pairs for measuring temperature of contact elements and lubrication agent, Talisurf-6 device for measuring topography parameters of contact elements and tool microscope.

Tribological processes in cutting zone take place both on front and back tool surface due to the contact of front tool surface and chippings and back tool surface with formed surface of the formed piece. The cutting processes shown in figure 1 can be presented with tribomechanical system which consists of cutting wedge of tool, chippings and formed piece, which are placed at the setting which consists of agent for cooling and lubrication.

In the presented tribomechanical system, chippings slide against front surface of tool at speed v_s, at normal loading F_{N1}, and back surface slides against formed surface at speed v at normal loading F_{N2}. Figure 1 shows the model of the cutting process. Since, in most cases, the intensive wear processes occure on the back surface of tool, the basic model of cutting process can be represented as shown in figure 2b, where sliding speed represents the cutting speed, and normal loading F_{N2} is a radial component of the cutting resistance. This means that "block on disk" block on the tribometer represents the tool, while disc is of formed object material.

In this work, cutting inserts of hard metal with or without coating and ceramic cutting inserts were used as a block. The width of all inserts was 4 mm. For investigations HSS and HSS.E of tool materials with and without coating special 4 mm wide inserts were made and coated in Institute for Copper – Bor.

Cutting insert of CBN were made of hard metal base of width 2 mm and layer of CBN of width 2 mm, so the results should be taken conditional.
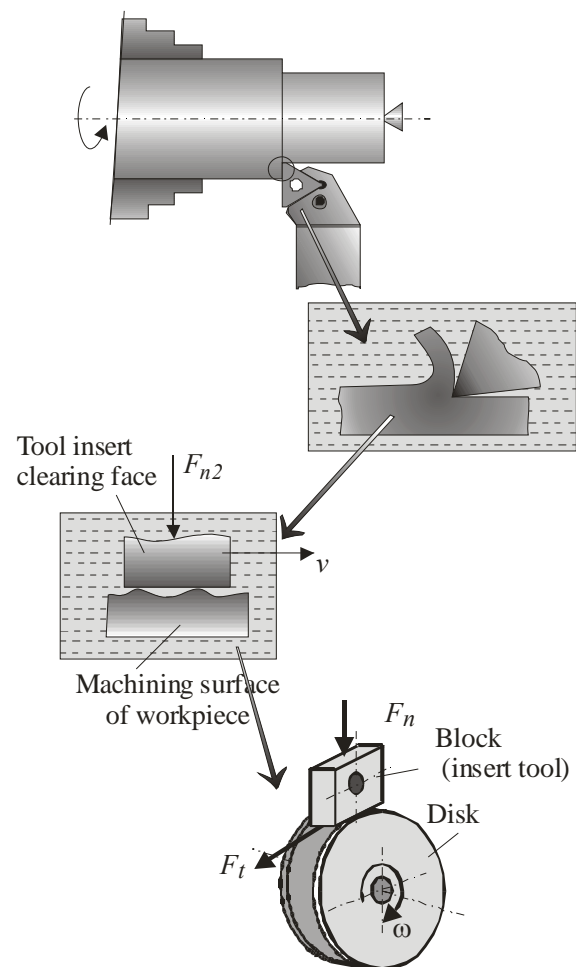

Figure 1. Tribological model of the cutting process

3. SOME INVESTIGATION RESULTS

By preliminary investigations in forming by scraping, the cutting resistances were measured with the aim of determining the normal loading in investigations on tribometer. These investigations were realized within particular range of cutting regimes which correspond to rough forming. Thereat, the values of radial component of cutting resistance of about 50 - 100 N were obtained. Investigations were carried out at cutting speed 180 m/min (3,0 m/s).

Based on these information, investigations on tribometer were conducted at sliding speed 2,7 m/s (160 m/min) and normal loading of 60 N, during 15 s, and then 100 N before strong vibrations appeared. The disc of Al alloy AlSi12CuMgNi of width 50 mm and hardness 130 HB. Block was made of different tool materials (Table 1.)

Investigations were conducted without cutting fluid, with the aim to identify real values of friction coefficient, and the investigations were stopped after appearance of strong vibrations in measuring system.

By realized investigations on tribometer, the basic experimental documentation was formed, which contains information on conditions of experiment execution: block and disk material, hardness, topography of contact surfaces and conditions in which contact is realized (loading, sliding speed, lubrication, temperature). The investigation results contain information on the following: friction coefficient and change of friction coefficient within time of contact realization.

Values of friction coefficient, according to table 1, measured in first 15 s of investigation period, during first contact period and normal loading of 60 N, are presented on picture 3, and middle values of friction coefficient after 20 s at the same sliding speed and normal loading of 100 N are presented on picture 4. Significant differences between these values can be noticed.

The lowest values of friction coefficient are measured during contact of Al disc with block of fast cutting steel without coating and ceramic Si_3N_4, Silinit-R, and hard metal without coating. Highest friction coefficient is measured during contact of Al disc with insert of hard metal with coating of Al_2O_3 ceramic. Similar differences were noticed with both lower and higher loading, but there are significant differences in time of investigation before appearance of strong vibrations when the investigations had to be stopped. Longest investigation time was measured

during contact of Al disc with insert of Si_3N_4, over 200 s. On most inserts sedimentation, the significant destruction of disc surface and material removal occurred.

Due to relatively fast sedimentation process on insert surface with loading of 100 N, it came to constant increase of friction coefficient, so the presented results present middle values before appearance of strong vibrations.

It was noticed that there was no sedimentation on ceramic Si_3N_4 and on part of CBN insert.

Table 1.

No.	Cutting insert	Friction coefficient	
		Fn 60 N	Fn 100 N
1	HSS.E, without coating	0,056	0,10
2	HSS, without coating	0,054	0,097
3	HSS with TiN coating	0,22	0,25
4	HSS with (TiZr)N coating	0,21	0,24
5	insert SNUN 120412 ceramic Si_3N_4 - SILINIT-R	0,048	0,05
6	insert SNMG 120412 hard metal P20, without coating, S25M – Seco	0,1	0,14
7	insert CNMA 120412 ceramic Al_2O_3 – K060 – Kenametal	0,19	0,19
8	insert SNMA 120412 hard metal P15 with coating P-415 PP-Corun	0,2	0,33
9	insert SNUN 120412 hard metal P15 with coating AC211 – Sumitomo	0,18	0,37
10	insert SNUN 120412 hard metal P15, without coating, P15/K15C - Tizit Plansee	0,19	0,26
11	insert SNMG 120412 hard metal P25 with coating, KC810 – Kenametal	0,25	0,38
12	insert CNMG 120412 hard metal P35, without coating, P35 - PP-Corun	0,13	0,31

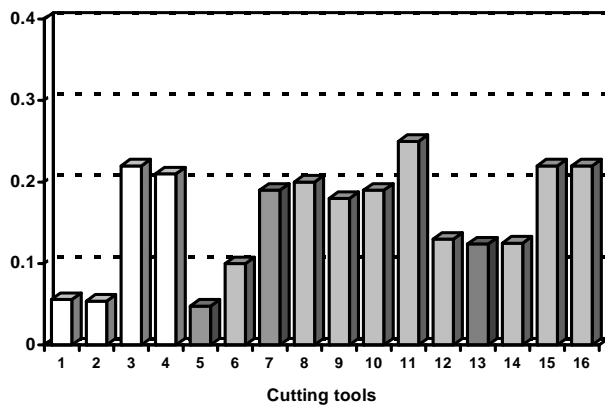| 13	insert SNMX 120404 EN CBN, TA 201 - Tizit Plansee	0,124	0,21
14	insert CNMG 120412 hard metal P25 with coating, GC3025 – Sandvik	0,125	0,28
15	insert SNMG 120404 hard metal P15 with coating, PGP 431 – Sandvik	0,22	0,35
16	insert CNMG 120412 hard metal, without coating, V0-5 – Valenite	0,22	0,33

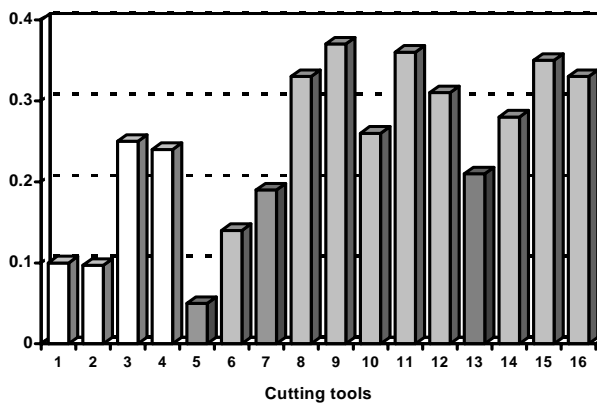*Fig. 2. Average values of friction coefficient during first 15 s of investigation with Fn=60 N*

Fig. 3. Average values of friction coefficient with Fn = 100 N

4. CONCLUSIONS

Due to limited space, in this work is presented only part of realized investigations. Based on comprehensive investigations it can be noticed that there are significant differences of measured friction coefficients on 'block on disc' tribometer between disc of Al alloy and lateral surface of cutting insert that represented block on tribometer.

Measured values can indicate the course of investigation with the aim of selection of cutting tool material, the surface layer of the tool that would be used for Al alloy machining. High values of friction coefficient lead to inappropriate machining due to sedimentation, increased temperature in cutting zone, increased temperature of agents for cooling and lubrication and increased tool wear.

Measured values of friction coefficient can be used for mathematical calculations with the aim of modeling and simulation of processes running in the cutting zone.

REFERENCES

1. *Ivkovic, B., Rac, A.,* Tribology, Yugoslav Association for Tribology, Kragujevac, 1995

2. *Ivkovic, B.,* Simulation of tribological processes in cutting zone on tribometer "block on disk", Tribology in Industry, Vol. 20, No3, 1998

3. *Nedić, B.,* Simulation of cutting processes on tribometer in the function of developing new cutting fluids for aluminium alloys machining, Journal MVM, Secial edition, Vol 30. Kragujevac, 2004.

4. *Lakić Globočki, G., Nedić, B., Golubović Bugarski, V.,* Aplication of "Block on disk" tribometer in researching materials workability, Balkantrib 05, Kragujevac, Serbia and Montenegro, 2005.