TRIBOLOGICAL PROPERTIES OF AL-ALLOY DESIGNED FOR DRAWING STAMPINGS IN AUTOMOTIVE INDUSTRY

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DOI : 10.17973/MMSJ.2018_06_201757

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Strict legislative requirements for environmental protection and tendency to lower consumption of fossil fuels force the car producers to still find new possibilities in the car-body design. As one of such possibilities there is effort to apply materials with low specific weight. Among these belong also Al-alloys that are affordable, but in comparison to steels also difficult to be technologically processed. In paper is evaluated the influence of new coating type on the tribological properties of alloy EN AW 6016 that is used in the automotive industry for drawing stampings. Tribological properties are evaluated by means of 3D surface color maps, where is shown friction coefficient in dependence on sliding velocity and contact pressure. Own state of surface is observed and documented by images from the optical microscope and magnitudes of surface sheet roughness that are measured in parallel and perpendicular direction regarding the rolling direction.

KEYWORDS

Al-alloys, Tribology, Drawing of Sheets, Car-body, 3D Surface Color Map, Friction Coefficient

1 INTRODUCTION

On the sheet stampings are nowadays in the automotive industry posing still stronger claims mainly in light of strength, surface quality and dimensional accuracy. Steady application of new types of materials with low specific weight that are based on the Al-alloys also means specific technological problems in production of car-body stampings [Davies 2003]. Low Young´s modulus of the Al-alloys causes large spring-back and greatly influences achieving of required shape and size accuracy of producing stampings. As another problem there is limited deformation ability of Al-alloys which is in contrast to required mechanical properties. It´s almost impossible to simultaneously fulfill these requirements. Thus as a very necessary condition for proposal technological procedure of production stampings from Al-alloys, there is need to solve deformation of material after achieving the final shape with required quality (sufficient strength of part, allowable sheet thinning, sheet wrinkling, to prevent creation of surface defects, etc.) [Polmear 2006].

Beside basic material characteristics is deformation behavior of formed sheet in tool greatly influenced by adjustment of the technological conditions as can be e.g. blank-holding pressure, feed rate of material, temperatures and lubricating methods. Wrought Al-alloys designed for forming have generally much higher friction coefficient than commonly used steel sheets. That is why tribological research is especially important.

Competitive pressures on the design changes at new car-body types strongly increase utilization of mathematical modelling of technological processes in the pre-production and production phases, because they offer flexible reaction during solving any problems. [Ashby 2007].However, as a basic presumption of such virtual modelling of technological processes, there is fact to know as much boundary conditions as possible, because they influence a lot production of sheet stampings.

This paper deals with evaluation the influence of new coating type on the tribological properties of alloy EN AW 6016 that is used for car-bodies outer panels. By tribological test as strip drawing test is measured the change of friction coefficient magnitude for samples without that coating and with new type of coating developed to lower friction coefficient. Basic used material EN AW 6016 was the same for the tribological testing.

2 METHODOLOGICAL BASES AND EXPERIMENTAL PART

2.1 *Static tensile test*

Static tensile test represents the basic test to obtain mechanical properties of the tested material EN AW 6016 [Pöhlandt 1998, ASM HANDBOOK]. Samples of sheet were cut-out in the directions 0°, 45° and 90° regarding the rolling direction. Methodology and evaluation of the static tensile test was performed acc. to standard EN ISO 6892-1. Measured values from the static tensile test for individual directions are shown in Tab. 1. Examples of engineering stress-strain curves from static tensile test are shown in Fig. 1.

Rolling direction	Proof Yield Str. $R_{p0,2}$ (MPa)	Ultimate Strength R_m (MPa)	Uniform Ductility A_g (%)	Total Ductility A_{80mm} (%)
0°	102,5±0,7	190,5±1,1	23,2±0,2	27,1±0,4
45°	103,7±0,6	192,3±0,9	27,1±0,3	29,3±0,3
90°	102,3±0,5	190,6±0,8	23,1±0,3	23,9±0,4

Table 1. Measured results from static tensile test

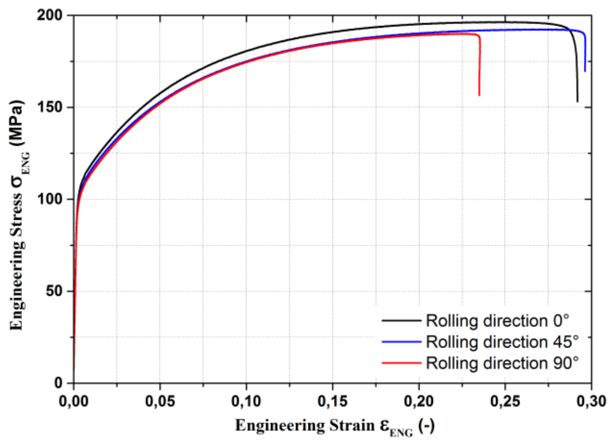


Figure 1. Static tensile test of material EN AW 6016

2.2 *Evaluation of sheet surface*

As a very important parameter that influences the tribological process there is state and surface quality of tested material. That´s why in this experiment were measured roughness values and were acquired surface images from optical microscope. Measuring of the surface roughness was performed by deviceMarSurf PS1. Surface images were acquired by device Olympus DSX 500. Measured values of surface roughness in the direction 0° and 90°regarding rolling direction are summarized in Tab. 2. Surface image of tested material EN AW 6016 is subsequently shown in Fig. 2.

Direction 0°		Direction 90°	
Ra (μm)	RPc (cm-1)	Ra (μm)	RPc (cm-1)
0,883±0,024	52 ± 2	0,831±0,019	74 ± 3

Table 2. Table of surface roughness for material EN AW 6016

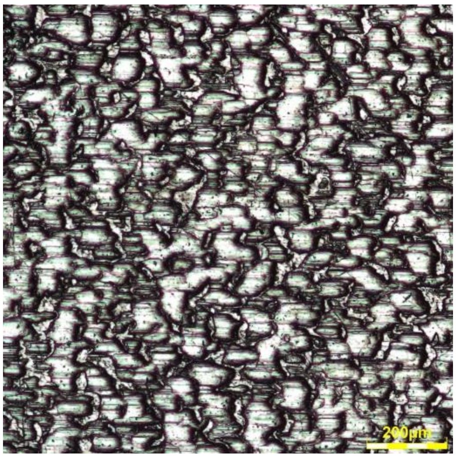


Figure2. Surface image for material EN AW 6016

Tested samples of sheet were delivered in two variants. In the first case was on the basic material EN AW 6016 applied only layer of semi-rigid lubricant Drylube E1 in the average amount as 0,8 ± 0,1 g·m^{-2}. In the second case was on the basic material applied nano-layer of the new coating and subsequently was on this coating applied the same amount of lubricant Drylube E1 as in the first case (0,8 ± 0,1 g·m^{-2}). Such amount of lubricant was determined by means of IR apparatus from company Fuchs. This device is shown in Fig. 3.

Figure 3. Measuring of lubricant amount by IR apparatus

2.3 *Tribological testing*

For tribological testing is at the Department of Engineering Technology TU in Liberec used tribological machinery SOKOL EVO II. Experiments are carried out with the help of strip drawing test between testing jaws. One jaw is fixed and the second is possible to control by means of hydraulic system which enables to achieve requisite contact pressure during actual tribological test. Regulation of hydraulic unit allows to perform tests under the constant pressure or at continuously increasing pressure. Sheet sample is drawn under constant sliding speed between jaws.

Sliding speed is possible to be changedfrom v = 1 mm·s^{-1}up to 400 mm·s^{-1}. Measured length after which are measured tribological conditions is selected always with reference to used sliding speed. As a main result there is graph of force vs. feed. These graphs serve as groundwork for evaluation of tribological properties for whole system: lubricant – tested sheet – tool. Equipment for tribological testing and principle of this test is illustrated from Fig.4 and Fig.5.

Figure 4. Equipment for tribological testing (SOKOL EVO II)

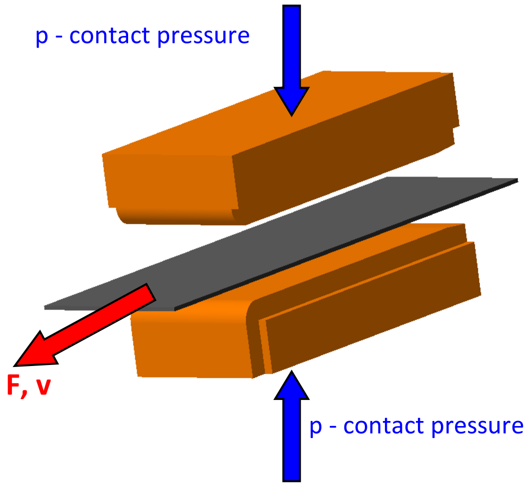


Figure 5. Principle of the tribological test

Instantaneous friction coefficient μ (-) is then calculated from the simple equation (1).

$$\mu = \frac{F}{2.p.S} \qquad (1)$$

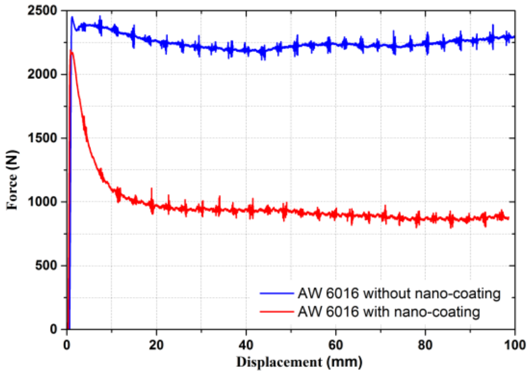
Where:			
	F	- measured force	(N),
	p	- applied contact pressure	(MPa)
	S	- contact area	(mm^2).

2.4 *Experimental determination of friction coefficient*

Friction coefficient for both tested materials was determined under the temperature 50°C. Such temperature was chosen regarding standard stamping tools temperature at production of car-body stampings. Moreover, temperature 50°C also make possible transition of used lubricant Drylube E1 form semi-rigid to liquid state. Sliding speed v (mm·s^{-1}) was chosen as follows: v = 1, 10, 50, 100 and 400 mm·s^{-1}. Magnitudes of the contact pressure were chosen regarding the commonly used holding pressures as follows: p = 1, 5, 10, 20 and 40 MPa.

Size of contacts area S was 1560 mm^2. Examples of result from the tribological testing is shown in Fig. 6 and Fig. 7, where is

p (MPa)	Sliding speed (mm·s^{-1})				0
1					52
5					24
1(					96
2(					59
4(					92



obvious influence arising from nano-coating on the magnitude of measured force F (N) during strip drawing test.

Figure 6. Measured course of tribological test (contact pressure 5MPa, sliding speed 10 mm s^{-1})

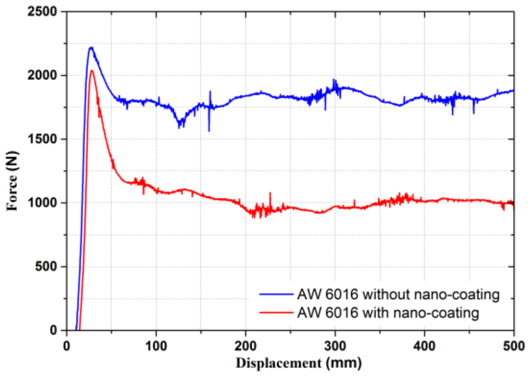


Figure 7. Measured course of tribological test (contact pressure 5MPa, sliding speed 400 mm s^{-1})

From the measured values of force vs. displacement was acc. to equation (1) calculated the friction coefficient μ (-) for every technological condition (magnitude of contact pressure and sliding speed). Calculated magnitudes of friction coefficient are summarized in the relevant Tables 3 and 4.

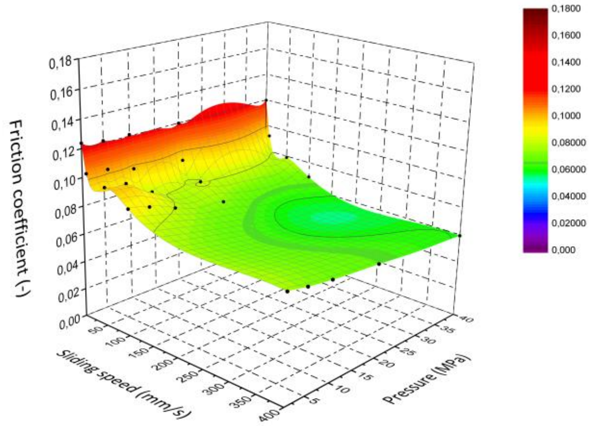
p (MPa)	Sliding speed (mm·s^{-1})				
	1	10	50	100	400
1	0,1625	0,1487	0,1403	0,1303	0,1204
5	0,1604	0,1437	0,1374	0,1277	0,1111
10	0,1585	0,1410	0,1301	0,1222	0,1069
20	0,1565	0,1379	0,1259	0,1197	0,0932
40	0,1552	0,1352	0,1197	0,1010	0,0875

Table 3. Table of measured friction coefficient magnitudes for material EN AW 6016 without nano-coating

Table 4. Table of measured friction coefficient magnitudes for material EN AW 6016 with nano-coating

For clear demonstration of sliding speed and contact pressure influence on the final magnitude of friction coefficient there were prepared 3D surface maps about such dependence. These 3D graphs for both tested materials are graphically illustrated in Fig. 8 and Fig. 9.

Figure 8. 3D surface map of friction coefficient magnitudes in dependence on sliding speed and contact pressure (material AW 6016 without nano-coating).



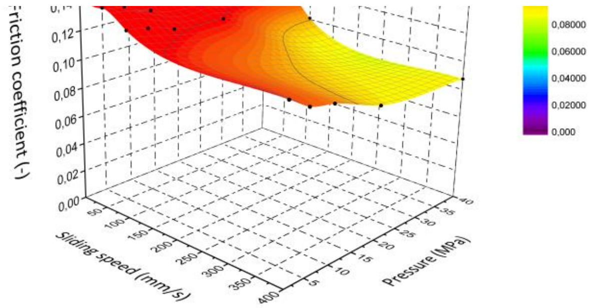


Figure 9.3D surface map of friction coefficient magnitudes in dependence on sliding speed and contact pressure (material AW 6016 with nano-coating).

3 CONCLUSIONS

Drawing of the car-body stampings represents one of the most complicated forming technological operations. Beside the mechanical properties of processing material is final quality of stamping influenced also by many technological factors. Among them play the crucial role mainly contact pressure, sliding speed and the forming temperature. Mentioned technological conditions greatly influence the own magnitude of friction coefficient which plays essentially role to achieve the quality stamping. In the case of higher friction coefficient at drawing stampings from thin sheet is there a risk of fracture occurrence in the critical areas of producing parts. Such reality is truly very important at drawing stampings having the lower mechanical properties of the basic material, where also belong aluminium alloys. So to lower friction coefficient by means of application different layers represents one of the possibilities how to positively influence the own stamping process for these stampings and how to achieve the trouble-free production.

In the article was tested influence of surface nano-coating on the magnitude of friction coefficient for material EN AW 6016. From the measured values is evident that such nano-coating positively influences (lowers) the magnitude of friction coefficient for this tested material and that for every tested combination between contact pressure and sliding speed was by application of the nano-coating achieved the lower friction coefficient. In comparison to the basic material without application of nano-coating, there was decrease of friction coefficient approx. by 30% for material with nano-coating. Higher decrease of such values was achieved in the areas of lower sliding velocities, where is influence of nano-coating very clear. Mutual comparison of 3D surface maps as distribution of friction coefficient for 2 variables (contact pressure and sliding speed) and for material with and without nano-coating is shown in Fig. 10, where upper surface belongs to material without application of nano-coating and lower surface belongs to material EN AW 6016 with nano-coating.

Application of nano-coating has a positive influence on the friction coefficient. However, regarding the whole complex process of production stampings in the automotive industry, it is truly very important to investigate influence of such layer on the strength of bonded joints, possibilities of subsequent welding and last but not least only the possibilities of car-body painting at application of such nano-layer.

ACKNOWLEDGMENTS

This publication was written at the Technical University of Liberec as part of the Student Grant Contest "SGS 21122" with the support of the Specific University Research Grant, as provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year 2017.

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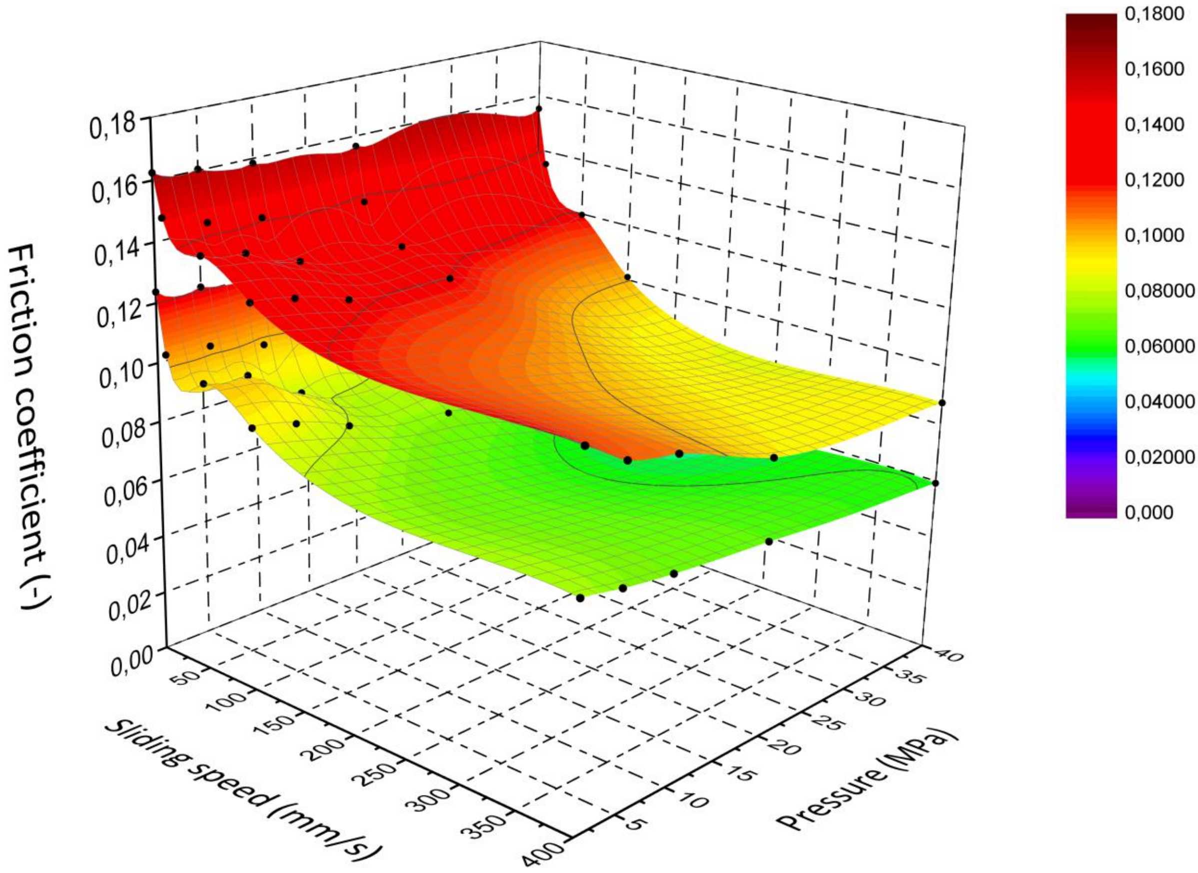

Figure 10.3D surface map of friction coefficient magnitudes in dependence on sliding speed and contact pressure (material AW 6016 without and with nano-coating).