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CHARACTERISTICS AND LIMITATIONS OF PHYSICAL TRIBO-MODELLING IN DEEP DRAWING OF THIN SHEET METAL

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Abstract: *The significance of contact friction in deep drawing is well-known, especially in manufacturing of auto body parts. The general approach in this area involves the recognition of the influence of the main tribological parameters – pressure, speed and temperature in the deep drawing process. The developed methods for physical modelling of tribological phenomena and the influence in deep drawing are very different. These methods basically have the appropriate physical model which imitates local area or a complete work piece in metal forming process. The indicators of models can be very different: the deformation forces or work, forming limit parameters, distribution of stress, strain or temperature, etc. This paper analyzes the classic and modern physical tribo-models in deep drawing, according to their characteristics and limitations.*

Keywords: d*eep drawing, contact friction, tribo-model, sheet metal, strip drawing.*

1. INTRODUCTION

In deep drawing of complex geometry parts, such as vehicle body elements, various stress-strain schemes may exist in particular zones of the work piece being formed, with tribological conditions influence which might often be complex. On work piece flange, next to pure tangential compression zone, parts without completely curved inner contour have uniaxial tension, which moves to bending field on the die edge. If there are draw beads on the flange, stress scheme gets complicated significantly. As a rule, uniaxial tension is dominant in the wall of the work piece which conveys the forming force. In the specified zones, it is necessary to reduce friction, i.e. to control friction on flange, in order to control sheet metal moving into die opening.

The influence of tribological factors in deep drawing process is as important as the influence of other main process factors – machine, tools and work piece material [1]. By using appropriate combination of specified factors, it is possible to realize reliable production and obtain high-quality piece.

In physical modelling of deep drawing process, i.e. modelling of contact friction influence, it is necessary to comply with similarities of stress-strain ratios, as well as similarities of main tribological parameters: speed, pressure and temperature on sliding surfaces. Figure 1 shows tribo-models in deep drawing. Basic tribo-models are: sliding between flat surfaces, bending with tension and sliding across the draw bead (strip draw tests) and complex tribo-models of stretching and pure deep drawing [2].

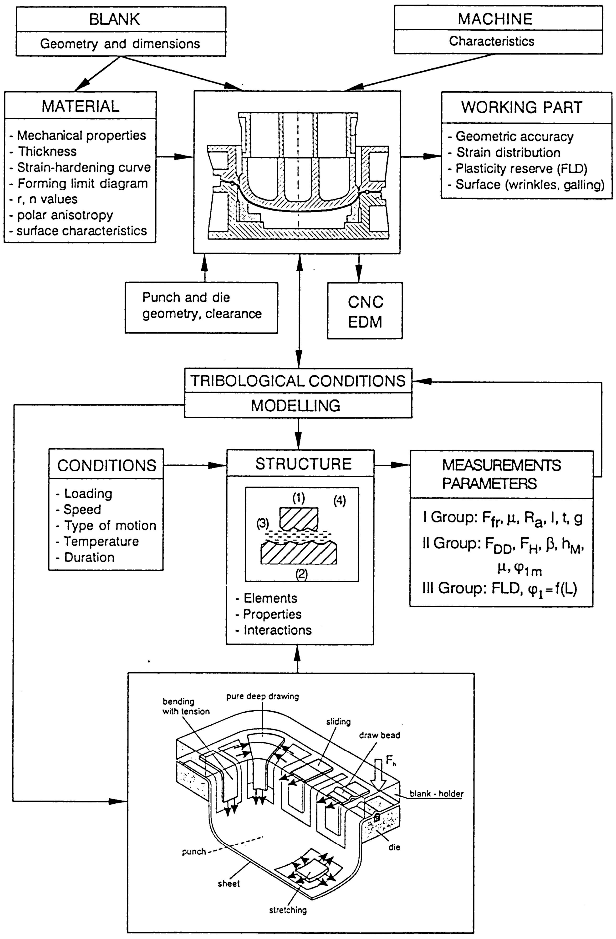

Figure 1. General scheme of tribo-modelling in deep drawing [1]

In general, with such approach, the following can be observed: local zone of the work piece being formed, several local zones and a complete work piece. Numerical modelling enables integral analysis of all individual work piece zones.

According to the size of the examined work piece zones and characteristics of the measuring parameters, the results of tribological research can be divided into three groups [2,3]: physical indicators (friction coefficient, friction force, sliding distance, etc.), macro indicators for the whole work piece (force and depth of drawing, limiting drawing ratio, etc.) and indicators of strain analysis with limit formability elements (strain distribution, position in forming limit diagram – FLD etc.) for particular zones or whole work piece.

Tribological investigations can be carried out in production and laboratory conditions, i.e. through real process and simulation tests. In the case of manufacturing conditions, it is not possible to change the basic kinematics of the process. In the simulation tests and modelling of tribological conditions of metal forming, it is possible to control all significant impacts. The main difference compared to the production tests is kinematics of metal forming processes. In accordance with the general scheme of tribo-modelling, shown in Figure 1. Figure 2 shows different simulation tests in sheet metal forming which include ironing models [4].

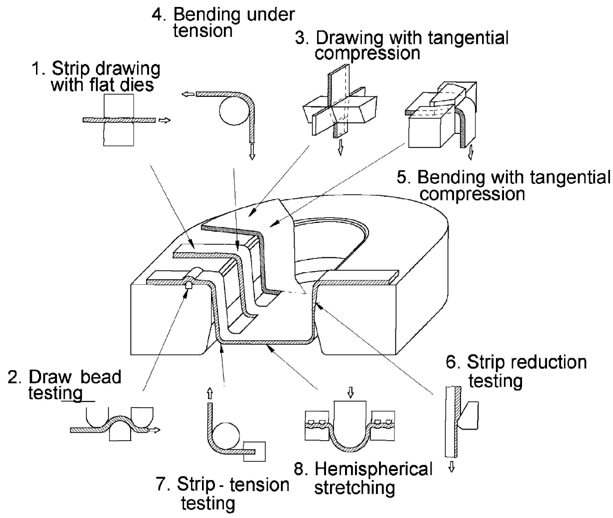

Figure 2. Schematic illustration of simulative tests for sheet metal forming [4]

The main test in this area is strip drawing-sliding between the flat surfaces of the holder and die (model 1 in Fig. 2). The introduction of new materials has led to the development of new deep drawing processes and new simulation of tribo-tests. Further in the text there is reference to some results of the development of tribo-research in the field of deep drawing tribology, with key characteristics and limitations.

2. RESULTS OF USING CONVENTIONAL AND HIGH STRENGTH MATERIALS

Low carbon steel sheets, with anticorrosion coating or uncoated, are massively used in making of passenger car bodies. The results of tribological research in the field of deep drawing of car body parts obtained from the material in class DC04 (C0148 P5) have been published in numerous papers.

In the following figures, typical results of the authors, when using strip drawing test for the material č0148p5, are shown. Markings in the pictures: material without coating – UC, hot zinc-plated – HZ, zinc/chromium coating – ZC, sliding speeds are v_1 = 0.33 mm/s and v_2 = 3.33 m/s.

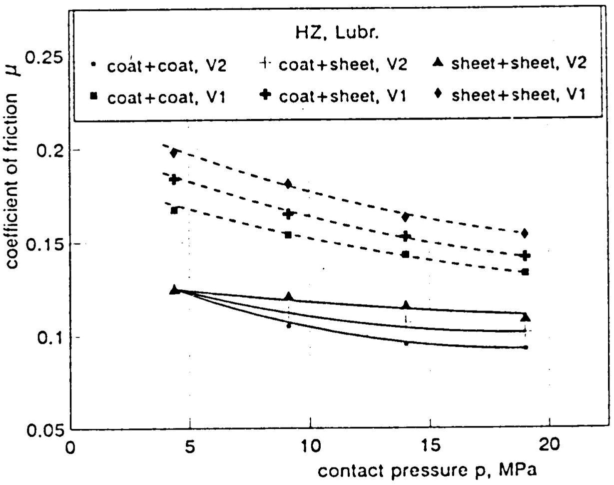

Figure 3. Friction coefficient change for sheet metal with coating

The coefficient of friction decreases with the increase of the speed and pressure. Sheet metals with coatings are sensitive to increase of the normal pressure, due to the possibility of the destruction of the coating.

I the real process, the contact parts of tools are heated. For this reason, for reliable modelling of classic strip-draw test, the contact elements are heated before testing the tools. The temperature of heating is in the range 25-100 °C. The scheme of such a device is shown in Figure 5 [5].

In accordance with the general requirements for weight reduction and increased car security, ultra high strength steels are increasingly being introduced in car production for important structural elements. These are the most common alloy steels marked 22MnB5, 27MnCRB5 and 37MnB4. In warm processing of deep drawing, the initial ferrite-pearlite microstructure with a tensile strength of about 600 MPa, transforms into a martensitic structure with a tensile strength of about 1500 MPa. Details of this procedure are given in papers [6,7]. Tribological research in these conditions is more complex and includes heating of the material to be tested.

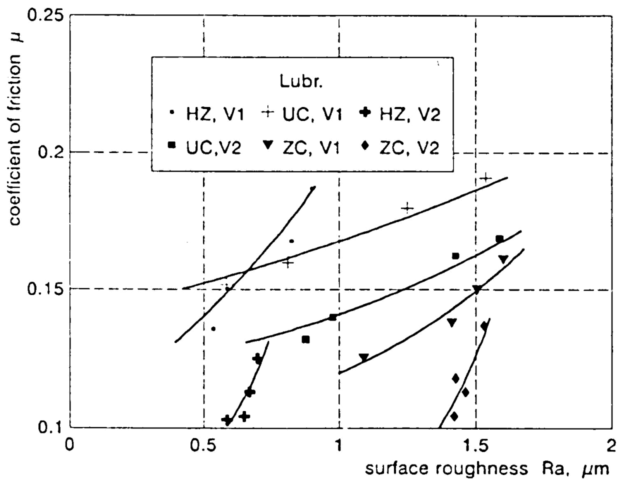

Figure 4. Friction coefficient as a function of average roughness

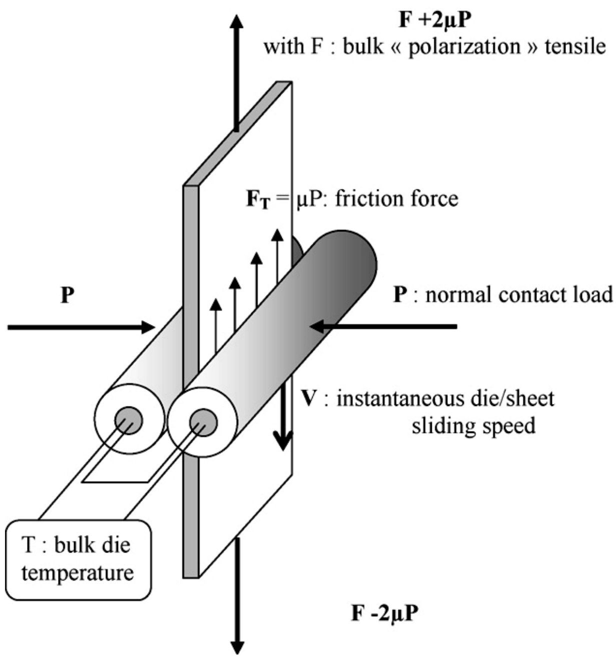

Figure 5. Strip drawing tribometer [5]

Device for strip-drawing test with heating specimens is shown in Figure 6 and schemes of testing procedure are shown in Figure 7 [6]. The highest temperature of the heating is 1100 °C, pressure force 200 KN, tensile force-sliding 20 KN, and max speed 30 mm/s. Changes of the coefficient of friction and the force of pressure and tension are shown in Figure 8 for t = 6000 s. When sliding is realized with constantly low friction characteristic, tribo-conditions are stable. Coefficient of friction decreases at the end of sliding, with respect to the use of lubricant for high temperature.

The paper [7] shows a series of different results for testing at hot condition. Different tribo-tests are used, Fig. 9. The well known pin-on-disc test, typical for other fields of tribology, is introduced.

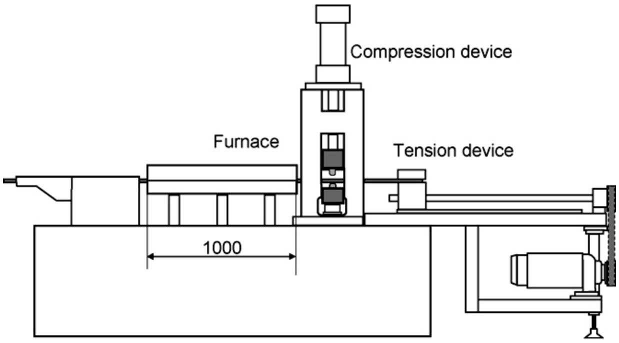

Figure 6. Schematic representation of hot flat strip drawing test machine [6]

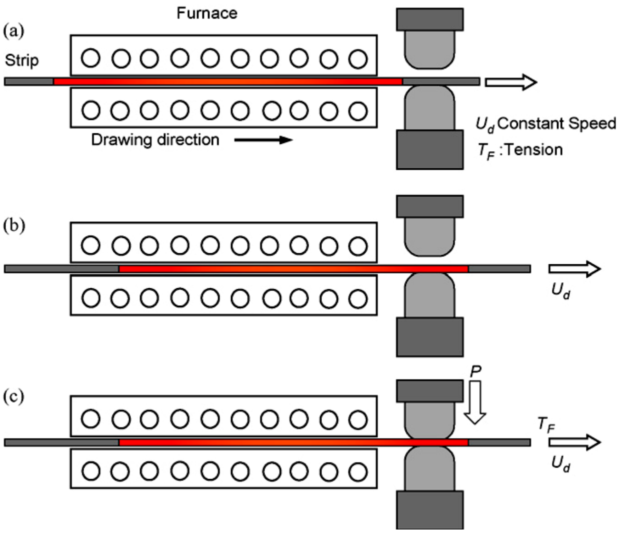

Figure 7. Schematic representation of test method [6]

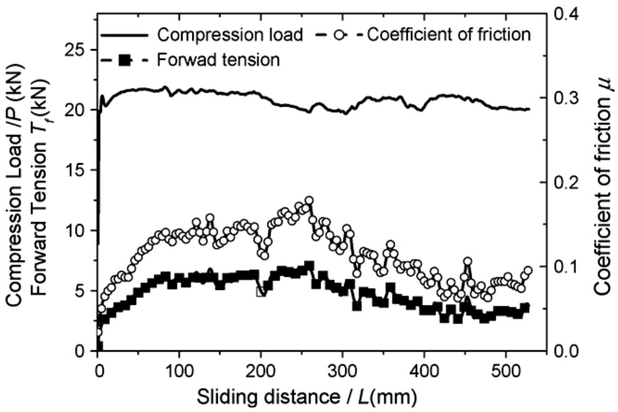

Figure 8. Relationships among compression load, forward tension, coefficient of friction and sliding distance [6]

Contact conditions between the sheet and the tools of the model pin-on disc are very different from those in sheet metal forming. The values of the coefficient of friction obtained in this way, Fig. 10, are unsuitable for use in the hot metal stamping. The coefficient of friction decreases with increasing temperature and normal pressure. Models of deep drawing and bending with tension are the closest to real conditions during processing in the hot condition.

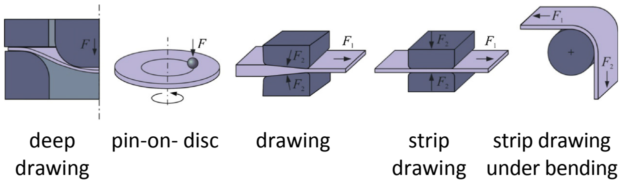

Figure 9. Principle of the test methods for the evaluation of friction characteristics [7]

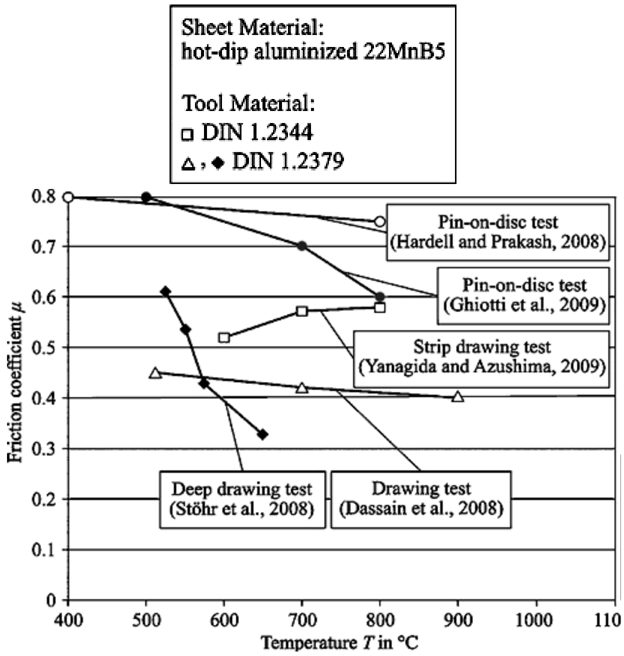

Figure 10. Friction coefficient against temperature [7]

Specific research of the phenomena of galling when using high strength steel sheets is described in the paper [8]. The occurrence of destruction of coatings on metal and of tools damage affects all the parameters of forming system: piece material, tools, machines and lubrication, Fig. 11.

For sliding test of the rotating ring (tool) per sample sheet, twist compression test is used, Fig. 12. The tests are performed in complex tribo-conditions and last for a relatively short time. By measuring the friction force and torque, the value of the coefficient of friction is determined. When value μ = 0.3 is achieved

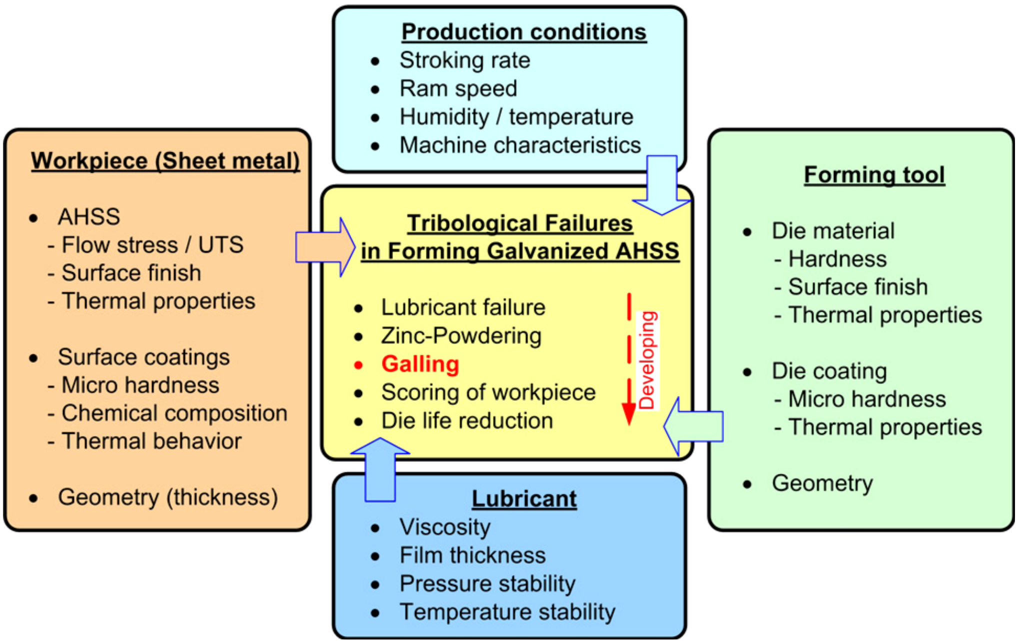

Figure 11. Factors influencing tribological failures in forming AHSS [8]

during metal-on-metal contact, the occurrence of galling is reported. The value μ = 0.3 was previously determined by laboratory tests.

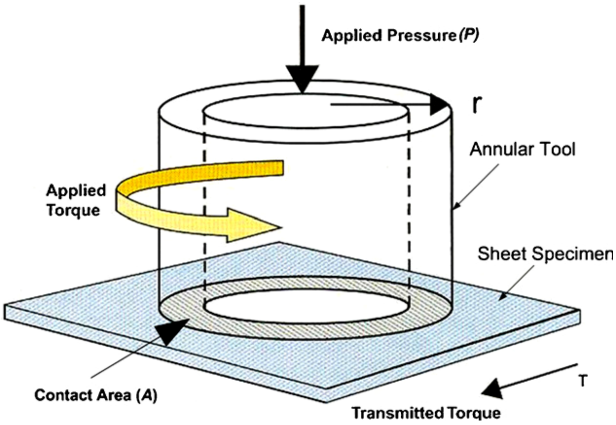

Figure 12. Schematic of twist compression test (TCT) [8]

The pressure in the contact can be extremely high, from 50 – 170 MPa, the speed is 10.35 m/s, sheet thickness 0.6 – 1 mm. In Figure 13, the change of coefficient of friction (COF) for two different lubricants is shown, and Figure 14 illustrates the galling on the active surface of the tool.

The applied procedure is used most often to support numerical modelling of complex mechanisms of friction at high local contact pressures. In real deep drawing process, normal pressure does not exceed the value of 50 MPa. In these experimental conditions galling is not registered.

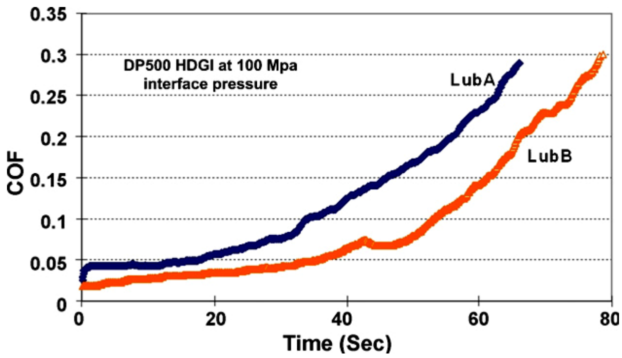

Figure 13. COF – time curves from TCT with different lubricants [8]

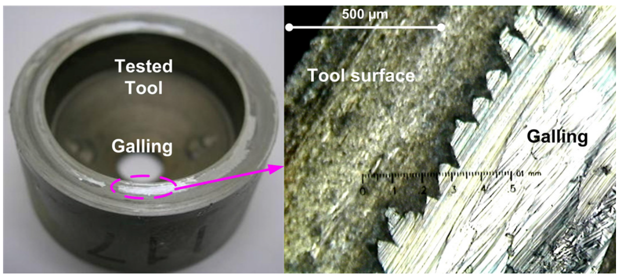

Figure 14. Galling observed on the tested tool surface at 170 MPa [8]

3. CONCLUSION

Development of tribological model in the field of deep drawing is adjusted to the development of the main components of forming system: materials, machines and tools. The basic requirement for the adequacy of tribo-model relies on the similarity of the main tribo-conditions: temperature, velocity and pressure.

In the case of deep drawing, it is necessary to achieve the analogy of the stress-strain relations.

When using high strength steel sheets for forming in the hot conditions, it is necessary to use the new procedures of tribo-modelling. For testing in extreme conditions tribo-developed models do not simulate real situations in real processes. The results of these studies indirectly suggest the importance of contact conditions, but are important in the process of numerical simulation.

For the completely numerical modelling of hot working process it is necessary to know the interaction of mechanical, thermal, microstructural and tribological characteristics. Formability at elevated temperatures and corresponding boundary criteria are a function of strain, strain rate, temperature and microstructural transformation.

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REFERENCES

[1] M. Stefanović: *Tribology of Deep Drawing,* Yugoslav Tribology Association, Monograph, Kragujevac, 1994 [in Serbian].

[2] M. Stefanović: Developments of tribo-models in deep drawing, in: *Proceedings of the YUTRIB '91*, Kragujevac, pp. 135-141 [in Serbian].

[3] M. Stefanovic, S. Aleksandrovic: Complex approach to tribo-modelling in deep drawing of thin sheets, in: *Proceedings of the BALKANTRIB 96*, 1996, Thessaloniki, pp. 214-221.

[4] N. Bay, D.D. Olsson, J.L. Andreasen: Lubricant test methods for sheet metal forming, Tribology International, Vol. 41, pp. 844-853, 2008.

[5] X. Roizard, J.M. Pothiea, J.Y. Hihn, G. Monteil: Experimental device for tribological measurement aspects in deep drawing process, Journal of Materials Processing Technology, Vol. 209, pp. 1220-1230, 2009.

[6] A. Yanagida, T. Kurihara, A. Azushima: Development of tribo-simulator for hot stamping, Journal of Materials Processing Technology, Vol. 210, pp. 456-460, 2010.

[7] H. Karbasian, A.E. Tekkaya: A review on hot stamping, Journal of Materials Processing Technology, Vol. 210, pp. 2103-2118, 2010.

[8] H. Kim, J. Sung, F.E. Goodwin, T. Altan: Investigation of galling in forming galvanized advanced high strength steels (AHSSs) using the twist compression test (TCT), Journal of materials processing technology, Vol. 205, pp. 459-468, 2008.