Transactions of the VŠB – Technical University of Ostrava, Mechanical Series
No. 1, 2012, vol. LVIII
article No. 1890

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PROJECT OF FORMING TESTS OF VARIOUS HEIGHTS BRAKE RIBS FROM VARIOUS SHEET-METAL THICKNESSES

NÁVRH ZKOUŠEK PROLISOVÁVÁNÍ BRZDICÍCH ŽEBER RŮZNÉ VÝŠKY Z RŮZNÝCH TLOUŠTĚK PLECHU

Abstract

The article deals with the forming of brake ribs of diffrent heights from various sheet-metal thicknesses to evaluate the required force with which the required holding force will be in correlation in the actual tool, thereby avoiding non-stamping of break ribs when clamping the blank holder at the start of the drawing process in practice. Four suitable metal sheets representing a wide range of used materials were selected for covering most of the problems associated with braking ribs in the automotive industry. Then four thicknesses worked with the most in practice were selected for these materials. After defining the tools and their scope of use together with working pressures and output, the most suitable dimensions of blank specimens for braking rib stamping were defined so as to have a sufficient reserve when testing samples in a real process, should the actual pressures and forces differ from those calculated in simulations. Then the article discusses simulations of the respective stamping process by means of the software AutoForm 4.06, using the finite element method to correspond to actual stamping conditions.

Abstrakt

Článek se zabývá prolisováváním brzdicích žeber různé výšky z různých tlouštěk plechu za účelem změření potřebné síly, se kterou bude v korelaci potřebná přidržovací síla ve skutečném nástroji, čímž se zamezí neprolisování brzdicích žeber při sevření přidržovače na počátku tažení v praxi. Pro co největší záběr problematiky prolisovávání brzdicích žeber v automobilovém průmyslu byly vybrány čtyři vhodní zástupci plechů, reprezentující celé spektrum používaných materiálů. U těchto materiálů byly následně vybrány čtyři tloušťky, se kterými se v praxi nejčastěji pracuje. Po definici strojů a jejich rozsahu použití společně s pracovními tlaky a výkonem byly nadefinovány nejvhodnější rozměry přístřihů vzorků na prolisování brzdicích žeber tak, aby byla dostatečná rezerva při testování vzorků v reálném procesu v případě, že by se skutečné tlaky a síly lišily od vypočítaných ze simulací. Následně se článek zabývá simulacemi daného lisovacího procesu pomocí softwaru AutoForm 4.06 využívajícího metodu konečných prvků tak, aby co nejvíce odpovídal skutečným podmínkám lisování.

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INTRODUCTION

The automotive industry is specific by the increasing forming complexity of used drawn shells and the use of materials with greater strength. Any company that wants to be competitive must keep pace with modern technologies and technological procedures, must try to introduce an innovative approach in its procedures, must be capable of dealing with technical and technological problems when complying with required geometric tolerances of parts and must be capable of producing them at a competitive price.

The requirement for using a minimum of weldments or differently joined drawn shells while using maximum reserves of metal sheet plasticity leads to high expectations regarding tool precision. Tuning such tools so that they function without defects and with minimum requirements for revisions during their entire operation life is all the more demanding the more the quality of the stamping technology design of the respective drawn shell was underestimated.

So each increase in the quality of stamping technology design of a specific drawn shell leads to the reduction of stabilization costs of the operation of the respective stamping tool during its operation life.

There is a series of procedures to correctly achieve formed surfaces of the drawn shell, i.e. without wrinkles or puckering due to springback effects. One of them is the use of braking ribs, i.e. protrusions formed in the die and blank holder (Fig. 4) which in a particular selected area of the flange increase radial tension during metal sheet drawing, thereby reducing or eliminating point tensions in this area at the same time. They are placed only in places where an increase in the braking intensity of metal sheet, and thus the achievement of a greater and with regard to size of the springback reduction also a more suitable deformation of the resulting drawn shell, is desirable.

Braking ribs are mainly used for irregular, large and complicated drawn shells such as car bodies where forming conditions are by far more complicated as compared to drawn shells of regular shapes. Brake ribs do not just brake the material flow, but also the direct movement of formed material in the corner parts of the die and contribute to the stabilization of the drawing process.

Two types of braking ribs are made in practice – ribs with run-outs at the end which are entirely in the flange area on the one hand and ribs whose ends are beyond the blank on the other hand so that during the clamping of the blank holder only the central parts of these ribs are stamped into the blank and there are no run-outs at the end. The use of a suitable rib type depends mainly on the blank size with respect to the size of the drawn shell.

1 PROBLEMS DURING THE DRAWING OF SHELLS WITH BRAKE RIBS

In practice there are cases of drawing dies having braking ribs in the area of the blank holder where an improperly chosen force of the blank holder causes imperfect stamping of braking ribs into the metal sheet so that the metal sheet is insufficiently braked during the drawing process and secondary wrinkling or puckering due to springback occurs on the walls of the drawn shell.

The degree of braking ribs stamping during clamping of the blank holder at the start of the drawing affects the overall quality of the drawn shell because the following may occur during the subsequent drawing process:

- local wrinkling of formed metal sheet,
- metal sheet folding,
- local compression of metal sheet,
- thinnning of metal sheet,
- tearing of material during forming,
- irregularity of tension continuity,
- springback due to insufficient deformation at the bending point,
- small overall deformation of the drawn sheet and resulting greater springback.

Therefore, the exact determination of forces required for braking ribs stamping avoids additional costs for tool adjustment, braking ribs profiles, blank holders, punch and die.

2 FORCE DIMENSIONING OF DRAWING DIES

The integral part of drawing die design is also its force dimensioning. An overdimensioned tool is unnecessarily robust and so the costs for its production are higher than those for a tool that optimally meets the requirements for forces it will work with.

To optimize drawing die dimensions, it is effective to use drawing process simulations such as those in the software AutoForm which uses the finite element method. Approximate values of forming forces, besides analyses of the drawing process proper, may be calculated by means of this software.

The combination of calculated forces for stamping braking ribs with reality is important for optimizing and stabilizing the metal sheet drawing process. Until now it has been common practice to design the drawing process with a certain braking rib profile, i.e. with a braking factor, and the forces required for stamping respective braking ribs are calculated by means of software. The whole drawing process of cups with trimming and springback is calculated using such designed braking rib profiles, and then further tool design is computed by using such calculated resulting forces and tensions. Such calculated forces affect the dimensioning of the tool and affect its robustness. In addition, they affect the designed number of pneumatic springs which generate anti-pressure against the direction of the blank holder movement so as to generate the respective blank holding force. If the required forces are under-dimensioned, the blank holder fails to stamp the braking ribs and so the blank holder with the braking ribs fails to brake the blank by the determined braking factor.

Therefore, effort is made to obtain results in simulation programs such as AutoForm 4.06 which are comparable to actual forces in practice.

If the effort fails to combine process adjustment in softwares using the finite element method so as to be comparable with actual force and tension states, the solution may be to find a transitional relation between the individual states. Process adjustment has a limited interface of properties even in the most modern softwares and cannot describe the actual situation. Because of its complexibility, it allows certain restrictions and simplifications which provide a view of the blank shell behaviour in the designed technology and force and tension conditions in the material being formed. If such process which would be subsequently reproducible even in case of various form changes of the drawn shell could be defined by softwares under marginal conditions, there would be the possibility to combine actual results with the calculated ones. Therefore, it is necessary to compare forces required for stamping braking ribs obtained by calculation in the software AutoForm 4.06 with the actual results obtained in the drawing process.

3 SHEET METAL MATERIALS USED FOR THE PRODUCTION OF DRAWN SHELLS

When designing a testing drawing device for stamping braking ribs, it was necessary to achieve the applicability of results for the drawing of the maximum spectrum of drawn shells used in the automotive industry. The repeating input variables are thickness and the actual material which the cup is drawn from (Fig. 1).

The thickness of material differs according to strength requirements for the drawn shell. The thickness of standard materials for the automotive industry ranges from 0.5 to 2.5 mm.

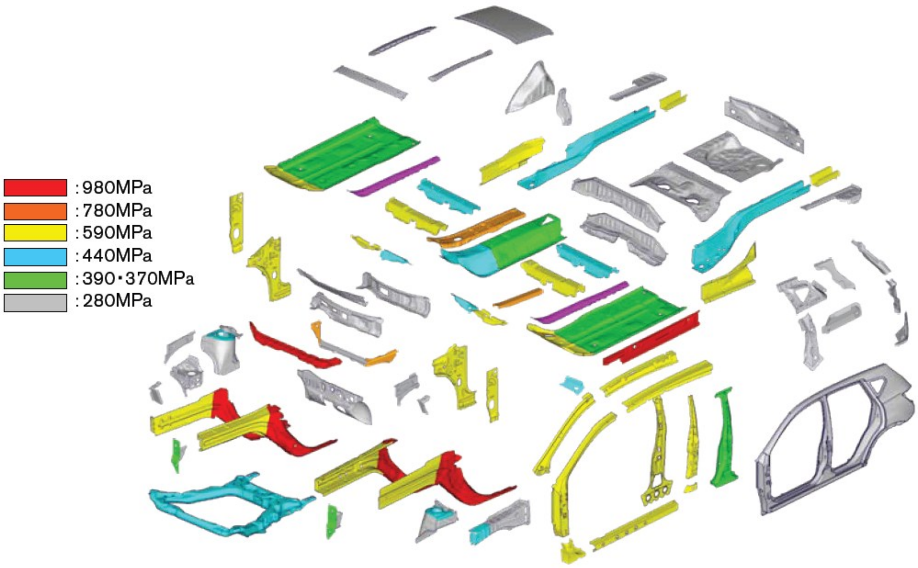

Fig. 1 Spectrum of basic strength parameters of materials involved in the construction of car bodies.

4 SELECTION OF MATERIALS FOR TESTING BRAKING RIB STAMPING

Materials for testing braking rib stamping were selected with respect to materials used in the automotive industry. A wide range of materials is used, from special formed materials to high-strength materials difficult to be formed.

Four materials were selected for testing:

- aluminium Al5182,
- well ductile material DX54D,
- strong material HX340,
- high-strength material DP600.

4.1 Aluminium Al5182

Aluminium Al5182 is a material of midium strength, well resistant to chemicals, age-hardenable. It has a very good polishability, is very resistant to corrosion. Material exposed to long-term action of temperature from 60 to 70 °C has a tendency to tension corrosion and intercrystalline corrosion. The material has satisfactory weldability, welded joints are resistant to corrosion almost as well as the basic material. Workability by shearing tools is reduced with material in soft state and satisfactory in harder state. The material has a very good plasticity in soft state. The material is suitable for medium-stressed constructions which shall be resistant to corrosion and sea water.

Tab. 1 Requirements for mechanical properties of Al5182 material according to EN 10292.

R_m [MPa]	R_p [MPa]	A_{80} [%]	r_{90} [–]	n_{90} [–]
150 ÷ 271	80 ÷ 135	min. 21	min. 0.853	min. 0.263

Tab. 2 Chemical composition of Al5182 material according to EN 10292.

Cu_{max} [%]	Fe_{max} [%]	Si_{max} [%]	Zn_{max} [%]	Cr_{max} [%]	Si_{max} [%]	Ti_{max} [%]
0.100	0.400	0.700	0.200	0.300	0.025	0.200

4.2 DX54D material

DX54D material has good stability during the stamping process. Microscopic surface fissures may occur in the event of bending or shrinking at the surface of acrylate (white fracture). It has good moisture resistance. the material has a constant good heat resistance at a temperature of ≤ 65 °C. No changes of glint, colour or grain composition after 10 minutes at a temperature of 80 °C. The surface is resistant to chemicals such as gasoline, amonium hydroxide, weak water and alcoholic solutions, cleaning agents without sand additives, concrete, gypsum.

Tab. 3 Requirements for mechanical properties of DX54D material according to EN 10292.

R_m [MPa]	R_P [MPa]	A_{80} [%]	r_{90} [–]	n_{90} [–]
260 ÷ 350	120 ÷ 220	min. 36	min. 1.66	min. 0.235

Tab. 4 Chemical composition of DX54D material according to EN 10292.

C_{max} [%]	Mn_{max} [%]	Si_{max} [%]	Al_{max} [%]	P_{max} [%]	N_{max} [%]	Ti_{max} [%]
0.010	0.300	0.0350	0.010	0.030	0.006	0.125

4.3 HX340 material

HX340 material is high-strength, hard rolled steel with good weldability. It is microalloy steel with a wide range of applications, mainly in the automotive industry, for the production of roof frames, bulding components, pipe outlets and electrical articles.

Tab. 5 Requirements for mechanical properties of HX340 material according to EN 10292.

R_m [MPa]	R_P [MPa]	A_{80} [%]	r_{90} [–]	n_{90} [–]
410 ÷ 510	340 ÷ 420	min. 21	min. 1.01	min. 0.135

Tab. 6 Chemical composition of HX340 material according to EN 10292.

C_{max} [%]	Mn_{max} [%]	Si_{max} [%]	Al_{max} [%]	P_{max} [%]	S_{max} [%]	Ti_{max} [%]
0.011	1.000	0.500	0.015	0.030	0.025	0.150

4.4 DP600 material

DP600 material is high-strength, hard rolled microalloy steel characterized by good weldability. It is used for parts made of thin metal sheets required to have high strength. This high-resistance steel is used for interior parts of automobiles.

Tab. 7 Requirements for mechanical properties of DP600 material according to EN 10292.

R_m [MPa]	R_P [MPa]	A_{80} [%]	r_{90} [–]	n_{90} [–]
590 ÷ 700	340 ÷ 420	min. 20	min. 0.801	min. 0.218

Tab. 8 Chemical composition of DP600 material according to EN 10292.

C_{max} [%]	Mn_{max} [%]	Si_{max} [%]	Al_{max} [%]	P_{max} [%]	S_{max} [%]	Ti_{max} [%]
0.100	1.100	0.500	0.015	0.025	0.025	0.150

Four metal sheet thicknesses were selected for braking rib stamping, covering a wide range of material thicknesses used in the automotive industry: 0.8 mm, 1.0 mm, 1.2 mm and 1.5 mm.

5 SELECTION OF THE TESTING MACHINE

The tensile testing machine ZD 40 (Fig. 2) with a maximum force of 400 kN and electronic computer recording belonging to standard equipment of laboratories and testing stations was selected. The movement of the upper ram is hydraulic, with the possibility to clamp the upper part of the tool with a mandrel of 20 mm in diameter. Further accessory includes a longitudinal sensor with the control unit EDC 60 having an accuracy of ±1 %. It is suitable to reduce the maximum force of the tensile testing machine by 25 % to ensure its operational safety. Therefore, the maximum operating force of the specified tensile testing machine is 300 kN.

A KISTLER dynamometer (Fig. 3), which is a piezoelectric sensor having a definition of 30÷500 kN was selected to measure forces. This dynamometer is robust, has an overload protection and is characterized by insensibility to ambient impacts such as temperature. The sensor has a definition of ±3.7 N.

Fig. 2 Tensile testing machine ZD 40.

Fig. 3 Dynamometer allowing to deduct compressive or tensile force.

The force necessary for braking rib stamping could be read from the tensile testing machine ZD40, but greater accuracy is achieved using the dynamometer KISTLER. This sensor also allows electronic recording of force variation in time so that the obtained values may be used for plotting the force-distance, or tension-deformation graph.

6 DETERMINATION OF THE BLANK SIZE

To simplify the construction of the tensile testing machine for braking rib stamping and to achieve its smallest possible dimensions, taking into account the table dimensions of the tensile testing machine ZD 40, it would be suitable to select one blank size for all material types.

When selecting the blank size, the scope of usability of the dynamometer and the tensile testing machine was taken into account. The optimal range of usability for the dynamometer is above 30 kN and 30 to 300 kN for the tensile testing machine. So there is a restriction by stamping forces for the blank size from 30 to 300 kN.

In addition, various metal sheet materials and their various thicknesses affecting the required force for stamping braking ribs were taken into account. Limiting the scope of forces required for braking rib stamping was based on the softest material with the smallest thickness and on the hardest material with the greatest thickness. The smallest force required for stamping a braking rib will have Al5182 material with a thickness of 0.8 mm and the greatest force for stamping a braking rib will have the high-strength material DP600 with a thickness of 1.5 mm.

The length of the rib is given by the size of individual blanks because the rib length is across the entire length of the blank. Run-outs of ribs (ends) are not contemplated because it would not be possible to use a single die so that it would have to be replaced depending on the profile of the braking rib.

The software AutoForm 4.06 which the braking rib stamping process had been simulated with was used for selecting the blank size.

7 SIMULATION OF BRAKE RIB STAMPING

To create a model of the drawn shell (braking rib) and other accessory areas (Fig. 4 and 6) required as inputs for the program AutoForm 4.06 using the finite element method, the software CATIA V5R19 was used.

Then simulations of braking rib stamping (Fig. 5) by means of the software AutoForm 4.06 using the finite element method were carried out so as to correspond to actual stamping conditions as much as possible.

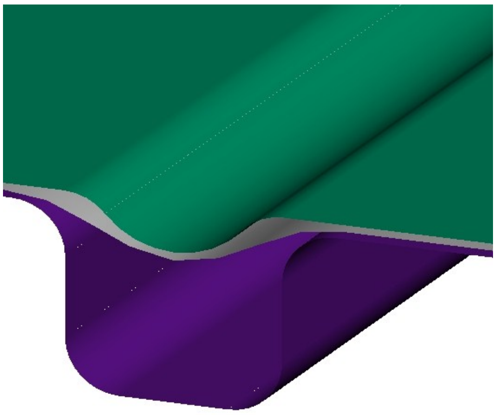

Fig. 4 Construction of braking rib areas required for calculation by means of the software CATIA V5R19.

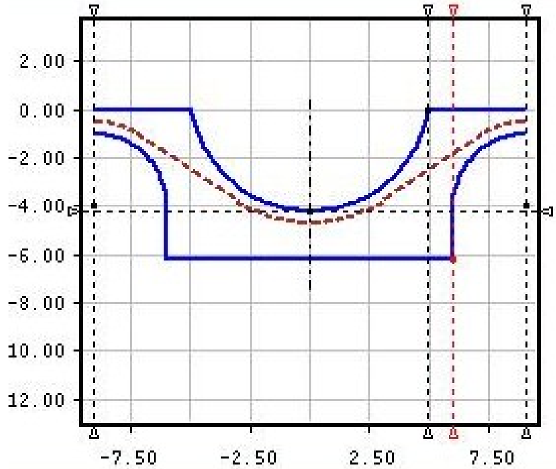

Fig. 5 Definition of the braking rib profile in the software AutoForm 4.06.

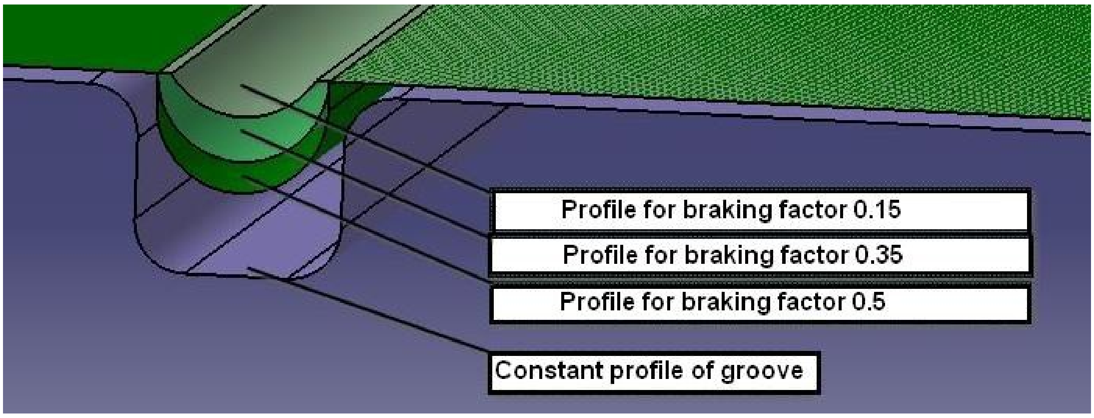

Fig. 6 Different braking rib profiles which affect the size of the braking factor during shell drawing.

After creating the models of the individual tool parts, which are the punch, the die and the blank holder (Fig. 7), the marginal conditions of the forming process (Fig. 8) were set in the software AutoForm 4.06 so as to correspond to the conditions during the movement of the blank holder in the actual tool. The advantage of simulations is that various options may be simulated by exchanging basic attributes, i.e. material type, material thickness and braking factor.

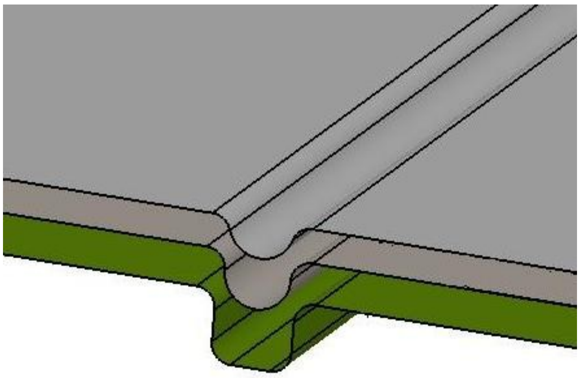

Fig. 7 Models of punches and dies created in the program CATIA for the following simulation of the braking rib stamping process.

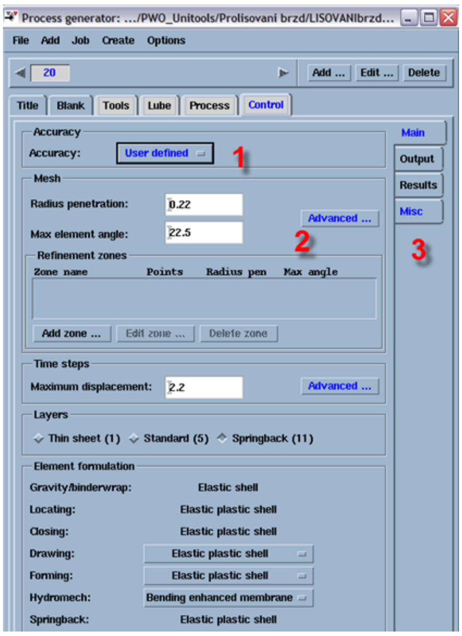

Fig. 8 Adjustment of the braking rib stamping process in the software AutoForm 4.06.

A series of calculations during which the blank size, the type of material, the thickness of material and the braking factor were changed was performed and the force required for braking rib stamping (Fig. 9) was determined for each alternative.

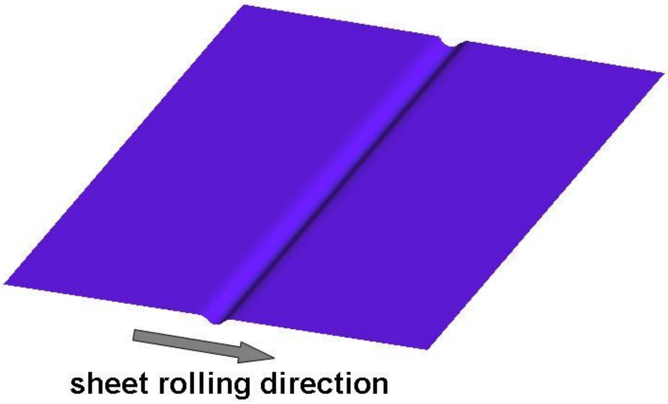

Fig. 9 Braking rib stamped in the blank.

After calculations and evaluations where the limiting condition was to keep the stamping forces within the range of 30 ÷ 300 kN and to maintain space for the tool of the given bed size of the tensile testing machine, two blank sizes were designed – one for softer materials (Al5182 and DX45D) and one for harder materials (HX340 a DP600). Fig. 10 shows the minimum force required for braking rib stamping, Fig. 11 the maximum force according to simulation for the selected blank sizes. Even though the minimum force was calculated to be 20 kN, the dynamometer records this force and therefore it may be used, despite the fact that the dynamometer indicates the most reliable results at a force greater than 30 kN.

The calculated blank sizes are shown in Tab. 9.

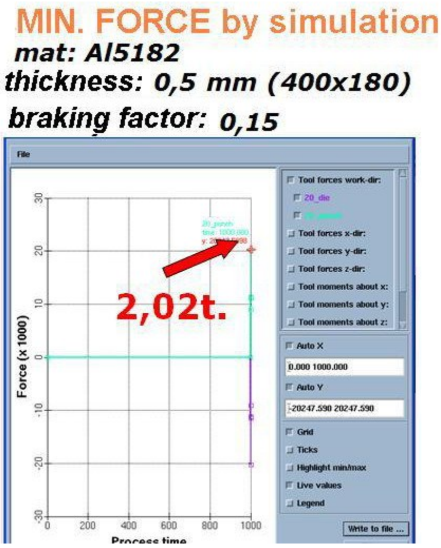

Fig. 10 Calculated minimum force required for braking rib stamping in the case of Al5182 material with a thickness of 0.8 mm.

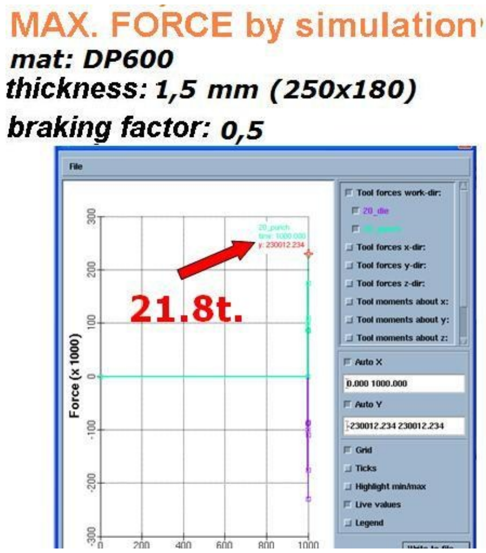

Fig. 11 Calculated maximum force required for braking rib stamping in the case of high-strength DP600 material with a thickness of 1.5 mm.

Tab. 9 Designed blank dimensions for braking rib stamping tests

Material	Blank size [mm]
Al5182	400×180
DX54D	400×180
HX340	250×210
DP600	250×210

The designed blank sizes may be cut with table shears. The alignment of blanks in the testing tool shall be secured by means of centering pins between which the blank of the respective size is placed.

8 CONCLUSIONS

Based on inaccuracies, faults and frequent necessities of adjusting braking ribs existing in practice in the area of the blank holder of the drawing tool for reasons of their insufficient stamping during the clamping of the blank holder, a testing tool testing forces required for braking rib stamping will be designed. This testing tool and the results obtained by it reduce additional costs related to tuning and adapting newly designed forming processes in manufacturing.

Four suitable metal sheets (see 4) representing a wide range of used materials were selected for covering most of the problems associated with braking ribs in the automotive industry. Then four thicknesses worked with the most in practice were selected for these materials. After that, three braking factors to be tested were determined. These braking factors are defined by the profile of braking ribs and their height. All types of braking ribs and their heights, or the braking factors, were created using the software AutoForm 4.06.

Based on braking rib profiles, tie surface areas of the punches, ties and blank holders necessary for the simulation of the forming process in the software AutoForm 4.06 using the finite element method were constructed in the software CATIA V5 R16.

The testing machine and the pressing force sensor were also taken into account during the construction of the tool for braking rib stamping. The tensile testing machine ZD 40 as a testing machine and a piezoelectric KISTLER sensor as a sensor of pressure forces were selected (see 5).

After defining the tools and their scope of use together with working pressures and output, the most suitable dimensions of blank specimens for braking rib stamping were defined so as to have a sufficient reserve when testing samples in a real process, should the actual pressures and forces differ from those calculated in simulations (see 7).

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Results in the contribution were achieved at solving of specific research project No. SP2012/162 with the name *"Optimization of Flat and Volume Forming Processes with the Use of Physical Simulation and Finite Element Method"* (*„Optimalizace procesů plošného a objemového tváření s využitím fyzikálního modelování a metody konečných prvků“*) solved in year 2012 at Faculty of Mechanical Engineering of VŠB – Technical University of Ostrava.