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Use of CAx systems in the design of the construction and technological process of innovative car body parts

Wykorzystanie systemów CAx w projektowaniu konstrukcji i procesu technologicznego innowacyjnych wytłoczek karoseryjnych

IRENEUSZ WRÓBEL *

Presented is the process of designing the construction and technological process of the passenger car door beam. The FEM beam strength analysis and FEM analysis of the hot stamping process of this beam were presented. The simulations were discussed. Conclusions and recommendations were made.

KEYWORDS: hot forming, variable thickness draw pieces, FEM simulation

Contemporary requirements for car operation and regulations included in safety standards force designers to develop innovative car body structures. In particular, they are trying to reduce the weight of passenger car bodies. New constructions are by 10÷15% lighter than the constructions of previous generations of the same models. At the same time, they meet all technical requirements for the safety of drivers and passengers.

To reduce the weight of the body, it is used for production of high strength steels with a strength limit of over 1500 MPa. According to safety standards, certain elements of the bodywork are designed so that they deform in a controlled manner during a collision. Fig. 1 shows two main car body zones with different mechanical properties that are responsible for the safety of the driver and passengers.

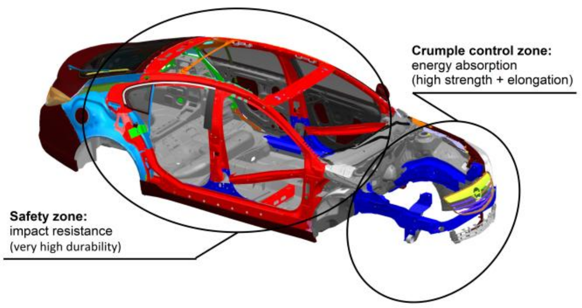

Fig. 1. Zones with different mechanical properties in the car body

Elements of the first zone should be characterized by high relative elongation, during the collision they should deform in a predetermined and controlled manner. The mechanical properties of the steel from which they are made should be as follows: strength limit: R_m = 400÷500 MPa, elongation: 15%. The components of the safety zone should have high strength and stiffness. Mechanical properties for this zone are: strength limit: R_m = 1500÷2000 MPa, elongation: 6%. It is important to ensure that the body of the car has the least weight.

Analysis object

The analysis object is the reinforcing beam, located in the front and rear doors (fig. 2). Its task is to protect the driver and passengers against the effects of a side collision. This beam belongs to the safety zone and should be characterized by very high durability. Fig. 2 presents exemplary constructions of reinforcing beams for doors.

Fig. 2. Typical constructions of door reinforcing beams

In the design process of the door beam (fig. 3) technical aspects related to its strength and technological aspects should be taken into account.

At the first stage, the assumptions of the project are defined. They are primarily related to the dimensions of the beam. A certain volume is defined in which the designed beam must fit. Strength requirements are very important. They follow directly from the safety requirements for cars. The strength of the beam is checked using a three-point bending test. The next assumption of the project is the weight of the beam, the maximum value of which cannot be exceeded. The beam is to be produced using hot stamping technology, thus all technological aspects related to its production should be taken into account.

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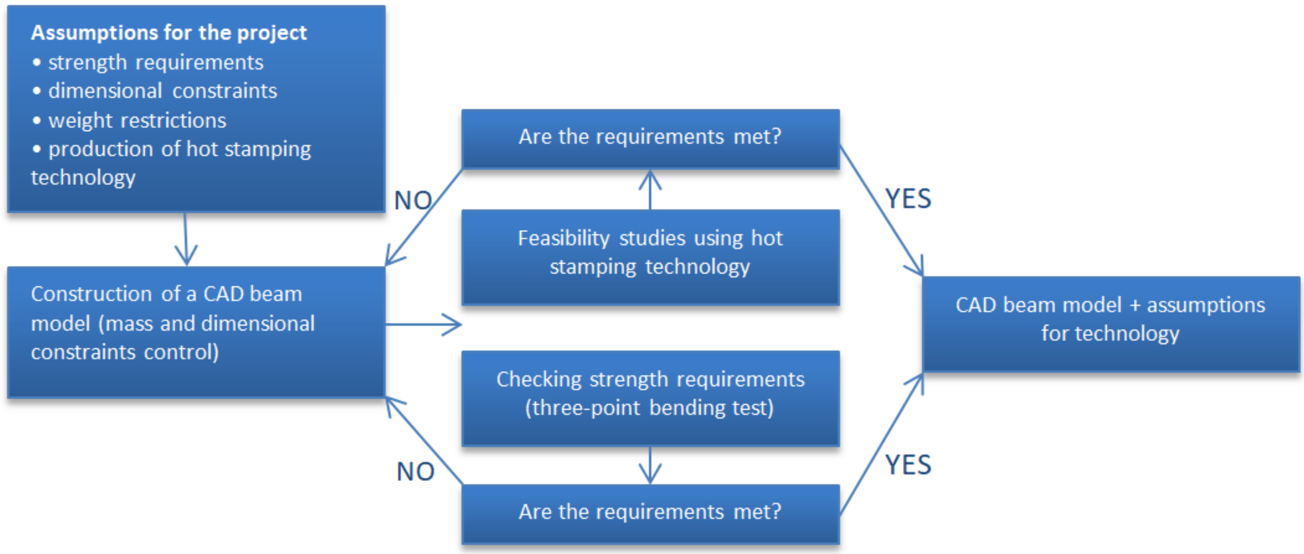

Fig. 3. The process of designing the beam structure and technology

The design process begins with the construction of a three-dimensional CAD model of the beam. During its construction, the engineer controls the dimensions of the beam so that the model is not larger than the assumed boundary volume (fig. 3). It also monitors the mass of the designed beam.

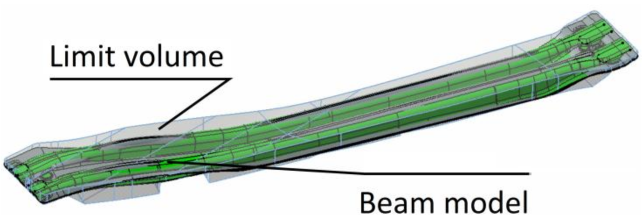

Fig. 4. Limit volume of the analyzed beam

The CAD model of the beam is analyzed in two aspects:

- its strength is tested in the three-point bending test,
- technological analyzes of the beam's performance are carried out in specialized software.

Both analyses are performed concurrently.

Three-point bending test

In order to verify the assumptions regarding the strength of the beam, non-linear MES analyses are performed – a three-point bending test is carried out. It is to confirm whether the reinforcing beam will meet the requirements of FMVSS 214. The result of this test is the force course with which the punch acts on the beam during three-point bending. This force should have a certain value, defined in the assumptions for the design of a new car body. Simulations of three-point bending are performed in LS Dyna or Abaqus systems. For the purpose of simulation, the CAD model and the discrete model of the beam, supports and stamp are built – as shown in fig. 5.

The appropriate degrees of freedom have been received in the beam supports. The stamp – cylinder Ø244.8 mm (12 inches) – moves along the y axis at a speed of 12 mm/s, at a distance of 150 mm. Between the beam and supports as well as the beam and the punch, contact elements with friction have been defined. The model thus constructed was analyzed in the LS Dyna system.

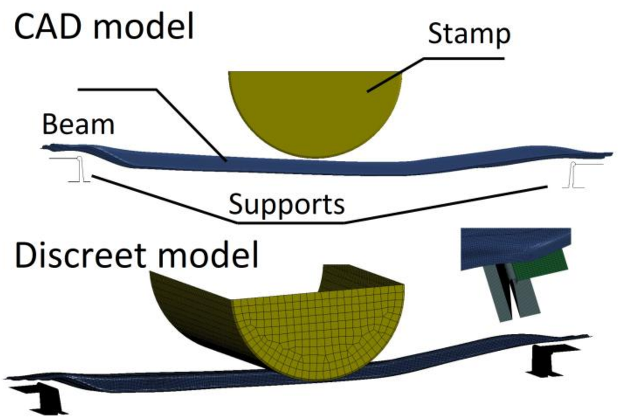

Fig. 5. CAD model and discrete model of beam, supports and punch for simulation of three-point bending

Results of three-point bending analysis

Fig. 6 presents exemplary results of the three-point bending test of a door beam in the form of reduced stress contours and plastic deformations.

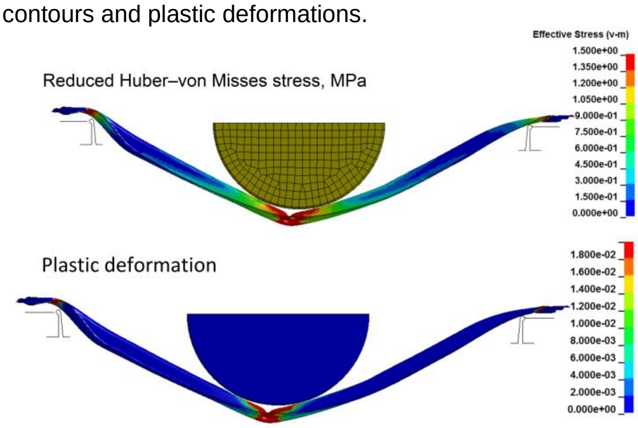

Fig. 6. Layers of reduced stresses and plastic deformations of the analyzed beam

The results of the three-point bending simulation of the beam initially confirmed the fulfillment of strength requirements. It should be noted that the presented results were obtained after three loops of the design process shown in fig. 3.

Simultaneously with the strength simulations, simulations of the hot stamping process were carried out.

Analysis of the technological performance of the beam

The hot forming process should be designed so that the finished extrudate does not have any defects in the form of cracks or wrinkles, it was made with the appropriate dimensional and dimensional accuracy and additionally had the required mechanical properties (R_e, R_m, hardness) and structure (martensite). For this purpose, computer simulation is necessary when planning the technological process and its key parameters. The input data in the hot stamping process are: type and thickness of the material of the form, the shape of the form, the temperature of the form after leaving the furnace, transfer time from the furnace to the die, forming time and hardening time, press force during hardening and final temperature of the extrudate. The analysis of the hot stamping process is carried out using specialized Autoform, Pamstamp or DynaForm software.

At the beginning, the technology of the extrudate was analyzed, searching for the optimal direction of opening of the die, and the angle of inclination of the individual walls of the extrudate was analyzed [6]. Fig. 7 presents the results of these tests in the form of contour lines.

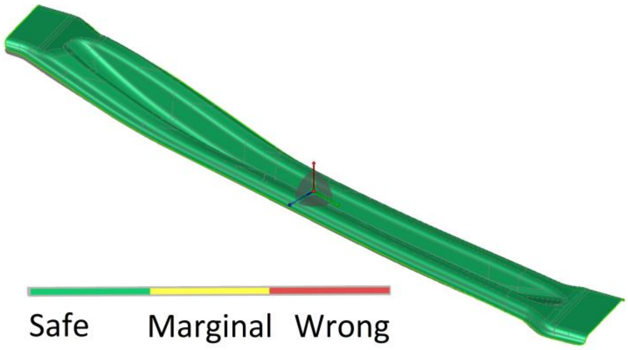

Fig. 7. Beam technological analysis

Green color means that all angles measured in relation to the die opening direction have optimal values, yellow color means areas with limit values of these angles, while red color – places where the shape of the extrudate should be changed, because it will not be possible to remove it from the matrix. In the case of presented extrudate, the green contour was on 100% area.

At the next stage, the concept of tools was developed. In this case, the tool consisted of a die, punch and clamp. The process of shaping the extrudate will take place in the following sequence: first the clamp closes the form in the matrix, then the stamp shapes the form in the matrix. The values of forces between the clamp and the matrix have been defined.

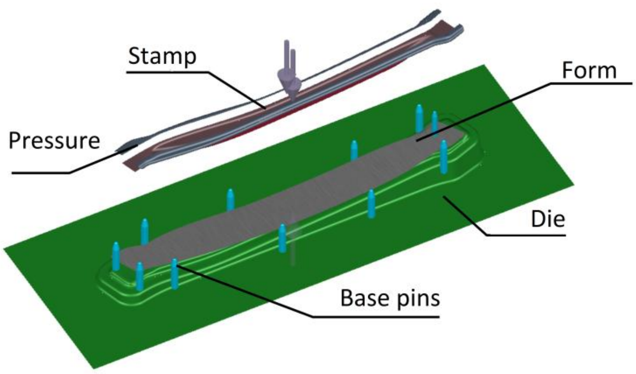

Fig. 8. CAD model of the tool

Appropriate distances between the elements of the tool were also assumed. In order to prevent uncontrolled shifting of the mold during pressing, it was planned to base the form in the die on its outline using the dowels and in one technological hole. For the planned tool concept, CAD models of dies, punches, clamps and base pegs were developed. Fig. 8 shows the CAD model of the tool. The model was analyzed in the Autoform system.

Results of the analysis of the hot stamping process

Fig. 9 shows results of the analysis. These are the FLD contours, the contours of the thickness change of the extrudate (thinning), the contours of martensite and the contours of the hardness of the extrudate after hardening.

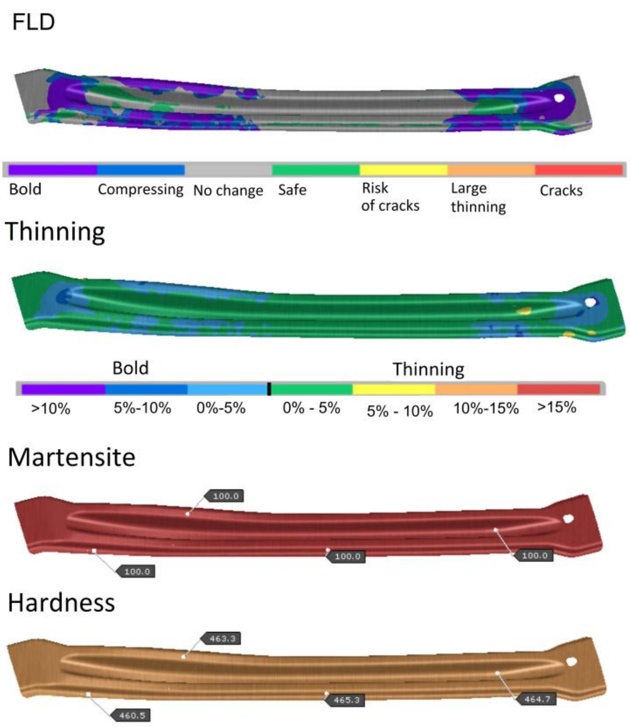

Fig. 9. Results of hot stamping analysis

Based on these results, it can be concluded that there is no risk of cracks or wrinkles. No too large extrusion was observed either. The extrudate has been properly hardened.

Fig. 10 presents stages of forming the extrudate.

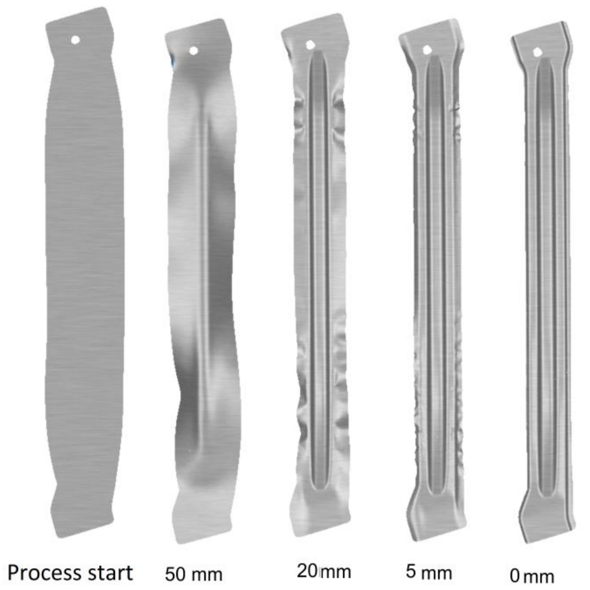

Fig. 10. Steps in the formation of the extrudate

Conclusions

Modern car body constructions must meet a number of safety requirements. They are described in the standards. Due to the environmental protection requirements, cars should also have the smallest mass. When designing a door beam, the following technical limitations should be considered:

- assumed dimensions (the beam model must not exceed the boundary volume),
- strength of the beam (the beam should have rigidity),
- limit mass (beam weight should not be greater than the assumptions),
- possibility of beam production using hot stamping technology.

Because some limitations are contradictory – for example, maintaining the proper strength of the beam and at the same time striving to minimize its mass – the most advanced CAD/CAE systems are used to design the beam and develop its technology. These are systems for building the CAD models, systems for non-linear strength analyzes (LS-Dyna, Abaqus) and systems for analysis of technological processes of hot stamping (PamStam, Autoform or Dynaform). Engineers, who design such constructions must be high-class specialists in the field of strength of materials and technologies of hot stamping.

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REFERENCES

1. Ming-Fu Li, Tzu-Shin Chiang, Jiun-Hau Tseng, Chia-Nung Tsai. „Hot stamping of door impact beam". *Procedia Engineering*. 81 (2014): pp. 1786–1791.
2. Shan Z.D., Ye Y.S., Zhang M.L., Wang B.Y. „Hot-stamping die-cooling system for vehicle door beams". *Int. J. Precis. Eng. Manuf*. 14 (2013): pp. 1251–1255.
3. Turetta A., Bruschi S., Ghiotti A. „Investigation of 22MnB5 formability in hot stamping operations". *J. Mater. Process. Technol*. 177 (2006): pp. 396–400.
4. Turetta A., Ghiotti A., Bruschi S. „Investigation of 22MnB5 Mechanical and Phase Transformation Behaviour at High Temperature". *IDDRG Conference, Proceedings*. (2007): pp. 147–153.
5. Hein P., Wilsius J. „Status and innovation trends in hot stamping of USIBOR1500P". *Steel Res Int*. 7, pp. 85–91.
6. LSDyna help and tutorial.
7. Autoform help and tutorial.

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