FEM simulation of hot forming stamping processes

Symulacja MES procesów tłoczenia na gorąco

IRENEUSZ WRÓBEL*

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Presented is the methodology for the analysis of manufacturability stampings manufactured using hot stamping steel 22MnB5 using finite element simulation. The simulation was performed for the B-pillar – a typical part of the car body. Defined simulation parameters having a significant impact on the results. Simulation results were showed and commented. Conclusions and recommendations were formulated.

KEYWORDS: hot forming, draw pieces, FEM simulation

Modern passenger cars should be as light as possible, with all the safety standards of such vehicles. You can see that new models of popular car brands have a weight of at least 20% lower than previous models. This trend has been observed for several years and is due to the high emissions requirements of cars [4, 5].

The reduction of body weight is possible thanks to the use of new materials and technology of body parts. The components of the body are designed for high mechanical strength (AHSS, DP, TRIP steel). However, the machining of these materials is technically difficult due to the high forces encountered during punching and pressing and the return spring effect [1-3].

In order to obtain parts of the body with the required mechanical properties, a hot pressing technology of 22MnB5 steel was developed. This is a well tempered steel designed for hot stamping with simultaneous shaping and tempering. It has ferritic-perlite structure after thermal-plastic treatment, but after martensitic treatment. With its thermal-plastic processing (hot stamping), its mechanical properties change. The yield strength and the strength limit for this steel prior to thermal and plastic treatment are shown in Table I.

TABLE I. Properties of 22MnB5 steel before and after thermal and plastic treatment

	Before heat-plastic treatment	After heat-plastic treatment
Re, MPa	320÷550	1050÷1100
Rm, MPa	500÷700	1450÷1500
Hardness, HV	190	430÷450

22MnB5 steel extrusions are formed by hot pressing. The scheme of this process is shown in fig. 1.

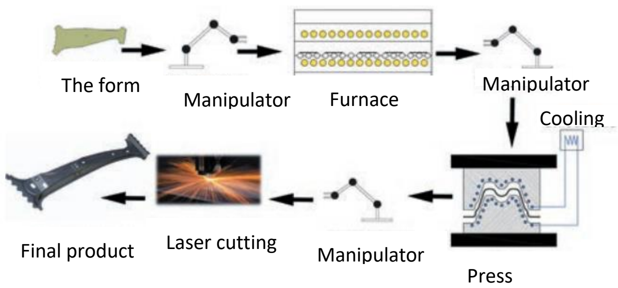

Fig. 1. Flow chart of the hot stamping process

The production process begins with a flat molded die cut that will provide accurate reproduction of the embossing stroke after embossing. The mold is transferred by the manipulator to the furnace, where it is heated to austenization temperature (920÷940 °C). The heated form is transferred by the manipulator to the die mounted in the press. The stamp is then closed with a die and for a few seconds (3÷5 s) their pressure is pressed with full force of the press. During this time a rapid cooling of the extrusion occurs and a martensitic transformation takes place. After the extrusion has cooled down to about 150 °C, the press is opened and another manipulator transfers the finished extruder to a special belt conveyor. During transport the extrudate is cooled to room temperature and finally packed and sent to the recipient. It can be noted that in this process plastic (plunging) and heat (hardening) are combined. It is important to consider the technical requirements of plastic processing and heat treatment at the same time.

Purpose of analysis

The embossing process should be designed so that the final embossing has no defects in the form of cracks or wrinkles; it is made with the correct dimensional shape (as in cold pressing) and additionally has the required mechanical properties (*Re*, *Rm*, hardness) and metallographic structure (martensite). In order to meet these requirements, computer simulation of this process is necessary during the planning process and its key parameters. The input data for the hot stamping process are: the type and thickness of the mold material, the shape of the mold, the temperature of the mold after the furnace exits, the time from the furnace to the die, the molding and hardening time, press force of the press during hardening, the end temperature of the molding and the speed of the elements die (punch, clamps).

The most important stage of the pressing process is the heating, the transfer of the heated mold from the furnace to the die, and the molding (pressing) along with the cooling, in order to obtain the required mechanical

* Dr hab. inż. Ireneusz Wróbel (iwrobel@ath.bielsko.pl) – Akademia Techniczno-Humanistyczna w Bielsku-Białej

and metallographic properties and the dimensional accuracy of the finished die.

Design of the hot stamping process

The design of the hot pressing process consists of several steps (fig. 2). In the first stage, the shape of the extruder is analyzed in terms of its technological nature. This analysis can be performed in CAD systems, such as VISI, NX, or in MES analysis systems for press processes such as PamStamp and Autoform. The optimal direction of opening of the dies is calculated and the tilt angles of the respective die walls are analyzed in terms of the possibility of removing the die from the die. The requirements for dimensional accuracy of the extrudate are also analyzed and the proposed process will be able to meet them. If the results of the analysis are successful (the extrudate has a technological shape and dimensional-dimensional accuracy requirements can be met), the next stage of the process design is followed. Otherwise, modification of the extruded shape is required.

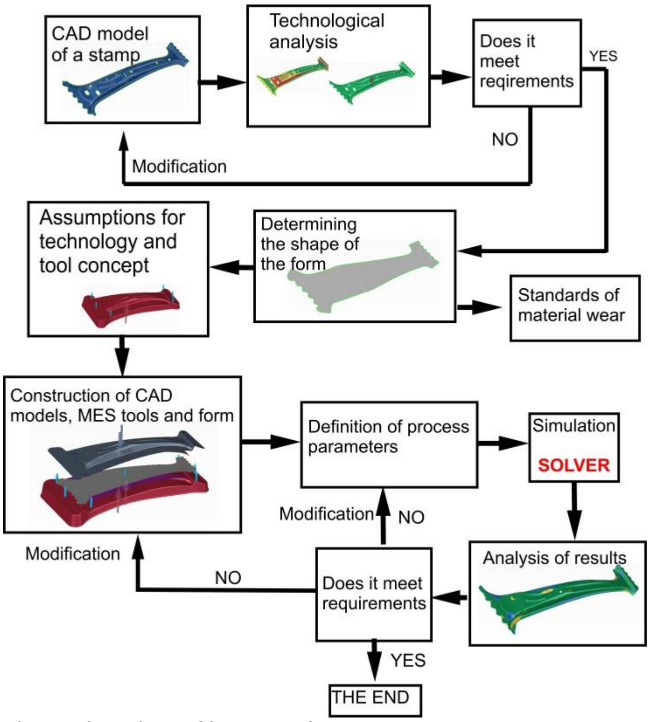

Fig. 2. Flow chart of hot stamping processes

The next step in the design of hot stamping processes is to determine the shape of the mold. This is so called. reverse process. Based on the CAD model of the finished embossing, the shape of the flat mold will be calculated to obtain a molded die. Sometimes, at the next stage of the simulation process, the profile of the process is optimized. At the next stage, the concept of the tool is developed, the die is defined, the punches, the clamps, the anchors and guiding pins, and the method of forming the tool in the tool. These activities are very important to the knowledge and experience of the engineer.

The aim of the next step is to check the correct tool concept. Prepare the CAD model, Discrete MES tools models, Formats. Define key process parameters such as mold temperature, tool temperature, and time of mold transfer from the furnace to the die; Tool kinematics are developed, etc. Then the MES analysis is performed. The final step is to analyze the results. The contours of the embossing of the embossing, the FLD (forming limit diagram), the structure obtained and the hardness are analyzed. If the results of the analysis are successful, then the assumed assumptions for the hot stamping process are correct. Otherwise modify these assumptions, change the concept of the tool, or modify the process parameters. In extreme cases, to correct the simulation results, the shape of the stamp should be modified.

Analysis of the hot stamping process of car B post

A typical element of the car body produced by the hot stamping technology is the B-pillar. Figure 3 shows the bar-shaped CAD model for which the manufacturing technology was developed and the necessary MES simulations were performed. The post is to be made of 1.6 mm thick steel, 22MnB5 steel.

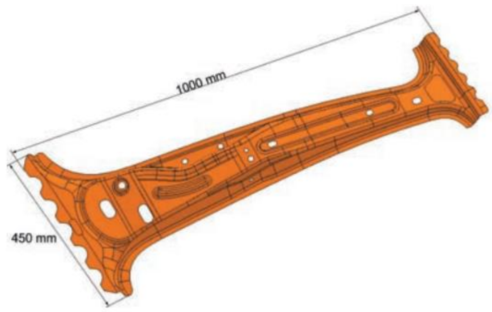

Fig. 3. CAD model of post B

Firstly, the technological analysis was performed - the optimum direction of opening of the die was investigated and the angles of the individual extruded walls [6] were analyzed. Fig. 4 shows the results of this analysis in the form of contours. Green means that all angles measured with respect to the direction of opening of the die have the correct values, the yellow areas indicate the limit values for these angles, while the red color means that in these regions the embossing shape should be changed. In the case of the analyzed part the green contour was 100% of the extruded surface.

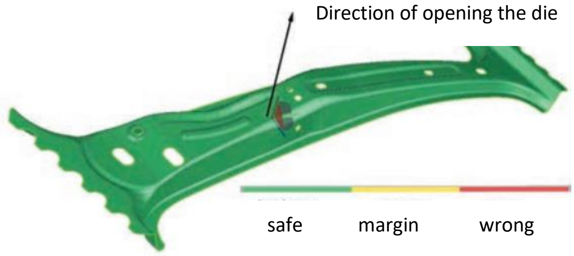

Fig. 4. Results of analysis of die opening and extrusion angles

At the next stage, the technological process of the production of extruders and the concept of tools was elaborated. In this case, the tool consisted of a die, a punch, and a top and bottom press. First, the upper clamp closes the mold in the die, then the seal closes with the mold on the lower clamp and, together with the lower clamp, closes on the punch. Appropriate clamping forces were applied between the upper clamp and the die and lower clamp and punch. The distance between the tool parts has also been assumed. In order to prevent uncontrolled movement of the die during embossing, it was planned to base the die in the die at its outline with six base pins and one technological hole in which one base was inserted. For this concept tools have been developed CAD models of matrices, punches, clamps and base pins. Figure 5 shows the CAD models of the tool.

By defining the shape of the form, one must assign the appropriate material properties. For the purpose of simulating hot stamping processes, the properties of the material associated with the phase change and the properties associated with the plastic characteristics of the material are defined.

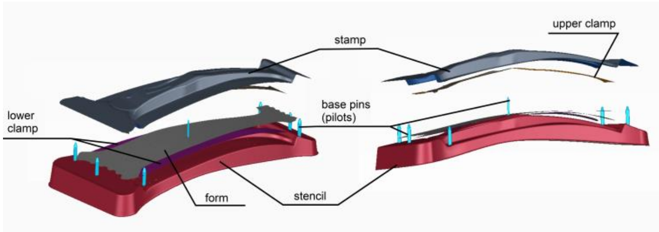

Fig. 5. Tool CAD models

Analysis of results

The most important results obtained by the simulation, which are analyzed by the engineers, include:

- layers of embossing,
- forming limit diagram,
- coatings with hardness distribution and decomposition of martensite in the extrudate,
- temperature at key moments in the process,
- deformation of the extrudate at different stages of the pressing process.

Fig. 6 illustrates the layers of embossing.

It is assumed that for 22MnB5 material the maximum cut can not exceed 15%. Fig. 6 does not exceed 12%. Thus, the extruder meets the requirements. Another very important result of the simulation of the hot stamping process is the imagery layers, how much martensite was formed during hardening, and the hardness to which the embossing (HV) was hardened. Structure layers - martensite content is shown in fig. 7.

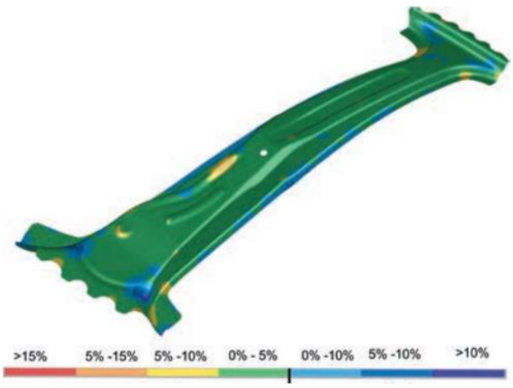

Fig. 6. Layers of embossing

In the case in question, the martensite content and hardness are normal.

The key results of the MES analysis, which are to be taken into account in the design of the hot melt process, are the mold temperature and extrusion temperatures at the key stages of the process: after removal from the furnace, from the furnace to the matrix, before tempering, pressing and hardening.

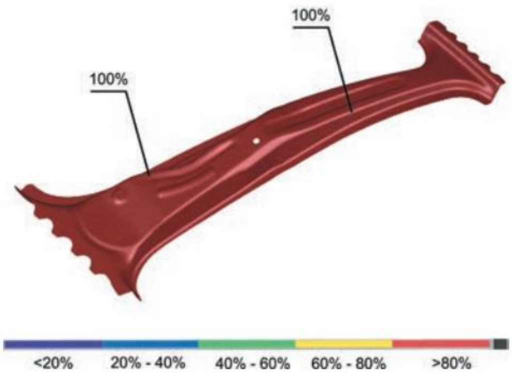

Fig. 7. Layers of structure - content of martensite

The temperature values obtained in the analyzed case are given in Table II.

TABLE II. Temperature at key stages of the process

Once removed from the furnace	After transferring the form to the stencil	Before the harden -ing process	Ready-made extrudate
920°C	820°C	720°C	150°C

Based on the data presented in Table II, it can be stated that the temperatures at each key stage of the process are correct and will be correct.

Conclusions

The design of the pressing process is complicated - it must take into account many technical factors related to plastic and thermal processing. In a comprehensive approach to process design, it is helpful to use CAx systems. They allow you to check the technology of the extrusion, and the analysis of the results of the process simulation allows you to verify the assumptions of the process. For the design of heat-plastic processing processes, knowledge of the field of plastics and heat treatment, especially hardening, CAD modeling, MES computational models is required. This knowledge allows you to correctly build the computational models, the correct definition of the MES simulation parameters of the process and the correct and efficient evaluation of the results. Engineering practice confirms that it would be very difficult or even impossible to design such complex and modern manufacturing processes without using modern CAx tools. The proposed and described procedure for designing hot stamping processes has proven itself in industrial practice.

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