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Procedia Engineering 183 (2017) 336 – 342

Procedia Engineering

www.elsevier.com/locate/procedia

17th International Conference on Sheet Metal, SHEMET17

Supporting lightweight design: virtual modeling of hot stamping with tailored properties and warm and hot formed aluminium

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Abstract

Although in the past complicated and often considered ‘exotic’ process, hot stamping of steel is now widely used in the automotive industry and for some safety components it becomes obligatory. The hot stamped parts are used in regions where very high strength is required. But for some applications also ductility needs to be incorporated in parts to guide the absorption of energy under crash loading, for other the material thickness has to be reduced smoothly due to lightweight. This will be achieved by tailoring the material properties within the component. This new generation of hot formed parts is already standard in the market, but still difficult in the engineering. And the next one is already in start position – aluminum warm forming is planned as a substitution of the heavier steels for structural parts, but newly also for outer panels, where they have to fulfil all requirements on visible parts. Light, strong, accurate, high quality and warm formed to improve the formability of the material. This paper describes successful engineering methods in virtual hot stamping process with tailored properties and of warm and hot formed aluminum parts.

Peer-review under responsibility of the organizing committee of SHEMET17

Keywords: Hot Stamping; 22MnB5 Steel; Tailored Properties; Hardness Estimation; Distortion Analysis; Cooling Channel Analysis; Virtual Die Spotting; Aluminium Hot Forming; Aluminium Warm Forming

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Peer-review under responsibility of the organizing committee of SHEMET17
doi:10.1016/j.proeng.2017.04.049

1. The Hot forming process

There are two principles of the steel hot forming process. The *direct* hot forming process has distinct steps to form the full component. Materials are cut from a coil and stacked. A material handling device will transfer the blanks into a furnace where the temperature of the blank will be increased above austenitizing temperature. The heated blanks will be transferred as fast as possible to the press. In the press the parts are formed and quenched consecutively through water cooled dies. Finally, the blanks are moved out of the press where the part will cool down until ambient room temperature. With the *indirect* hot forming process, the blank is cold formed and trimmed and then subsequently heated and quenched in a die. The final part typically has over 1,500 MPa tensile strength, if quenched properly, and minimum springback [1,2].

2. Important parameters for accurate virtual process engineering

Compared to conventional cold forming, the hot forming process of (22MnB5) steel parts is very complex. Additional items to consider are for example:

- Material parameters as function of temperature and strain rate
- Phase transformations in the blank and final hardness. If the cooling rates are below a critical value, also other phases than martensite will occur in the final product, like bainite and ferrite. In the CCT diagram in Fig. 1 different phases and corresponding hardness as a result of various cooling rates are shown.
- Cooling channel design and quenching duration (avoid hot spots)
- Distortion due to non-uniform phase transformations

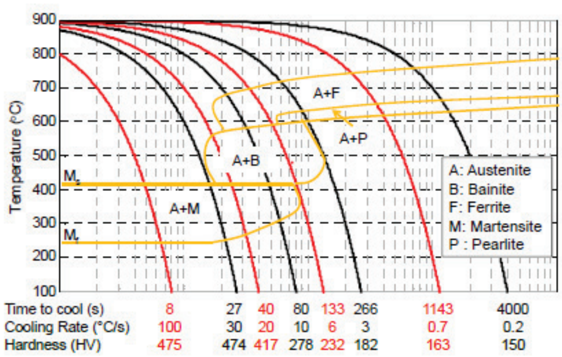

Fig. 1 Continuous cooling transformation (CCT) curve for a 22MnB5 steel [3]

The traditional stamping engineer is confronted with all these new areas where he has to have a high level of knowledge to get the final process right. To help him to get a better insight in the mechanisms involved, virtual engineering of the hot forming process can help to understand where potential problems are coming from and help to take the right countermeasures or predict issues already before the actual tools are built. In the following the most critical aspects to get a well-engineered virtual hot forming process are highlighted. In this paper the explicit sheet metal forming simulation code ESI PAM-STAMP is used to generate the examples given.

2.1 Material description

As indicated in the previous section, correct characterization and modelling of the material is of highest importance to get good results for final strength and distortion:

- the flow stress curves should be accurately modelled