

A STUDY OF MATERIAL-TECHNOLOGICAL MODELLING FOR CHOOSING THE IDEAL COOLING RATE FOR DESIGNING PRODUCTION OF CLOSED DIE FORGINGS USING 30MnVS6 STEEL

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Abstract

Production of forgings contains complex and demanding processes that consist of a number of forging operations which can also include post-forge heat treatment. An optimized manufacturing line is a prerequisite for obtaining prime-quality products which in turn are essential for profitable operation of a forging company. Problems may, however, arise from modifications to the manufacturing route due to changing customer needs. To prevent the production line from being temporarily suspended for changeover and optimization. The use of material-technological modelling with the required modifications can be tested and optimized under laboratory conditions outside the plant without disrupting the production. Thanks to material-technological modelling, the process parameters can be well controlled and varied rapidly in response to changes in market requirements. Outcomes of the modelling runs include ideal parameters for the manufacturing process of the forging part and results of microstructure analysis. This study describes the use of material-technological modelling for exploring and studying the impact of the maximum amount of deformation and its effect on the critical deformed area correlated with different rates of cooling of a particular forged part from the finish-forging temperature on its microstructure.

Keywords: Material-technological modelling; 30MnVS6; True strain; Closed die forgings

1. Introduction

A large number of parameters are playing the main roles in forging processes. The key ones include temperature, strain magnitude and strain rate. The combination of their values together with cooling conditions impacts the final resulting properties of forged parts. It is often impossible to map their effects in actual operation, mainly due to financial constraints associated with production. The best available solution is the use of material-technological modelling. This method involves simulation of the real-world forging process in a laboratory in order to study the effects of process

parameters without interrupting or slowing down production in the forge shop [1, 2]. As a result, countless trials can be run which – if carried out in the factory – would lead to a result of a major financial burden.

The product of material-technological modelling is a specimen with a processing history identical to the actual manufacturing route for the forged part [3, 4]. This approach enables microstructure characterization, analyzation and mechanical testing unlike FEM simulations. The designing of this modelling process requires specific data collected from the real-world production [5]. This data include temperatures, intervals between operations, and cooling rates, as well as results from the FEM simulation of the forming process which include deformation values, and are used for developing material-technological modelling specifications [6, 7, 8].



Fig. 1. General view of the forged part, a cross-section with the point selected for modelling, and its total true strain level

2. Experimental

This material-technological modelling study was conducted to correlate the true strain level of the critical deformed area which has the minimum thickness and to study the effect of the different cooling rates which follow the deformation process directly from the finish-forging temperature with resulting microstructure of a particular forged part. Unlike the real life forging part which is made by two separate processes, forging and normalizing heat treatment. This forging is used for making part of the driving wheel system of a truck (Fig. 1). Its final microstructure was specified as a mixture of ferrite and pearlite.

Material-technological models were constructed for the critical point on the forging's cross section. For this point, FEM simulations using the DEFORM software reported the following true strain levels: $\phi = 2.8$. Cooling curves starting at the finish-forging temperature were plotted for these point (Fig. 2). The curves, i.e. the associated cooling rates, were designed to enable a particular limit cooling rate to be identified: the one at which no bainite forms in the material within the critical cooling interval of 950/300 °C.

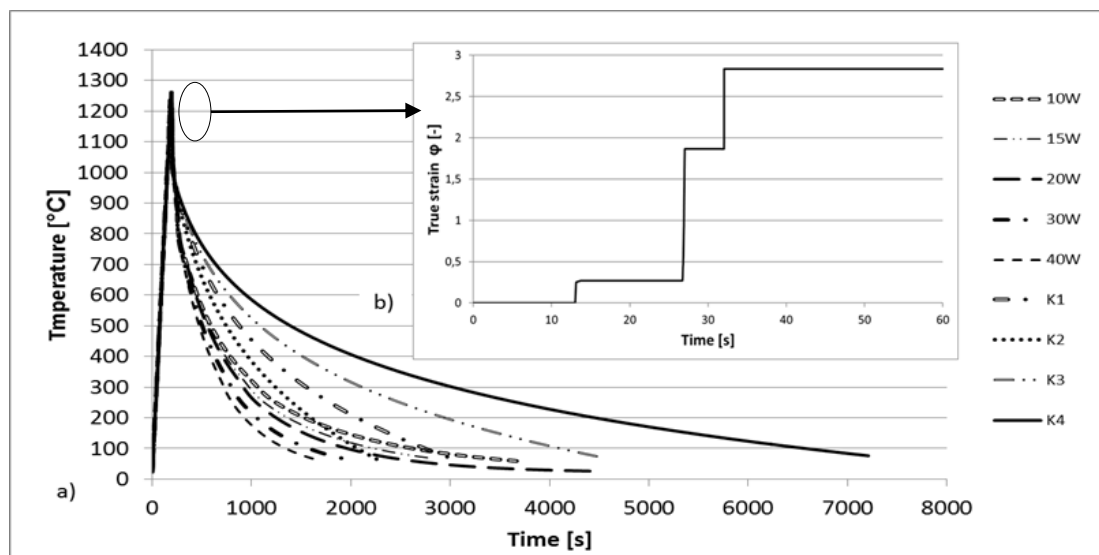


Fig. 2. a) Cooling rates from the finish-forging temperature in the material-technological models of the chosen point, b) Profile of true strain introduced during forging operation at the finish-forging temperature

Modelling was carried out in a thermomechanical simulator provided with an electrical induction-resistance heating system which offers heating rates of up to 100 °C/sec with an accurate cooling rates control. The specimens obtained by material-technological modelling were sectioned to prepare metallographic sections. The experimental material was 30MnVS6 steel (Fig. 3).

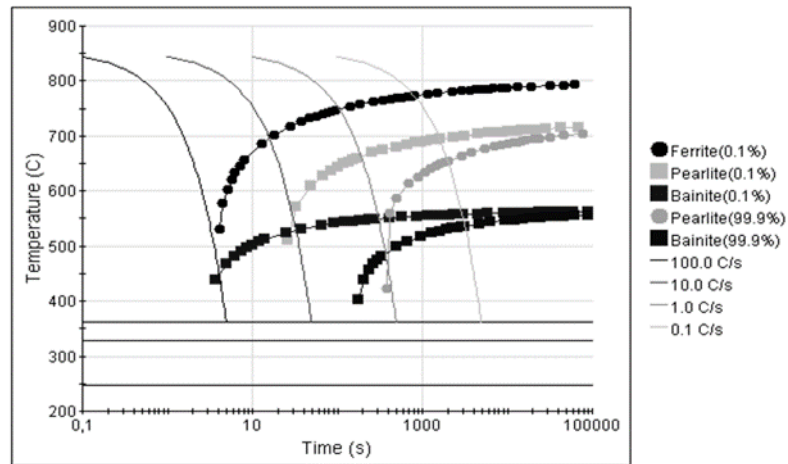


Fig. 3. CCT diagram for the 30MnVS6 steel as computed and constructed using the JMatPro program

3. Metallographic examination

The metallographic examination was carried out to study the critical area with the highest deformation and thinnest wall of the cross section, in this case, depending on the results from this examination we can choose whether the microstructure will contain a combination of bainite, ferrite and perlite or just a ferritic-pearlitic microstructure. The microstructure of the specimens was revealed with 3 % nital and examined under optical microscope.

All specimens which had cooled according to K1 curve consisted of ferrite, pearlite, and a small amount of bainite (Fig. 4). Bainite was also found in specimens cooling according to K2 curve (Fig. 5). K3–K4 curves led to ferritic-pearlitic microstructures (Fig. 6, 7).

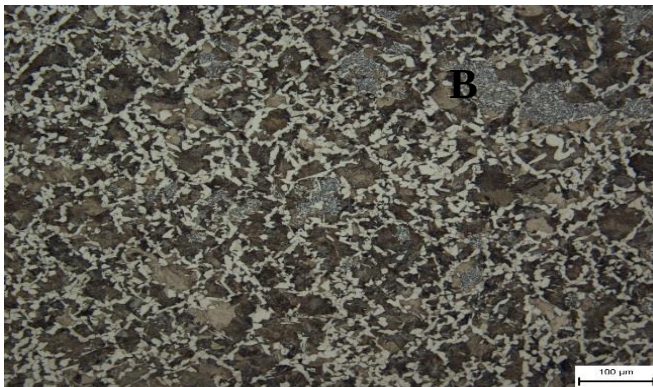


Fig. 4. Micrograph of specimen cooling according to K1 curve

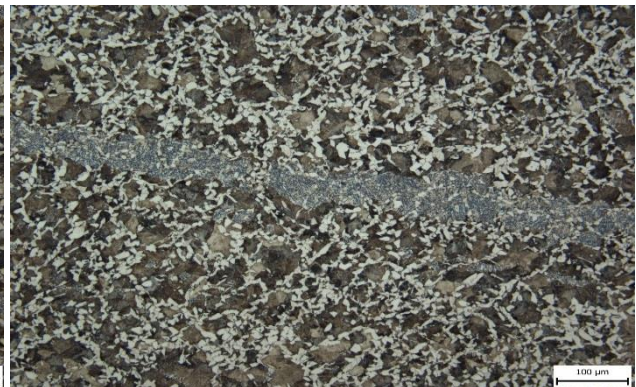


Fig. 5. Micrograph of specimen cooling according to K2 curve

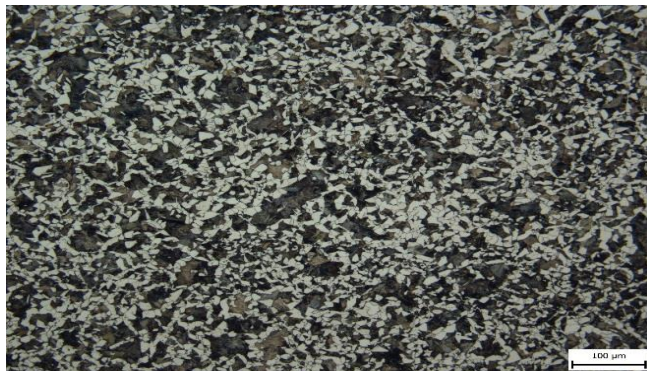


Fig. 6. Micrograph of specimen cooling according to K3 curve

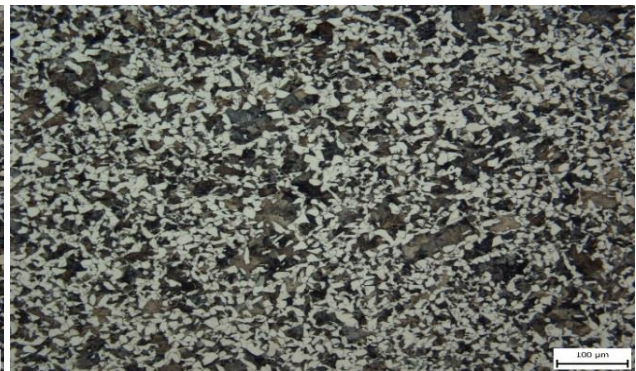


Fig. 7. Micrograph of specimen cooling according to K4 curve

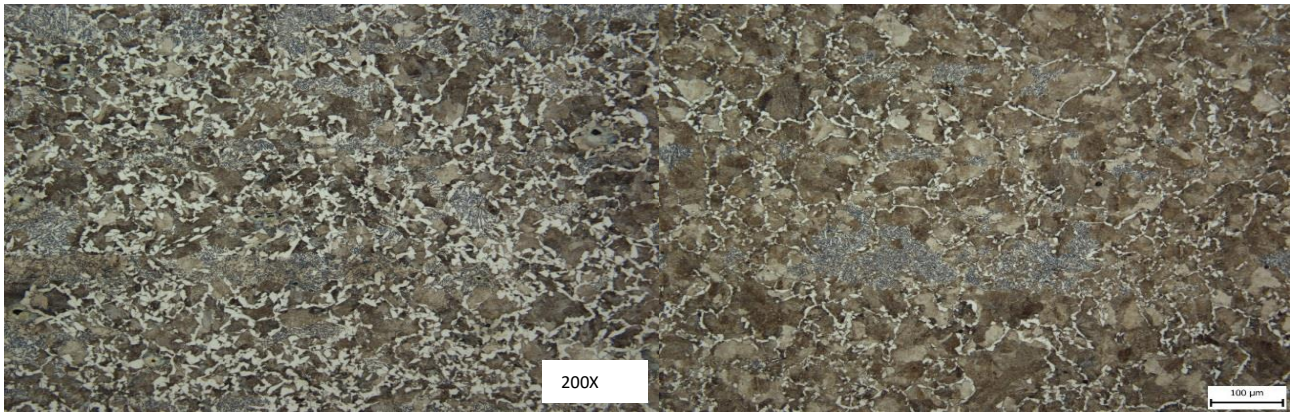


Fig. 8. Micrograph of specimen cooling according to 10W curve

Fig. 9. Micrograph of specimen cooling according to 15W curve

The content of bainite was found also in the specimens according to 10W curve which has faster cooling rate than the previous cooling rates (Fig. 8). The rest of samples which were treated with faster cooling rates contained bainite in their microstructure with a combination with ferrite and perlite as shown in (Fig. 9, 10, 11).

The highest content of bainite was found in the specimens with the cooling curve 40W which has the fastest cooling rate as shown in (Fig. 12).

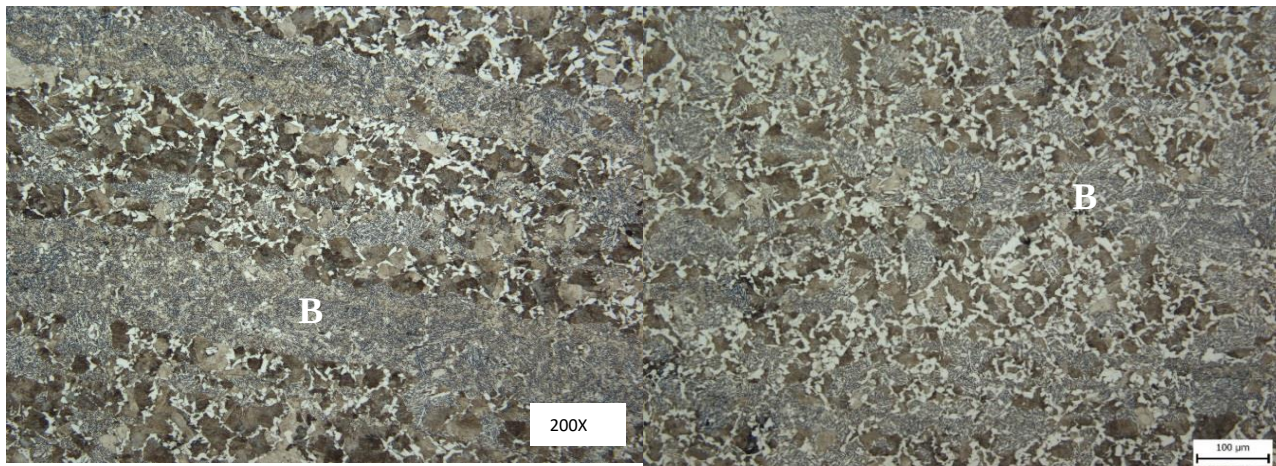


Fig. 10. Micrograph of specimen cooling according to 20W curve

Fig. 11. Micrograph of specimen cooling according to 30W curve

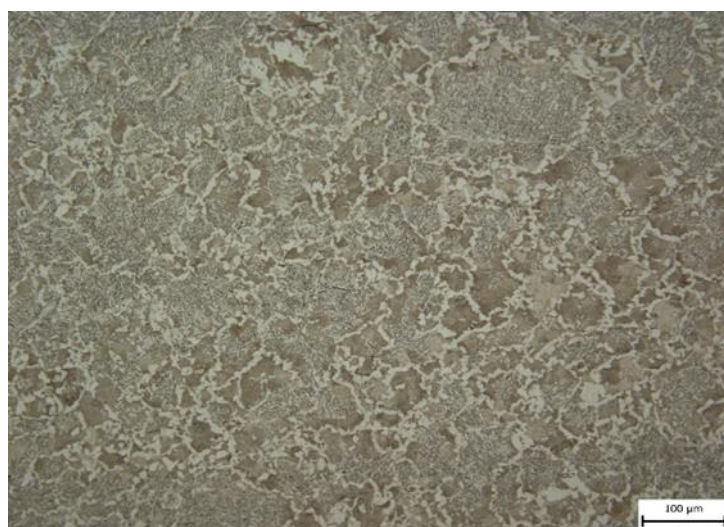


Fig. 12. Micrograph of specimen cooling according to 40W curve

4. Conclusion

Using material-technological modelling, correlation between true strain level, the rate of cooling of a particular forged part from the finish-forging temperature and the resulting microstructure was examined. FEM simulations using the DEFORM software reported the following true strain for the critical deformed area in the cross section: $\varphi=2.8$. Material-technological models were constructed for this critical point to describe the forging process in thermophysical terms. One boundary condition for this study required the final specimens to contain exclusively ferritic-pearlitic microstructure. The critical cross section area was chosen because of the smallest thickness, which means fastest cooling rate compared with thicker areas from the same part. This can insure for us that when the critical area doesn't contain bainite, the whole specimen will not contain it.

Important conclusions were drawn from the experiment and verified. The prescribed ferritic-pearlitic microstructure can be obtained by cooling through the 950/300 °C interval longer than 1600 seconds which is presented in the cooling curve K3 and K4.

For future study, we will try to find out the best cooling process and media to achieve the results obtained from the material-technological modelling in the real life production, so that the forging process will be directly followed by the controlled cooling process.

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