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Wydział Inżynierii Materiałowej

PRACA DOKTORSKA

Opracowanie technologii umożliwiającej uzyskanie wymaganych właściwości wytrzymałościowych i technologicznych wytłoczek kształtowanych ze stali 22MnB5 z zastosowaniem chłodzenia poza tłocznikiem

mgr inż. Robert Krupa

Promotor:

dr hab. inż. Krzysztof Radwański

Promotor pomocniczy:

dr inż. Władysław Zalecki

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DOCTORAL DISSERTATION

Development of technology enabling the achievement of the required strength and technological properties for sheet metal parts made of 22MnB5 steel using cooling outside the stamping die

MSc. Eng. Robert Krupa

ABSTRACT

The production of high-strength structural elements of car bodies by heat treatment with quenching in the hot stamping process is an energy - intensive and relatively time - consuming process compared to cold stamping. In order to shorten the production cycle, alternative hardening strategies are considered, such as cooling the workpiece outside the die. One such strategy is presented in this doctoral thesis. The main objective of the dissertation was to develop the method and parameters of heat treatment with immersion hardening outside the stamping tool, allowing to obtain the required mechanical properties and shape accuracy of final products in the form of sheet metal parts intended for the automotive industry.

Based on the existing state of the art, the following scientific thesis was formulated: immersion hardening of sheet metal parts, previously cold-formed from manganese-boron 22MnB5 steel, allows to obtain the shape accuracy and mechanical properties achieved by the conventional method of production using hot stamping and die quenching. In order to prove the thesis, dilatometric tests, microstructural analyses and strength tests were carried out for heat-treated steel according to an experimental cycle with quenching in water at room temperature, in oil at 20°C and 80°C. The characteristics of the material obtained during uniaxial tensile tests, three-point bending tests and hardness measurement on the cross-section of the experimental part after various heat treatment variants, allowed to draw conclusions and compare the results with the required mechanical properties for the steel after hot stamping and die quenching. The tests confirmed the thesis for the samples quenched in oil at 20°C and 80°C, the required mechanical properties, i.e. yield strength $R_{p0.2}$, tensile strength R_m, total elongation A_{50}, hardness HV and bending angle α_{Fmax} were within the limits of technical specification. However, for water-hardened specimens, the values obtained for A_{50} and α_{Fmax} exceeded

the lower limit of the specification. Oil quenching resulted in better ductility of the material compared to water quenching. The improvement of the plastic properties of the material after oil quenching was caused by a decrease in the cooling rate and the occurrence of the phenomenon of martensite auto – tempering below the martensitic transformation start temperature M_S.

The applied temperature and time parameters of heat treatment had an impact on the shape stability of the experimental part. It was shown that cooling in water caused large quenching distortion (warping) and the surface deviations of the tested part had a large scatter, exceeding the permissible surface tolerance limits. Quenching in oil contributed to much smaller values of the part surface deviations, the spread of which was within the tolerance range. The change in oil temperature from 20 to 80°C did not significantly affect the changes in the surface deviations of the experimental parts and the changes in the mechanical properties of the material, which makes it possible to extend the technological window in the heat treatment process with immersion hardening.

Based on the research carried out, it was concluded that immersion hardening in oil at 20°C and 80°C shows the application potential for geometrically and dimensionally defined components. In this doctoral thesis, the assumptions of heat treatment with immersion hardening were developed for an experimental sheet metal part, previously cold-formed. A concept was also presented to reduce the quenching distortion of the parts, with the assumption of a shorter production cycle compared to the conventional hot stamping and die quenching technology currently in use. An innovative strategy and direction of further research was proposed on the application of hot stamping with incomplete quenching of the workpiece in the die within M_S-M_f temperature range and then final immersion quenching outside the stamping tool.