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QUALITY-BASED OPTIMISATION IN RESISTANCE SPOT WELDING OF SHEETS

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Miskolc, 2003.

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In the past years a firm tendency in designing thin-sheet constructions has aimed mainly at reducing weight and saving materials. These constructions are rather complex geometrically and to join a lot of components needs a great number of welded joints to be made in various spatial positions. The application of resistance spot welding here is very advantageous and unavoidable at the same time.

Resistance spot welding is considered as a complex process of electrical, thermal, mechanical and metallurgical phenomena, furthermore these factors do not act independently, but in interaction of each other. Research activity was focused on contribution to general knowledge and on definition a complex qualitative parameter, with which the qualification of welded joint would be possible and which takes into consideration the mentioned phenomena simultaneously.

Design of experiment, optimisation

As far as designing complex constructions is concerned, more and more information is requested to establish the supporting power of the resistance spot welded joints. In the research work the strength index numbers of spot welded joints and the relationship between technology and strength under the given circumstances were examined. The first task of the work was optimising the technology of resistance spot welding based on statistical methods and by using one and multi-objective functions. As possible solutions to tasks in which optimal values are to be found the Box-Wilson, the Taguchi and the Harrington methods were used. The results of experimental methods were compared together and evaluated them.

Quality-based optimisation

The most important step of experimental design and technology-optimisation is the definition of the quality parameter (objective function). Selection of an incorrect objective function causes serious problems during working out the optimal welding technology. In these cases corrective procedures are needed. The goal of the research work was to analyse the fracture (tear) mechanism during the tension-shear tests of the spot welded joints with different joint geometric parameters. With the help of applying complex objective function (fracture (tear) arc), a real optimum of the technology can be obtained with both the strength and aesthetical factors being considered (quality-based optimisation). For the resistance spot welded joint of steel sheets classifying conditions were built up from the geometric parameters.

Boundary value problem, numerical solution

The object of present study was modelling the early stage of resistance spot welding, i.e. the phase, in which the first melting appeared. The fundamental problem of analysis of extra short time resistance spot welding is the description of interfacial resistance between two metal sheets. The temperature and strain dependencies of this resistance are not known exactly and its measurement is extremely complicated and it can be done just with significant errors. To study this early stage of the process, a thermomechanical model was constructed to investigate the mentioned phenomena. Theoretical examination of the model was executed using Finite Element Method and the numerical solution of problem was accorded. Modelling results were controlled and proved by experimental methods. Supposing contamination free surfaces, the goal was to determine the effects of the mechanical and thermal loading. For this purpose the temperature characteristics were investigated, and the formation of yield locus in detail.

Results

1. From the characteristics of resistance spot welded joint of steel sheets qualifyer conditions could be given using the $Y = \frac{k \cdot T_a}{s}$ expression.
    a. Goal function was definied to classify the welded joint analyzing the crack of resistance spot welded joint.
    b. The goal function built up by comparing the cracking curve during the tension-shear tests of resistance spot welding joint is suitable for technology optimisation independently from the welding machine.
    c. The concept of the optimal quality welded joint was given.
2. A simplified thermomechanical model was constructed to investigate the early stage of the formation of resistance spot welded nugget. Theoretical analysis was done by using FEM, and the numerical solution of the task was given. The results were verified by metallographic methods.
    a. In the case of extra short time welding the maximum of the plastic deformation is in the periphery of the contact surface. It was demostrated, that the temperature distribution is uniform at the contact surface.
    b. In the case of long time welding the plastic deformation is uniform at the contact surface. It was demostrated, that the temperature is much higher at the centre.
    c. The extra short time welding is the most suitable welding program to produce the optimal quality welded joint.