NUMERICAL ANALYSIS OF RESIDUAL STRESSES IN WELDS OF THICK-WALLED PRESSURE VESSELS

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1. Introduction

Failures caused by fatigue in welded structures result in substantial costs each year all over the world. The premature fracture is often attributed to existence of residual stresses, which have their source in welding technology. Application of concentrated source of heat, high temperature gradients, phase and volume changes during the process make this problem difficult to analyze. Additional changes of material constants and yield stress values lead to a nonlinear problem, which should be analyzed as coupled [1, 2]. Also experimental assessment of residual strains or stresses in welds is rather limited due to high cost of investigations. The above observation influenced the development of various numerical methods and codes focused on weld simulation. This problem attracts many researchers since seventies of the past century. The first successful trials can be found in papers [3-6]. The extensive review of numerical modelling and simulation of welding process is presented in [7].

Nowadays there are several codes based on the Finite Element approach oriented to weld simulation, as for example: SYSWELD®, MSC Marc/Mentat®. It is also possible to use the universal FE code ANSYS®, in which the authors perform the simulations. Below the results of welding simulation of two plates are presented. The thickness of plates was chosen in such a way that the weld can be made in a single pass. Further calculation will be preformed for a thick-walled cylindrical chamber, where the welding process becomes more complex – needs more passes, preheating before welding and heat treatment after welding.

2. Numerical modelling of welds

Welding is one of the most common methods of joining elements made of low carbon or alloy steels. This method involves many different phenomena and results in complex stress and strain state in structures. Appearance of high temperature gradient in the process, phase and volume changes in joined materials and simultaneous changes of material constants are the main source of residual strains and stresses. Additional complication arises from the movement of the heat source along the weld path during the manufacturing process. This causes that the thermal problem should be regarded as a transient one. Finally, the analysis is performed in two basic steps. The thermal analysis is the first one. Locally applied heat source causes thermal dilatation resulting from thermal expansion. This is supplemented by the volume changes due to phase transformations. All these phenomena result in deformation, which is usually permanent due to rapid reduction of the yield stress with temperature increase. The thermal analysis is followed by the mechanical calculation made on the base of the temperature distribution. The whole analysis is nonlinear and is performed in several steps.

3. Results of exemplary numerical simulation

The problem of welding of thin plates is usually analysed as two dimensional [8, 9]. In the present paper the whole structure was modeled as three dimensional and the weld was made in one pass. At the beginning of the process the full geometry was defined and then the procedure of element annihilation was utilized. Next the sub-volumes on the weld path were animated with the velocity corresponding to the velocity of welding. The exemplary results of such approach are shown in Figure 1. Here the distribution of temperature and residual strains at the end of the welding process are presented. As it can be seen, the residual strains are located in vicinity of the heat-affected zone, which confirms the earlier observations [8, 9].

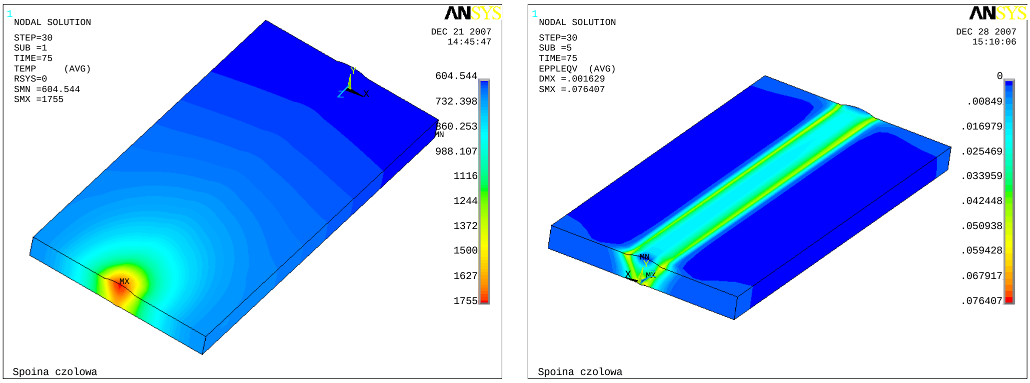

Figure 1 Distribution of temperature and residual strains in two plate welding process

The preliminary investigations show, that the standard finite element code ANSYS enables the simulation of welding process, and it has been decided to use it in modelling of welds in more complex, thick-walled structures.

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4. References

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