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DETERMINATION OF WELDING RESIDUAL DISTORTIONS OF LARGE STRUCTURES

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ABSTRACT

Welding technology is one of the main joining techniques used in industry for parts assembly in aeronautics, automobiles and ships. One major industrial concern is to limit the use of clamping tools to reduce the cost and facilitate the automation of assembly lines. Optimization of the welding sequence and process is one way to reach this goal. However, experimental optimization requires prototyping and measurements which are extremely expensive and time consuming and finally, very few solutions can be used.

Finite element simulations can be used in that aim but the difficulty is, on one hand, that welding processes involve complex physical phenomena and, on the other hand, that where local models are sufficient to predict stresses, only global 3D models can correctly evaluate distortions. But in an industrial context, a complete 3D mesh is ruled out because of heaviness and cost of the calculation. A great number of methods have therefore been developed. The current tendencies concern essentially the research of more effective and robust algorithms, the parallel calculations and the reduction of model size. This review concentrates principally on the third way.

Dong et al. [1] used the shell elements to study the influence of the thickness and welding velocity on the residual stress. But only a simple case using austenitic stainless steel is considered, the phase transformations during the cooling are not taken into account. Faure et al. [2] proposed and developed a shell element adapted to welding as well as to other high temperature processing. The thermal analysis accounts for dependence of thermal properties upon temperature and metallurgical phases, and transformation latent heats. The metallurgical and mechanical calculations are based on a multi-layer formulation similar to those commonly used for composite shells. The mechanical computation also accounts for non-linearities; for instance, a large displacement formulation is used in order to correctly evaluate distortions. The element used is based on the Mindlin-Reissner theory; it allows for consideration of thin as well as thick shells and avoids shear locking phenomena.

The most popular method consists of mixing 3D and shell elements. The simplest version of this method required the use of a fine 3D mesh for the entire welding bead. Faure et al. [3] proposed a more elaborate but less time-consuming adaptive 3D/shell approach. This approach consisted of restricting the use of 3D elements to a small block

around the HAZ. The local 3D mesh thus represented a small portion of the bead only, so that it had to move with the heat source within the coarser shell mesh. However, this approach gives rise to difficulties related to the connection between the 3D block and the shell mesh. Duan et al. [4] used some specific elements (transition elements) on the boundary of the 3D block to assure the compatibilities with the shell elements.

The inelastic strains due to welding are called “inherent strain” by Ueda et al. [5]. They affirmed that the inherent strains exist only nearby of the welds, and that les residual stresses and distortions are determined by theirs distributions and amplitudes. The inherent strains can be obtained with simple analytical calculations based on the relations with welding parameters. An elastic analysis is finally sufficient to predict the residual distortions. Inspired by this method, Michaleris et al. [6] evaluated the welding distortions using an applied plastic strain method, where the plastic strain field computed by a 2D welding simulation is applied as initial load on a structural 3D analysis. Solid elements are used in the structural analysis and shell elements for the plates and truss for the welds.

Souloumiac et al. [7] developed a local/global approach in order to determine the welding residual distortions of large structures. It is assumed that plastic strains induced by the welding process are located close to the welding path and only depend on local thermal and mechanical conditions. The plastic strains obtained by the local model are then projected to a complete shell of whole structure as initial strain. The final distortions can therefore be computed using an elastic simulation. This method is precise and permits to model all kinds of welds such as weld T, multipass, etc. It's certainly one of the most promising methods.

In this article, the methods used to calculate the welding residual distortions of large structures will be presented and compared.

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