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NUMERICAL ANALYSES USING IN PRODUCTION OF WELDED PARTS

Abstract:
By help of numerical analyses it is nowadays possible to simulate the whole technological welding process and to better understand, on the basis of the acquired results, how the individual input parameters affect the whole technological process, mainly the quality of the resulting material structure and the level of the final deformations and distortion. The submission presents the so called local-global approach method, which enables to solve even complicated constructions with more welds. By applying this method we can obtain final deformations or distortions, including the overall effect of individual welds. Thanks to the characteristics described above, this method is often successfully applied to predict distortions and deformations before the welding itself.

Keywords:
welding simulations, Local-Global approach, projection methods, Sysweld programme

INTRODUCTION

Due to high demands on the quality of welds there is a need for a bigger number experimental check welds, which are carried out before the proper welding of real elements. These experiments are used, for example, to confirm the suitability of the chosen welding technology, material properties, preheat temperature, filler material, etc. To sum it up, they are used to validate the welding process. Further comes the measurement of the material properties in the weld zone. These experiments make production more expensive and at the same time they are highly time-consuming (especially in heavy constructions). Consequently, numerical welding simulations find wider application not only in the development studios, but also during the production preparation phase. In the last few years there was a big expansion of such analyses, which in some cases already replace experimental tests. We may expect that in near future the numerical analyses will reflect the reality much better than experimental measurement of the individual parameters of the process.

The France ESI Group company Sysweld programme is one of the most complex programmes for welding process simulations.

SYSWELD PROGRAMME

Sysweld programme is based on the finite elements method and the solution is founded on a phase transformation. The computation itself is devided into two stages: thermal-metallurgic analysis and mechanical analysis. The thermal-metallurgical analysis solves the computation of *nonstacionary temperature fields, phase transformation, hardness of the structure, and of the austenitic grain size, as appropriate. This is quadrated with the material input data, which should be entered in a temperature dependent form.*

On the figure 1 we can see an example of output from thermal-matelurgical analysis. There is temperature field on the fillet weld shape model. Red elipse marked molten zone. [4,5]

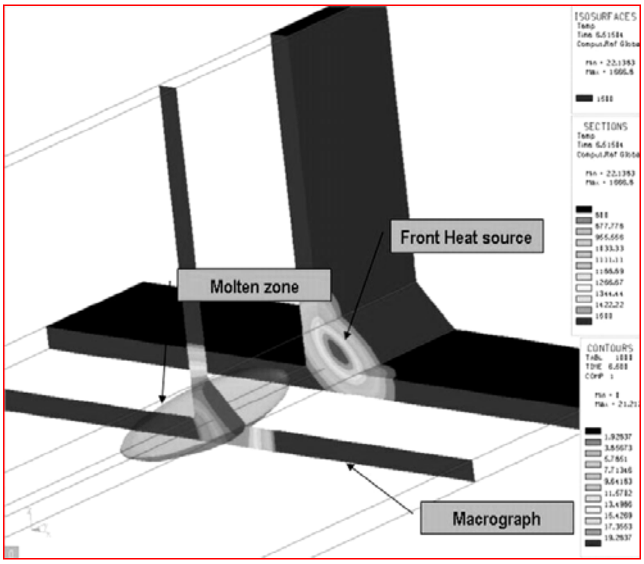


Fig. 1 Temperature field on the fillet weld shape model

The mechanical analysis follows the thermal-metallurgical analysis and it is not possible to carry it out without a previous thermal load of the scale. It enables to compute a time curve of the individual stress tensor factors, main stress values, spatial stress-strain state according to the HMH theory, as well as the shear stress Tresc analysis. The elastic and plastic deformation computation. Elastic and plastic deformation computation of the individual components as well as of the resulting stress tensor. It is, inter alia, able to compute e.g. the strees energy density. Input values for viscoplastic material behavior. Due to high demands on the quality of welds there is a need for a bigger number experimental check welds, which are carried out before the proper welding of real elements. Consequently, numerical welding simulations find wider application not only in the development studios, but also during the production preparation phase. [1,6] On the figure 2 we can see an example of output from mechanical analysis. There are computed distorsions after welding, which are display on the initial shape. [2,6]

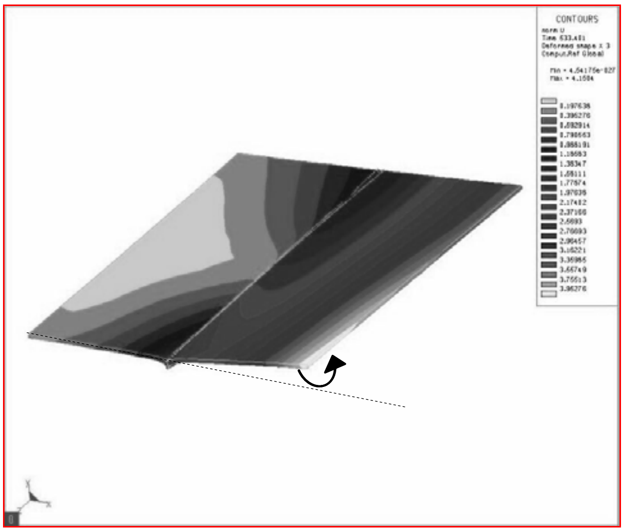


Fig. 2 Computed distorsions after welding

LOCAL-GLOBAL APPROACH

In case standard SYSWELD methodology is used for solving the simulation computation, the required mesh (i.e. fine meshing) leads to an excessive model size and consequently to unbearable prolongation of computation time. A simplified method called the local-global approach is proposed to overcome this limitation and to provide a solution to simulate complicated constructions. The size of the model is therefore not limited. Another advantage is that the individual welding sequences and clamping conditions can be further adjusted to minimize distortions. The main idea is to create a local model that represents only a part of the weld with its results (constraints and strains). This model is then projected on the global model depending on the trajectories (paths) of the various welds. The input data is then completed by the order in which the welds are carried out and by the clamping conditions of the structure.

The Local-Global Approach is based on local as well as global phenomenon:

- *Local phenomenon - High temperature and material non-linearity appear in very small areas around the welding joint. Plastic strains are concentrated around this small zone.*
- *Global phenomenon - Global distortion of the assembly is due to local plastic strains induced by the welds. The behaviour of the global structure can be considered to be elastic.*

The simulation of the welding joints (residual plastic strains and stresses) can therefore be separated from the global computation (distortion). [1,6]

PROJECTION METHODS

They are methods for extraction and projection from local to global model. In practice there are two types of projection from local to global model, independent of the type of a weld joint, whereas the effects of the welding joints are applied to the global model through the tensor field of plastic strains computed during the welding simulation for the local model. A projection method called extrusion can be used in case of steady state welds, where the results of the mechanical analysis are identical for the whole weld. The principle of this method is demonstrated on Figure 3. Results of the mechanical analysis for the local model are extracted and projected to the global model. The condition is that the local and global mesh must be identical.

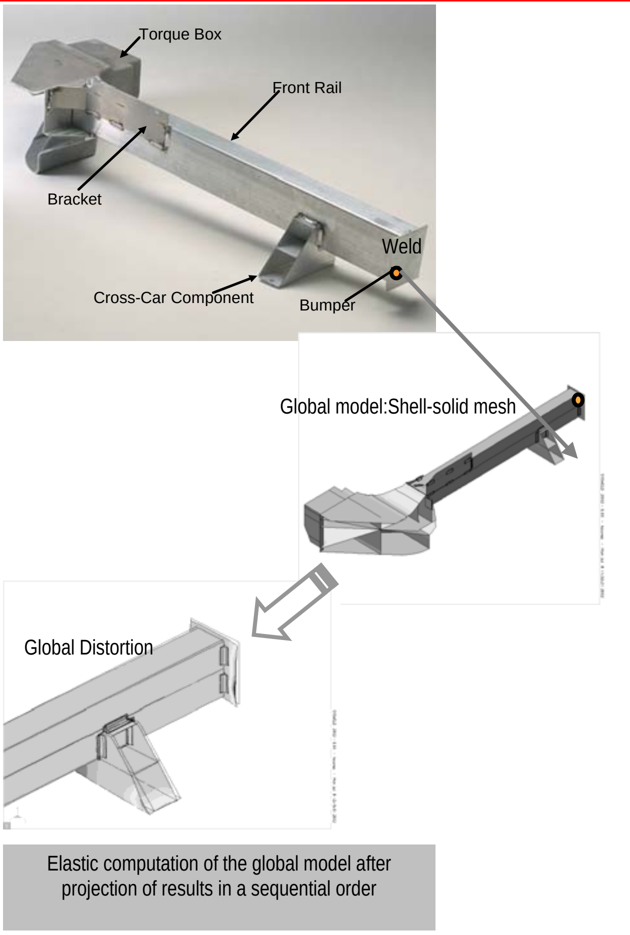


Fig. 3 Principle of extrusion method

For geometrical reasons, a block method can by used in case of short joints or in case intersections appear between welds. This method is mainly suitable for short joints in non steady state and all other configurations. In this case the plastic strain distribution is not continuous along the welding path. The principle is that the whole local model together with the respective results is projected to the rough mesh of the global model as shown on Figure 4. [5,7].

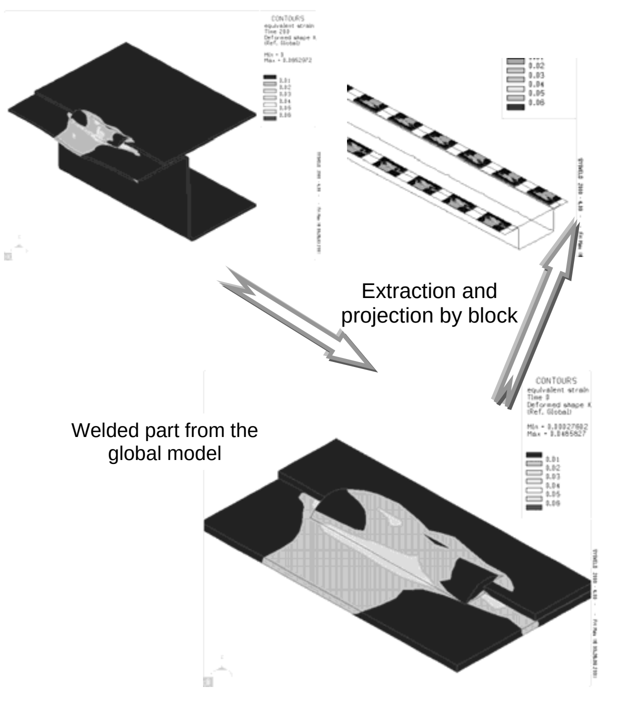
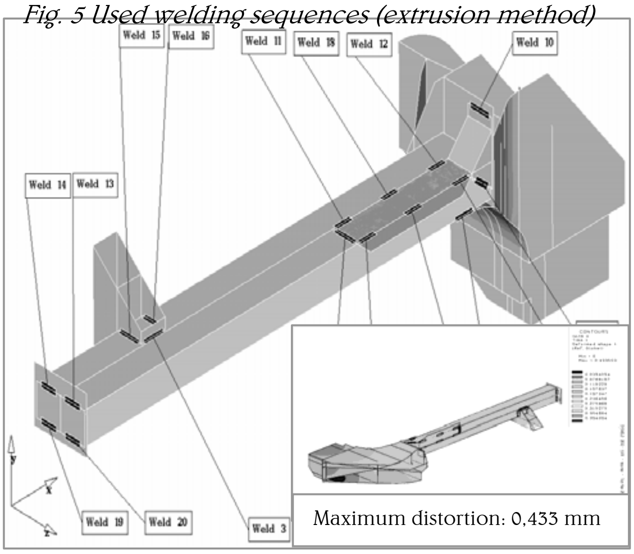


Fig. 4 Principle of block method

Fig. 5 Used welding sequences (extrusion method)



and final distortions

EXAMPLES OF APPLICATION OF INDIVIDUAL PROJECTION METHODS

As an example of the application of extrusion method, the contribution mentions welding of a front rail (automotive industry), which is welded of five parts by 22 weld joints. Figure 5 shows welding sequence, which gives the lowest distortions. On the small figure we can see final distortions after welding, maximal distortion reaches 0,433mm value.

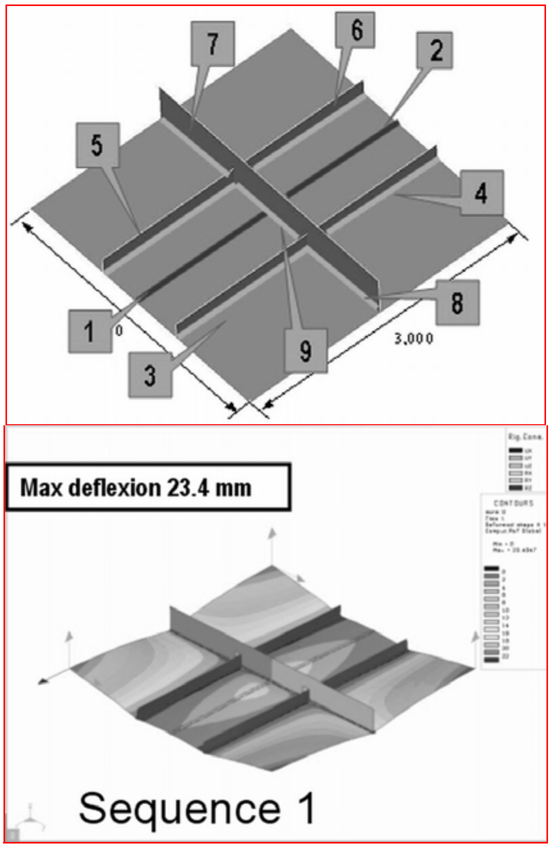


Fig. 6 Welding sequence No. 1 (extrusion method)

As an example of the block method, the contribution mentions welding of a profile demonstrated by figure 4. This profile is welded by means of twenty welds and similarly as in the previous case, there are different welding sequences. Once optimizing those sequences we can minimize the distortions resulting from welding. Figures 8 and 9 again shows a comparison of two sequences. We can see that both sequences are not suitable from the point of view of the final distortions. It is necessary to keep on searching for a better sequence, or to adjust the structural design, parameters, or the welding method itself. [3,7]

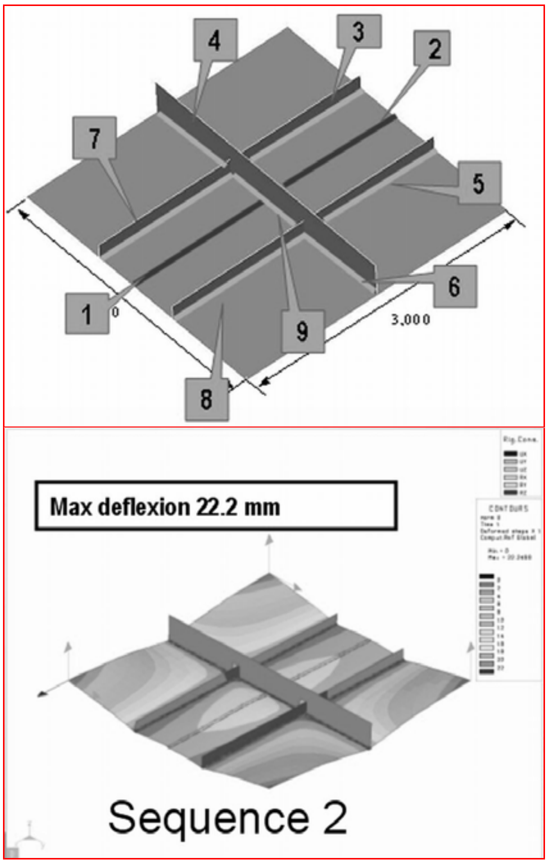


Fig. 7 Welding sequence No. 1 (extrusion method)

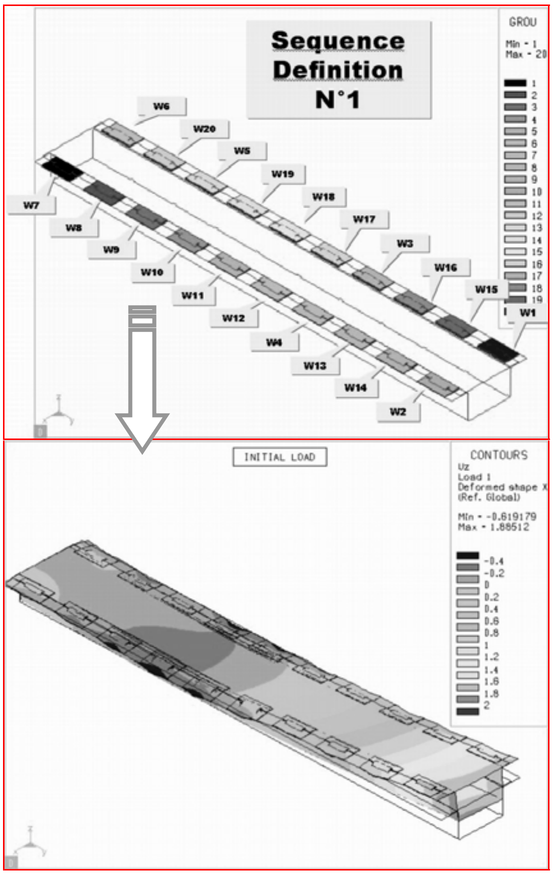


Fig. 8 Welding sequence No. 1 (block method)

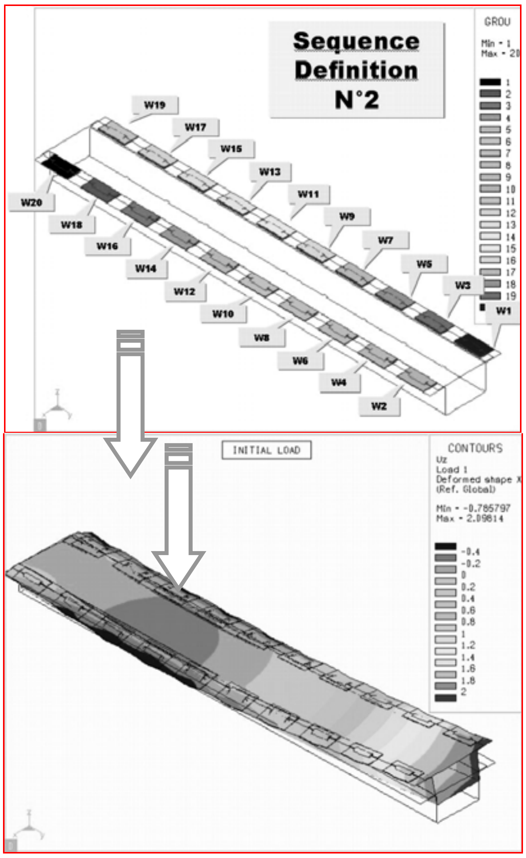


Fig. 9 Welding sequence No. 2 (block method)

CONCLUSION

As shown above, application of the local-global approach method enables us to solve rater complicated structures and subsequently predict final distortions without having to conduct expensive experimental tests. However, we must keep on mind that the quality of the simulation results highly depends on the quality of the local model simulation, and that the residual stresses and plastic strains in the welding joint are highly dependent on the global stiffness of the assembly structure, including the effects of the clamping tools. That is why it is necessary to pay a special attention to the choice of the local model simulations and especially to the boundary conditions applied to the limits. This is the key point for the success of the method as well as for obtaining the relevant results.

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