Predicting tolerances in the design of welded automotive chassis

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Abstract

Nowadays, chassis design is more and more characterized by the use of lightweight materials, such as aluminum, for downsizing reasons. Nevertheless, the assembly of thin aluminum structures represents a challenge from a technological point of view, especially due to the distortions caused by the welding process. The prediction of welding distortions is mainly carried out by means of Thermal Elastic Plastic (TEP) Finite Element Analysis (FEA), that is capable to replicate the transient thermal heat flux generated by the torch during welding. Nevertheless, this requires high computational efforts, especially for handling complex geometries typical of the automotive design. To overcome this problem, in this paper, the local/global approach has been adopted, to predict distortions due to the welding process. As a case study, a top class car aluminum chassis has been chosen. Moreover, a sensitivity analysis on the effect of the variation of the process input parameters (dimensional tolerances and heat input variation) on the final distortions has been added.

Introduction

The prediction of welding distortions in assembled structures has been tackled mainly by means of numerical methods based on the thermal-elastic plastic (TEP) analysis, in which a thermal analysis is carried out, including welding and cooling phases. The resulting temperature distribution provides the initial loading condition for an elastic analysis, yielding distortions with a very good comparability with the experimental results ([1]). Handling complex geometry, as the automotive components, requires high computational efforts ([2],[3]). Few works are dedicated to the reduction of distortions due to the welding process, to fulfil tight tolerances on the dimensions and shape of the chassis components, ([4][5]). To overcome this problem, in this study, the FEA simulation of the welding process for assembling an aluminum chassis has been proposed, by means of the local-global method. This method allows to reduce the computational effort with respect to an entire model analysed by TEP FEA. This is because the TEP analysis is carried out only on a (local) portion of the model. Hence, the residual stresses of the local model are used as initial conditions for the global model, to evaluate distortions by means of a static analysis. The aim of this paper is to predict distortions due to welding in a complete chassis, with an acceptable accuracy and a reduced computational effort by means of a local/global approach on the entire assembly of the chassis of a top class car. Even if this approach has been already addressed in the literature, only simple automotive components like extruded parts or plates have been analysed ([3],[5]). A sensitivity analysis has been carried out, to study the effect of the combination of **dimensional tolerances and heat input variations** on the results.

Method

The proposed method, for predicting welding distortions in the automotive chassis is based on a local/global approach (Fig1). First, a ***local model*** is built including the joints to be welded. The local model is discretized by means of a refined mesh, to carry out a **TEP analysis**. Input data to the TEP analysis are the Goldak parameters describing the heat flux distribution, as well as the material behavior deriving from experiments. In this step, thermal and mechanical simulations are performed in cascade, to find out residual stresses. As a second step, the ***global model*** is built, stitching boundary nodes of the local model to the corresponding ones in the global model. Hence, the plastic deformations computed in the TEP analysis, are used as initial conditions for the elastic FEA simulation which is carried out on the entire structure (global model). Resulting final distortions are checked in specific reference points and compared to values required by standards in the automotive industry. Hence, a sensitivity analysis has been carried out, analysing the **best case** (maximal value of plate thickness combined with minimum value of the heat input (h_{max}, q_{min})) as well as the **worst case** (minimal value of the plate thickness combined with a maximal heat input (h_{min}, q_{max})).

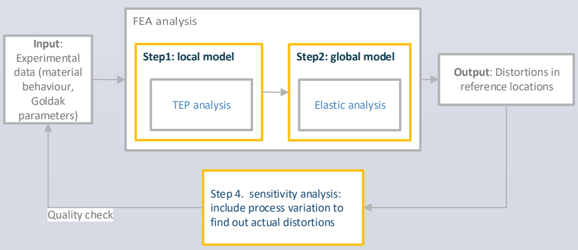

Fig. 1 Proposed method for the evaluation of the distortions of automotive chassis

Results

A four members, aluminum chassis of a top class car has been chosen as a case study. Of the four members, two are shell molded (1, 3 in Fig. 2, left) and two are extruded, (2, 4 Fig. 2, left).

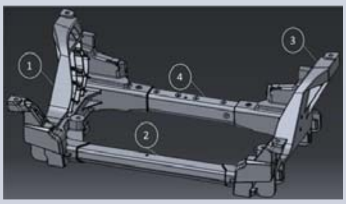

Fig. 2 The four members-aluminum chassis as a case study for the welding simulation

The local models are sub-assemblies of 4 adjacent overlap joints, replicating the actual bead. Two local models have been built, using Tetrahedral elements. Boundary conditions are applied, to replicate the fixture system used in the experiments. Hence, the TEP analyses have been implemented for the two local models separately. Given the temperature range as the initial thermal load condition, the corresponding stress values on the local models have been evaluated (Fig. 3).

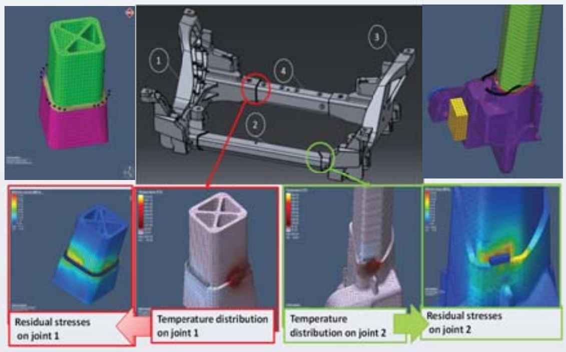

Fig. 3 TEP analyses on the local models

Residual stress resulting from the TEP analysis on the local models are used as initial conditions for the elastic analysis carried out on the global model to get the distortions (Fig.4).

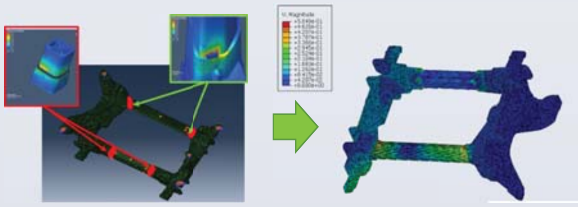

Fig. 4 Elastic analysis on the global model

The values of the resulting simulated distortions have been compared to the tolerance zones defined by the automotive industry standards, on the same reference points. Even if results lay within the tolerance zone, accuracy of the model should be increased. To this aim, a sensitivity analysis has been added to study the effect of the dimensional tolerances and the heat input variation on the final distortions. The Inherent strain based method has been used for carrying out FEA simulations on a thin aluminum T-joint [6]. Results show that *a combined effect of the dimensional tolerances on the plates thickness and the variation on the heat input provides non-negligible distortion on the structure* (Fig.5).

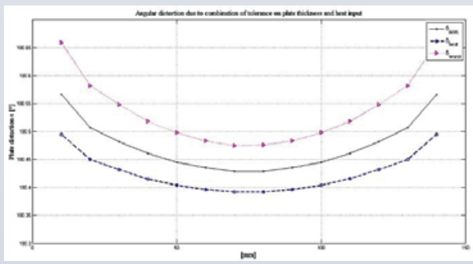

Fig. 5 Angular distortion due to the variation of the thickness of the plates and the heat input

Conclusions

A method for predicting welding distortions in the automotive chassis design has been proposed. In particular, results show that distortions are fully included in the tolerance zone, as required by the automotive standards. Further work will include the optimization of the *welding sequence* for minimizing distortions, as well as more GD&T on the chassis components.

References

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