

https://dspace.org/

Multi-objective optimization of thermo-mechanical modelling of friction stir welding

Topper, Candice Catherine

2015-05-07
http://hdl.handle.net/10539/17664

Downloaded from a DSpace repository. https://dspace.org/

Abstract

This research work is primarily focused on the simulation of the thermal effects on the Friction Stir Welding (FSW) process on aluminium alloys for aerospace applications. The main objective is to be able to realistically characterise the thermal input of a FSW process by means of an accurate parametric Finite Element thermal model, verified using thermal imaging camera data as a benchmark.

FSW is a solid state joining process. A rotating tool is plunged into the joint line between two clamped plates. The heat transfer input mechanism in the FSW process is due to the frictional contact between the tool and the work-piece plates. Since the FSW process occurs at solid state, no melting occurs and hence the yield strength of the material is temperature dependent.

Obtaining accurate measurements of temperature for the FSW process has proven to be challenging. Preliminary experimental observations in obtaining temperature variations in the material was performed using thermocouples but issues arose, one being the inability to obtain a complete thermal representation of the tool and the work-piece as thermocouples were placed along the FS weld only as control points. Research was undertaken using a thermal imaging camera. The type of camera used has a sensitivity that is able to detect temperature differences as small as 0.04°C. This experimental approach gives direct information of the temperature at all points of the work-piece, obtaining a complete external thermal assessment of the process. This is also beneficial in obtaining images of the temperature distribution in the tool itself also if it is rotating and partly submerged into the work-piece.

Since the temperature field directly affects the final residual stress distribution in the joint, an accurate thermal model of the FSW process is required to assimilate the numerical simulation with the process that actually occurs in reality. The new release of the Finite Element (FE) software ANSYS Release 14 was used. This novel version is capable of modelling the specific features required to assimilate the FSW process by using the ANSYS Parametric Design Language (APDL). The APDL language has new specific features designed for frictional heat generation, plastic heat generation and temperature controlled bonding contacts. The formulation of the model is based upon the thermal-mechanical model specifically developed by Zhu and Chao [20]. ANSYS APDL language is parametric by nature as such, it is well suited to be efficiently implemented into a multi-objective

optimization platform, such as the modeFRONTIER software, in order to further improve the FSW simulation.

The quantitative experimental data obtained from the thermal imaging camera was used to match and verify the numerical results of the FSW FE model. An accurate FSW thermal model will help to achieve a deeper understanding of the different phases of the process and an enhanced control of the key parameters of this technology, significantly reducing the required testing phase. It has many benefits over previous models including;

- The model is a fully developed thermal-structural model whereby the thermal and structural effects of each other are modelled together
- The model does not incorporate symmetry to account for the advance and retreating side of the weld as this has an effect on the temperature distribution and can be seen in the frictional stress developed where the one side clearly depicts a higher stress than the other
- It incorporates material properties changing with temperature

Results obtained prove to be of some comparison with not only the literature but experimentally as well. Although there is some comparison, further investigation needs to be conducted on the convection coefficients as well as the friction coefficient and recommendations have been suggested for these parameters. However, a fully parametric thermo-mechanical model has been developed and it is able to be implemented into an optimisation tool such as modeFRONTIER.