NUMERICAL INVESTIGATIONS ON THIN WALLED LASER WELDED STRUCTURES

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1. Introduction

Due to the high cost efficiency of laser welded components the importance of this manufacturing method increases ongoing. A very small heat affected zone, low welding distortion as well as very short manufacturing station times attract this joining technology very much. Therefore, the behaviour of laser welded parts in respect of stress distribution is investigated. The influence of the weld seam’s structural stiffness on the distribution of residual welding stresses is evaluated. In subsequent studies the behaviour of the weld overlap of laser welded thin walled tubular joints has been investigated. This particular region is unavoidable in circumferential welding operations and is assumed to be critical in terms of annealed region and subsequent fatigue cracking.

2. Numerical investigation

To study the stress distribution an axisymmetric specimen design was chosen. The specimen was welded in full penetration mode without filler material. This particular design allows displaying the overlap region of welded tubular joints. The weld seam’s geometrical surface and root topography was assumed to be flat for case studies. Evolution of local residual stress state behaviour of the specimen can be influenced by an inner contact section of the specimen (fig. 1). Process parameters like weld velocity and clamping conditions were applied as in the real laser manufacturing process. Heat input of the numerical laser source was calibrated by an inspection of the metallographic section. Good accordance to real martensite distribution in the specimen could be achieved. Energy ramps were introduced to depict the real evolution of laser beam power during welding. Laser energy was ramped up to 100 % of power within an angle of 30 degrees. Afterwards, a steady state laser process of 360 degrees was performed. Subsequently, the laser power was decreased to zero within 90 degrees.

Fig. 1: Axisymmetric specimen geometry and boundary definition

3. Simulation results

Stress distribution Residual weld seam stress distributions were evaluated in a steady state process region. Axial (fig. 2 & fig. 4) and tangential residual stress charts (fig. 3 & fig. 5) were assessed numerically by simulation in unclamped and cooled down condition and evaluated at the weld seam’s top and bottom surface. The material behaviour of the case hardening steel was assumed to be isotropic. This is in good accordance to investigations performed at ferritic plates [1].

Fig. 2: Residual axial surface stress
Residual axial surface stresses are shifted from compression to tension state due to enabled specimen contact. Tangential surface stresses are located in tension level in both contact conditions and also get shifted to higher level by enabling specimen contact. Generally the tangential stress is higher than the axial one. Residual stresses are switched to higher level when contact is enabled (fig. 6). The overall stress in this particular weld overlap region is higher than the residual stress evaluated in the steady state process zone.

Opposite to the surface stress distribution the weld root shows tension stress level in axial as well as in tangential direction. Tangential stresses have a higher level than axial ones. Root stresses are higher than surface stresses.

Weld overlap region Residual tangential stresses show higher maximum stress levels than axial stresses on the weld seam’s surface as well as on the weld seam’s root face.

Residual stresses are switched to higher level when contact is enabled (fig. 6). The overall stress in this particular weld overlap region is higher than the residual stress evaluated in the steady state process zone.

Fig. 3: Residual tangential surface stress

Fig. 4: Residual axial root stress

Fig. 5: Residual tangential root stress

4. Fatigue assessment

It can be stated that cracks pre-dominantly get initiated at the weld seam root region (fig. 7). This is in good accordance to the simulated stress evolution at the weld seam root region. No preferred fatigue damage of the weld overlap region could be observed despite higher stresses and contact pressure level.

Fig. 6: Axial and tangential stress distribution in weld overlap region

The fatigue behaviour is driven by evolution of the geometric root notch. Further investigations are performed to investigate crack initiation and propagation in similar as well as in dissimilar laser weld joints.

5. Acknowledgements

Financial support by the Austrian Federal Government represented by Österreichische Forschungsgesellschaft mbH within the national Bridge program is gratefully acknowledged.

6. References