DETECTION OF THE FATIGUE OPERATING LIFE OF THE WELDED JOINT OF AN ALUMINIUM ALMGSI07 ALLOY AT UNIAXIAL TORSION STRESS OF THE SPECIMENS

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Abstract:
The paper deals with an experimental measurement of the fatigue operating life of a specimen from the aluminium AlMgSi07 alloy on a built testing equipment, into which the welded joint was implemented. An importance of the measurement is in a comparison of achieved results with the same material, which was not subjected to welding. The result of the research is verification of the influence of welding on the fatigue operating life of the concrete material at torsion stress.
KEYWORDS: MATERIAL, FATIGUE, STRESS, ALLOY

1. Introduction

If the material is exposed to the action of the variable forces, respectively to the strain of the supercritical size, after some time there is a fracture, which is the result of the complicated processes in the structure of the material. The maximal stress value is so low that the material endures its static effect without any damage. Gradual eroding has a cumulative character and is based on creation and spreading of cohesion failures. From the time of observation of the fatigue failure, like a basic fatigue characteristics is used a Wöhler´s curve, which shows dependence between stress amplitude of simple symmetric cyclic loading and the number of cycles to the fracture. Wohler's curve is not a suitable material characteristic for the field of low cyclic fatigue. In the first place, it is because of big plastic strains, which leads to the significant difference between values of contractual stress σ_a determined on the basis of the initial cross-section, and of the real stress in the sample, in the second place, because of small slope of the curve in the studied area. From the practical point of view of fatigue strength calculations is more appropriate characteristics in the field of low cycle fatigue dependence of the amplitude of the total strain γ_{xy} from the number of cycles to the fracture N_f , which is called Manson – Coffin's curve, fig.1.

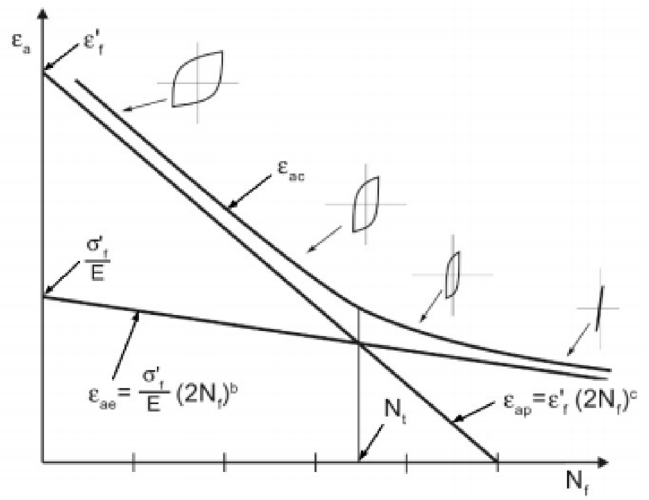

Fig. 1: *Manson – Coffin's curve*

2. The experimental material

The expansive development of the materials helps to the fact that constantly it is more used materials on the other basis than the iron. The example is replacement of the heavy constructions by the lighter ones, from the materials with lower density. It is for instance aluminium and its alloys, which have very favourable ratio of the strength to density and from the terms of the output, aluminium is between non-iron metals on the top in the world. Because of this reason a commercial aluminium AlMgSi07 alloy with a normalised chemical composition was chosen like an experimental material for the carrying out of the fatigue testing. Testing material was supplied in the shape of rod of circular cross section with a diameter 10mm and length 1520mm. Then it was divided on a bend saw BOMAR 1300 and achieved measure of semi-finished product for the production of the testing sample with the length 150mm. The geometry of the sample is precisely defined (fig. 2) and results from the constructional solution to the fatigue testing equipment, in which the testing will be carried out. Because of this it was conveniently used a semi-finished product with a diameter of the 10mm when it was not needed a further treatment of the diameter of the sample.

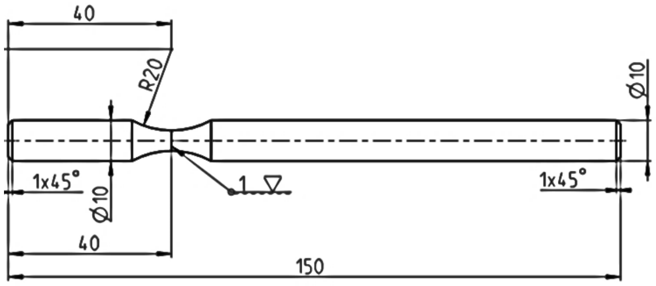

Fig. 2: *The geometry of the testing sample for the fatigue testing status*

3. Testing equipment

The experimental detection of the fatigue characteristics of the aluminium AlMgSi07 alloy was performed at a workplace for measurement of the fatigue on the fatigue testing equipment (fig. 3). Considering the character of the testing equipment, the loading was realized in the controlled amplitude of the strain with the zero medium component of the strain.

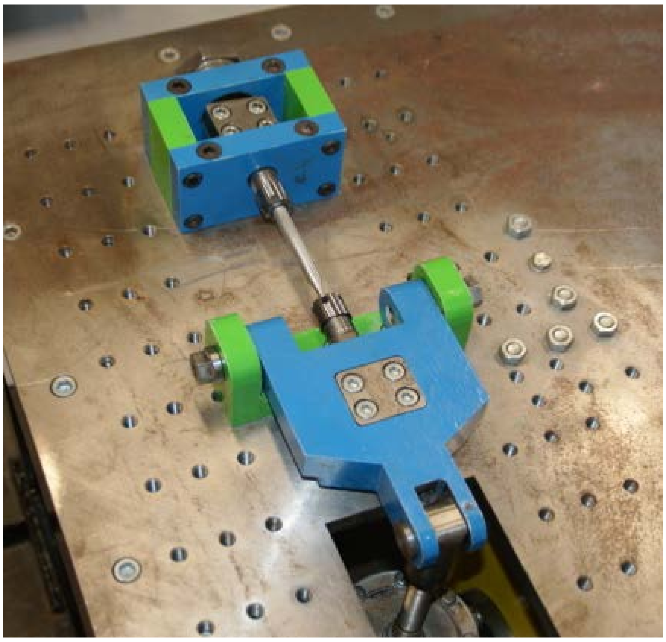

Fig. 3: *Made fatigue testing equipment*

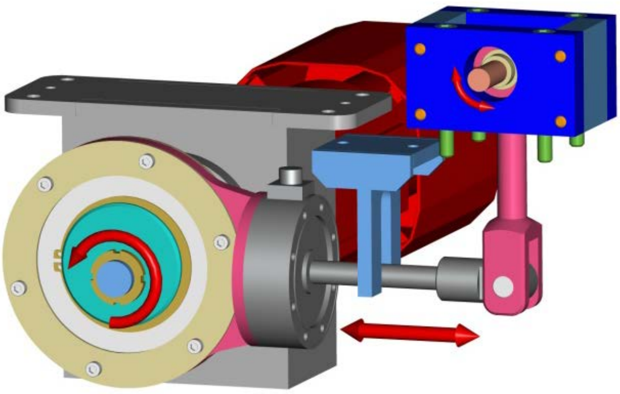

Fig. 4: *A model of stress mechanism for the cyclic torsion stress of the sample*

Loading mechanism for the cyclic torsion stress of the sample (fig. 4) is driven by synchronous servomotor, whose speed is regulated by the frequency changer up to 100 Hz. The rotational movement of the servomotor is transmitted by the excenter through the force transducer on the crank, which is acting linear motion.

4. Measurement of the fatigue life

Input characteristics of the material were experimentally detected from the tension diagram of the welded material AlMgSi07 (fig. 5).

To be possible to immediately express the size of the amplitude of the relative strain γ_{ac} for the each stress level, it was needed to create calibration dependences (fig. 6, 7) of the relative strain from the number of excenter teeth, whose change of the relative position by rotation, size of the displacement is set. The values of the strain were gained by the FEM analyses at all stress levels in the place of concentration of the stresses by the finite element method.

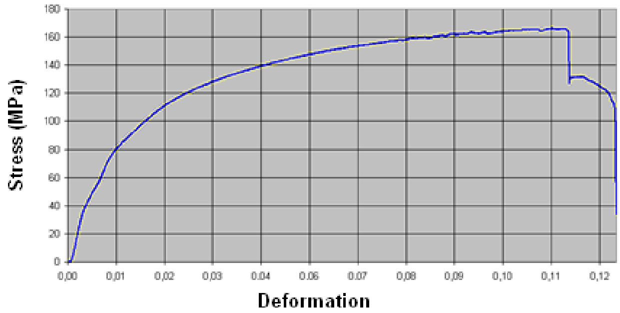

Fig. 5: *Diagram of the static tensile test performed on the welded material AlMgSi07*

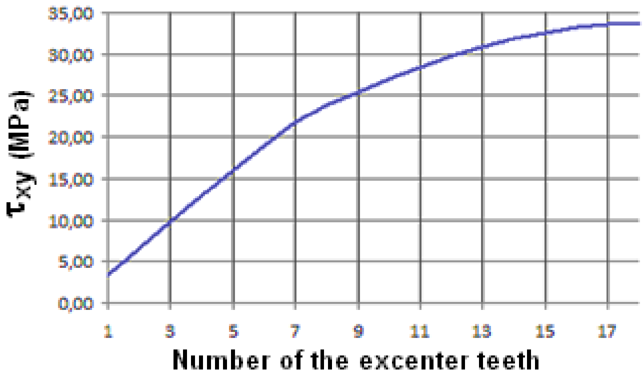

Fig. 6: Values of the stress at the torsion stress of the welded samples, e = 4 mm, material AlMgSi07

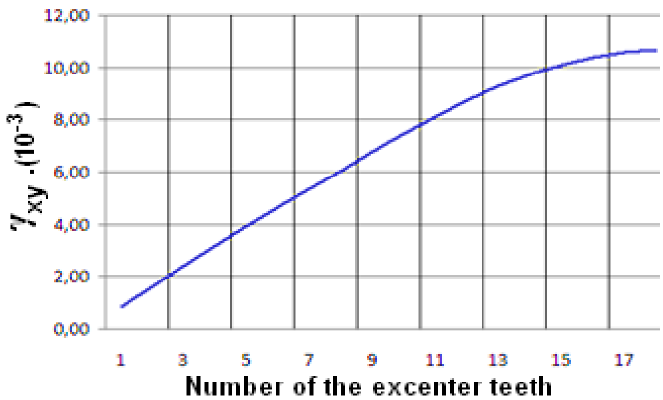

Fig. 7*: Values of the strain at the torsion stress of the welded samples, e = 4 mm, material AlMgSi07*

By the analysis of the state of stress, it was proved the veracity of the assumption that the largest stress at the fatigue testing will be in the area of sample contraction (fig. 8). The analysis was performed in the computing program ADINA. After making of the strain dependence of the testing sample, it was realised the measurement of the fatigue life of the material on the welded testing samples, which were cyclic torsion stressed. Size of the load was changing.

Measuring numbers of cycles for each loading were processed into Manson-Coffin´s curve $\gamma_{ac} - \log N_f$ (fig. 9) for uniaxial torsion stress.

From the graph, it is liquet that with gradual decreasing of the amplitude of the strain there is an increase of cycles to fracture. Behind the limit of 105 cycles we already talk about high cycle fatigue. Above this value another criterions are used for comparison with an experiment than at low cycle fatigue. Object of research is field of extremely stressed weld joints, so low cycle fatigue.

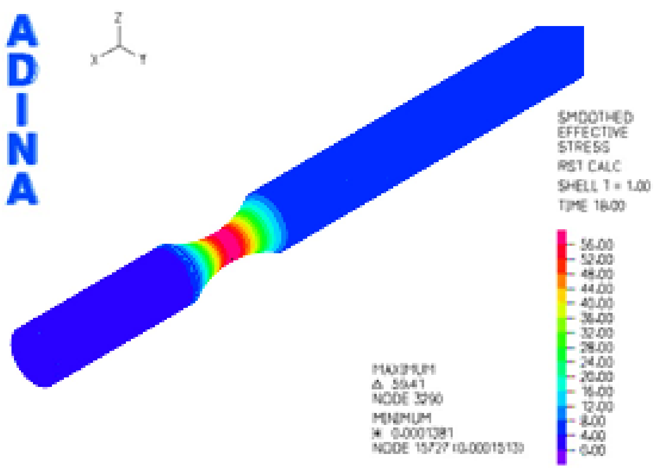

Fig. 8: *Distribution of effective stress by HMH theory in the sample from material AlMgSi07, which was torsion stressed, at maximal strain*

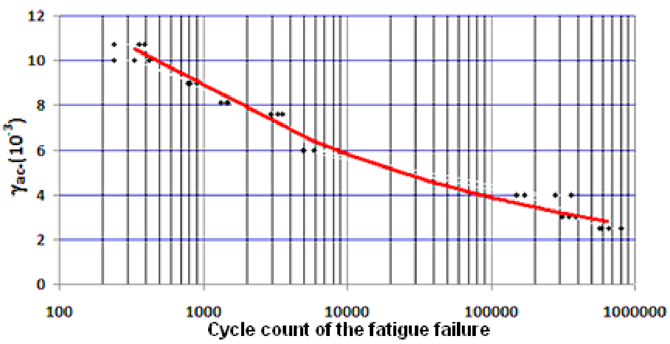

Fig. 9: *Manson-Coffin´s curve of the welded material AlMgSi07 stressed by cyclic torsion*

5. Comparison of results

Because of verification of accuracy of the measurement of the testing equipment it is appropriate to perform a comparison of measuring results with fatigue criterions. Such a comparison is possible with usage of program fatigue Calculator. Fatigue Calculator is program from the internet page Fatigue, where it is possible to easy and quickly makes an estimation of the fatigue life. By this programme we can find out a number of cycles, at which a fatigue fracture happen at a low cycle and also at a high cycle fatigue. Because of the fact, that we have available a possibility to compare the experimentally gained results with the computing, we choose the same conditions of the method of loading of the testing rod – sinusoidal cyclic stress. Because of simply comparison, all found numbers of cycles to the fracture at individual loading level were processed into a graph (fig. 10).

Values of the stresses, respectively strain in the required units are inserted to the programme from the calculated tensor and it is for τxx. It is worked with the symmetric frequency of the loading cycles 30 Hz. After starting a calculation of the life for the field of the low cycle fatigue, Fatigue Calculator displays calculated values of the number of cycles to the fracture with different models of damage, and they are Nf Fatemi-Socie (F-S), Nf SWT, Nf Brown-Miller (B – M).

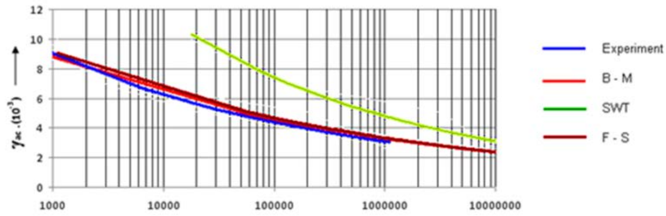

Fig. 10: *Comparison of Manson-Coffin´s curves of chosen fatigue criterions for the valuation of low cycle uniaxial fatigue and from experimentally achieved values at torsion stress of samples*

6. Conclusion

In the paper, there is described an issue of the measurement of the low cycle uniaxial fatigue of the welded material AlMgSi07 on the built testing equipment in the torsion. Gained results will be served for the comparison with the results from the experiments for the same material without the usage of welding technology.

Acknowledgements

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7. Literature

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