THE SIMULATION AND THE EXPERIMENTAL VERIFICATION OF THE INFLUENCE OF THE TIG – WELDING OF THE ALUMINIUM ALLOY ALMGSI07 ON CHANGES OF THE MECHANICAL PROPERTIES IN COMPARISON WITH THE BASIC MATERIAL

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Abstarct: *The aim of this investigation is to evaluate the influence on fatigue behavior of the welded aluminum alloy AlMgSi07. For the experimental measurement of fatigue of these welds, it is needed to analyse all the changes, which will occur in the weld material in comparison with the basic material. The modern computer simulation and the experimental verification are strong tools for achievement of the required results, for instance a change of the structure, residual stress, a range of the heat affected zone, a deformation of the workpiece etc.*
Keywords: *sinusoidal cyclic loading, fatigue test, stress, structural material*

1.   INTRODUCTION

Welding (Figure. 1, 2) as a modern, highly productive manufacturing technology found an application almost in all industrial departments but the requirements on the quality of the weld joints still rise. The welded machine-parts and constructions are normally used in the manufacturing, despite the fact that the welds are often source of ignition of cracks and defections, which may lead even to collapses [1,2,3].
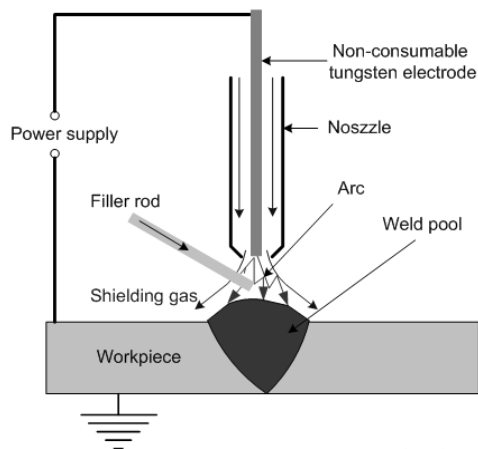
Figure. 1 Schematically shown principle of the welding with the TIG-method

The construction should be designed to be able to be used for the whole time of the life expectancy with the certain likelihood.
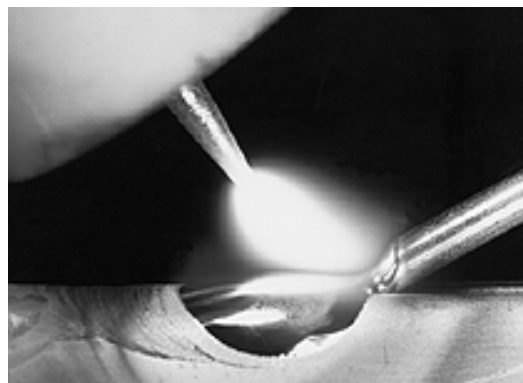
Figure. 2 The real welding with the TIG-method

It equally leads to bigger amount of experimental so-called validation welds, which are done before the welding of the real machine-parts and to increasing of the direct costs.

Figure. 3 The simulation of the TIG-welding of the specimen created in the SysWeld program, the temperature gradient in the time t = 0,5 s

The program SysWeld developed by the ESI Group company is based on the finite element method and it serves for the creation of the virtual numeric simulations of the welding (Figure. 3, 4) and of the heat treatment. The results of numerical analyses are temperature field, a distribution of the particular material structures, hardness in the HV units, a size of the austenitic grain, a total plastic deformation, a residual stresses and a global distortion of the welded units [4,5,6].


Figure. 4 The simulation of the TIG-welding of the specimen created in the SysWeld program, the temperature gradient in the time t = 1 s

The SysWeld is also able to solve changes of the chemical composition of the material emerging during the heating and cooling of the material.
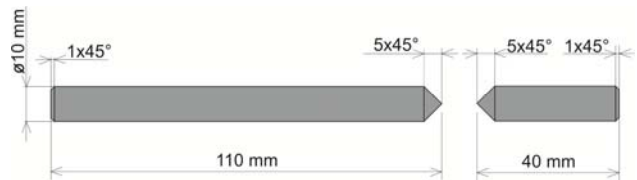
2. HE SIMULATION OF THE WELDING

The following was the creation of the FEM model of the weld of the workpiece (Figure. 5). For the solving of the issue, computer software called SysWeld, which belongs to the world's top of the programs for the complete solution to the issue of the weld joints, was used. If it was used the same shape of the welding area as that one, which was used during the practical welding (Figure. 6), there would be a problem with the creation of the FEM net, when very acute angles would arise in elements [7,10]. Therefore, the shape of the welding area was suiTablely adapted, which, though, does not have another influence (from technological aspect) on the creation of the weld joint, unlike that shape, which was used at welding. The only difference would be in more complicated creation of the welding area on the real workpiece. After the creation of the model, the simulation of the welding of the workpiece was carried out. (Figure. 7).
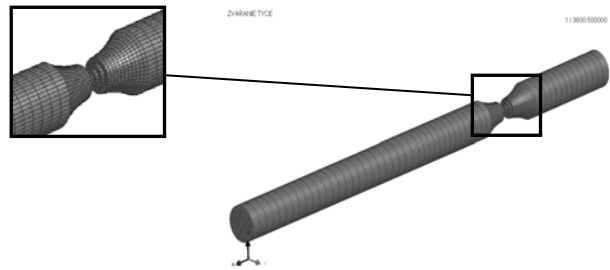
Figure. 5 The creation of the FEM model of the weld surface with the graduation,the simulation created in the SysWeld program

After previous experimental measurements it was found that it is this shape of the weld surface (Figure. 6) which is the most appropriate geometry because of the highest achieved tensile strength after welding of the specimens.

Figure. 6 Selected geometry of the weld surface of the specimen

The simulation of the welding was carried out. Temperature in the place of the contact of the electrode and the weld at the time t = 0, 5 s reached the amplitude 288° C. At that time cool ends of the workpiece had temperature 44° C.

Their heating is indirect, it arises through the conductivity, thus lead of the heat in the material. The conductivity depends on the coefficient of the thermal conductivity of the material λ. The more we increase the amount of the alloying elements in an alloy, the more the thermal conductivity of the material decreases. Aluminum itself conducts the heat very well, what is however in this case undesirable, because during the welding, the structure in the whole volume of the workpiece is overheating. Time of the welding of the workpiece was 30 seconds and of the simulation of the welding of the workpiece likewise. During that time, weld joint (Figure. 7) with the strength 166 MPa was created, what was proved at the previous measuring by the tension test [8,9].
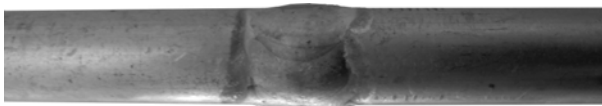

Figure. 7 Made weld joint

The arrangement of particular temperatures immediately after the completing of the welding is explained in the Figure. 8. Right after the welding, the maximal temperature was observed in the location of the weld. It has reached 410° C. The lowest temperature was at longer site of the workpiece from the weld joint and its value was 105° C.

Figure. 8 The temperature gradient during the welding in the time t =30, 5 s

After the production of the workpiece, only slow cooling itself had followed so that the manipulation with the workpiece was possible. This time was about 1 hour. The result of the welding is FEM model of the welded workpiece (Figure. 9).
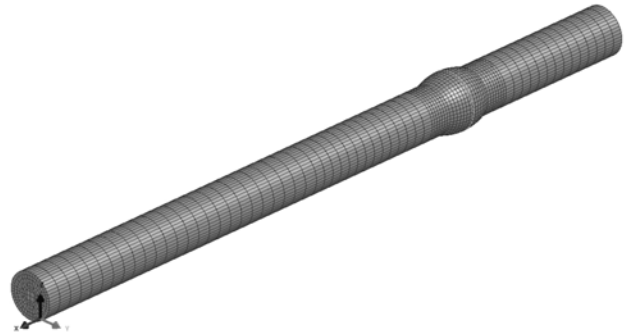

Figure. 9 FEM model of the welded specimen

On this analytic model the analysis for the displacement during the welding, changes of particular phases because of temperature and detection of the tensions at time was carried out. In the Figure. 10 we can see displacement in the nodes at time t = 29, 995 s, what is the time, when the biggest displacement on the workpiece during the welding was observed. The value of the displacement was 0,306 mm and the location of the occurrence was in the welding area, concretely on the limit of the meltdown.
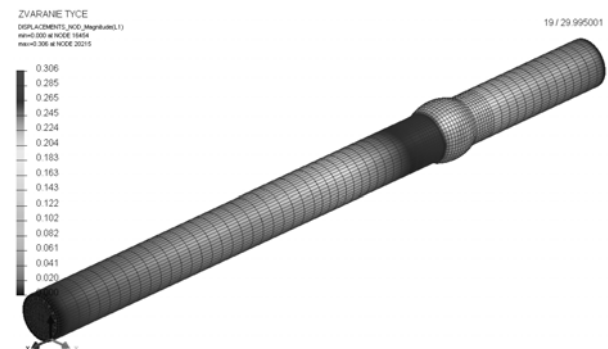

Figure. 10   FEM model of the maximal total displacements

During the welding, phases changed because of the temperature and different chemical composition of the basic and additional material, (Figure. 11), and those phases could stay in the volume of the workpiece also after cooling. Phase 1 represents the basic material, which was not influenced by the temperature during the welding – in the picture it is part of the workpiece with the pink coloration.
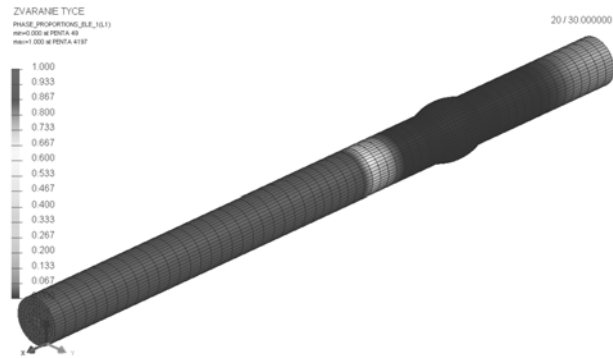
Figure. 11 Percentage of the phase 1 at the end of the welding of the workpiece, t = 30 s

After cooling to the temperature of 20° C change in the phase 1 was observed. It is from the reason that after the welding, weld bead still had high temperature, which, because of conductivity, spread to the material and influences the material by the heat (Figure. 12).
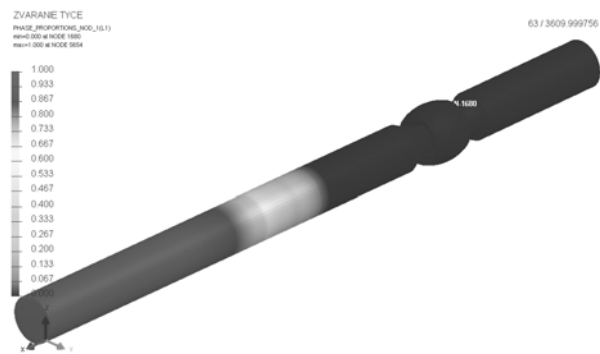

Figure. 12 Percentage of the phase 1 after cooling of the workpiece, t = 3600 s

Weld joint is created by two beads in the shape of a halfcircle. Phase 2 represents representation of the additional material and its influencing by the temperature in the bead No 1. The second halfcircle represents the second bead, which is a phase 3. After cooling, the representation of phases 2 and 3 in the workpiece will be looking like the Figure. 13 explains.
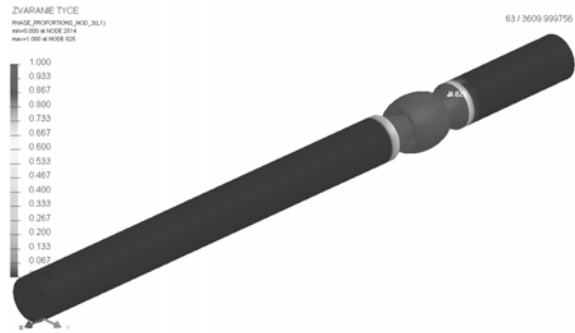
Figure. 13 Percentage of the additional material in the workpiece after cooling

The last phase in the workpiece during the welding is the heat affected zone
(Figure. 14). It is such a zone, which was not melted down by the given heat from the welding, but temperature field was so huge, that the structure has been changed. This was proved by the change of the hardness, when it decreased unlike the basic material (Table. 1).
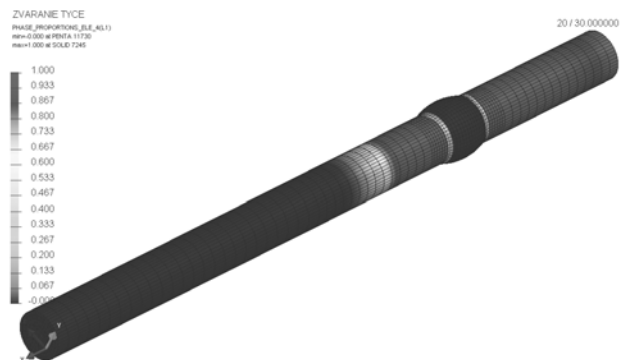
Figure. 14 Presentation of the heat affected zone in the workpiece

The measurement of the hardness of the basic material, heat affected zone and weld metal proved softening of the material (Figure.15) by the influence of the heat input towards basic material. Comparison of the hardness of the basic material with the weld is more complicated, because by the influence of the additional material which was AlSi5 alloy, change of the chemical composition occurs and so other value can be expected. This additional material was used because of the fact that the basic material AlMgSi07 is an alloy which is more difficult to weld. This additional material ensures a sufficient tensile strength of the weld joint.
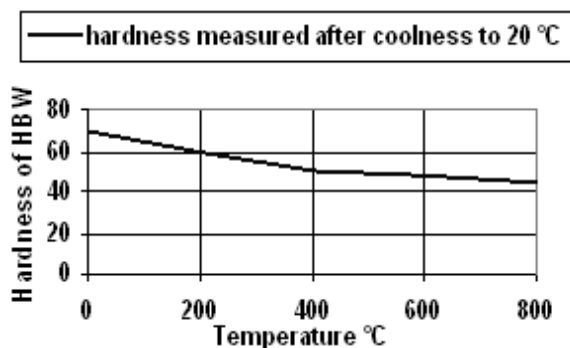
Figure. 15 Graphic dependence of decline of AlMgSi07 material's hardness from heating during welding

The change of the chemical composition, structure and hardness in the place of the weld are not the only changes, which occurs in the sample.

Tablele. 1 Hardness measuring specimen

Hardness measuring point					
Basic material		Heat affected zone		Weld metal	
Measuring number	Value HBW	Measuring number	Value HBW	Measuring number	Value HBW
1.	61	1.	52	1.	46
2.	69	2.	46	2.	48
3.	65	3.	50	3.	48

By the influence of the welding residual stresses may arose and also the strength may decreased in regard of formation of the cracks and other errors in the weld joint. Proof of these is an image of the microstructure of the weld joint (Figure. 16).
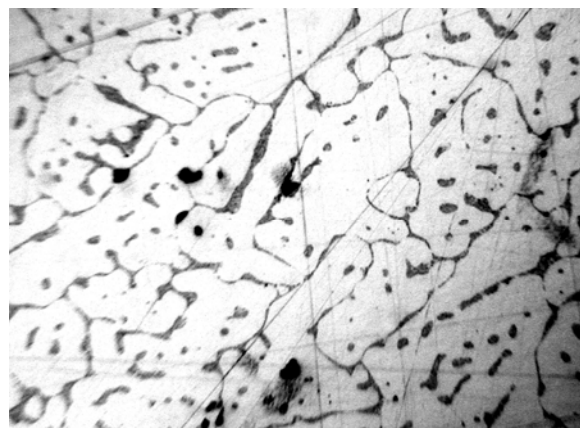

Figure. 16 Microstructure of the welded joint of the specimen

In the microstructure of the weld joint there are defects, which cause decreasing of the strength of the sample. The bigger is amount and size of these errors, the lower is strength. They are different seam, cavities and inclusions.

3. CONCLUSION

In this paper the simulation of the welding of the specimen from the aluminium alloy with the TIG - technology was carried out. By the comparison with the basic material there were detected changes, which arose by the influence of the welding. One of these changes is also possible formation of the residual stresses in the welded panel. These stresses will be the subject of the next research and detection of their sizes. It is important for assessment of the influence of the welding on fatigue life of the samples, which are manufactured for this research.

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