DETERMINATION OF STRESS AND DEFORMATION DURING LASER WELDING OF ALUMINIUM ALLOYS WITH THE PC SUPPORT

JOZEF MASCENIK, SLAVKO PAVLENKO

Department of Design and Monitoring of Technical Systems, Faculty of Manufacturing Technologies with a seat in Presov, Technical University of Kosice, Presov Slovak republic

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jozef.mascenik@tuke.sk, slavko.pavlenko@tuke.sk

The submitted paper deals with laser welding of aluminium alloys with the application of the computer support in the welding process. Currently, laser welding represents one of the most common processes as it allows accepting of high quality welds with minimal thermal zone in case of diverse materials such as steel, high-strength steel, aluminium or titanium. The use of computer support for the company is also very important in the welding process. To produce a successful product every modern company must use new methods of production control and monitoring such as modelling, simulations, information processing and quality control [Mascenik 2014]. This paper points out an application of computer support in the laser welding sphere, i.e. laser welding of aluminium alloys. At the same time the paper specifies aluminium alloys and points to determination of stress and estimate of the weld deformation by means of simulation in the program of SOLIDWORKS.

KEYWORDS

aluminium alloys, laser welding, stress, deformation, simulation

1 INTRODUCTION

Nowadays, the technology of laser welding is broadly used. However, the less known is the fact that laser welding of metals represents one of the latest methods of creation of integral joints. It is characterized by exceptional precision, performance and high quality of weld. Metal heating and melting in the working area is carried out by a laser ray. The method allows welding of heterogeneous materials. Despite high costs and complicated equipment, the popularity of the method has been increasing. The equipment has become available for home workshops [Dobransky 2019].

Aluminium alloys are used in different branches of industry owing to rare combination of properties: low density in case of high values of specific strength, corrosion resistance, and heat conductivity. According to relation between elasticity, strength and density the high-strength aluminium alloys predominate over low carbon steel and low-alloy steel, pure titanium and worse than high-alloy steel with high strength and titanium alloys. The laser welding process of aluminium alloys is related to a number of properties which influence technology, selection of method, of modes and of properties of weld joints. This is also a significant reason for using computer support [Gaspar 2013].

2 LASER WELDING

The term "laser" originated as an acronym for the English Light Amplification by Stimulated Emission Radiation. It is a source of coherent electromagnetic emission of optical range which is based on the use of induced emission of light through the system of excited atoms, ions, molecules or other particles of substance (of an active medium) occurring in an optical resonator.

The first working solid-state ruby laser was discovered by Theodore Mayman in 1960. His work was based on Einstein´s work from 1917 which proved possibility of effect of laser emission. Laser consists of gas or crystallic medium stimulated by the energy source which emits the waves of identical length that are in the phase as well. By means of mirrors the part of emitted light gets reflected back to atmosphere. Nowadays, hundreds of types of commercial lasers exist, yet available are only CO2, Nd: YAG, excimer and diode lasers with capacity high enough to be used in case of manipulation with materials.

Lasers suitable for welding include neodymium-doped yttrium aluminium garnet (Nd: YAG), fibre and diode. Each of them offers unique functions which get adapted to particular applications. Pulsed laser Nd: YAG represents the largest installation base with maximal performances and width of pulses proposed for microwave welding. For instance, pulsed lasers Nd: YAG ranging from 25 up to 50W are commonly used for welding of 0.015-inch weld joints. Lasers with fibres having been developed recently offer extraordinary flexibility in case of adjustment of welded dimensions and the best penetration performance per watt which allows high-speed welding. 300 W lasers can weld with thickness of 0.01 inch with dimension of 2 inch per second and 20 W pulsed lasers can produce point welds with diameter of 0.001 inch in a foil thicker by 0.001 inch. Architecture of fibre laser is the shaping one with laser forces available on multi-kilowatt levels which are used in case of penetration welding with thickness of up to 0.25 inch [Coranic 2019].

A diode laser is a well implemented laser technology which is used in case of a number of applications of plastic welding, especially in automotive industry for welding of rear light, for example. Plastic welding by lasers represents current sphere of growth related to development of plastics and lasers which can weld plastics. Recently, the diode laser has been available on multi-kilowatt levels suitable for welding of metals [Majernik 2018].

3 ALUMINIUM ALLOYS

The most common and widespread metal in the earth crust is aluminium with the weight of 8% contrary to 5.8% which is weight of iron. It is gained from bauxite containing 50% of hydrated aluminium oxide as well as ferric oxide, silicon dioxide and titanium. As the production of primary aluminium is energy-intensive, it is very important to use it. The colour of aluminium can be easily changed and recycled to make a new product therefore it represents material ideal for processing. Low density of aluminium is one of the main reasons of used in automotive and aviation industry [Mascenik 2016].

The increase of use of aluminium in welding production industry and its acceptance as excellent alternative of steel for a number of applications results in increase of demands related to those who participate in development of aluminium projects to get acquainted with such group of materials. In fact, seven series of wrought aluminium alloys are known. If diverse series of aluminium alloys are taken into consideration, it becomes obvious that considerable differences do exist in case of their properties and consequent use. The first point of recognition after understanding the identification system is that within the frameworks of the given series there exist two types of distinctively different types of aluminium. It is the case of heat-treatable aluminium alloys and alloys of anti-corrosion treatment of aluminium. Such distinguishing is important especially in assessment of influence of arch welding in case of these two types of materials. Serial aluminium alloys of type 1xxx, 3xxx and 5xxx do not rank among the heat-treatable ones and they are stress resistant. The series of aluminium alloys produced in series 2xxx, 6xxx and 7xxx rank among the heat-treatable ones and the 4xxx series consist of heat-treatable and incombustible alloys. Alloys of alloys 2xx.x, 3xx.x, 4xx.x and 7xx.x are heat-treatable. Heat-treatable alloys obtain optimal mechanical properties through heat treatment process and solution heat treatment is the most common one. Solution of heat treatment is the process carried out by increasing the alloy temperature to have alloying elements or compounds dip into solution. Consequently, water quenching follows during which oversaturated solution is produced at indoor temperature. Deformation bonding represents the method of increasing the strength by cold treatment [Straka 2020b].

4 LASER WELDING OF ALUMINIUM ALLOYS

Further particularity of aluminium is aluminium oxide which automatically reaches the layer of 10-20 nm (medium thickness) on the surface of aluminium sheet. If the layer is removed by milling, for instance, it shall be instantly generated again. Natural surface oxide prevents strong material from corroding which means that aluminium can stand humidity and saline medium 100 times better contrary to steel and 15 times better than zinc coating. Melting temperature of surface oxide is of 2050°C and therefore if aluminium oxide melts during welding, oxide remains solid in the form of oxide fragments. If welding temperature is not high enough for oxide to melt, defects or malfunctions may occur such as incorporation into weld re-approval [Straka 2020a].

Physical properties of aluminium are unique in a high degree. The first property is its density which can be applied in case of steel. The second property is heat conductivity which is three times higher than conductivity of steel. The second property is protective surface oxide. The aforementioned physical properties along with all other ones are important in case of laser welding. Welding errors represent the main cause of defects and malfunctions of welded structures and thus they must be avoided. The final proposal of a European standard on laser welding of aluminium has been in force since December 1999 and it describes quality levels for imperfection. For the highest quality level, which is rather strict, precisely defined requirements must be met [Krenicky 2012].

5 APPLICATION OF COMPUTER SUPPORT IN LASER WELDING

Welding industry has been developing dynamically along with the latest technological trend. Such technological trend has been constantly improving the quality, precision and versatility of welding processes. Nowadays, welding process is a high-tech skill which uses powerful lasers, electron beams and sometimes explosive materials for metal bonding. Computers have become an inseparable part of welding processes. Computer systems are traditionally used in welding technologies for modelling, for device control, for production support and production monitoring and currently they are becoming rather important tools for information processing and quality control [Balazikova 2019].

Computer technologies have contributed to improvement of welding productivity and quality. Effective harmonization of technologies and economy has helped determine the best production conditions. It has led to development of more effective modelling approaches which increased productivity and quality. Simulation processes include determination of project requirements, complexity of welding properties and requirements related to welding documentation [Metalcutting 2020].

Some of the methods by which computers facilitate work of welders include the following:

- Possibility of easy selection of material and method of welding by computer technology and by complicated simulations which detect the slightest changes in parameter of proposal with high definition.

- Solution of complicated issues: to find solutions for complicated and unclear problems is a significant task prior to rise of artificial intelligence and operation analysis. Simulated solution of annealing represents one strategy of solution which shall hep find exact solutions of such complicated issues. Therefore, the best and the most optimal solution of every complex issue is the use of computer mathematical methods.

- Engineering estimate of calculated results shall be calculated again by computers. It helps achieve exact results, determine exact expectations and prospects of modelling tools for higher production quality [Dobransky 2011].

5.1 *Determination of Stress and Weld Deformations*

By means of the programme of SOLIDWORKS Simulation it is possible to locate distribution and extent of stress in and around the weld as well as the corresponding weld size. However, the calculated stress occurs as the result of a force acting upon welded elements yet not due to the heat influence which is many times more important from technical point of view [Krenicky 2008]. For simulation, the proposed length of welded joint was of 100 mm and proposed welding speed was of 0.3 m/min out of which it is clear that welding time shall reach 20 seconds.

Prior to very simulation it is inevitable to set up parameters in the programme in the module of thermal study. In case of properties we change type of solution of transfer and total tome of monitoring to 21 seconds with one second for welding start. Consequently, both welded materials were defined.

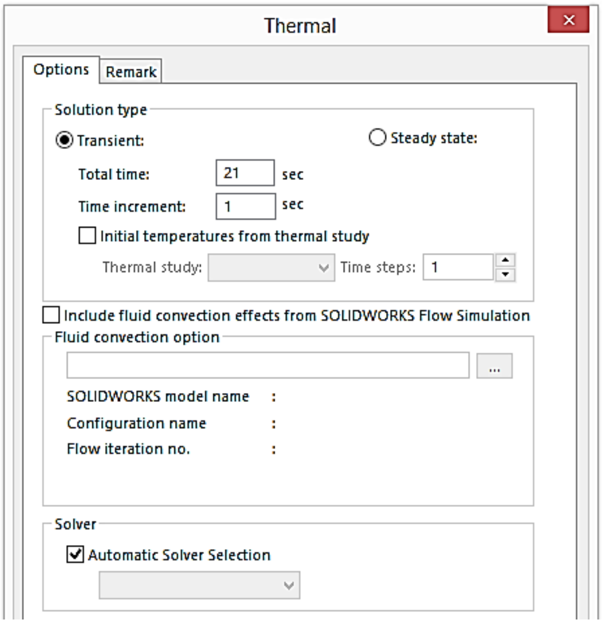

Figure 1. Setting up of parameters in the "Thermal" module

Two types of heat load have been generated. In case of the first heat load the initial temperature is selected and set up to 20°C. For the second type of heat load the heat performance of 2000W is applicable. In this case we use the time curve which is set up as follows: in case of x = 0 (the second one 0) y = 0 (without heat load) in case of x = 1 (the second one 1) y = 1 (heat load of 2000W) in case of x = 2 (the second one 2) y = 0 (without heat load). This operation must be repeated for all weld parts with correct synchronization (Fig. 2).

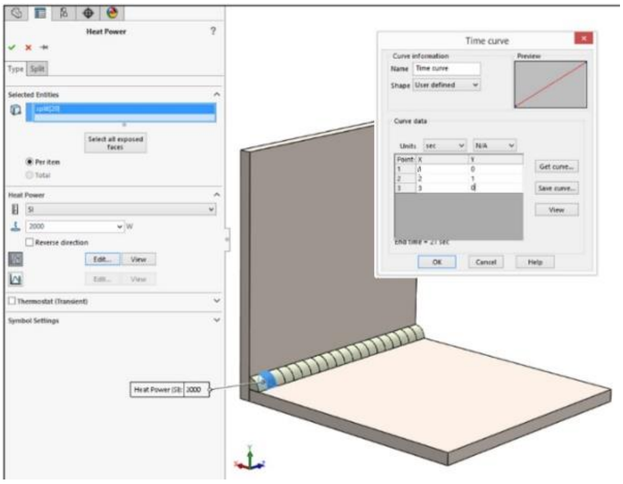

Figure 2. Definition of heat load on the second welding level

After setting up the parameters on the individual levels, it is possible to trigger simulation in the programme for the total time of 21 seconds. The results of the first analysis are shown in the following figure (Fig.3).

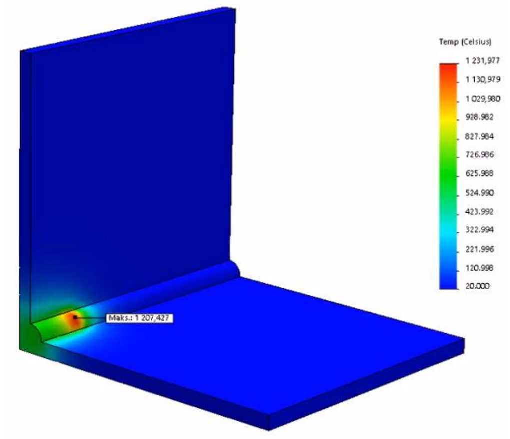

Figure 3. Result of the 1st analysis

Finally, nonlinear study is carried out: end of step time must be set up to 21 seconds with permanent time prolongation to 1 (Fig. 4).

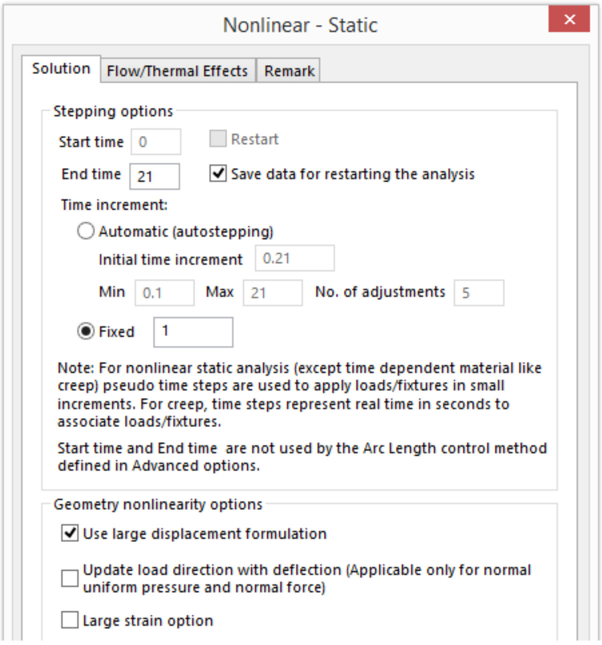

Figure 4. Properties of nonlinear simulation (setting)

On the Flow/Thermal Effects Card it is inevitable to select temperature form the option of thermal analysis (Fig. 5). A global contact is added and solid geometry is defined on the bottom area of a plate and then the simulation is performed [Coranic 2018].

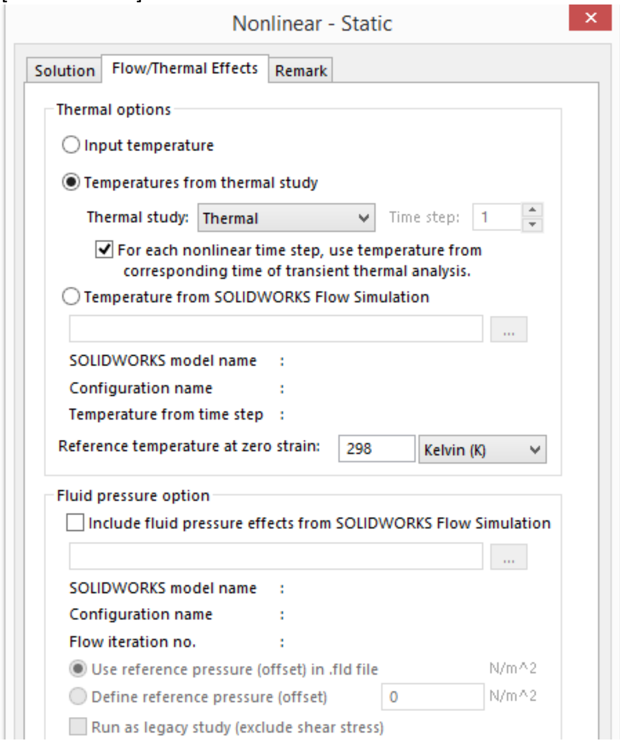

Figure 5. Properties of nonlinear simulation (Flow / Thermal Effects)

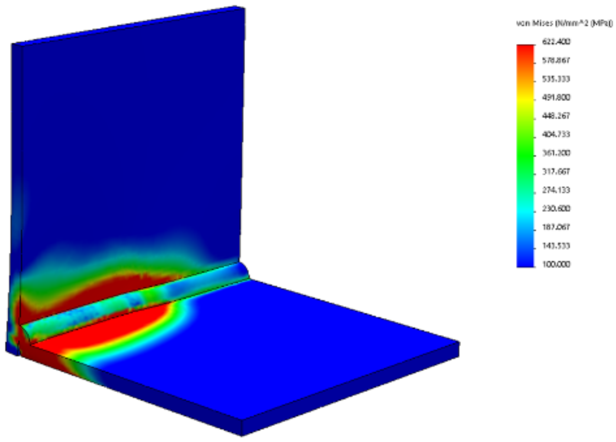

Figure 6. Graph of stress during the 10th second

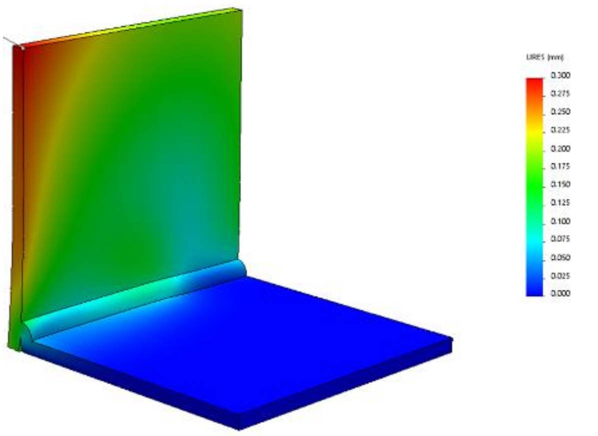

Figure 7. Graph of deformation (illustration of simulation) during the 13th second

In consequence of simulation we can analyse distribution of stress during the 10th seconds, for instance (Fig.6) and the sphere of deformation can be analysed during the 13th second, for instance (Fig.7).

6 CONCLUSION

Computer support is very important in production process because welding of aluminium alloys by laser is connected with a number of properties which influence technology, selection of method, of modes and of properties of weld joints. To obtain high quality weld joints a thorough preparation of surface for welding is required. The basis rests in correct selection of welding parameters. In welding of aluminium alloys the crystallic structure and mechanical properties of metal joints change in relation to alloy composition, methods and parameters of welding. Combination of high reflection coefficient, heat conductivity and heat capacity of aluminium leads to a need to carefully select optimal modes of laser welding of aluminium alloys. Using the programme SOLIDWORKS Simulation it was detected that the stress having occurred during welding was more precisely distributed and the corresponding weld size was as expected. The results of complete research can help create better idea of weld effect upon bound materials and at the same time it points to possibilities of application of computer support even in case of this issue.

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CONTACTS

M.Sc. Jozef Mascenik, PhD.
Department of Design and Monitoring of Technical Systems, Faculty of Manufacturing Technologies with a seat in Presov, Technical University of Kosice, Presov, Slovak Republic
Bayerova 1, Presov, 080 01, Slovak Republic
+421 51 772 6337, jozef.mascenik@tuke.sk, www.tuke.sk