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IMPROVEMENT OF PRODUCTIVITY IN AL WELDING

A. Stepanov, A.Laansoo

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Abstract: *Share of welding Al and Al alloys in Estonian enterprises is increasing, in shipbuilding and automobile industry subcontracting. Creation of a new high strength alloys demands implementation advanced and cost-effective welding processes with high productivity. Productivity and quality of welding ship components in two enterprises are improved by using mixture of Ar and He shielding gases. Increasing He content up to 70% provides higher heat and depth of welds and reduce number of defect Optimal cross section of welds was obtained. A new mechanical welding process – friction stir welding (FSW) was implemented for welding Al components. Training of welders, development of appropriate welding procedures are essential in implementation new engineering materials.*

Key words: welding of Al, MIG, TIG welding, FSW, shielding gases, productivity

1. PRESENT SITUATSION

During the past years, the products of Estonian machine manufacturing, ship repair and metallurgy industry have become more varied. In addition new enterprises have also been established in the fields of road vehicle construction, train construction, special purpose ship construction. This has brought about implementation of new technologies, new materials and also new quality requirements for the products.

The development of the companies of Estonian engineering, shipbuilding and metalworking industry has contributed to the growth of capacity both in general production and export to European Union member states by 5 to 10 % each year. According to the data provided by the Estonian Statistical Office, the relative importance of handling sector has grown gradually approximately. 7-9 % in the year. Export constituted almost 60% of the production.

In order to stay competitive on the international markets, productivity needs to be improved. This problem is being more and more discussed in Estonia. The following diagram shows the developments of enterprises in this industry sector.

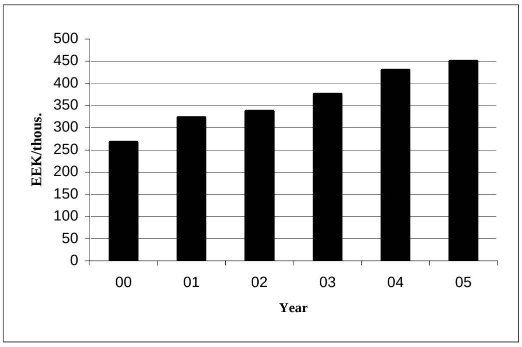

Fig 1 Efficiency of enterprise

As can be seen, the efficiency of enterprises has increased by approximately 35-40% in the last 5-6 years (e.g. [8]). This is a good result, but many experts believe that in the next five years, the productivity and efficiency has to increase by at least 200%. A prerequisite for such an increase is more complex products and more up-to-date technologies.

2. PRODUCTIVITY IN ESTONIAN WELDING INDUSTRY

The annual net turnover of labour force productivity per employee in the Estonian engineering industry has been increasing year by year and has reached the level of 1 million EEK in several enterprises (e.g. [5]). As a whole, the labour force productivity in machine building industry enterprises increased by 14% during the year 2006. At the same time, the competitive abilities of machinery industry enterprises are showing a low increase, as the growth speed of productivity is often on the same level with the growth speed of labour force expenses. In many enterprises, the number of employees decreased by 1-5%. The way to increase labour force productivity in the conditions of limited labour force resources is to develop technological processes, using more productive and more efficient processing methods and new modern materials and developing more complex products with higher additional value. In welding production, this means transitioning to use of more expensive and technologically more complex materials, like high-strength and highly refined steels and aluminium alloys, and also participating in co-operation networks. These materials require the implementing of strict welding procedures and high personnel qualification, and optimum use of pre-heating and follow-up thermal processing. A continued growth of welding works is estimated to take place in the world wide scale. The future visions of the American Welding Society for 2020 estimate an increase of the volume of welding works by up to 25%, a decrease of the cost of welding operations by 33% and a decrease of the energy costs by up to 50%. An increase of welding productivity by up to 100% is hoped to be achieved from increase of welding speed, from decrease of welding defects and their elimination expenses, from improving of welding procedures, from developing control methods and from decrease their volume. The productivity of welding production can be assessed via welding speed or via the amount of metal deposited – the deposition rate. The calculation of labour force expenses is based on the time spent on welding. Labour force expenses and other expenses are depending on duty cycle or operating factor, which is the rate of time of welding arc and total paid time This rate can be improved by using work pieces with better quality, by decreasing the time spent on picking and tacking the work pieces, with decreasing the amount of welding deformation, and with decreasing the time spent on setting up welding parameters. This can be achieved by using machine welding and automated welding processes.

Implementation low cost automation of welding processes by using workpiece manipulators (welding positioners, rollers, welding head carries) can improve operation factor from 20-35% up to 50% (MI/MAG welding).

There are many enterprises in Estonia active in welding of aluminium products. This includes, for example, construction of special purpose aluminium bases, sub-contracting for road vehicle construction, sub-contracting for train construction. Presently, the share of enterprises dealing in welding Al and Al alloys in the total number of enterprises in Estonia is increasing very rapidly. The specialists of the Welding Society of Estonia have the opinion that in the last 3-4 years this share has increased 4-5 times (e.g. [9]).

Two of these enterprises are specialised solely on aluminium welding, mainly for manufacturing of ships ad ship segments.

Aluminium welding is more complex and differs from steel welding. The oxide layer on the surface of aluminium details absorbs moisture, and this can cause defects and pores to appear. Also, due to higher thermal conductivity of the material, pre-heating is often needed, especially when

welding thicker work pieces. The temperature of preheating must be controlled precisely. In using arc welding processes, hot cracks can form in the welding seam or in the vicinity of it, and avoiding this requires a very careful selecting of filler materials and control thermal cycle of welding. Theoretically, the pre-heating workpieces can be avoided by using high energy input welding processes, i.e. so-called thermal input welding processes. In MIG welding, the welding defect characteristic to this welding method can appear – lack of side wall fusion, and this could be avoided by increasing the welding energy and by using more precise movements of the welding gun during the welding process. The high thermal expansion rate of aluminium brings about larger distortions and cracks of welded sections, and this means required use of welding fixtures and special techniques in order to decrease such deformations. In view of the above stated circumstances, it can be said that mechanical welding processes with heating of the material below its melting point would be well useful. Also, Friction Stir Welding (FSW) is beginning to be used in the world wide practice (e.g. [6]).
This solid state welding process was invented in 1991. The process is based on rotating tool. Problems with hot cracking and porosity are eliminated, and residual stresses and distortion are greatly reduced.
Also, there is no need for welding materials and shielding gases, and no need for special training of the welding personnel. FSW machines are commercially available.
Arc welding processes- metal inert gas welding also referred to as MIG with process number 131 and TIG, with process number 141 have been widely implemented.
Welding productivity and welding arc power can be increased significantly by adding helium to argon, in the amount of 30-50% and in certain cases even in the amount of 70%. As the heat input increases, it becomes possible to weld also thicker workpieces without preheating, thus decreasing the defect of lack of side wall fusion. This improves welding speed and welding productivity. This Thesis deals with possibilities for improving welding productivity in two Estonian enterprises in welding different types of aluminium alloys .

3. DEVELOPING OF TECHNO-LOGIES

The processes accompanying welding are a big prerequisite for improving the productivity. In the following, such activities affecting productivity are shown that must get attention in a welding enterprise.

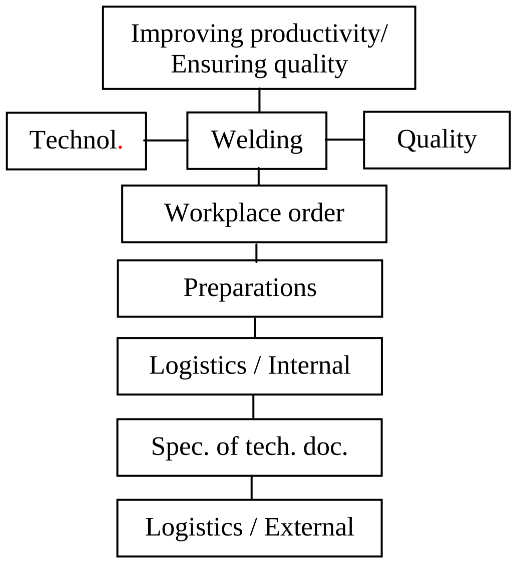

Fig. 2 Improving productivity/Ensuring quality

As shown on the scheme, the preparation processes have a significant role. Exact supplies of materials and smooth co-operation with suppliers enable savings of over 50% of the time spent on manufacturing of the products. Additionally, workplace order and routes within the enterprise ensure a significant saving in time spent (e.g. [4]). Also, the technical documentation and the relevant specifications must be correct and clearly legible. Both the preparations made by engineers and by welders and helpers have a deciding role.

Upon increase of the share of welding of Al and Al alloys, the 141 and 131 welding processes have been implemented widely, whereas Ar and He mixtures with rates of 30% Ar, 50% Ar and 70% Ar are used in welding of 3 mm and thicker materials, in order to improve productivity. Additionally, FSW technology is used. The most used materials in production after common Al (grade 1200 according to EN 573), AlMg and AlMgSi alloys (grades 5754 and 6082 according to EN 573) (e.g. [2]).

In case of products with the welding process determined by the designer, for example the use of Ar and He mixtures is implemented for the 141 welding process, with the maximum ratio of 70% He. The use of this mixture allows for increasing the productivity by approx. 30-40%, compared to using 99.9% Ar. Also in case of the 131 welding process, when making long welds, the 70% He mixtures are used. This allows for increasing the productivity by 25-35%.

Fig. 3 Cross-section of TIG weld

As productivity and quality must coexist, the choice of technology to be used must be based on both these aspects. If there is a requirement for a one-sided weld with a full penetration , and the welding method is also determined by the designer due to calculation reasons, then often the 141 welding process is used. This ensures a better root penetration welding and a better cleanliness of the weld. A macro-grind section of such a weld is given in the following picture (thickness 10.0 mm and material according to EN 573 6082 T6) (e.g. [4]).

As can be seen from the picture, this is a multilayered weld. This specific weld has been made by 12 runs. The following picture shows a macro image of a similar material used in a technology test of ship construction (thickness 10.0 mm and material according to EN 573 5083 H 111). This is a three run (bead) weld.

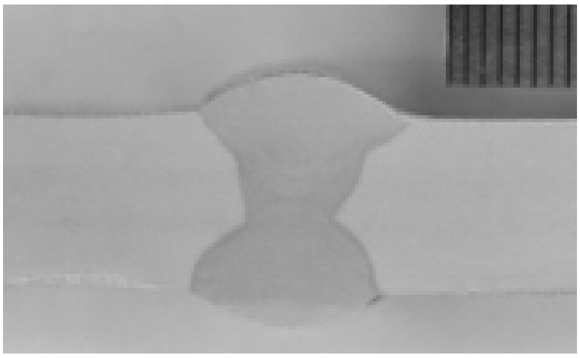

Fig. 4 Cross-section of MIG weld

Thus it can be concluded that different technologies with materials of the same thickness yield different welding times in multiples.

The shortcomings of this method are high prices of equipment, complexity of harnesses and applicability of the technology to only a certain type of welds.

In the following, a comparison is given about single run butt welds(BW) of 3.0 mm thickness made different (141, 131, FSW) welding processes. Optimal welding parameters used in tests were:

MIG welding

-arc voltage 20-22 V, welding current 110-130 A

TIG-welding

-arc voltage 14 V, welding current 70-80 A. electrode diameter 2.4 mm

Table 1 Welding parameters / welding productivity –welding speed

Welding process	Welding position	Welding speed cm/min
141	PA	15
131	PA	40
FSW	PA	80

In addition to this example, the possibilities for optimising the welding process 141, using equal welding parameters, have been studied. One option is to mechanise the process, i.e. auto use uninterrupted feeding of welding wire and helping holders for turning the welding detail. This would result in a time improvement of nearly 2 times upon manufacturing the detail. These are but some examples of developing the welding technologies. The most important role in improving the productivity of a welding enterprise lies in complex management of circumstances.

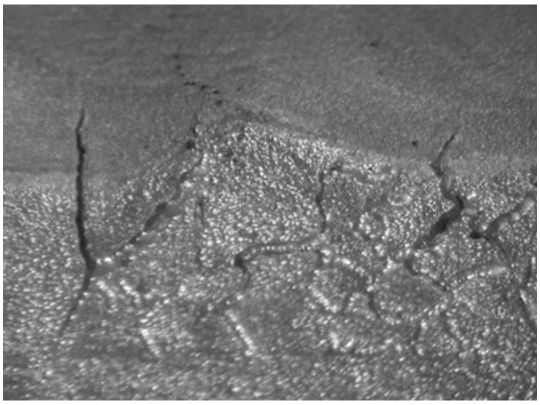

Fig. 5. Cracks in Al alloys welds

The peculiarities resulting from the different properties of materials are a very important factor in optimising the technologies. In this research, the most well known of these is the heat input resulting from welding and resulting in structural changes and stresses within the welded material. This results in various cracks (Fig.5) and defects, also depending on the nature of the welded material. For example, one of the problems is macrostructure of AlMgSi T type welding seam, described below in this document. Upon welding Al alloys (group 23), it is extremely important to take into account the minimum heat input, the cleanliness of welding, and the temperatures between layers. Depending on material properties and the standard EN 1011-4, the maximum recommended temperature between layers is 100 °C. But in case of the welding seam studied, this was not observed and so microcracks appeared.

Quality assurance is also very important in improving the productivity. For this, it is unavoidable to conduct technological tests. Upon implementing new technologies, the WPS (welding procedure specification) approval is important. In case of more complex welding seams, work tests are also needed.

Welders of have been trained and qualified according relevant standards in Tallinn Training Center.

Approval of welding procedures and welding procedure tests different Al alloys groups with different thicknesses have been carried out by according relevant ISO standards.

In welding of Al and Al alloys, it is important to use optimum technology according to the requirements stated for the product. It is important to assure the quality of welds. At the same time, higher productivity ensures a competitive edge of an enterprise.

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4. RESULTS AND CONCLUSION

The results of the study conducted for this Thesis show that Estonian enterprises are paying more and more attention to modern, innovative technologies, implementing environmentally friendly processes.

In aluminium and aluminium alloys welding, mixtures of argon and helium have been implemented as shielding gases. This has resulted in an increase of productivity and decrease of amount of welding defects.

Quality assurance is also very important in improving the productivity. For this, it is unavoidable to conduct technological tests. Upon implementing new technologies, the WPS (welding procedure specification) approval is important. In case of more complex welding seams, work tests are also needed.
Implementing modern technologies(FSW) in aluminium and aluminium alloys welding allows in some cases for avoiding the pre-heating stage, thus resulting in an increase of productivity.
Timely WPS preparation and approval, continually welding personnel training greatly facilitates the implementing of new technologies

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6. CORRESPONDING ADDRESS

Aleksandr Stepanov
M.Sc. EWE, Project Manager, Tallinn Center of Industrial Education
Sõpruse pst. 182, 13424 Tallinn, Estonia
Phone: +372 511 46 28
Fax: +372 603 00 58
E-mail: aleksander@tthk.edu