ATLANTIS PRESS

Advances in Engineering Research (AER), volume 157

International Conference "Actual Issues of Mechanical Engineering" (AIME 2018)

Trend of Application of Automated Welding Process of Cold Metal Transfer in Structures Made of Aluminum Alloy

I.E. Arzhannikova Postgraduate student
Orenburg State University
Orenburg, Russia
e-mail arzhannikovaie@mail.ru

N.Z. Sultanov Doctor of Technical Sciences, Professor
Orenburg State University
Orenburg, Russia
e-mail Sultanov@mail.osu.ru

***Abstract*—The urgency of the investigated problem is caused by the need to improve the quality of welded joints of aluminum thin-walled structures of aerospace engineering. The purpose of the article is to substantiate the application of automated welding technology with the process of cold metal transfer for butt joints of thin-walled structures made of AMg6 aluminum alloy. Comparative analysis is the leading method in the study. The article describes the optimal welding regime for welded joints with a thickness of 2.0 mm and the obtained values of performance indicators. The performed research works established that a new welding technology could be effectively used for thin-walled aerospace structures. The article materials could be useful in the implementation of the new welding method for obtaining the quality welding joints of thin-walled structures.**

***Keywords*—welded joints, aluminum alloy, cold metal transfer**

I. Introduction

Nowadays only using the latest technologies makes it possible to solve the problems of mastering advanced models of modern equipment, to withstand tough competition in the world market.

Currently welding of aluminum alloy structures is traditionally carried out by manual arc welding with a non-consumable electrode (TIG).

The structures of AMg6 are to be deformed due to a relatively high coefficient of thermal expansion during welding. Reduction of deformations in structures can only be achieved by choosing a welding method and technological techniques that reduce deformation.

In welded joints, the aluminum alloy AMg6 is capable of retaining up to 95% of the strength of the base metal at high ductility and corrosion resistance [1]. In this case, for sheet metal constructions, as a rule, the technology of manual arc welding with a tungsten electrode under argon is used [1, 2, 3]. It should be noted that in traditional technology of arc welding with a tungsten electrode, the problem is repeated defects of welded joints - pores, a chain of pores and tungsten inclusions as a result of manual welding. Additional operations are required: X-ray inspection, defect removal, welding of the defective area, and repeated X-ray inspection. A typical problem is the low welding speed, which is an average of eight meters per minute, depending on the skill and qualification of the welder. The lack of highly qualified welders in the labor market does not allow one to correspond to the regulatory documents on welding technology. In addition, the welding speed is influenced by the deposition rate of the welding wire and the welding current, which arbitrary increase leads to overheating of the workpiece surface. The above-mentioned problems of technology slow down the production process, reduce productivity, increase costs and time for the output of the finished product [2, 3].

The problems existing for the traditional arc process up to the present time can be removed by applying the arc welding process with the transfer of metal not through the arc, but with an entirely new method of tearing off the drops of molten metal of the electrode wire [2, 3].

The process of cold transfer of metal Cold Metal Transfer (CMT) in welding with a consumable electrode is a completely new welding technology, which is based on a controlled low heat input. This is a controlled arc welding process with metal transfer by the method of tearing off molten metal drops of an electrode wire [1], which is automatically supplied to the product before a short circuit occurs. At the moment of closure, the wire is retracted until the drop of molten metal separates. After separating the droplet, the wire is fed again forward towards the product, and the process is repeated. The frequency of the wire vibration is up to 70 Hz. The thermal effect varies from hot to cold, and vice versa. As a result, the average temperature is much lower than in the process of arc welding by a non-consumable electrode. In general, the time of heat supply to the welding seam is shortened. The CMT process is characterized by a lack of spatter and a stable arc burning, less heat and penetration. As a result, during welding, the mixing of the welded layer and the base metal is much less than in the case of arc welding by a non-consumable TIG electrode [2]. This guarantees a reduction in time and a two-fold decrease in the consumption of filler metal.

Research work on justifying the use of advanced automated welding technology with the CMT process is sought-after direction in solving the problems of the TIG technology used for the construction of aerospace structures made of aluminum alloy [4, 5].

The aim of the work is to substantiate the application of the automated welding technology with the CMT process for thin-walled structures of AMg6 aluminum alloy.

II. REZULTS

The welding experiment was carried out using a new method of detaching droplets of molten metal electrode wire on samples of 300 * 300 mm in size AMg6 alloy on the Fronius TPS 5000 CMT MV power supply. Comparative analysis is the leading method in the study. Comparative tests were performed on butt-welded joints of samples measuring 300 * 300 mm, made by two methods of welding: a consumable electrode with a CMT process and a non-melting tungsten electrode TIG. The welded plates of 150 * 300 mm of AMg6 alloy were taken from one batch with a thickness of 2 mm. The joints were assembled at the stand and fixed with pneumatic clamps. Welding joints were made without cutting. The chemical analysis of welded plates and welding wire was carried out [4].

Welding was carried out at the optimal for each mode conditions selected based on good gas protection conditions, process stability, uniform filling of the forming liner and formation of the seam bead. While welding the ten samples made by arc welding with non-consumable tungsten TIG electrode, maintained mode: arc voltage 14 V, welding rate 0.002 m/s, the flow rate of protective gas (argon) 0.13 l/s, the current 80-85A, power supply TIR 315, thickness of tungsten electrode 3 mm, welding wire AMg6 2 mm. When welding ten samples made by welding with the CMT process, the optimum regime was maintained, the data obtained are shown in Table 1.

TABLE I. OPTIMUM WELDING MODE WITH CMT PROCESS

Welding current, A	*Arc voltage, V*	*Welding rate, m/s*	*Argon flow rate, l/s*	*Diameter of welding wire, mm*
95	14.5	0.013	0.16	1.2

Mechanical tests of all welded joints and base metal were carried out. The base metal was tested along the rolled metal. For each welding method, the macrostructure of the joint, the microstructure of the joint, the joint fusion zone, the transition zone of the fusion of the seams with the base metal, the microstructure of the base metal were studied. To identify and evaluate the factors directly influenced by the properties and performance of the welded joint, we conducted studies of macrostructure, microporosity, crystallization features, microstructure and chemical composition. The variety and number of defects in the welded joints was studied [4].

The chemical analysis of the base material for Mg content showed 5.8% in the TIG sample, 5.92% in the automated CMT welding.

Samples for mechanical tests were made in accordance with GOST 6996-66. Mechanical tests of the base metal on the temporary tear resistance were carried out. Based on the test results, the calculation of the average values showed that the permissible percentage of the base material is 0.9% closer to the properties of the base metal while welding with the CMT process [4].

To conduct metallography, scanning electron microscope JCM-6000 was used. The macrostructure of welded joints of AMg6 alloy samples under manual arc welding with a non-consumable TIG electrode and a consumable electrode using the CMT process is shown in Fig. 1. The sample obtained with the use of CMT possesses the greatest density from macrosections of samples. In the samples obtained by manual arc welding with non-consumable TIG electrode, oxide foams are found [4].

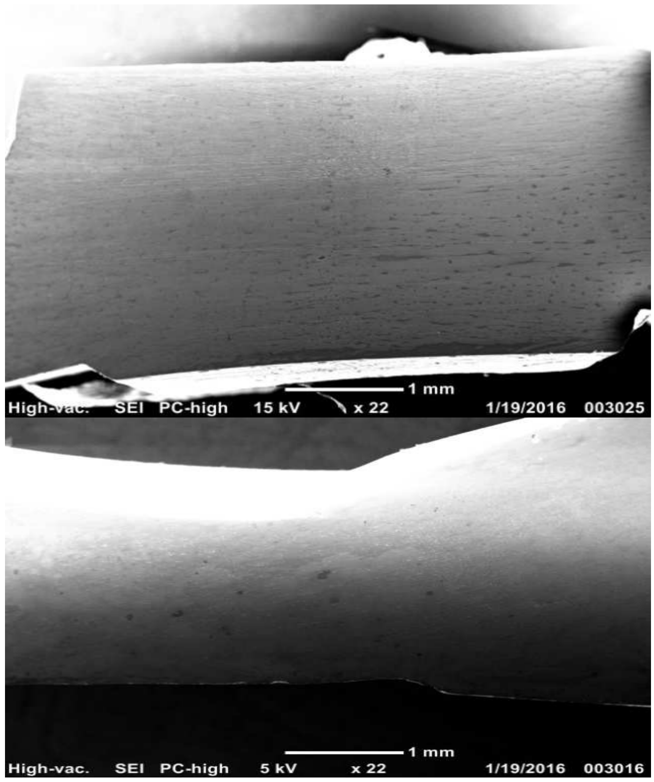


Fig. 1. Macrochips of samples made by arc welding with non-consumable tungsten electrode TIG (from below), welded with a consumable electrode with the CMT process (from above)

Analyzing the results obtained, it can be concluded that when welding with a consumable electrode using a new method with minimal overheating of the droplet and bath metal, a finer-grained structure of the weld metal, much less porosity and microporosity are observed. This is due to the minimum overheating and the shorter crystallization time of the weld metal [4]. The revealed factors significantly influence the increase of the strength properties and the density of the weld metal and the butt joint as a whole.

Preparation and etching of microsections of welded joints of AMg6 alloy samples was carried out according to the accepted procedure for manufacturing aluminum sections in acetic-chlorine electrolyte. Microsections of welded joints of the best samples are shown in Fig. 2.

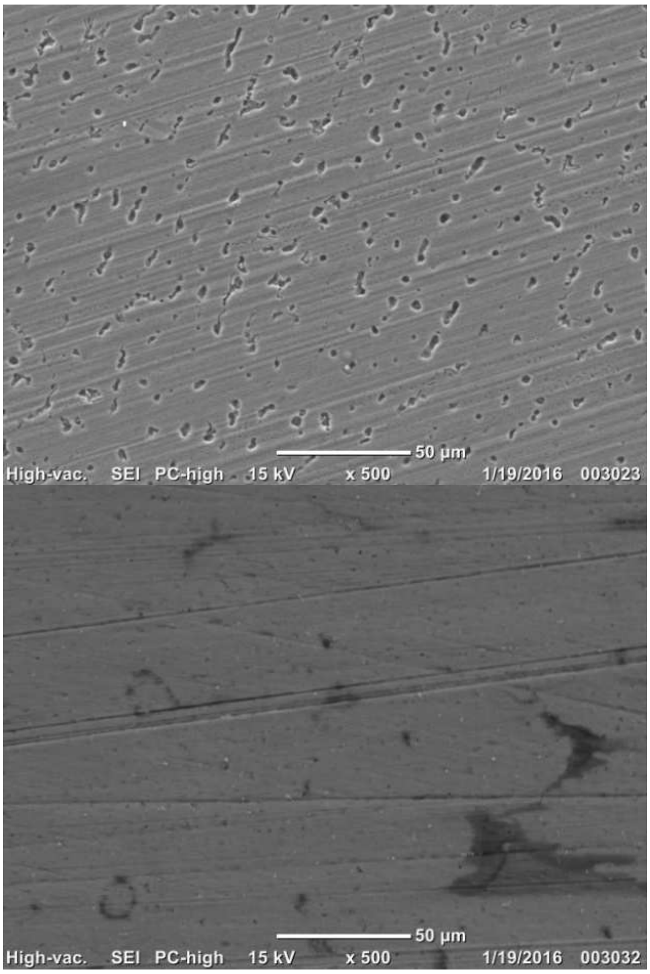


Fig. 2. Microsection of the welded joint of a sample made by welding TIG (from above) and microsection of a sample welded with the CMT process (from below)

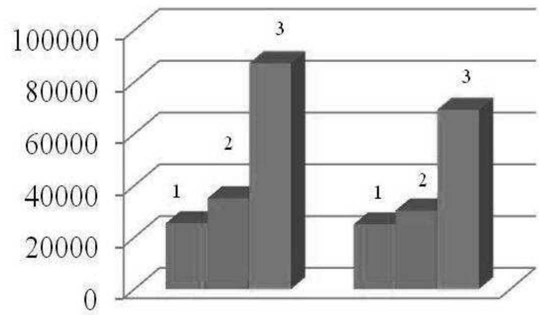
The microstructure of the base metal is a solid solution with small inclusions of secondary phases of various shapes and etchings. As we approach the joint, the dimensions of some intermetallic compounds increase, and the nature of their distribution also changes. Most of the intermetallic inclusions are located along the boundaries of partially recrystallized grains. It should be noted that separate micropores of a round or elongated shape measuring up to 0.01 mm are found at the location of inclusions and next to them [4, 5].

The microstructure of the weld by a non-consumable and consumable electrode is characterized by dispersed inclusions of secondary phases on the background of a solid solution. The structure of the welded sample in Fig. 2 from below is denser without defects. In the joint welded by non-consumable electrode, small micropores are detected. The microstructures of welded joints of AMg6 alloy when welding by different methods differ little. In the structure of the compounds by a non-consumable electrode, in Fig. 2 from above, a greater number of micropores and micro-fibrils are found in the fusion zone in regions of accumulation of secondary phases, along the deformation bands of the weld metal, and also oxide foams. Comparative studies of the microstructure show that the number of micropores and microschloids is smaller in samples welded with a consumable electrode using CMT [4].

It should be noted that an increase in the mechanical properties and quality of welded joints with the use of cold droplet transfer is a reduction in microporosity and micro-flocculation, a reduction in the structure of the weld metal and an increase in its uniformity, and a decrease in the burnup of alloying elements [4]. The manifestation of these factors is caused by a decrease in the overheating of the metal droplets and the weld pool. Accordingly, the residence time of the metal at high temperatures and the time of crystallization of the weld pool are reduced. Under such conditions, the formation of defects is less likely, which confirms the study [5].

An analysis of the cost calculation of a product design unit made at the welding section of the plant [4] showed that using the developed technology reduces production costs by 20.6%. The prime cost of structure was reduced due to the reduction of expenses for filler material by 59%. The labor intensity decreased by 78% due to the increase in the welding speed to 0.013 m/s. The duration of the welding process was reduced by 20%.

Clearly, the economic effect on cost reduction for the compared options is shown in Fig. 3.



1 - expenses for the salary of the main workers;
2 - material costs per unit of structure;
3 - prime cost per unit of structure.

Fig. 3. Comparison of the cost ratio using traditional TIG technology (left) and using CMT (right)

The economic effect on the calculated data was 1071433 rubles. The payback period is less than the normative, so the use of automated welding with the CMT process for structures 2 mm thick from AMg6 is economically justified.

III. Conclusion

In the framework of the above study, it was found that automatic welding of CMT provides stable properties and quality of weld joints with a thickness of 2.0 mm not lower than the level achieved by the low-productivity and expensive TIG method [4]. This is caused by a smaller overheating of the metal droplets and the weld pool due to the optimal programming of the melting and transfer of electrode metal. Reduction of overheating leads to a decrease in the porosity of the weld metal, the time of crystallization, the burnup of the alloying elements, and the grinding of the weld metal structure. All this causes an improvement in its composition and properties [3, 4, 5].

The results of calculation of technical and economic indicators confirmed the efficiency and economic feasibility of the welding technology with the CMT process.

The review of the literature showed that further complex theoretical and experimental studies are needed to develop mathematical models, methods, algorithms and software for the automated design of the technological process of CMT welding.

As a result of the research carried out, it has been established that the welding technology with the CMT process can be effectively used for thin-walled structures of aerospace engineering. The trend of the application of the welding process of CMT is connected with the use of the highly functional Fronius welding equipment and the robotic complex. The materials of the work can be useful for the introduction of a new welding method for obtaining high-quality welded joints of thin-walled aerospace structures, increasing productivity and efficiency in general.

References

[1] N. Bay, “Cold welding,” Met Constr, vol. 8, pts 1–3, pp. 6-10, 1986.

[2] B M. Patchett, “MIG welding of aluminium with an argon chlorine gas mixture,” Met Constr, vol. 10, pp. 8-10, 1978.

[3] J. Norrish, “Advanced welding processes,” vol. I, W.P.L., Cambridge: England, 2006, p. 279.

[4] I. E. Arzhannikova, N. Z. Sultanov, “Automated welding with cold metal transfer in butt joints for structures of aluminum alloys,” Intelligence. Innovation. Investment, Russia, vol. 3, pp. 145-150, 2016.

[5] I. E. Arzhannikova, N. Z. Sultanov, “Modern technological solutions for welding aluminum alloy in the aerospace structures,” Modern scientific researches: theory and practice, materials of International scientific-practical conference, Sophia, vol. 1, pp. 48-52, 2017.