v. 2, n. 21, 2022

Journal of
Engineering
Research

THE INFLUENCE OF ELECTRIC VOLTAGE ON THE QUALITY OF SUBMERGED ARC WELDING IN THIN PLATES

Júlio Cezar Pedrosa da Silva
IFG / Goiânia
http://lattes.cnpq.br/7453077878804679

Gustavo de Castro Lopes
IFG / Goiânia
http://lattes.cnpq.br/2398384294256166

Matheus Abrão Abdala
IFG / Goiânia
http://lattes.cnpq.br/3136667891323073

Aldemi Coelho de Lima
IFG / Goiânia
http://lattes.cnpq.br/7292226429014604

Ildeu Lúcio Siqueira
IFG / Goiânia
http://lattes.cnpq.br/4582663864916718

Abstract: This work consists of the analysis of the quality of the weld between thin sheets, carried out by the submerged arc welding process, with the use of different electrical parameters, in order to observe the influence of these parameters during the process, which is used on a large scale in manufacture and maintenance of parts, equipment and structures. For this, welds were made in 6 mm thin sheets using five different pre-established electric current ranges; in addition, the welded parts were examined in a non-destructive test by the magnetic particle method so that it was possible to verify the defects in the weld region. A strong relationship was observed between the working electrical current range, the surface quality of the weld and the ease of handling the equipment; lower currents (up to 300 A) allowed better handling, also resulting in better surface quality of the part; the most intense currents (400 A or more) presented difficult handling, high penetration and, therefore, showed clearer weld defects.
Keywords: Submerged Arc, Thin Sheets, Weld Quality, Magnetic Particle.

INTRODUCTION

The present project aims to develop research focused on the area of submerged arc welding, in view of the vast application of the process and the little scientific production of it. There are some welding processes such as coated electrode, MIG (Metal Inert Gas), TIG (Tungsten Inert Gas), but little is addressed, both in literature and in articles, about the submerged arc process, despite the fact that it has a higher rate of welding. metal deposition than the others and their weld beads present better surface quality. Of the few works related to this process, [Jorge et al. 2015] who carried out a study of the mechanical and microstructural properties of carbon steel welded joints obtained by the submerged arc process, aiming to increase productivity in the manufacture of pipes for anchoring equipment. The work of [Pardal et al. 2011], who presented the results of the characterization and evaluation of the corrosion resistance of a welded joint corresponding to a 35 mm wall thickness UNS S31803 duplex stainless steel (AID) pipe welded by TIG welding (GTAW) processes at the root and submerged arc (SAW) in filling and finishing.

The submerged arc welding process is widely used in high thickness parts, such as in shipbuilding, having a weld bead with excellent surface quality [Borba et al. 2015]. This factor makes the submerged arc a very versatile and interesting process. Thus, it becomes very useful to know the parameters that affect the quality of the weld bead, analyzing different voltages and working currents, with possible formation of defects. In this way, weld beads were made, using the submerged arc process, varying these parameters and later the quality of the weld was evaluated through non-destructive testing.

This process is widely used in high thickness parts and has a weld bead with excellent surface quality. This factor makes the submerged arc a very versatile and interesting process.

Thus, it becomes very useful to know the parameters that affect the quality of the weld bead, analyzing different voltages and working currents, with possible formation of defects. In this way, weld beads were made, using the submerged arc process, varying these parameters and later the quality of the weld was evaluated through non-destructive tests.

GENERAL GOAL

To analyze the quality of submerged arc welding at different voltages, applied to thin sheets, using non-destructive tests.

SPECIFIC GOALS

- Conduct a bibliographic study;
- To cut the plates to make the welding;
- Perform welding by varying electric current;
- Inspect weld quality using magnetic particle testing.

LITERATURE REVIEW

In the submerged arc welding process, the heat required for the material to melt is generated by an electric arc that is formed between the workpiece and the consumable end, both of which are covered by a layer of granular flux. Therefore, the arc is covered and hidden, not producing visible radiation (Fortes, 2004).

During welding, the heat produced by the electric arc melts a part of the flux together with the electrode tip. The soldering zone is always surrounded and protected by the scorching flux, and is still superimposed by a layer of unmelted flux. The electrode remains slightly above the base metal and the electric arc develops in this position. As the electrode moves along the joint, the molten flux separates from the liquid weld metal in the form of slag. The weld metal has a higher melting point than the slag and so solidifies while the slag is still molten, protecting the newly solidified weld metal, which is very reactive with oxygen and nitrogen from the atmosphere. With further cooling, the unmelted flux is removed, and the slag quickly detaches from the weld metal (Brandi, Wainer, & Mello, 1992). The basic scheme of operation is illustrated in figure 1.

The electrodes used in the submerged arc are normally coated with copper, in order to avoid surface oxidation during storage. They are manufactured in specified chemical composition ranges and drawn to desired diameters. It is a process that provides high yield, as there is no metal loss by projection. Submerged arc welds have good ductility and impact toughness, as well as good uniformity and finish in the appearance of the weld beads. The mechanical properties of the weld are compatible with those of the base metal used, and the process has a high deposition rate.

Submerged arc welding has the advantages of high welding speed; high deposition rate; good weld metal integrity; process of easy handling without emission of sparks, splashes and fumes; better working environment and greater safety for the welder; production of a good slag, which protects from impurities and is easy to remove. However, it has limitations such as the welding position, possible only for flat and horizontal position, and limitation in relation to the type of joint, being possible to work only with in-line joints. Figure 2 presents the basic components of submerged arc welding equipment.

To carry out the inspection of the quality of the weld obtained, non-destructive tests are carried out. Among these non-destructive methods, two can be highlighted: magnetic particle and penetrant liquid.

In order to inspect the quality of the weld obtained, a non-destructive magnetic particle test was carried out. This test consists of subjecting the piece to a magnetic field. The existing discontinuities in the part, that is, the defects, will cause a leakage field of the magnetic flux existing in the part. The magnetic particles will be attracted, due to the emergence of magnetic poles and will be agglomerated in the region where there is a discontinuity. The agglomeration will indicate the contour of the leakage field, providing visualization of the shape and extent of the defect present [Andreucci 2009].

METHODOLOGY

To carry out this work, the following materials and equipment were used:

- 6 mm thick steel sheet;

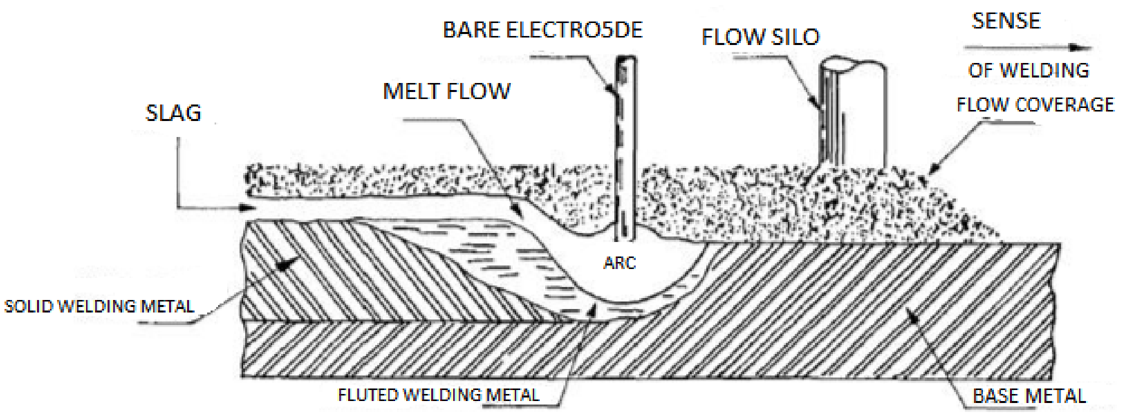
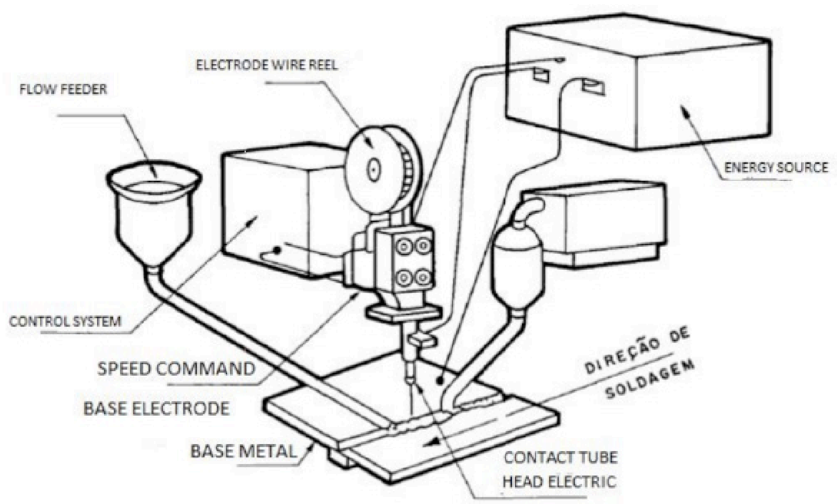


Figura 1 – Funcionamento do processo de soldagem com arco submerso



WELDING DIRECTION(DIREÇÃO DE SOLDAGEM)

Figure 2 - Submerged Arc Welding Equipment

- Submerged arc welding equipment;
- Magnetic particle testing equipment;
- Liquid penetrant testing equipment

Firstly, a sequence of tests was carried out on the submerged arc welding machine (Figure 3) to define the exact parameters (electric current and voltage). Then, some 6 mm thick plates were selected and then an alternative saw was used to cut them in half, obtaining smaller length plates, as shown in Figure 4. Subsequently, the submerged arc welding was started.

The welding process was performed using a single wire spool as electrode, however, the working current was varied in the range of 200 amperes to 600 amperes. The table advance was done manually through the crank, however the advance speed was kept constant for all the weld beads. Then, the weld beads were analyzed by non-destructive magnetic particle and liquid penetrant tests.

To perform the magnetic particle test, the equipment and parts with the weld beads were selected. Then, for each plate, the fluid with the magnetic particles was applied to the weld bead and then an apparatus was used to magnetize the plate. Finally, a black light was used to visualize the discontinuities present in each piece and then the result performed in each piece was recorded by photo.

RESULTS

From the sequence of tests performed on the submerged arc welding machine, it was possible to obtain better control over the electrical parameters of the equipment, as shown in Table 1.

According to the methodology applied, it was possible to carry out the welding process in the desired current range, as illustrated in Figures 5 to 9. In Figure 5, it can be seen that there was a continuous welding; however, not the entire piece showed complete penetration, manifesting itself only at the end of the piece. This weld profile can present some problems when the part is subjected to tensile tests or other mechanical stress. In summary, it can be inferred that, even for this small thickness, the use of submerged arc welding under these conditions is unfeasible.

Figure 6 shows the welding carried out with a current of 300 A. There was no total penetration in the samples carried out under these conditions, however, the bead presented an extremely interesting visual aspect: it is possible to verify that there are no surface bubbles in the piece; having a slag full of bubbles, but showing a perfectly executed bead, without any clear defect, gives a very positive and uniform visual aspect. This cord presents an improvement in relation to the previous one, in terms of continuity and homogeneity, whether visual, superficial or even penetration into the samples.

Figure 7 shows the welding performed with a current of 400 A. In this step, a clearer discontinuity of the bead was observed. Although almost complete penetration has been achieved, the appearance of the cord is visibly discontinuous, displaced, even poorly made; this discontinuity occurred, in part, because the part moved a little on the table, due to the high rate of energy involved in the process. However, there was a more heterogeneous part than the previous ones, but with superficial and penetration defects.

Figure 8 shows the welding performed with a current of 500 A. This step presented the worst weld quality among all performed. It is visible that in all tests carried out under these conditions there is a great discontinuity in the process, which goes against any definition of welding, as well as any possible application of a part under these conditions, whether ornamental or structural. Therefore, it is concluded that, under these conditions, the welding of a thin sheet becomes completely

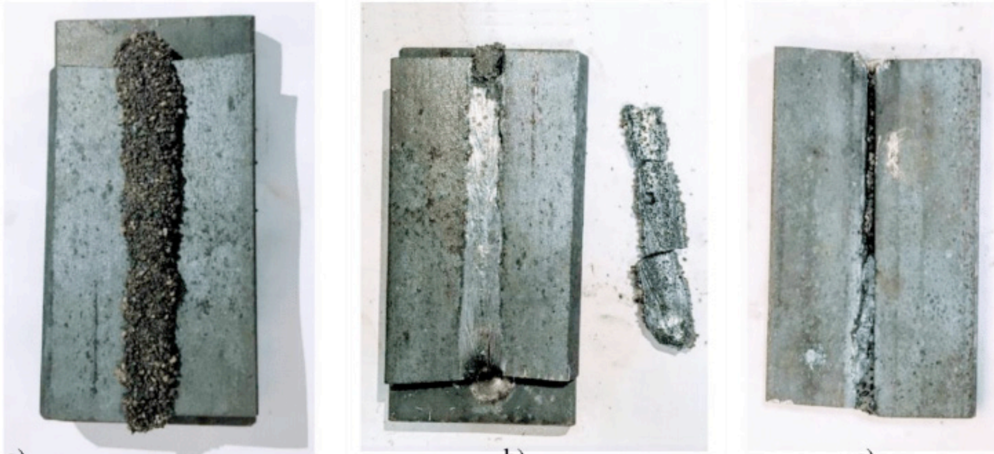
Figure 3 – submerged arc welding machine

Figure 4 – 6 mm sheets for welding

Potentiometer [%]	Chain [A]	Tension [V]
26	200	40
40	300	38
52	400	34
70	500	32
>80	600	32

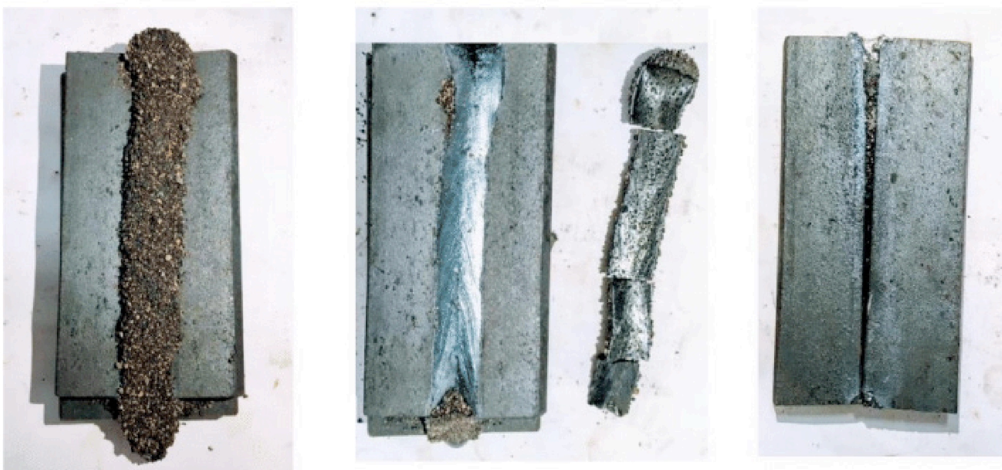
Table 1: List of submerged arc welding machine parameters

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172212216091



a) b) c)

Figure 5 - Welding on the 200 A plate – a) With slag b) no scum c) background of the piece



a) b) c)

Figure 6 - Welding on the 300 A plate - a) with scum b) no scum c) background of the piece

a) b) c)

Figure 7– Welding on plate 400 A – a) with scum b) no scum c) background of the piece

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3172212216091

unfeasible and undesirable; there was a complete visual penetration, but this does not compensate for the inhomogeneity presented along the weld bead.

Figure 9 shows one of the samples for a current condition of 600 A. Although the part is visually better than the previous one, the part also presents very marked visual heterogeneity, with the presence of large bubbles at the bottom of the part, a large discontinuity in the cord being interrupted at the ends in a natural but messy way, a complete penetration but that doesn't seem to add much to the piece other than deformations.

After the visual analysis, it can be seen that the cords made at 300 A present higher quality than the others; however, for a more complete verification, a non-destructive test was carried out on each of the parts, which aims to show the defects internal to the weld bead. The results obtained are shown below, from the magnetic particle test, as shown in figures 10 to 14.

In Figure 10, we see that a small biting region was formed, a defect that is usually caused by the high energy used in a very thin piece. Some bubbles can be seen, as well as a crack at the bottom, very discreet. With the magnetic particle test, it can be observed that, despite the aforementioned, there are no major defects in the part, surface or subsurface.

Figure 11 shows the increase in undercuts on the sides of the weld beads, in addition to the considerable increase in the thermally affected zone; both occurred were already expected, due to the increase in current, and, consequently, in the welding energy. The piece on the right has a deeper central region with less reinforcement than the rest of the piece, in addition to the presence of a crack. The weld made at 400 A, shown below in figure 12, showed few defects, being much superior to the others. As expected, the piece presented more bites than the previous ones and an increase in the thermally affected zone. A series of bubbles was also observed which, although not very expressive, are a large-scale failure, in addition to observing reduced reinforcement at the end of the weld bead. The piece presents visual heterogeneity, but does not present a clear visual crack, as in the previous cases.

Figures 13 and 14 present the results for the 500 A and 600 A welds, respectively; these steps presented very similar welding conditions, and this was reflected in the results, which were also very similar.

As can be seen in figures 13 and 14, the two welding conditions generated parts with major structural defects, such as very significant mixtures and thermally affected zones that encompass almost the entire part. Both also presented quite considerable pores, as well as cracks along the piece.

These last conditions present serious discontinuities for the welding, which makes them undesirable and completely unfeasible, in addition to providing a perforation in the plate, which was no longer continuous and accentuated due to the existence of a copper joint, which allowed continuity without perforation of the part. However, it must be noted that, from 400 A, it was very difficult to solder, sticking the piece to the joint cover, which only came out with the application of a very rough and aggressive manual effort, aided by by tools.

CONCLUSION

It was observed that in submerged arc welding the surface quality of the weld bead depends on the working current range. Welds carried out with electric current up to 300 A resulted in better ease of operation of the process, in addition to superior surface quality in relation to higher currents (400 A - 600 A). In addition, there was no total penetration in the procedures performed with currents of

a) b) c)

Figure 8 – Welding on plate 500 A – a) with scum b) no scum c) background of the piece

a) b)

Figure 9 – Welding on the plate 600 A –5 a) no scum b) background of the piece

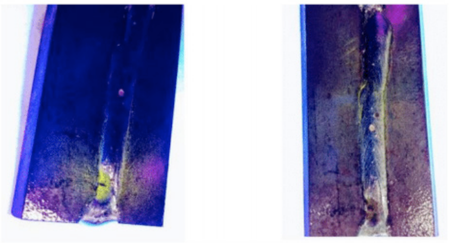


Figure 10 – Magnetic particle test on plate 200 A

 DOI 10.22533/at.ed.3172212216091

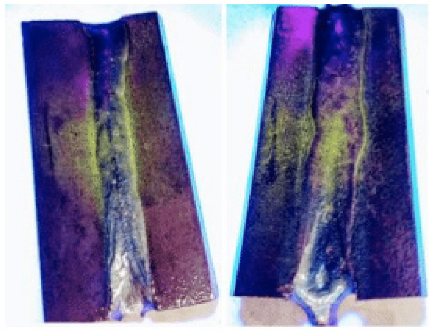


Figure 11– Magnetic particle test on plate 300 A

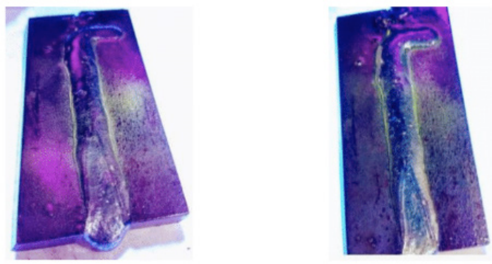


Figure 12 – Magnetic particle test on plate 400 A

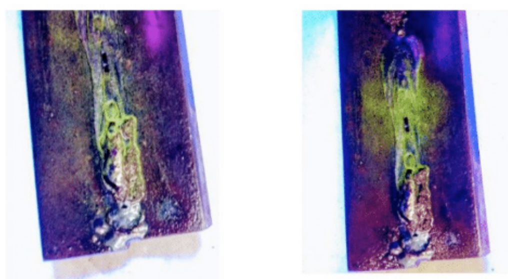


Figure 13 – Magnetic particle test on plate 500 A

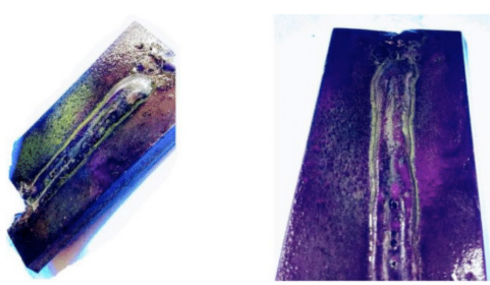


Figure 14 – Magnetic particle test on 600 A plate

200 A and 300 A.

The welding process was more difficult at currents from 400 A, the plates suffered an initial impact from the arc opening and moved during welding, impairing the continuity of the process, the surface quality of the weld bead and compromising the position of the weld bead. In addition, in this current range, the total penetration of the weld began in parts of the bead, reaching in some cases to perforate part of the plate, as occurred in the procedure carried out at 600 A.

REFERENCES

Andreucci, R. (2009). Ensaio por partículas magnéticas. Editora Associação Brasileira De Ensaios Não Destrutivos e Inspeção. São Paulo.

Borba, T. M. D., Flores, W. D., Turani, L. d. O., and Cardoso Junior, R. (2015). Avaliação da soldabilidade do aço naval eh36 tmcp soldado por arco submerso com elevado aporte de calor. Soldagem & Inspeção, 20(1):92–104.

Fortes, C. (2004). ESAB - Processos de Soldagem: Arco Submerso. Disponível em: <https://www.esab.com.br.>

Jorge, J. C. F., Souza, L. F. G. d., Marouco, E. d. S., Santos Filho, O. R. d., and Diniz, J. L. C. (2015). Propriedades mecânicas e microestruturais de juntas soldadas pelo processo a arco submerso com elevado aporte térmico. Soldagem & Inspeção, 20(3):347–358.

Pardal, J. M., Souza, G. C. d., Tavares, S. S. M., Fonseca, M. d. P. C., Ferreira, M.

L. R., Martins, L. M., and Samra Filho, O. A. (2011). Caracterização e avaliação da resistência à corrosão na soldagem de tubulação de aço inoxidável duplex uns s31803 pelo processo a arco submerso. Soldagem & Inspeção, 16(4):310–321.

Wainer, E., Brandi, S. D., and de Mello, F. D. H. (1992). Soldagem: processos e metalurgia. Editora Blucher.