Erosion and Cavitation Tests Applied to Coating Welded with Blends of Stainless Steel and Cobalt Alloys

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Abstract

The process GMAW with its your applications using two wires pointing in the market as an alternative to coating when high productivity is desired. Potential variants emerge from this process as GMAW cold wire and GMAW double wire. One of the biggest difficulty is the setting of its parameters, which in addition to duplicate compared to conventional GMAW, act in a dependent manner. A greater understanding of this technology applied to coatings on turbines in various positions is critical so that you can master the process and its variables, aiming to enhance the application in industry. It was proposed in this study an experimental evaluation to verify the influence of some variables on the profile of cord and wear resistance. For this it is proposed in this paper to make deposits with weld metal AWS 308LSi stainless steel and alloys of cobalt (Stellites 6 and 21) plates in carbon steel SAE 1020 in flat positions. In the characterization of wear in the lining was used the determination of the hardness and surface topography. It is concluded that cobalt alloys have superior resistance to erosive damage with emphasis on the Stellite 21 alloy in erosion and cavitation in Stellite 6. In an intermediate position with respect to wear are mixtures of austenitic stainless steel and cobalt alloys. Therefore, it is essential to study welding processes with multiple wires as proposed in this paper aiming the best combination of alloys for resistance to cavitation-erosion phenomena.

Keywords: GMAW Cold Wire, Cobalt Alloys, Erosion, Cavitations.

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1. INTRODUCTION

In its design, the hydraulic turbines are designed to obtain a high yield and durability without, however, eliminating a phenomenon of continuous action known as cavitation. In these cases, the exchange of this component becomes economically unfeasible. Cavitation gradually removes part of the turbine material, causing catastrophic situations if proper recovery and protection measures are not taken.

It is evident to hydroelectric power plants the importance of the control of the erosion caused by cavitation, being one of the main causes in the reduction of the billing. Added to these factors are the presence of fluids with differentiated aspects in the different hydrographic basins of the country. In some cases, the presence of small solid particles and sand, which probably generate an increase in the mass loss of the coating by erosion in the hydraulic turbines, is noticeable.

Faced with this concern, special attention is justified with the application of a protection in this component so that it presents greater time of operation, providing an increase in the interval between the interventions of maintenance. Usually in these cases the economically viable option is the realization of a metal coating deposited by welding process that provides a low dilution and high productivity.

In this sense, [1] cite that, in the 60's, researches were looking for a new type of steel for the manufacture of hydraulic turbine rotors with greater resistance to cavitation. Therefore, soft martensitic stainless steels have emerged as an alternative to the limited weldability of conventional martensitic stainless steels, which are highly susceptible to cold cracking and require strict preventive measures during welding. With this objective, a steel with a lower C content was achieved and 4 to 6% by mass of Ni was added. The CA6NM alloy has high flow stress, good corrosion resistance and cavitation, and better weldability than conventional martensitic stainless steels, being increasingly used in hydraulic turbine rotors, pumps and compressors, as well as components in the chemical and petrochemical industry. However, its behavior to fracture and fatigue and in welded joints is not always explored. In relation to a hydraulic turbine, the weld is used in two different situations: in the union of the blades to the axis of the turbine when of its manufacture and in the repair of areas crinkled or that they underwent cavitation. After welding the blades during their manufacture, a heat treatment is provided to ensure adequate levels of toughness.

Currently, the turbine rotors are made of low carbon and medium carbon steel. Since the repair due to erosive wear must be performed with products that better withstand the effects of cavitation, it is normally necessary for the deposition of materials having intermediate properties between those of the base metal and the coating known as buttery, generally using stainless steels. The welding processes commonly applied in coating are GMAW, tubular wire, submerged arc, GTAW with hot or cold wire feed, transferred arc plasma (PTA), double wire GMAW and wire cold GMAW wire cold (Figure 1).

Among the materials applied in the repair by welding of cavitation damages, [2] cites traditional stainless steels type AISI 308 and 309, stainless steels to Co and Co-based alloys (commercially called Stellites), the latter being characterized by Grinding difficulty and high cost. Currently, cobalt alloys are known for their high mechanical resistance to corrosion, wear and high temperatures.

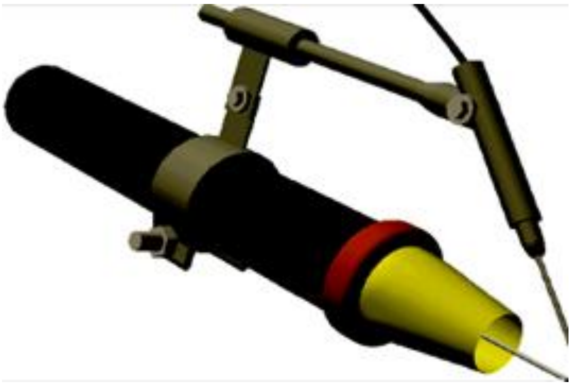

FIGURE 1: Auxiliary head for wire addition in MIG / MAG process with cold wire.

With the increase of the demand of the consumer market in search of processes with higher deposition rates and, consequently, reduction of the global costs involved, new variants were developed aiming at the greater production, as for example the GMAW double wire. In coating welding, this technique is especially used, due to its advantages as higher productivity, through increases in deposition rate and welding speed coupled with low thermal input. The use of two synchronized electronic welding sources, two wire feeder heads, computer programs to control the synchronism of the operation, involving the increase of the consumption of inputs such as electric energy, gas, among others.

The objective of this work is to make a systematic study to obtain suitable welding parameters with the double wire GMAW processes, in order to produce welded coatings, from commercial alloys applied in hydraulic turbines with due resistance to erosion and cavitation.

2. MATERIALS AND METHOD

For GMAW welding with cold wire, the experimental workbench consists of the welding source, the electrode wire feed system, the cold wire feed system, the test body holder, welding torch, welding systems acquisition and data monitoring system. In double wire GMAW welding, the assembly consists of a similar system to the previous case with the use of two welding sources working in parallel.

Welding sources allow the imposition of current or voltage. In the current adjustment mode, constant or pulsed current control is possible and the voltage adjustment allows only constant voltage control. In the work, only the option in which the sources work with the tension adjustment (constant tension mode) was used. The electrode wire feed system is an accessory of the welding source. With an electronic rotation adjustment, this system presents an adequate control to carry out the tests of this work. It should be noted that the feed system was mounted on a support at the welding source to facilitate the passage of the wire (straight torch), reducing the possibility of problems with the oscillation of the feeding speed, and consequently, the reliability of the results.

In the welding tests, a XY coordinate table was used, connected to a computer with interface hardware, that by means of a program, it is possible to determine the values of the coordinates that the welding torch will run with a resolution of 0.5 mm, nominal range 600 mm on the x-axis and 850 mm on the y-axis.

This torch movement system allows the realization of triangular weaving with the adjustment to the horizontal position. In this work, the weave adjusted in the MIG / MAG cold wire welding was with an amplitude of 10 mm and an oscillation frequency of 1.0 and 1.5 Hz.

In order to monitor the electrical signals of the arc (current and voltage), a National Instruments® acquisition board, coupled to a microcomputer with LabView® software, was used both for the acquisition of current and voltage signals and for the treatment of these signals .

The current signal was obtained by the Hall effect sensor (EH-2 plate). Since the acquisition plate has a signal input range of 0 to 10 V, a voltage divider DTS-6 was used to obtain the voltage signal, and the two plates were connected to the source input.

This step of signal acquisition was performed due to the need to monitor the welding conditions with determination of the energy generated by the source, disregarding the thermal efficiency, for all the conditions of materials and protection gas used.

The material selected as base metal was steel ABNT 1020 because it is easily found in the market, which makes it economically feasible for this research. Test plates were made in the dimensions of 300 mm in length, 60 mm in width and 12.5 mm in thickness, and were brushed to remove dirt. During the preliminary tests on welds in the horizontal position initially, the test plate was secured to the workbench and the coating cord was deposited. However, due to the presence of defects with the draining of the welding cord, a thin sheet of common steel was used for anchoring the first weld bead deposited. This plate was cut into the dimension 300 mm long, 25 mm wide and 3 mm thick. The addition metals used in the welding are stainless steel wires with low percentage by mass of carbon, with specification ER308LSi, Stellite 6 and Stellite 21.

In order to perform the tests, the protection gas was used, whose composition is 98% Ar + 2% O_2. This gas is the most used by the industry in the welding of stainless steels, being feasible in the application of the combination with cobalt alloys.

The composition of the gas, due to the importance for this work, was evaluated with an Oxybaby brand analyzer, showing variations of up to 1% more or less in the composition of O2. The protection gas flow rate remained fixed at 14 l/min, in the cold wire GMAW, and was adjusted through the use of a flow meter called a turbine.

For double wire GMAW welding, the shielding gas was used with a flow rate set at 30 l/min. The gas flow is higher due to the use of a torch dedicated to this process with isolated potential whose nozzle is almost double the diameter of a conventional GMAW torch.

In the GMAW double wire process, the flat position was selected due to the constant occurrence of hump during the preliminary tests for the process with cold wire GWAW in the horizontal position.

In the configuration of the double wire GMAW process in parallel, the voltage was set at 30 V, with a distance contact nozzle part at 25 mm. The position of the torch ranged from 15° to 30°. The welding speed was 60 and 80 cm/min. The feed velocities adopted were 12 and 14 cm/min. An example welded test piece in the parallel configuration with 3 (three) coating passes is shown in Figure 2.

FIGURE 2: Welded coating in the flat position by the MIG / MAG double wire process.

The welding procedure for the GMAW process with cold wire consists basically of fixing the test piece together with the anchor plate to a fixed base on the welding table, allowing positioning in the horizontal position. Thereafter, the anchoring plate is added to carry out the first welding pass. Next, four more passes are applied in the horizontal position (Figure 3).

The specimens for the erosive test have a thickness of 3 mm and are drawn directly from the weld metal by removing the substrate and then cutting two samples in each test in length dimension 10 mm and width 8 mm, as shown in Fig. 4. For this purpose, a planer was used in the machining of the lower part of the specimen until the weld metal appeared. Then, with a top milling cutter, material was removed in the lower part of the specimen to the thickness close to the desired one. At the top of the weld bead, the machining was done to obtain a flat finish and without the unevenness of the passes, using a top milling cutter.

For the sanding, the specimens were embedded, passing through the sanding sequence of 100, 220, 380, 600 and 1200 μm, in order to obtain a smooth surface. Then, the mass of the specimens was measured for attachment to the sample port (Figure 4) to be inserted into the multi-component fluid vessel. The sample holder rotates in a similar way to a propeller, causing the particles to impact the specimen, causing wear by erosion

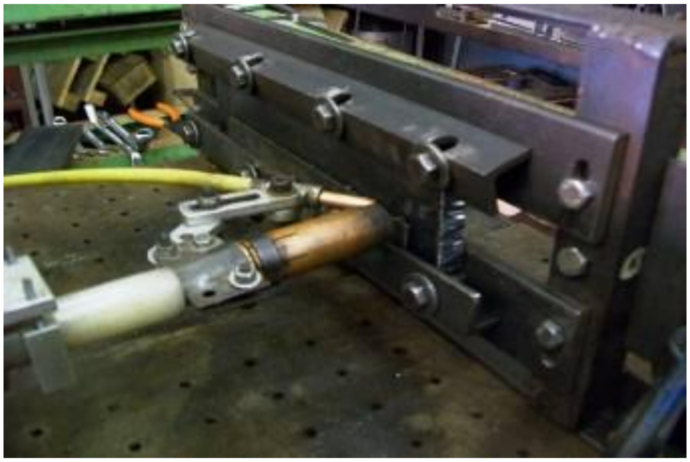

FIGURE 3: Experimental assembly for the GMAW process cold wire, with horizontal torch in the neutral position.

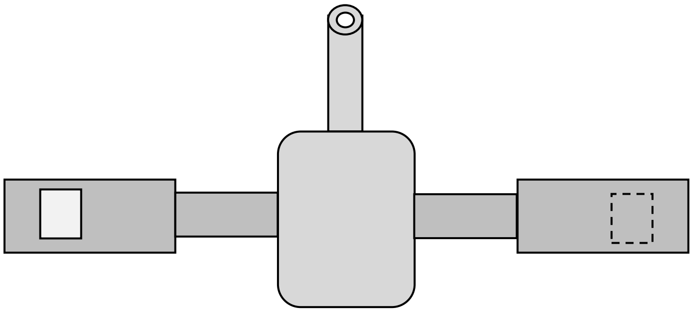

FIGURE 4: Illustration of the fixation of the specimens in the sample port.

The tests were performed by ultrasonic vibration method, according to ASTM G32-10 (2010), in a Sonic Mills equipment, modified to the indirect method, or stationary sample method. In this method, the bubbles generated by the counter body act on the test sample, causing a cavitational damage of 40 to 60% lower than that verified in the direct method (SILVA et al., 2013). The distance between the sample and the counter-body directly influences the wear, the value of 0.5 mm being the distance where the intensity is maximum.

The test sample was attached to a sample holder inside the liquid (distilled water) and positioned at a distance of 0.5 mm from an AISI 304 stainless steel counter body mounted on the sonotrode. The distance between the sample and the backstop was adjusted using a pneumatic device with an end-of-stroke sensor and a micrometer with a resolution of 0.01 mm. The sonotrode vibration frequency was 19.3 ± 0.1 kHz and the oscillation amplitude was maintained at 45 µm, peak to peak. The test temperature was 25 ± 2 ° C, controlled through a cooling system. The immersion depth of the sample in the test liquid was approximately 5 mm.

To determine the wear, the test was stopped at regular intervals of 1 h, the samples were cleaned with acetone in an ultrasonic bath for 5 min. The mass loss was determined through an analytical balance with a resolution of 0.001 mg and a maximum mass of 210 g. The balance used is Sartorius, with calibration certificate no. 1726/2013, issued by Mitutoyo Sul Americana Ltda. Five mass measurements were taken to determine mean values.

The total times of cavitational erosion were 40 h when the cobalt alloys were present, aiming at the determination of the maximum rate of permanent erosion. The experimental bed is shown in Figure 5.

FIGURE 5: Experimental bench and assembly detail, 1 - system for adjusting the sample height by means of micrometer, 2 - sonotrode, 3 - stainless steel counter body (AISI 304), 4 - sample, 5 - cooling system, 6 - sample holder.

3. RESULTS AND DISCUSSION

The objective of this step is to evaluate the influence of the combination of austenitic stainless steel and cobalt alloys in the welding of the coating on carbon steel plates, and then to submit these test specimens to erosion and cavitation tests.

The weldability and characteristics of the test plates are shown in the GMAW welding process cold wire in the horizontal position and GMAW double parallel wire and series in the flat position. The wires are austenitic stainless steel with ER308LSi specification, combined with a cobalt alloy (Stellite 6 or 21). The welding conditions for the tests are set forth in Table 1 to 3.

TABLE 1: Welding Conditions MIG/MAG Cold Wire.

WC	U (V)	V_f (m/min)	$V_{f\ AF}$ (m/min)	V_w (cm/min)	Addition Metal	Cold Wire
AF1	23	7,5	1	80	ER308LSi	Stellite 6
AF2	23	7,5	1	80	ER308LSi	Stellite 21

TABLE 2: Welding Conditions MIG/MAG double wire.

WC	U (V)	V_f (m/min)	V_w (cm/min)	Wire 1 (Master)	Wire 2 (Slave)
DA1	30	12	60	ER308LSi	Stellite 6
DA2	30	12	60	ER308LSi	Stellite 21

TABLE 3: Welding Conditions MIG/MAG Wire Series.

WC	U_1 (V)	U_2 (V)	V_{f1} (m/min)	V_{f2} (m/min)	V_w (cm/min)	Wire 1 (Master)	Wire 2 (Slave)
DS1	32	30	14	12	80	ER308LSi	Stellite 6
DS2	32	30	14	12	80	ER308LSi	Stellite21

The test plates were submitted to the erosion tests with the removal of the test specimen, in the region between the 4th and 5th pass in the GMAW cold wire process and in the 2nd and 3rd pass for the GMAW double wire processes. In the first part of this item, the essays will be presented individually and then a discussion will be made in a comparative way. Figure 6 shows the erosion performance of the AF1 sample. A similar feature to the preliminary tests performed with pure austenitic stainless steel is the high increase in mass loss at the point of 120 minutes, resulting in final wear values similar to blends with cobalt alloys. In the AF1 sample, erosion rate values of 0.36 mg/min and accumulated mass loss of 36.78 mg were obtained. In AF3, even with the presence of the cobalt alloy (Stellite 6), the erosion rate was 0.36 mg / min and accumulated mass loss was 43.21 mg.

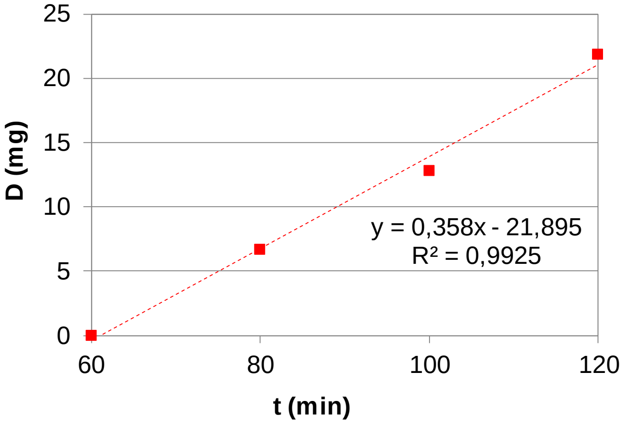

FIGURE 6: Erosion Rate for AF1 Sample.

Comparing the sample AF1 with the AF3, it is verified that the values of erosion rates are very close. In the 90 ° erosion test of [3], 316 L austenitic stainless steel presented an erosion rate of 10 mm3/min. The same authors show that Stellite 6 under identical conditions of erosive wear had an erosion rate of 11.9 mm3/min. The 316 tanks have a Vickers hardness of 200 HV and those of the Stellite 6 alloy, the value of 450 HV.

Finally, these authors concluded that materials traditionally resistant to abrasion, such as Stellite 6, will not necessarily perform differently at 90° erosion. Apparently, the situation is similar to that of adding small amounts of Stellite 6 to austenitic stainless steel in cold wire GMAW welding, ie their influence is practically nil in increasing erosion resistance.

In the double parallel wire GMAW tests, the added amounts of the cobalt alloys are higher in relation to the cold wire GMAW tests. This is because the feed rate of both wires is the same in the GMAW dual parallel wire process.

For the DA1 test the highest erosion rate occurred at 80 minutes with a value of 0.30 mg/min and the total accumulated mass loss was 22.45 mg. This point of 80 minutes presented the greatest uncertainty, with a high absolute value and probably corresponds to the exceedance of the incubation. The mean erosion rate is 0.18 mg / min with a correlation of 94%. The low correlation in this assay is associated with the high uncertainty at 80 minutes. In other points, the uncertainty values were relatively lower. The DA2 test showed a maximum erosion rate of 0.15 mg / min at 20 minutes, with accumulated mass loss of 14.39 mg. Note that the 20-minute point may be the exceedance of incubation, with low absolute values when compared to the other assays such as, for example, DA1. The average erosion rate is presented in Figure 7 with a value of 0.13 mg/min. Comparing the results obtained for the austenitic stainless steel tests, under identical welding conditions, with an erosion rate of 0.13 mg/min, the DA2 test presented values slightly lower, of the order of 0.13 mg/min.

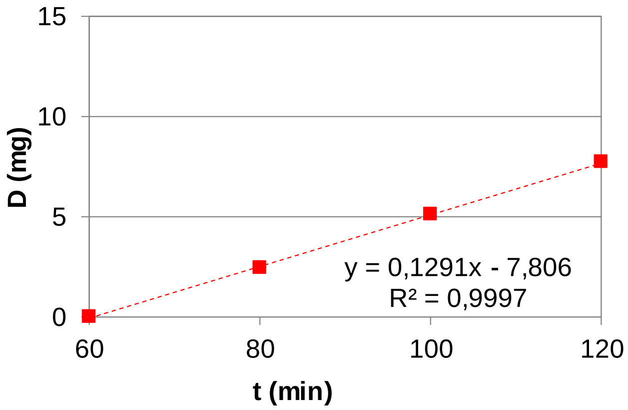

FIGURE 7: Erosion Rate for Sample DA2.

For the DA1 test, addition of Stellite 6 did not provide such satisfactory performance, with an erosion rate of 0.18 mg / min. [4] showed in their research that the Stellite 21 alloy presents better performance, with low erosion rate, compared to Stellite 6 alloy for normal incidence.

For the DS1 assay, the incubation may have been disrupted at 100 minutes, exhibiting slight reduction at the end of the assay. The total accumulated mass loss was 19.12 mg, that is, lower than that obtained in DA1. The mean erosion rate of DS1 has a value obtained of 0.20 mg/min. In DA1, a reduction in the wear value to 0.20 mg/min occurred at 120 minutes, influencing the erosion rate result. In the DS2 test, the first 20 minutes have the highest erosion rate of 0.16 mg/min. It is generally noted that there were no large fluctuations in the results except for the reduced value of 0.12 mg/min at 80 minutes.

The average erosion rate is presented in Figure 8, with a value of 0.13 mg/min, the lowest one being observed for the GMAW double wire test with the wire mixtures of different compositions.

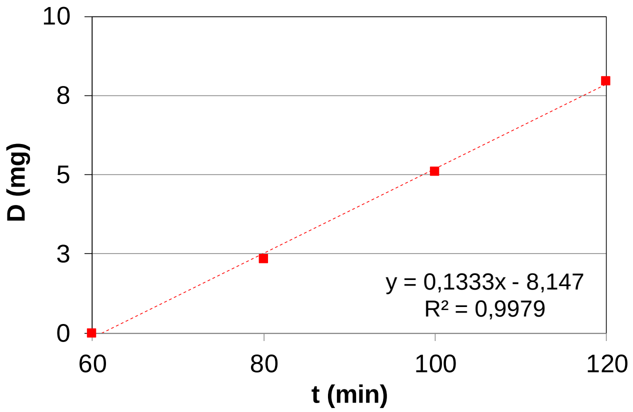

FIGURE 8: Erosion Rate for Sample DS2.

The erosion rate of austenitic stainless steel coating is 89% higher than DS1 and 180% higher when compared to DS2. For the double wire MIG / MAG process, the two cobalt alloys were advantageous in reducing the erosion rate, being again the highlight for the low erosion rate of DS2 when using Stellite 21.

Table 4 shows the values of erosion rate and accumulated mass loss for the 2 hours of erosion and in the evaluated periods after the incubation for the tests performed with austenitic stainless steel and cobalt alloy blends.

TABLE 4: Values obtained for total loss of accumulated mass (D), loss of accumulated mass between 1 and 2 hours (D_{1-2h}) and erosion rate between 1 and 2 hours (Tx_{1-2h}).

WC	**AF1**	**AF2**	**DA1**	**DA2**	**DS1**	**DS2**
Material	308+6Co	308+21Co	308+6Co	308+21Co	308+6Co	308+21Co
Dil (%)	16,72	16,62	35,98	37,19	45,63	34,47
D (mg)	43,21	31,09	22,45	14,39	19,12	17,17
D_{1-2h} (mg)	21,82	16,59	10,85	7,73	11,70	7,96
Tx_{1-2h} (mg/min)	0,36	0,28	0,18	0,13	0,20	0,13

In general, it is noticed that the presence of the Stellite 21 cobalt alloy influences more satisfactorily in the reduction of accumulated mass loss. This is because, comparatively, the values of erosion rate and accumulated mass loss are smaller when using this material for all welding processes.

The specimens that were welded with double parallel wire GMAW have the same feed velocity in both wires, therefore the addition of metal occurs in similar quantities, and the results of DA1 and DA2 are the best obtained for the proposed combinations.

Note that, in general, the accumulated mass loss and the erosion rate have the highest values for the cold wire GMAW tests (AF1 and AF2). The addition of cobalt alloys probably influenced the reduction of mass loss only in the AF2 assay, since AF1 is at a level similar to the previous tests. Note that the DA2 and DS2 tests with addition of cobalt through the Stellite 21 alloy have the lowest accumulated mass losses. Comparing DA1 / DS1 and DA2 / DS2, the presence of more cobalt alloys added in the parallel double wire GMAW process positively affects the wear reduction.

[4] attributed the best performance of Stellite 21 to erosion with normal incidence to its higher hardness. The intermetallic carbides formed in the Stellite 21 alloy have hardness compatible with materials rich in Cr carbides.

Figure 9 shows the comparison in terms of hardness of the hardened layer (Hsup) and substrate (Hsub) between the samples. In general, samples with Stellite 21 addition exhibited superior hardnesses in the hardened layer for the same welding process after erosion, providing a reduction in the accumulated mass loss. This finding is valid for AF2, DA2 and DS2. The fact that DA2 has a lower hardness in the hardened layer in relation to AF2 and yet has a lower erosion rate shows that it is essential to obtain a thick and homogeneous hardened layer on the surface to generate an increase in the wear resistance. In the GMAW process double parallel wire compared to the GMAW cold wire.

The thicker and homogeneous hardened layer in DA2 is probably the result of the greater addition of Stellite 21.

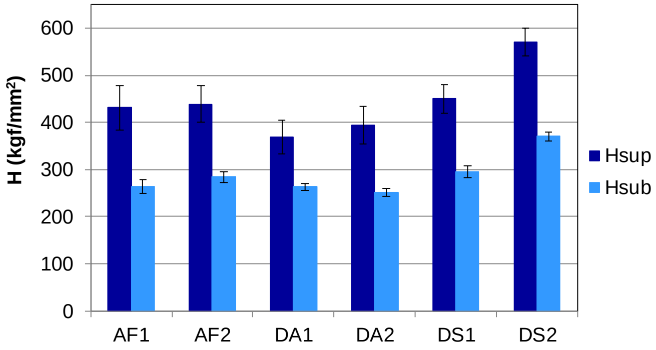

FIGURE 9: Surface hardness after erosion and substrate hardness.

The eroded surface of the test body DS2 is shown in Fig. 10. The presence of a region strongly affected by wear with prolonged depression throughout the assessed section is noted in Fig 11 e 12. It is believed that this point is a region of junction between strands. This region can be part of the zone affected by the heat, presenting regions of low resistance, therefore, with preferential wear.

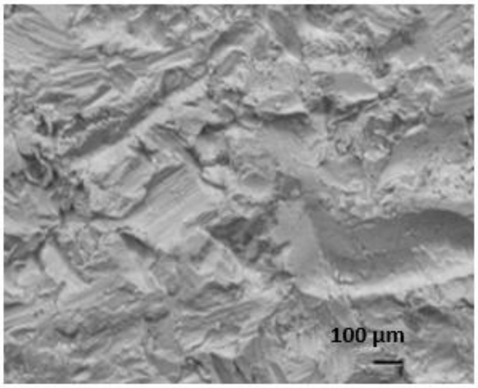

FIGURE 10: Topography of the DS2 assay by scanning electron microscope.

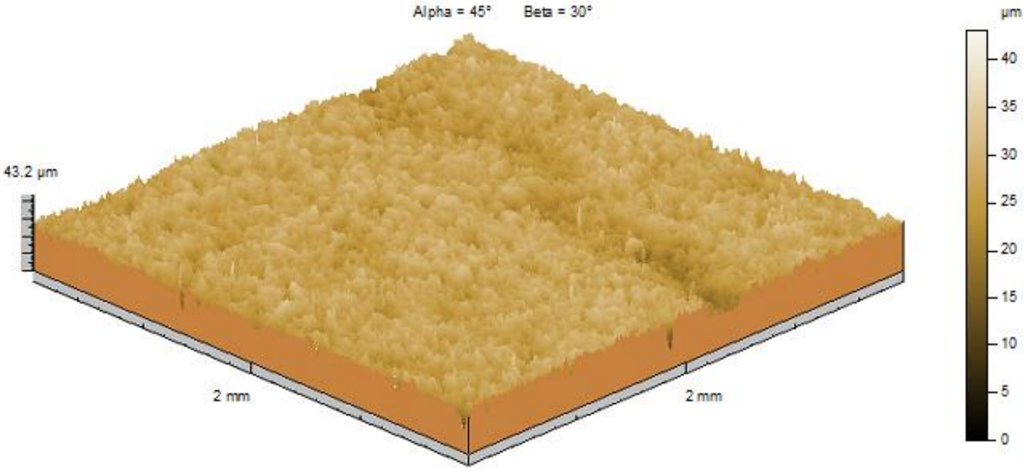

FIGURE 11: Diagrama de nível de DS2.

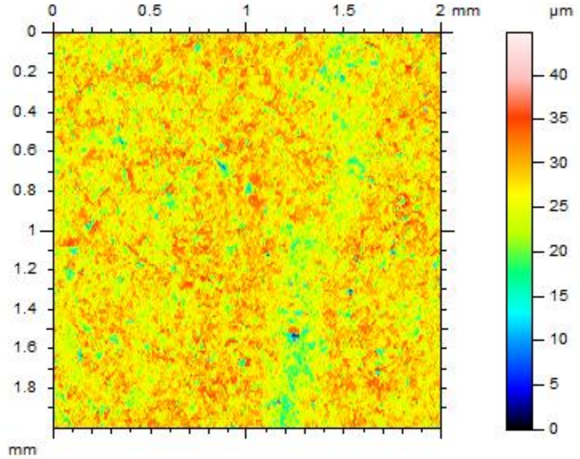

FIGURE 12: Three-dimensional topography of the DS2 sample.

It is noted that the values of Sa and Sq are high, the largest of the tests of this phase of blends in stainless steel and cobalt alloys. However, this high roughness value does not reflect the presence of severe wear. Perhaps without the occurrence of preferential wear in the DS2 sample, one of the welding conditions would be more resistant to erosion wear. Likewise, the parameter St has a high value due to the large amplitude of peaks and valleys. As there were isolated peaks and valleys, the values of Ssk and Sku are also high.

The results of cavitation in the samples of austenitic stainless steel and cobalt alloys, welded by the GMAW processes, are shown in the horizontal position and the GMAW double parallel wires in the flat position are presented and discussed. In the cavitation erosion tests, samples AF1, AF2, DA1 and DA2 were evaluated because they represent the extreme conditions of the quantity of cobalt alloys in the sample, ie, 50% in the addition metal for the GMAW double wire process and 12% for the GMAW cold wire. In addition, the weld bead for the GMAW dual wire series process presented an oscillation in its width that would make it difficult to make larger specimens, as in the case of the cavitation test.

The instantaneous erosion rate of all samples in a mixture of alloys of austenitic stainless steel and cobalt alloys evaluated in cavitation is shown in Figure 13. It is observed that samples AF2 and DA1, although welded with different cobalt alloys, Have an identical feature.

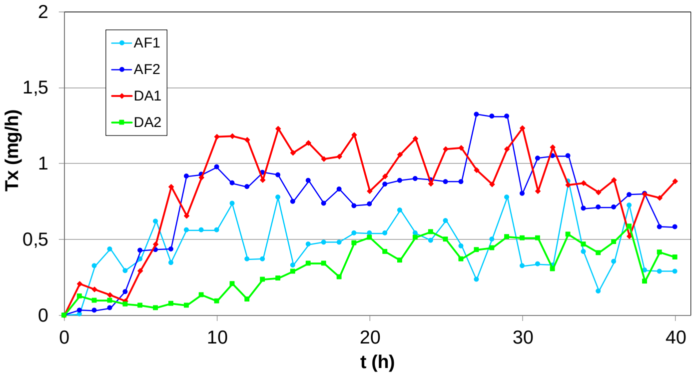

FIGURE 13: Cavitation rate of austenitic stainless steel and cobalt alloy combinations.

The exception occurred at the beginning because DA1 overcame the attenuation as early as the 1st hour and AF2, probably at the 5th hour. In Figure 14, samples are evaluated at this stage in terms of mass loss accumulated.

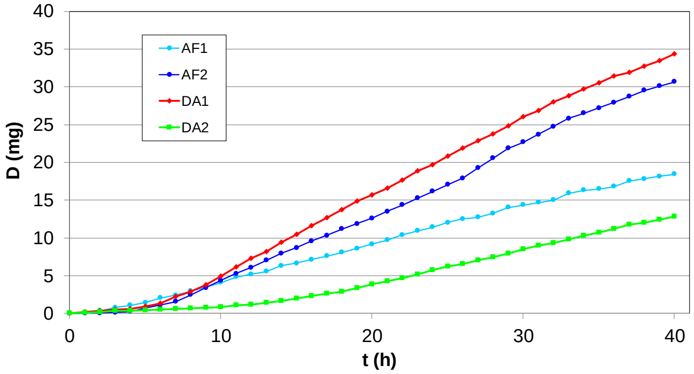

FIGURE 14: Loss of mass by cavitation of the combinations in austenitic stainless steel and cobalt alloys.

The best performance of the DA2 sample in relation to the cavitation wear resistance stands out in view of its characteristic also superior in the erosion. Thus, it is believed that the addition of the Stellite 21 cobalt alloy in the samples, in amounts equal to that of the austenitic stainless steel as it occurs in the parallel double wire GMAW process, can provide a much superior resistance to the coating.

In small quantities, performance is apparently unaffected by the presence of Stellite 21, as in the AF2 sample. Another finding is that the AF1 sample has a better resistance to cavitation than AF2. Finally, the sample DA1 is surprising because it presents a very close behavior soldered only with austenitic stainless steel.

In the work of [5], tests were performed with Stellite 21 and Hidroloy 914, being evident that the resistance to cavitation is not related to the hardness, as it happens in the erosion. In this case, in different surface treatments in materials of similar hardness, the resistance to the cavitation found was different. According to [6], in cobalt alloys, the longer the time for phase transformation to occur, the longer the incubation time and the better the resistance to cavitation.

As in the GMAW double wire parallel one of the addition metals is austenitic stainless steel and the other in cobalt alloy, there may have been an uneven mixing in the weld bead, and a preferential wear in regions of less resistance, including region of the heat affected zone. The topographic aspect of the DA2 sample is shown in Figure 15.

Note with a sample DA2 with addition of Stellite 21 with a deposit with uniform microstructure, without a presence of regions so strongly affected by the wear. However, it is still possible to note some pronounced reliefs and valleys in Figure 15 and 16 that the mass loss is not significantly affected.

With respect to cavitation, it is evident that the initial hardness of the specimen is not the main factor influencing its resistance, as it happens in erosion at normal incidence. Test piece DA2, welded with Stellite 21, has the lowest surface hardness (H=251 kgf/mm^2) of the test specimens tested. However, it presented the lowest rate of cavitation erosion. On the other hand, AF2 test specimens with the greatest hardness (H=284 kgf/mm2) have a performance below AF1 (H=264 kgf/mm^2), being one of the test specimens with the highest cavitation wear.

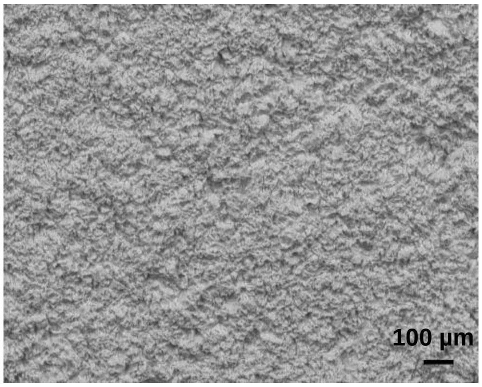

FIGURE 15: Topographic appearance of the cavitated sample DA2, Scanning Electron Microscope.

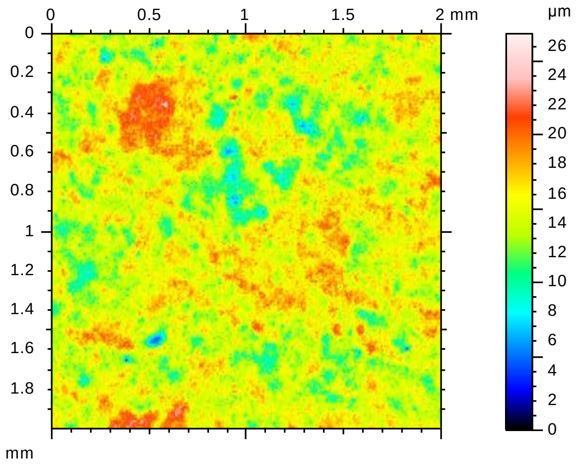

FIGURE 16: Sample level diagram DA2.

4. CONCLUSIONS

GMAW welding in the horizontal position with austenitic stainless steel energized addition metal and cold cobalt alloy wire presented a suitable surface appearance, with deposition efficiency above 90%, being a satisfactory alternative for welding coating.

In all cases, the presence of cobalt alloy in the electrode wire alters the dynamics of the fusion well, not presenting a cord with the same regularity of the austenitic stainless steel.

The GMAW double parallel wire and flat plane series combining austenitic stainless steel and cobalt alloys has a differentiated behavior in relation to the use of addition metals of the same composition. The benefits of using the addition metal combination in the sense of reducing wear are evident. However, it is necessary to deepen the understanding of the characteristics of the arc and the melting pool. It is believed that the phenomena involving the magnetic attraction of the arcs act by diverting only the austenitic stainless steel, generating a pool of fusion in some unstable and heterogeneous way.

Erosion proves the benefit of using addition metal with a combination of austenitic stainless steel and cobalt alloy which, depending on the welding conditions, can achieve a much higher performance. One of the hypotheses is that the high hardness achieved by the surface with the presence of cobalt, especially when using Stellite 21, provides a higher mechanical resistance, reducing wear. Welded coatings with the combination of austenitic stainless steel and Stellite 21 cobalt alloy tended to exhibit superior erosion performance regardless of the welding process used. Nsoesie et al. (2014) attributed the best performance of Stellite 21 to erosion with normal incidence to its higher hardness. The intermetallic carbides formed in the Stellite 21 alloy have hardness compatible with materials rich in Cr carbides.

The double wire GMAW welding process and series presented the greatest resistance to erosion mass loss. This is an indication that a higher welding energy of these processes is likely to provide a significant microstructural change, with a higher hardness in the coating, consequently with a reduction of erosion wear.

In erosion, the roughness parameters had close performances in all the tests. It is also not possible to directly correlate the roughness parameters with the mass loss or erosion rate, this being attributed to the great heterogeneity of the surface of the coating.

The resistance to cavitation has become superior when combining austenitic stainless steel with Stellite 21 cobalt alloy. Such performance for 20 hours reached 23% of the observed values for both austenitic stainless steel wires. With this, the mass loss observed for 40 hours in this test was lower than that observed for austenitic stainless steel wires in 20 hours.

When comparing the cavitation performance of the combination of austenitic stainless steel and the Stellite 6 cobalt alloy, it is believed that the result is even better in terms of wear resistance. This fact was clearly demonstrated in the cold wire MIG / MAG process for the cavitation tests.

It is not possible to relate erosion and cavitation, as shown in the samples AF1 and AF2 for the combination of austenitic stainless steel and cobalt alloys. The wear present in pure erosion is strongly affected by the surface hardness and consequently the coating composed of Stellite 21 has advantage in reducing wear. In cavitation, conversely, the presence of Stellite 6 is the most advantageous in terms of lower mass loss.

As future work is proposed to make a mathematical analysis covering the loss of mass to relate them to the parameters of roughness and hardness. The aim is to construct models capable of estimating the loss of mass in materials applied in coatings, reducing the scale of experiments and the cost involved in the research.

5. REFERENCES

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