academicJournals

Vol. 8(36), pp. 1730-1740, 25 September, 2013
DOI 10.5897/SRE2013.5638
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Wear resistance in hardfacing applied in substrate SAE 1020 using welding process Gas Tungsten Arc Welding (GTAW) alloy Stellite 6 in powder form

Paulo Cezar Moselli[1], Marcelo Falcão de Oliveira[2] and João Roberto Sartori Moreno[1]*

[1]Mechanical Engineering Department, Universidade Tecnológica Federal do Paraná – UTFPR, Av. Alberto Carazzai, 1640 - Cornélio Procópio/PR, - Zip Code 86300-000, Brazil.
[2]Materials Engineering Department, Universidade de São Paulo, Escola de Engenharia de São Carlos, Av. Trabalhador São Carlense, 400 - São Carlos, SP - Zip Code 13566590, Brazil.

Accepted 16 September, 2013

This article describes an innovative application of hardfacing using Gas Tungsten Arc Welding (GTAW) process with alloys in powder form incorporated directly into the weld puddle. Stellite 6 alloy was used on the substrate of SAE 1020 steel mainly due to wear resistance. The good wear resistance is due to the characteristics of Co-Cr carbide dispersed in a matrix alloy deposited. Vickers hardness data, deposition rate, dilution, optical micrograph and Scanning Electron Microscopy (SEM) with the corresponding EDS spectra analysis were performed and compared with the results of the processed PTA. The results showed pore-free coating without surface oxidation and dilution higher than the PTA process. Microstructural analysis showed a finer microstructure for the PTA process, possibly due to the low dilution rate. But it was found that for the semi-automatic GTAW process, there also appeared dendritic microstructure little finer than the proximity permitted good properties of both processes, PTA automatic and semi-automatic GTAW. The hardness obtained through PTA and semi-automatic GTAW were similar throughout the deposited material, as areas rich in Co-Cr carbides in the matrix were intense. Therefore, the wear resistance and the PTA processes GTAW automatic, were approximately 19.2% higher for 9 g/min deposition rate and 8.9% in deposition rate of 19 g/min, for the highest dilution with automatic GTAW.

Key words: Gas Tungsten Arc Welding (GTAW), PTA, hardfacing, wear resistance.

INTRODUCTION

It is dishonorable to see that parts are degraded by wear mechanisms such as abrasion and corrosion, as examples of parts subjected to rigid and durable hardfacing are as related by Pradeepet al. (2010).

Aiming to extend the lifetime of parts and reduce costs with the same exchange, periodic repairs are performed with welding coatings deposition on worn areas. These repairs should be of high quality, such as Stellite 6 alloy which is cobalt based alloys with matrix in complex carbides. They are resistant to wear corrosion and galling and retain its properties at elevated temperatures. Its exceptional wear resistance is mainly due to the dispersion of hard carbide matrix Co-Cr alloy. Today's trend is to use alloys and compounds on substrates to generate the formation of carbides, nitrides, oxides, among others, increasing the wear resistance. The choice of the type of coating and the alloy to be deposited depends on several factors, such as operating conditions, characteristics of the base metal and the cost/benefit processing. The use of Stellite 6 alloy in powder form or

*Corresponding author. E-mail: joaosartori@utfpr.edu.br.

Table 1. Composition of the nominal substrate (SAE 1020) and filler (Stellite 6).

	Co	Fe	C	Cr	Ni	W	Si	Mo	Mn	P	S	Others
SAE 1020	-	Bal.	0.19	-	-	-	-	-	0.4	0.03	0.04	-
Stellite 6	Bal.	2.13	1.13	30.85	2.39	4.65	1.40	0.35	0.25	0.005	0.006	0.40

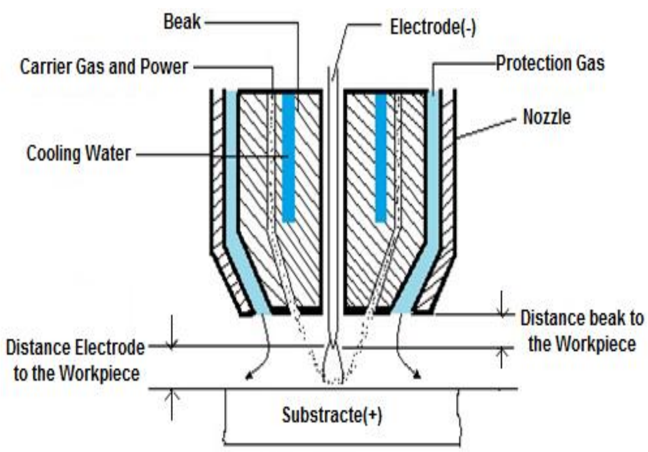

Figure 1. Device used for powder deposition by GTAW process - schematic representation.

rods, for the deposition of coatings constituted by pure chemical Gas Tungsten Arc Welding (GTAW) process, has gradually been used in an attempt to improve the properties of the coatings. Such studies have achieved results with excellent quality both in wear resistance as well as corrosion in the maintenance of these properties at higher temperatures. The behavior of these properties is directly related to the process parameters such as welding current, because its intensity and type directly influences the dilution and microstructure of the deposit according to Bond and D'Oliveira (2012) and Madadi et al. (2011). The GTAW process has important features, since they have weld beads of high quality, free of debris, rust, and waive any treatment after welding. The fact is that this process use filler materials in powder form allowing deposition of a wide range of chemical compositions, including allow the development of alloys with properties to meet specific operating conditions as mentioned by Davis (1993). The welding process Gas Tungsten Arc Welding (GTAW) or TIG, is a process that uses an arc between the non-consumable tungsten electrode by using alloys in powder form directly in weld puddle of metal, thus creating hard coatings and efficient with regards to wear.

MATERIALS AND METHODS

SAE 1020 steel was used as substrate, with machined dimensions 100 × 50 × 12 mm, and were later rectified to remove oxides, oil and dirt, aiming to achieve a better performance and quality of the weld bead. Also, an alloy based on cobalt, commercially known as Stellite 6 WM manufactured by Deloro Stellite, was used as filler metal in powder whose particle size is around 45 and 180 μm and hardness around 405 HV. Table 1 shows the nominal chemical composition of the substrate alloy and Stellite 6, supplied by the manufacturer. For the deposition of metal powder, an automatic feeding system type ADP-2 was used and the deposition speed was controlled by adjusting feed amount. Each plate was deposited on a cord with the torch developing a displacement in the form of oscillation with amplitude of 25 and 4 mm of period, respectively.

Figure 1 shows the device used for applying the coating by GTAW process; such device was developed and adapted to the torch for depositing the alloy directly over the weld puddle.

For comparison among the processes PTA – Powder (PTA) and GTAW–Powder (GTAW), welding parameters used are shown in Table 2, where the number 1 correspond to 9.5 g/min dilution rate and the number 2 the rate 19 g/min.

Since the micro structural analysis was performed by using KOZO metallographic microscope, model 300 XVM with digital camera model DCM510 CANNON, on surfaces and in the regions of interface between the coating and substrate, with magnification of 200 times. The attacks were carried out with a solution consisting of 15 mL H_2O, 15 mL HNO_3, CH_3COOH 15 mL and 60 mL HCl according to Takeyama and D´Oliveira (2004) specifically to reveal the dendritic structure of an alloy rich in cobalt.

The quantification dilutions were performed by the method of area ratio based on participation of the substrate to form the coating by using the Digital Image Tool for calculation and delineation of the areas.

The micro hardness were made in the central cross section of the cord by a Micro test Micro hardness, HV 1000B with a load of 500 g, according to ABNT NBR 6672/81.

RESULTS AND DISCUSSION

Micrographic analysis

Figures 2, 3 and 4 show micrographs of deposits by GTAW process and the PTA process carried out near the interface coating/substrate and surface coating are similar to results obtained in other works (Paredes et al., 2006; Crook, 2010) where more refined structures present near the surface. On the other hand, in the fusion zone there is always increased dendritic growth followed by a microstructure characterized planar hypoeutectic both of the automatic procedure as for the semi-automatic.

We can see that the microstructures of the processes with higher dilutions may be related to the emergence of retained austenite, that is, phase may cause a decrease in coating hardness and consequently higher wear.

The dendritic structure rich in cobalt and chromium becomes coarser near the surface which gives even more depending on the dilution, increased hardness and

Table 2. Parameters used to compare PTA-Powder and GTAW-Powder process.

Continuous Current	PTA1 *	PTA2*	GTAW 1 */**	GTAW 2 */**
Current	155 A			
Amplitude	25 mm			
Distance between passes	4 mm			
Welding speed	12 cm/min			
Shielding gas flow	15 L/min		10 L/min	
Carrier gas flow	3.5 L/min		1.5 L/min	
Plasma gas flow	2.5 L/min		-	
Electrode distance to the workpiece	-		10 mm	
Sharpening the electrode tip	-		30°	
Nozzle distance to the workpiece	10 mm		13 mm	
Deposition rate - g/min	9.5	19	9.5	19

P.S.: * Automatic, **Semi-automatic.

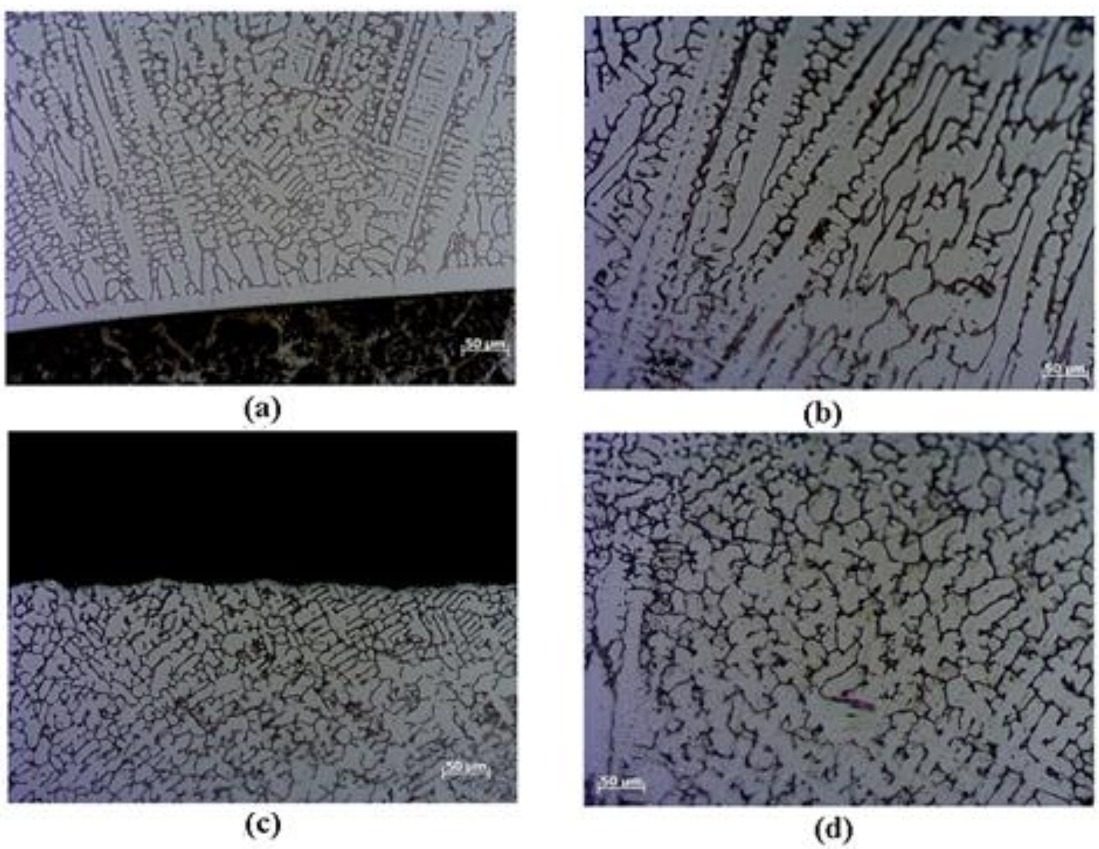

Figure 2. Micrographs of Powder Coating GTAW1 automatic (a) close to the interface and (b) near the surface and GTAW2 (c) close to the interface and (d) near the surface.

better wear resistance.

However, it can be viewed by the micrograph from Figure 4 that in case of the micro structure PTA which appeared more dendritic refined than the GTAW process, perhaps this can be caused due to the low dilution of the process itself PTA according to Balasubrarnanian (2009). It is noted that all micrographs are similar to results obtained by other researchers as Fei et al. (2006), Buchely et al. (2005), working with the process PTA and GTAW where the finer structures are close to the surface being that in the region close to the fusion there has been a growing planar, which is expected because of the large

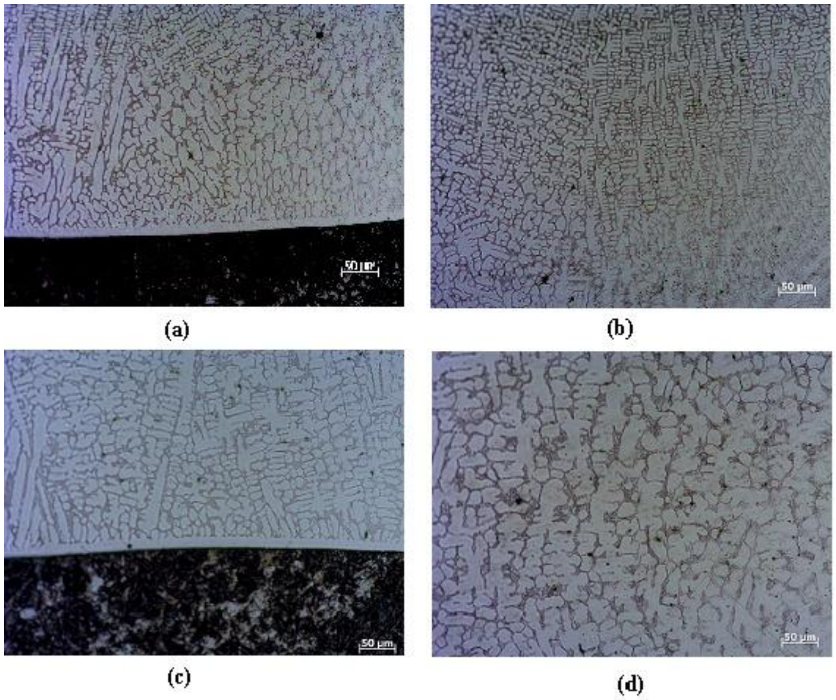

Figure 3. Micrographs of Powder Coating GTAW1 semi-automatic (a) close to the interface and (b) near the surface and GTAW2 (c) close to the interface d) near the surface.

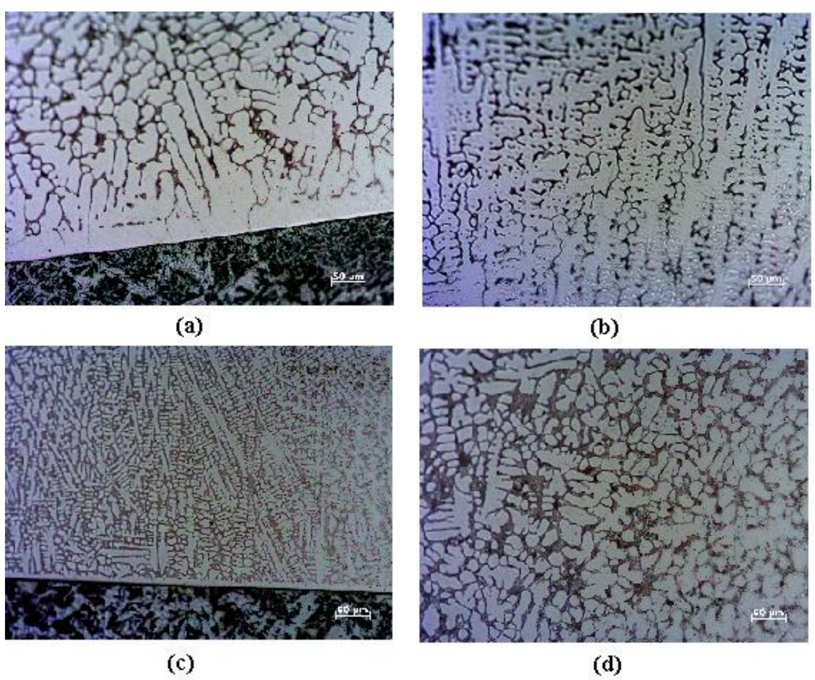

Figure 4. Micrographs of Coating PTA1 (a) close to the interface (b) close to the surface and PTA2 (c) close to the interface (d) near the surface.

local thermal gradient and subsequently dendritic growth. Denser structures have been observed in the case of eutectic welding process PTA deposited on the surface layers with Stellite 6. What can be noted is that this

Table 3. Deposition efficiency and dilution of coatings.

Parameter	PTA1*	PTA2*	GTAW 1*	GTAW 2*	GTAW 1**	GTAW 2**
Deposition rate g/min	9.5	19	9.5	19	9.5	19
Efficiencytodiluition %	93	93	94	87	85	85
Diluition %	7.0	4.2	17.4	7.0	10.0	5.0

P.S. : * Automatic, **Semi-automatic

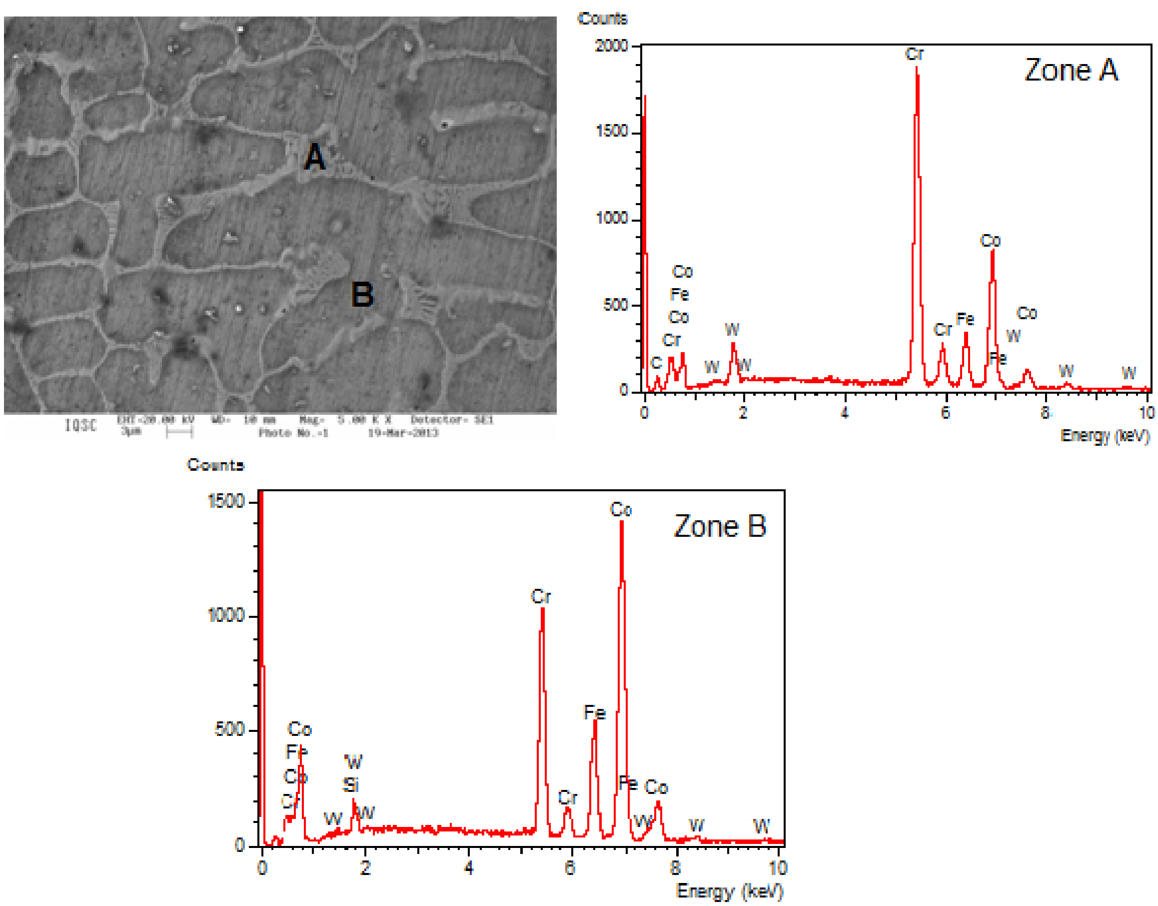

Figure 5. SEM of the coating GTAW1– automatic close to the surface of the coating and its EDS zones A and B.

structure tipic solidification of Co-based coatings, more specifically, the alloy Stellite 6, or in all of them that are hypoeutectic, the microstructure is dendritic primary solid solution with cobalt CFC surrounded by eutectic inter-dendrític as related for Buchely et al. (2005).

Determination of dilution

Analyzing only the cords deposited by GTAW-powder, there was observed a considerable reduction of dilution, when increasing the deposition rate, reaching values very close to PTA. This observation is in accordance with that found in Fei et al. (2006), where there was higher deposition rate for a particular energy level; smaller is the dilution according to Balasubrarnanian (2009) and Madadi et al. (2012).

The manual low dilution procedure or semi-automatic may be due to the non-constant welding speed. Table 3 shows analysis results related with dilution and calculation of income for the deposition processes PTA1 and PTA2 automatics, GTAW1 and GTAW2 semi-automatic and automatic respectively.

Scanning Electron Microscopy (SEM)

Figures 5, 6, 7, 8, 9 and 10 show the analysis of results

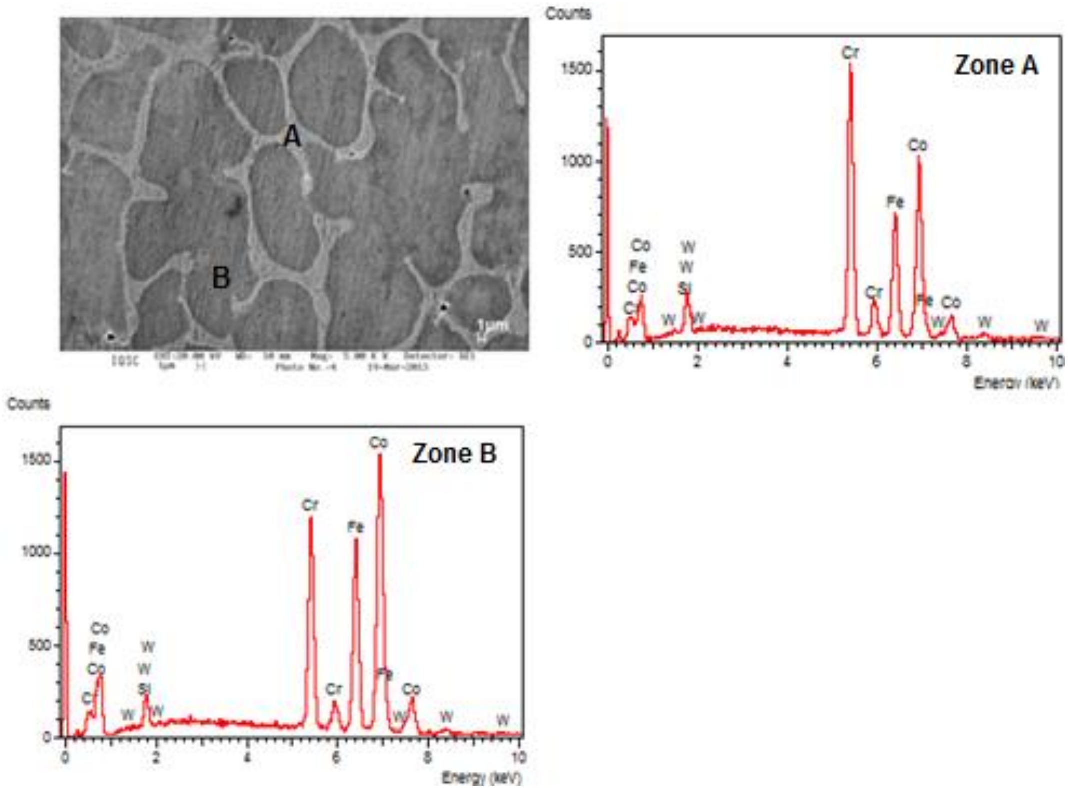

Figure 6. SEM of the coating GTAW2- automatic close to the surface of the coating and its EDS zones A and B.

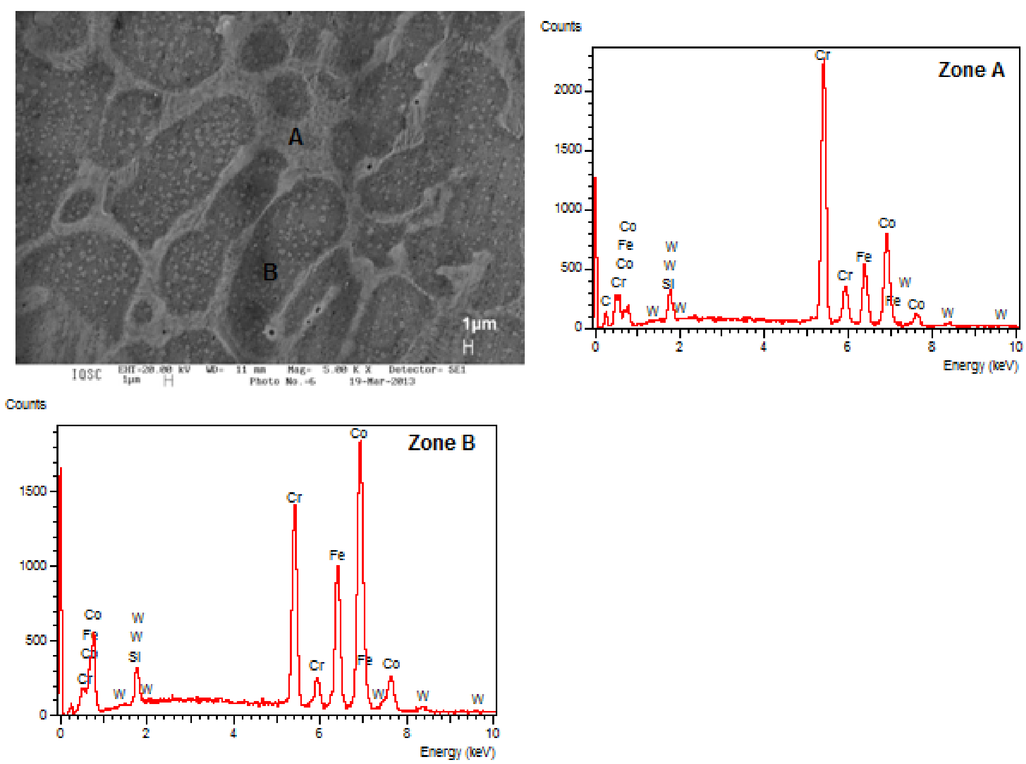

Figure 7. SEM of the coating GTAW1 semi-automatic close to the surface of the coating and its EDS zones A and B.

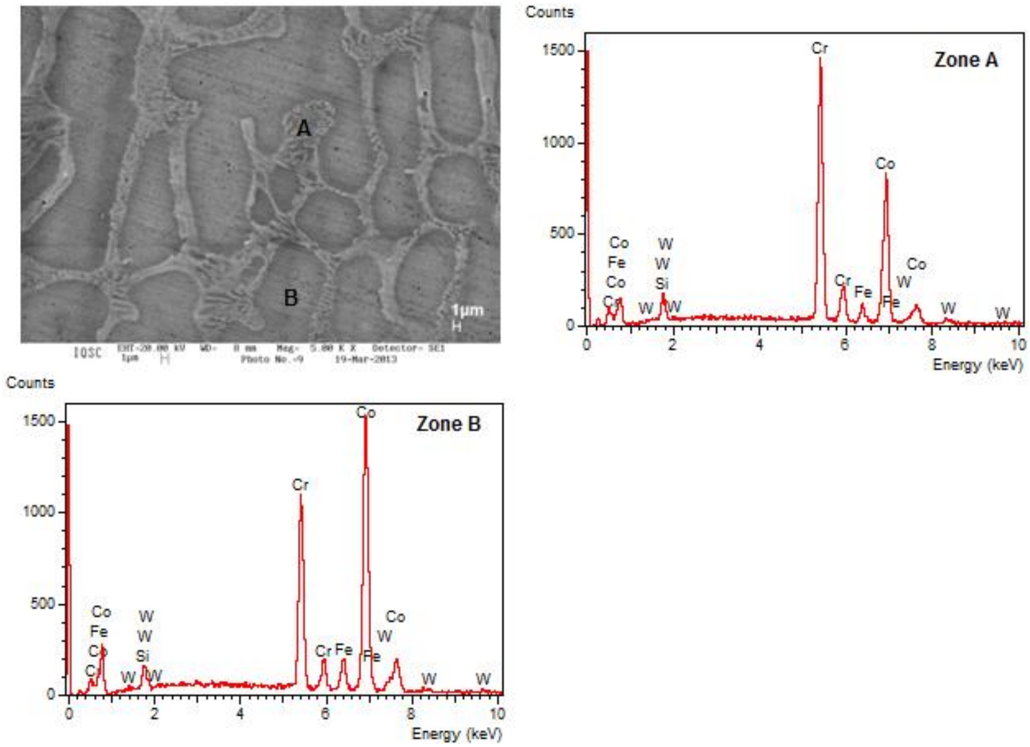

Figure 8. SEM of the coating GTAW2- semi-automatic close to the surface of the coating and its EDS zones A and B.

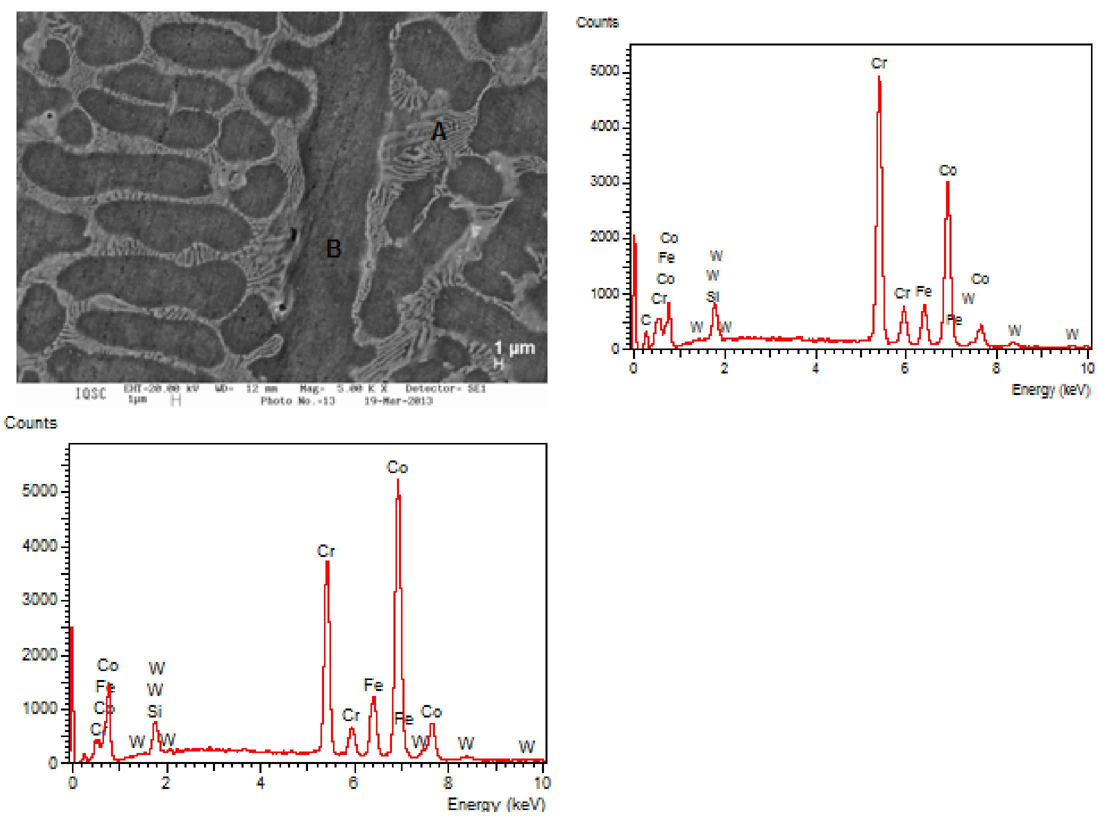

Figure 9. SEM of the coating PTA1- automatic close to the surface of the coating and its EDS zones A and B.

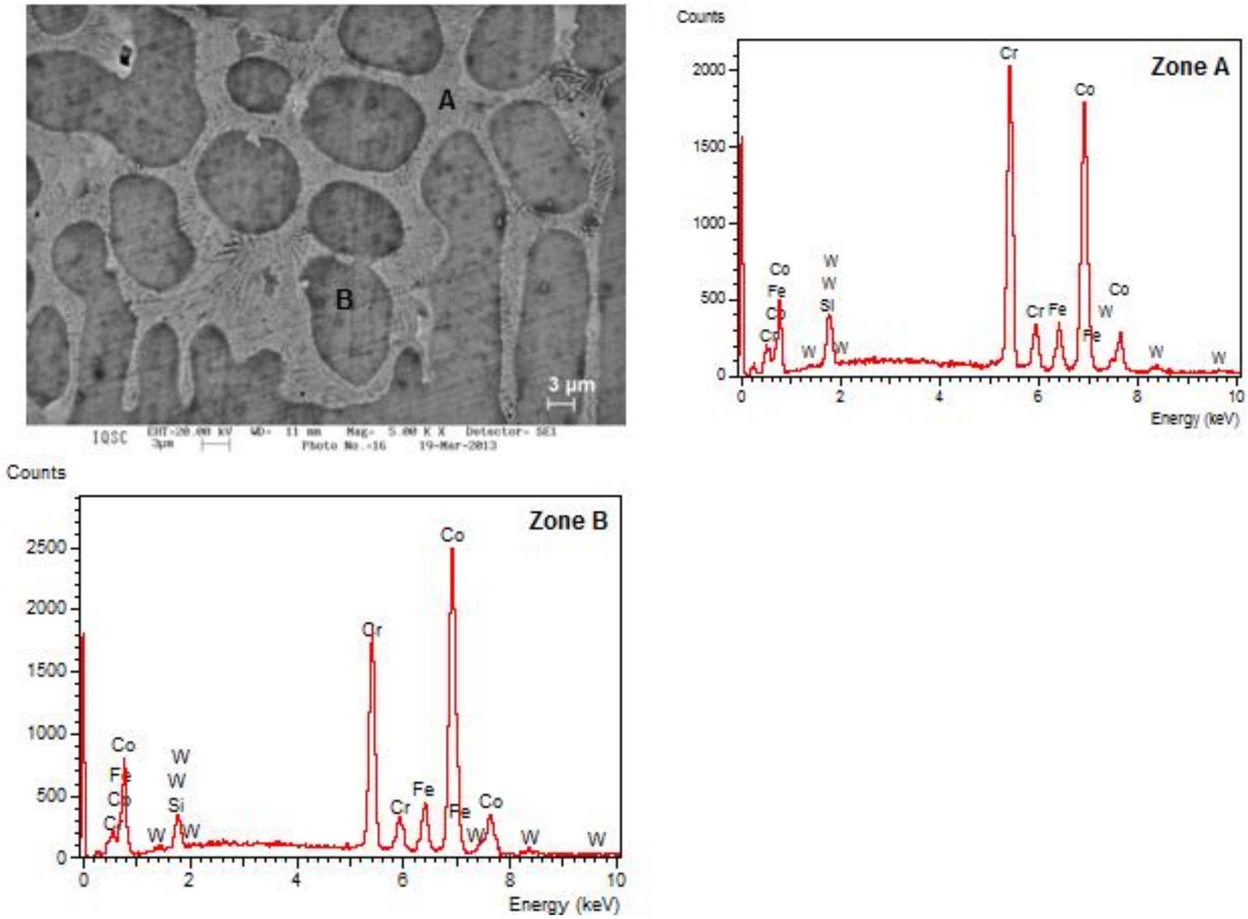

Figure 10. SEM of the coating PTA2- automatic close to the surface of the coating and its EDS zones A and B.

of Scanning Electron Microscopy with corresponding EDS spectra analysis of the regions that identify the structure near the surface of the coating and dilution rates of 9.5 and 19 g/min, respectively for the three conditions proposed in this paper: GTAW automatic, GTAW semi-automatic and PTA. Each condition was observed to be near the surface regions of the coating and near the interface with the base material. We observed a similar microstructure and characteristic for coatings with cobalt-based alloys, as well as a chemical composition similar to the three conditions with small variations caused by differences between dilutions according to Balasubrarnanian (2009).

Determination of the wear resistance

The equipment "wheel" rubber promotes the three-body abrasive wear in the closed system where the sand particles are trapped between two surfaces that slide each other, according to ASTM G65-00. In this case, the tests were conducted by the procedure of type A, rotating the axle 200 rpm normal load of 130 N, and test time 10 min. Subsequent to the determination of mass loss was calculated volume loss, as determined by the standard test.

Figure 11a and b show a comparison of volume loss between tests of coatings, and we can observe a better performance in both conditions for coating GTAW semi-automatic 10% dilution with values very similar to the PTA automatic 7% dilution. It was also observed in the Figure 11b in condition for deposition of 19 g/min, but the wear values were smaller than the values of the deposition condition of 9.5 g/min. This behavior can be attributed to the low dilution values for the coatings deposition rate of 19 g/min, even with the coating composition closest to the composition of the alloy deposited.

However, analysis of these graphs revealed that in accordance with margins of error behavior of the coatings were similar. On the other hand, the volume loss was more pronounced with the conditions for the deposition of 9.5 g/min in automatic conditions probably to be associated with the appearance of austenite and lower cobalt content in the matrix of these levels as observed in Tables 4 to 9 respectively. This may have contributed to this decrease of hardness and higher volume loss of coatings.

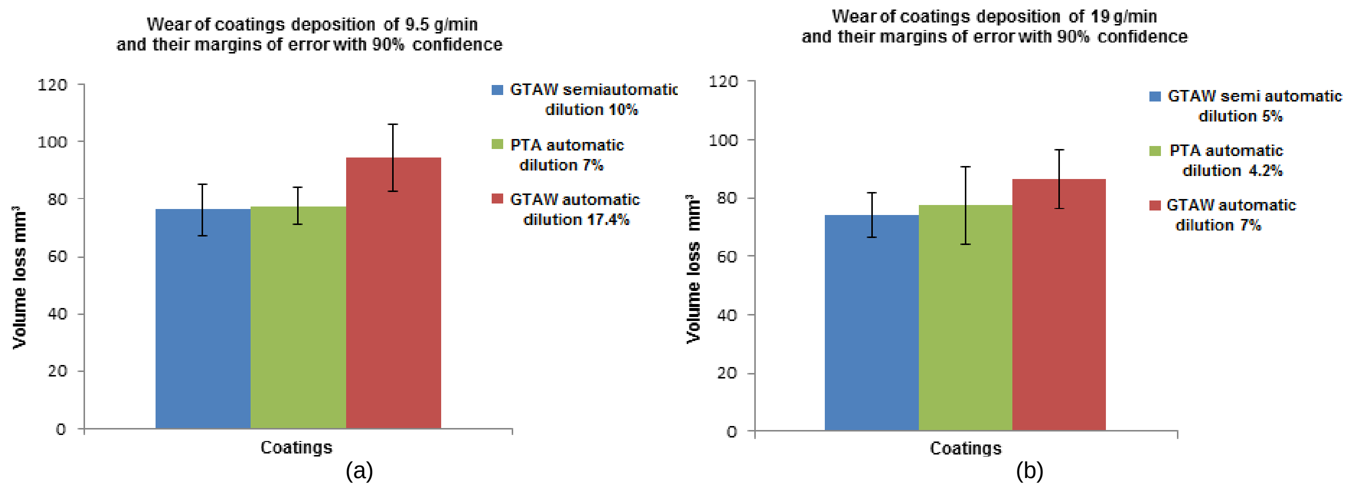

Figure 11a. Loss of volume wear test under the condition of deposition of (a) 9.5 and (b) 19 g/min, respectively.

Table 4. Chemical composition by EDS analysis detected the zones A and B of deposition GTAW 1 automatic nearsurface.

Elements	% em A	% em B
C	6.32	-
Cr	42.08	22.00
Fe	10.63	16.93
Co	33.85	56.53
W	7.12	3.75
Si	-	0.79
Total	100	100

Table 5. Chemical composition by EDS analysis detected the zones A and B of deposition GTAW2- automatic nearsurface.

Elements	% em A	% em B
C	-	-
Cr	30.96	19.35
Fe	23.13	27.93
Co	39.15	48.60
W	6.02	3.39
Si	0.75	0.73
Total	100	100

Table 6. Chemical composition by EDS analysis detected the zones A and B of deposition GTAW1-semi-automatic nearsurface.

Elements	% em A	% em B
C	8.58	3.81
Cr	43.68	19.77
Fe	13.94	22.09
Co	27.54	50.29
W	5.71	2.81
Si	0.55	1.23
Total	100	100

Table 7. Chemical composition by EDS analysis detected the zones A and B of deposition GTAW2- semi-automatic nearsurface.

Elements	% em A	% em B
C	-	-
Cr	44.18	24.53
Fe	4.46	6.07
Co	46.17	65.43
W	4.08	3.04
Si	1.11	0.93
Total	100	100

Table 8. Chemical composition by EDS analysis detected the zones A and B of deposition PTA1-automatic nearsurface.

Elements	% em A	% em B
C	7.71	-
Cr	36.60	22.98
Fe	8.35	11.43
Co	40.50	60.84
W	5.99	3.67
Si	0.86	1.07
Total	100	100

Table 9. Chemical composition by EDS analysis detected the zones A and B of deposition PTA2-automatic nearsurface.

Elements	% em A	% em B
C	-	-
Cr	34.41	23.95
Fe	6.75	8.18
Co	53.32	63.03
W	6.44	3.95
Si	1.08	0.89
Total	100	100

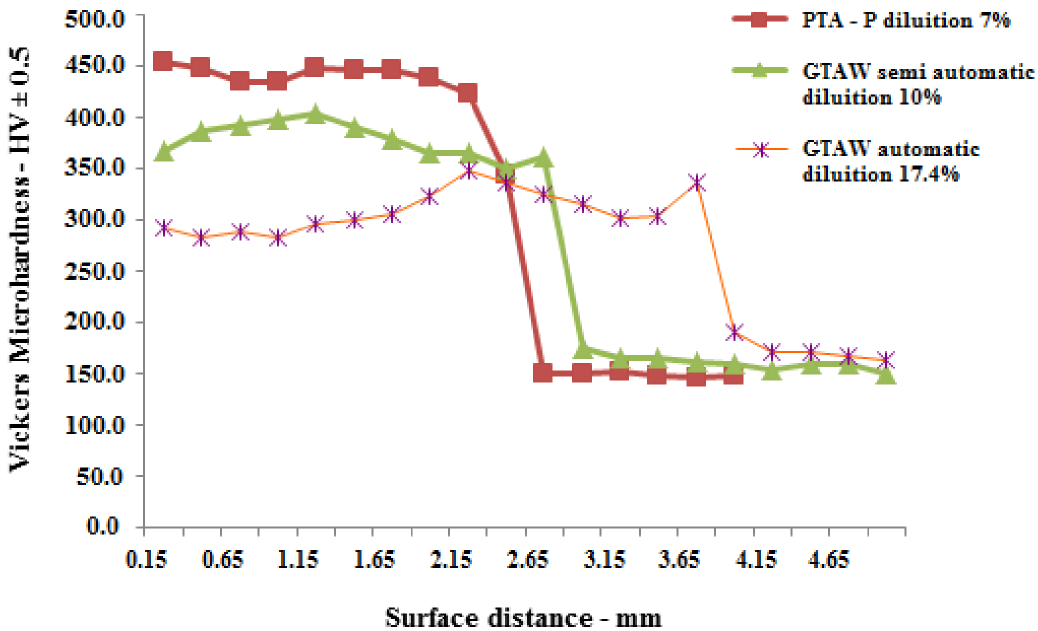

Figure 12. Micro hardness profiles for deposition of 9.5 g/min.

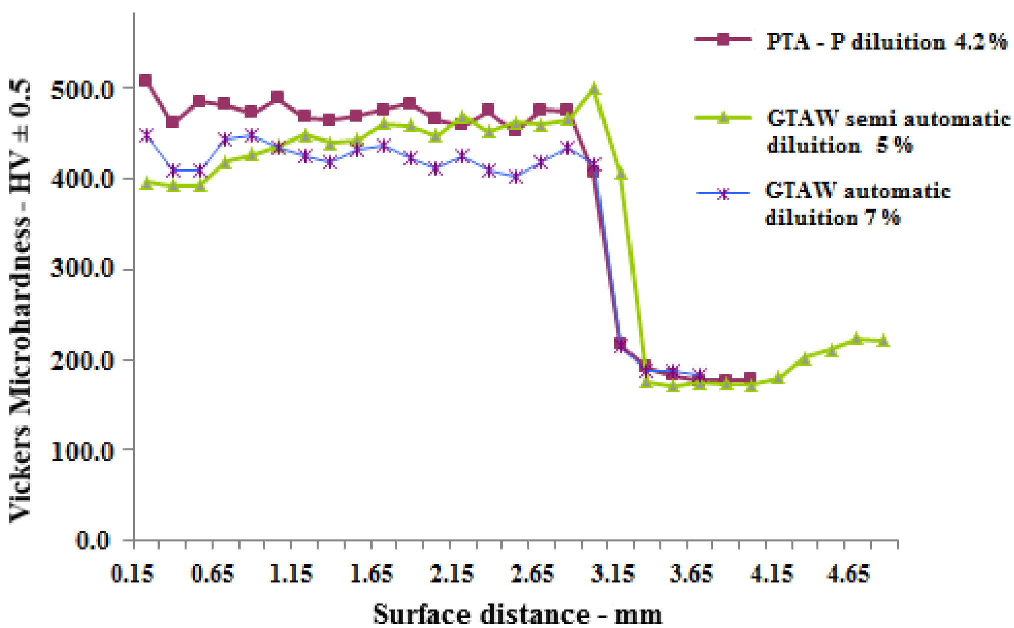

Figure 13. Micro hardness profiles for deposition of 19 g/min.

Determination of hardness

Figures 12 and 13 show the micro hardness profiles obtained based on the distance between the indentations and surface coatings for the deposition conditions of 9.5 and 19 g/min, respectively.

It is observed that for the condition of deposition of 9.5 g/min, there was a better behavior for the GTAW-Powder semi-automatic observing an increased concentration of values between 280 and 400 HV.

However, for the deposition rate of 19 g/min, it is possible to observe that the results are very close in both cases, even considering dilution rates for each specific process: automatic and semi-automatic/manual.

Therefore, the best performance was attributed to the semi-automatic process, perhaps due to the movement of the operator welding torch and also welding speed shifting, which caused a lower dilution and consequent higher refining in the microstructure.

Conclusions

As the main purpose of this work was focused on the production of hard coatings by GTAW process and also developing a device adaptable to any GTAW/TIG torches, it was observed that its performance was similar to other processes such as the PTA, or it produced hard coating with deposition of the alloy in a powder form directly into the weld puddle.

Therefore, it is observed that with improved GTAW-Powder process parameters, for example, increased deposition rate, increasing the speed and decreasing the welding current, particularly for the manual process, the coatings were found to have better characteristics regarding resistance to wear.

The hardness obtained by the process GTAW-Powder was higher for semi-automatic process with lower dilutions, but with increase in the deposition rate, the amounts tend to increase throughout the surface. However, the wear resistance values were very close to the PTA, with better performance for the GTAW process semi-automatic.

The increase in deposition rate induced a decrease in the values of dilution GTAW-Power process, approaching the hand to the PTA process, and this decrease of the dilution influence the results of hardness and wear.

It was also observed that chromium and cobalt contained in the alloy Stellite 6, in the low dilution rates increased, thereby coating the best performance in terms of wear, mainly because cobalt carbides distributed in coatings made at low dilution rate and the GTAW process semi-automatic.

ACKNOWLEDGEMENTS

Mechanics Engineering Department of the UTFPR - CornélioProcópio - PR - Brazil and Materials and Manufacturing Department of USP - EESC - São Carlos - SP - Brazil.

REFERENCES

Balasubrarnanian V (2009). Application of response surface methodology to prediction of dilution in plasma transferred arc hardfacing of stainless steel on carbon steel. J. Iron Steel Res. Int. 16(1):44-53.

Bond D, D'Oliveira ASM (2012). Effect of Current and Atomized Grain Size Distribution on the Solidification of Plasma Transferred Arc Coatings. Mater. Res. 15(5):770-774.

Buchely MF, Gutierrez JC, Leon LM, Toro A (2005). The effect of microstructure on abrasive wear hardfacing alloys, Tribology and Surfaces Group, National University of Colômbia, Medellin-Colômbia. Sci. Direct Wear 259:52-61.

Crook P (2010). Cobalt and Cobalt alloys Properties and Selection: Nonferrous Alloys and Special-Purpose Materials. ASM Handbook - 2. 10thed.

Davis JR (1993). Hardfacing Weld Cladding and Dissimilar Metal Joining. Welding Brazing and Soldering, ASM Handbook - 6.

D'Oliveira ASCM, Paredes RSC, Santos RLC (2006). Pulsed current plasma transferred arc hardfacing. J. Mater. Process. Technol. 171(2:)167–174.

Fei YH, Zao YY, Li HC, Truan SL (2006). Microstructural characteristics of PTA- overlayed NbC on pure Ti. Surf. Coat. Technol. 24(1):6881-6887.

Madadi F, Ashrafizadeh F, Shamanian M (2011). Effect of pulse current on microstructure and wear resistance of Stellite 6/tungsten carbide claddings produced by tungsten inert gas process. Surf. Coat. Technol. 205:4320-4328.

Madadi F, Ashrafizadeh F, Shamanian M (2012). Optimization of pulsed TIG cladding process of Stellite alloy on carbon steel using RSM. J. Alloys Compds. 510:71-77.

Pradeep GRC, Ramesh A, Prasad BD (2010). Rew: Paper on Hardfacing Processes and Materials. J. Eng. Sci. Technol. 2(11):6507-6510.

Takeyama RR, D´Oliveira ASCM (2004). Aumento da resistência de revestimentos de Co pela adição decarbonetos de tungstênio. XVI CBECIMAT - Porto Alegre - Brazil.