ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

Tome XII [2014] – Fascicule 1 [February]
ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]
a free-access multidisciplinary publication of the Faculty of Engineering Hunedoara

[1.] Tatiana LIPTÁKOVÁ, [2.] Monika HALAMOVÁ, [3.] Ayman ALASKARI

INFLUENCE OF SURFACE TREATMENT ON CORROSION BEHAVIOR OF THE WELDED AISI 316L

[1.] University of Zilina, Faculty of Mechanical Engineering, Department of Materials Engineering, Univerzitna 1, 01026 Zilina, SLOVAKIA
[2.] College of Technological Studies, Department of Mechanical Production Technology, P. O. Box: 42325 Shuwaikh 70654, KUWAIT

Abstract: The surface treatment impact on corrosion resistance of the stainless steel AISI 316L welded by the TIG method is studied. Chemical and mechanical surface finishing changes its chemical composition, real size, energy and topography. The mentioned phenomena have great influence on corrosion resistance of the stainless steel which is caused by existence of stable, thin and well adherent passive layer. Because the quality of the passive film is strongly influenced by welding, the surface treatment is very important with regard to its susceptibility to local corrosion. Surfaces of the welded stainless steel were finished by the mechanical methods (grinding, garnet blasting) and chemical one (pickling). The properties of variously prepared surfaces were studied by SEM. Corrosion resistance was determined by the exposition test using for local corrosion evaluation and metallographic analysis. The experimental outcomes confirmed that the surface finishing has significant effect on the corrosion behavior of welded stainless steel AISI 316L.
Keywords: stainless steel, welding, surface finishing, local corrosion, grinding, blasting

1. INTRODUCTION

Stainless steels are construction material with an excellent corrosion resistance and good mechanical properties (strength, resistance to high temperature ductility, toughness). Therefore they are used in conditions that require high reliability and durability of the material [1,2,3]. In certain corrosive environments the austenitic stainless steels are sensitive to a local corrosion attack (pitting, intergranular corrosion).

Corrosion resistance to local forms of corrosion depends on quality of the passive layer created by chemical reaction of stainless steel with oxygen at normal temperature. The protective ability is affected by metal structure, chemical composition (especially by the elements such as Cr, Mo, Ti, N) and also significantly by the surface treatment [3,4,5,6].

High temperature of welding evokes in this material change of structure by formation of undesirable phases and this factor determines the properties of the oxide layer, consequently their corrosion resistance can be therefore reduced. Welding heat in austenitic steels affects mainly filler or melted metal (WM) and the area between the weld metal and base material (BM) - heat affected zone (HAZ). The size and character of the heat effect depends on chemical composition of stainless steel and welding parameters [7,8]. High temperature during welding influences oxidation processes on the metal surface and changes character of oxidation products. Therefore it is appropriate to apply surface treatment after welding [9,10,11]. In practice, blasting by metallic and non-metallic particles, grinding or cutting operation are used for surface treatment of stainless steel. It is necessary to realize all mechanical treatments to avoid unacceptable oxidation, excessive roughness of surface, contamination. In many cases, it is acceptable to combine mechanical treatment with chemical treatment (pickling, passivation) [5,10,11].

2. EXPERIMENT

2.1 Experimental material

The austenitic stainless steel AISI 316L is used as an experimental material. The chemical composition is in Tab. 1.

Table 1. Chemical composition of the AISI 316L steel

Element	Cr	Ni	Mo	Mn	C	Si	N	P	S	Fe
Content of elements, [wt.%]	16.51	10.21	2.10	0.91	0.013	0.65	0.015	0.038	0.006	rest

The microstructure of the AISI 316L steel in transverse and longitudinal section is created by austenitic polyehedral grains with deformation and annealing twins formed during rolling and annealing. In longitudinal section, deformation texture is very strong and there are present delta ferrite and inclusions.

Specimens were cut and prepared from the original plate AISI 316L (120 mm x 60 mm) by waterjet cutting and welded by TIG method with using the filler. The dimensions of the plate were selected to ensure the ease and homogeneity of the welding process (such as work-piece clamping and manipulation, avoiding high residual stress and using only one welding filler rod when needed). Welding parameters in argon atmosphere are shown in Tab. 2. Rod of filler metal has the same chemical composition as the base material AISI 316L steel. During the welding process gas argon was used for a double protection against oxidation.

Table 2. Welding parameters of the used TIG method

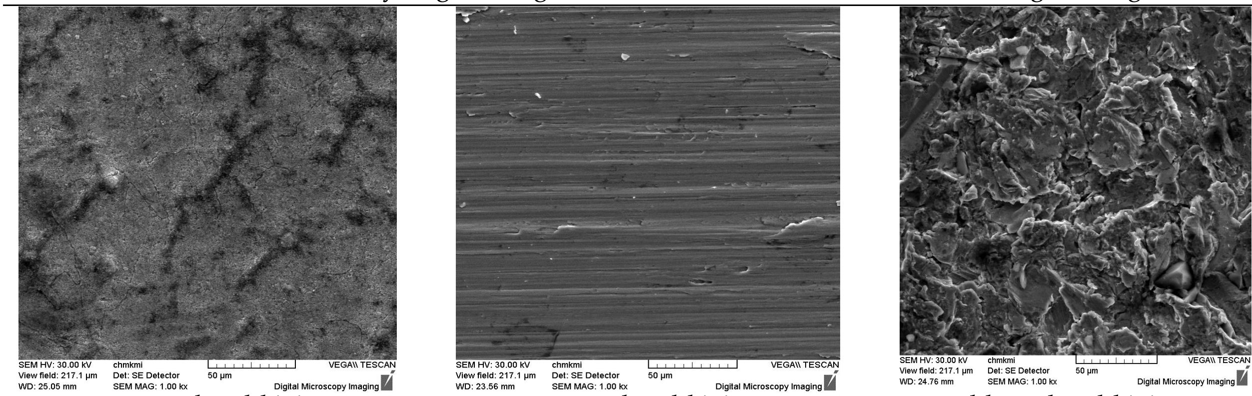
Filler diameter, [mm]	Electrode diameter, [mm]	Used current, [A]	Argon flow, [l/min]
2.4	1.6	115	7

Surfaces of the welded specimens were prepared by grinding and sandblasting. Initial surface grinding was performed to level up the surface of the welded area. This was done by using surface grinding with Al_2O_3 belt with grit of 80. Then each sample was grinded by Al_2O_3 belt with grit of 180. This method provided the welded surface with better surface finishing and better roughness. Sand blasting was performed on some samples with pressure of 6 bars and garnet abrasive grit of 80 (31 wt.% SiO_2, 21.6 wt.% Al_2O_3, 37 wt.% FeO, 7.4 wt.% MgO). The blast pointed at 90 degree angle and lasted for about 60 seconds for each sample. Surface of third group of specimens was without mechanical treatment. In addition, three specimens from each group (untreated, grinding, garnet blasting) were pickled for 30 minutes at temperature of 22±2°C in solution with composition 100 ml of 50% HNO_3, 5 ml of 38% HF, 395 ml of H_2O. These specimens were then cleaned and rinsed with distilled water and then left for sufficient time to dry out. Surface was investigated by SEM and the EDX analysis was carried out. All specimens were then weighted with accuracy of 10^{-5}g to determine weight loss after corrosion test.

2.2. SEM surface evaluation after various treatments

Surface of the specimens was assessed by scanning electron microscope (SEM). The analysis was focused on the character of the surface in the WM and compared. In Fig. 1 the surfaces of weld joints after different mechanical finishing are shown. There are visible differences between surfaces of welded metal finished by different way as well as chemical composition obtained by using the EDX analysis (Tab. 3). On the surface of untreated weld joint is high amount of C in the weld metal created as weld residual.

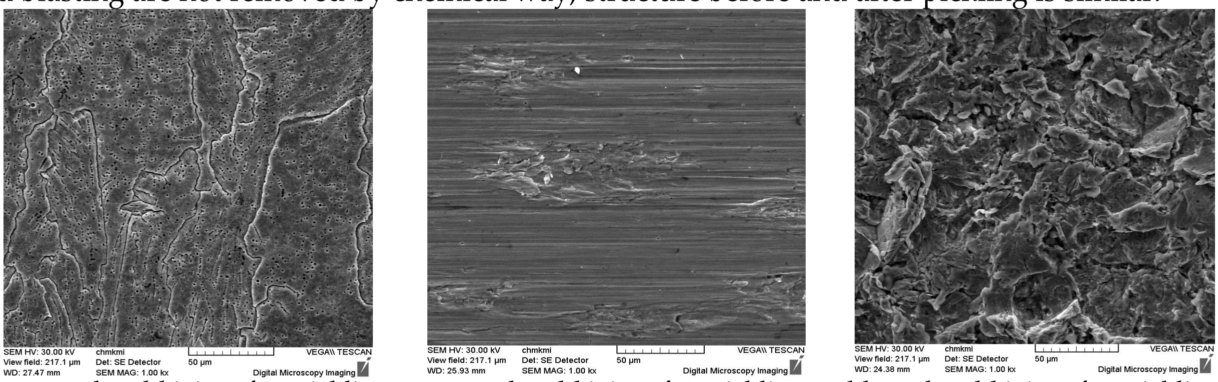
The increased oxygen content indicates a very intensive surface oxidation in comparison especially with the oxygen content in the grinded weld joint. Products of weld reactions were removed and the grinded surface became homogeneous. By blasting there is not reached homogeneity in chemical composition of the studied areas. The roughness and surface topography are poor, in the created crevices corrosive solution can be concentrated resulting restriction of passive layer formation. The surface is also contaminated by blasting agents and some welding products are pushed into the metal surface. These factors can considerably influence susceptibility to local corrosion.



untreated weld joint ground weld joint blasted weld joint

Figure 2. SEM images of weld surfaces with various mechanical treatment

The impact of pickling is reflected on the structure (Figure 2) and chemical composition too in the Table 3. The untreated specimens are partially purified, mainly of welding products (decrease of the oxygen content). The chemical composition of the grinded specimens before and after pickling is nearly the same and it is very similar to primary metal, surface topography is little different. The surface of blasted specimens is chemically cleaned poorly. Impurities erased during welding and blasting are not removed by chemical way, structure before and after pickling is similar.



untreated weld joint after pickling ground weld joint after pickling blasted weld joint after pickling

Figure 3. SEM images of weld surfaces with various mechanical and chemical treatment

Table 3. Chemical composition of the surface after various finishing

Elements	Weight %					
Surface treatment	untreated	untreated + pickled	ground	ground + pickled	blasted	blasted + pickled
C	10.29	9.66	5.53	6.29	5.58	6.14
O	24.22	0.37	0.52	0.71	10.36	7.14
Mg	0	0	0	0	1.44	0.83
Al	0	0	0	0	1.60	1.34
Si	0.85	0.47	0.47	0.57	3.03	1.85
S	0.02	0.06	0.06	0.07	0.07	0.20
Ca	0	0	0	0	0.68	0.37
Cr	16.10	14.79	14.97	15.06	13.01	14.26
Fe	33.53	62.37	67.21	65.88	53.22	58.26
Ni	12.43	9.04	9.11	9.36	8.23	7.90
Mo	1.94	3.52	2.14	2.06	2.78	1.72

2.3 Corrosion test

Welded specimens of AISI 316L with various surface finishing (individual or combine treatments) were tested for resistance to pitting corrosion. The immersion test was carried out in the solution of 6% $FeCl_3$ according to the standard ASTM G 48. The environment temperature during the test was 21°C. After exposition of 72 hours in the test solution the specimens were removed from the immersion vessel, cleaned with demineralized water and dried. The weight losses were determined and corrosion rate evaluated with the accuracy of 10^{-5} g. Table 4 shows the results of immersion tests. To compare mechanical finishing, the grinding is much better from corrosion point of view than blasting. The chemical pickling was effective for the untreated and ground surfaces which resulted in higher corrosion resistance. In the case of specimens after garnet blasting, pickling has a negative effect on their corrosion resistance and the corrosion rate increased. The weld products and blasted particles into subsurface layers of material are not removed by pickling, crevices around the stuck particles are extended and it influences homogeneity of passive layer. Metalographical analyses of the tested specimens after corrosion test is in a good agreement with the weight analysis.

Table 4. Corrosion rates of the AISI 316L stainless steel in 6% $FeCl_3$ solution

Type of surface treatment	Average weight losses [g]	Average corrosion rates [$g \times m^{-2} \times h^{-1}$]	Type of surface treatment	Average weight losses [g]	Average corrosion rates [$g \times m^{-2} \times h^{-1}$]
without treatment	0.31488	3.49866	without treatment + pickling	0.23469	2.60766
grinding	0.28204	3.13377	grinding + pickling	0.23387	2.59855
garnet blasting	0.39604	4.40044	garnet blasting + pickling	0.56692	6.29911
a) No chemical treatment			b) With chemical treatment		

3. CONCLUSIONS

- Mechanical and chemical treatment strongly affects geometry and chemical composition of the welded stainless steel AISI 316L surface. It does result in variation of corrosion resistance to pitting corrosion.
- According to the results obtained from immersion test in the 6% $FeCl_3$ solution it can be said that the most suitable mechanical treatment is grinding. Garnet blasting is unsatisfactory method for treatment of the welded AISI 316L steel since it accelerates corrosion process because non continuous passive layer is created.
- Pickling increases purity of the surface (ground and untreated specimens) and improves corrosion resistance. Corrosion resistance of blasted samples becomes after pickling even worse.
- Taking into account experimental results, incorrect surface treatment can increase the rate of pitting corrosion of the welded AISI 316L twice.

ACKNOWLEDGEMENT

The research was supported by Scientific Grant Agency of Ministry of Education, project VEGA grant No. 1/0066/11. The authors thank for their support.

REFERENCES

[1.] LIPTÁKOVÁ, T. 2009. Pitting corrosion of stainless steels. Žilina: EDIS. ISBN 978-80-554-0083-9. 2009. (in Slovak)
[2.] LEFFLER, B. 2012. Stainless steels and their properties [online]. [cit. 2012-29-11]. Available on the internet: http://www.hazmetal.com/f/kutu/1236776229.pdf.
[3.] TEOH,S.H. 2000. Fatigue of biomaterials, a review. International Journal of Fatigue, 22,10, November 2000, p.825.
[4.] GHOSH, S. – KAIN,V. 2010. Effect of surface machining and cold working on the ambient temperature chloride stress corrosion cracking susceptibility of AISI 304L stainless steel. Materials Science and Engineering A 527 2010 p. 679–683.
[5.] SZKLARSKA – SMIALOWSKA, Z. 2005. Pitting and crevise corrosion. Texas: NACE International. Houston. Texas. 2005.
[6.] FAJNOR, P. – LIPTÁKOVÁ, T. – KONSTANTOVÁ, V. 2010. Influence of AISI 316Ti stainless steel surface treatment on pitting corrosion in various solution. Materials Engineering. Vol. 17. No. 3/2010.
[7.] PADILHA, A.F. et al. 2007. Precipitation in AISI 316L (N) during creep tests at 550 and 600°C up to 10 years. Journal of Nuclear Materials 362 p.132–138. 2007
[8.] WOO, I.- KIKUCHI, Y. 2002. Weldability of High Nitrogen Stainless Steel. ISIJ International.; Vol. 42,No. 12, p. 1334-1343, 2002
[9.] DAVID, S.A. – VITEK, J.M. – ALEXANDER, D.J. Embrittlement of Austenitic Stainless Steel Welds. Journal of Nondestructive Evaluation, Vol. 15. Nos. 3/4, 1996
[10.] ZATKALÍKOVÁ, V. – LIPTÁKOVÁ, T. 2011. Pitting corrosion of stainless steel at the various surface treatments. Materials Engineering. Vol. 18. 2011 p. 115-120.
[11.] KOŽUH, S. – GOJIČ, M. – KOSEC, L. 2007. The effect of annealing on properties of AISI 316L base and weld metals. RMZ – Materials and Geoenvironment, Vol. 54, No. 3, p. 331-344, 2007
[12.] MATHIESEN, T. et al. 2004. Improved method for ASTM G48 corrosion testing of welds. Nordic Innovation Centre – Oslo, 2004, Nord Test Technical report 548.