ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-TUPH15

FRICTION STIR WELDING ATTEMPTS FOR UHV APPLICATIONS: STAINLESS STEEL/ALUMINUM

A. Ermakov†, C. Martens, U. Naujoks, DESY, Hamburg, Germany

Abstract

At DESY in Hamburg an investigation was started to join aluminium chambers with stainless steel flanges by friction stir welding. First results will be presented.
It will be shown that there is only a small effect of hardening in the contact zone at the stainless-steel side, a small amount of particles are given and the diffusion zone is about 3 microns, but with a very irregular effect on the structured junction.

Because of that, the influence of the surface and the welding parameters on the process will be investigated in the future.

OBJECTS FOR WELDING

The choice between different materials in UHV applications becomes more and more important. An investigation was started to combine aluminium chambers with standard UHV-flanges from stainless steel. Friction stir welding attempt was implied on standard UHV-flange type of NW100 (316LN) with Al insert (AN EW 6082 T6) as blind flanges for UHV usage. An industrial enterprise welded a series of flanges with different welding parameters (part of flange presented on Fig. 1). The samples #1, 2 taken from two welded flanges were investigated by means of hardness (Vickers, HV1), X-Ray fluorescence (Al is not visible due to technical limitations) and SEM/EDX element analysis measurements.

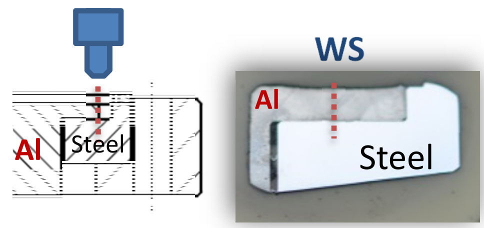

Figure 1: Part of flange with Al-insert. Position of welding seam.

HARDNESS

On Fig. 2 shown the results of hardness measurements in welding seam HAZ/TMAZ areas of sample #1. The hardness values in Aluminium part along the joint interface in WS area has in average 61.5HV1.

In both HAZ/TMAZ in measured region the Al alloy material is ca. 10% harder as in welding seam. The initial hardness of Al alloy is about 90HV so the softening of Al alloy close to welding seam area is obviously due to the temperature rise by welding. The distribution of hardness values in stainless steel shows the hardening of material in welding seam area close to joint interface. Due to relative lower thermal conductivity of stainless steel the hardness values are normalized in distance of about 1mm away to the hardness of stainless steel of ca. 160HV1. Similar variation of hardness of welding partners observed in articles [1-3]. It is reasonable to assume that hardening of material can be caused by at least 3 factors: one of them is deformation or pressure from the welding tool coming from Al side, temperature influence or the building of associated phases.

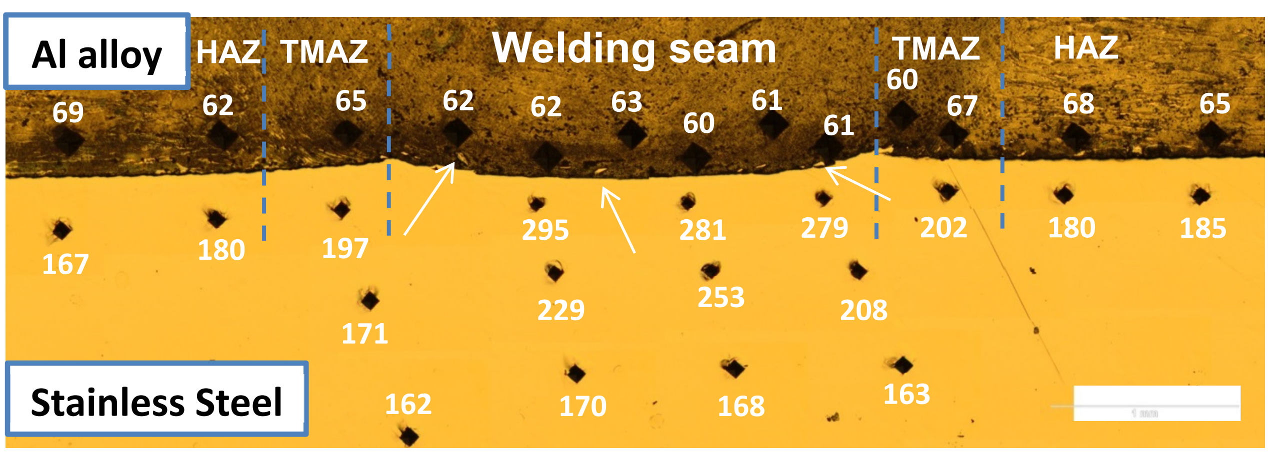

Figure 2: Distribution of HV hardness values measured along welding seam area and TMAZ/HAZ areas. Arrows show the small particles of stainless steel fraction mixed by welding with Al alloy.

† alexey.ermakov@desy.de

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-TUPH15

The deformation and subsequent temperature influence applied by submerging the welding tool into the depth could cause the hardening of stainless steel partner. The number of friction stir welding attempts done by different researches on similar metals confirm also the building in relative narrow welding seam band the phases like Al_5Fe_2, $Al_{13}Fe_4$, Al_3Fe or Fe_3Al [4-8]. The detection of these phases in scope of this task is not possible due to technical limitations. The hardness measured in stainless steel part close to joint interface is ca. 285HV1. This hardness level can be attributed most likely to stainless steel surface mechanical deformation.

MICROSTRUCTURE OBSERVATION

The appearance of small particles of stainless steel fraction in narrow band in Aluminium alloy part close to joint interface is observed (some visible particles are marked with arrows on Fig. 3). These particles are visually observed and its presence confirmed by X-Ray fluorescence element analysis done in some locations of Al partner close to joint interface as well as in one location as reference in stainless steel (Fig. 3).

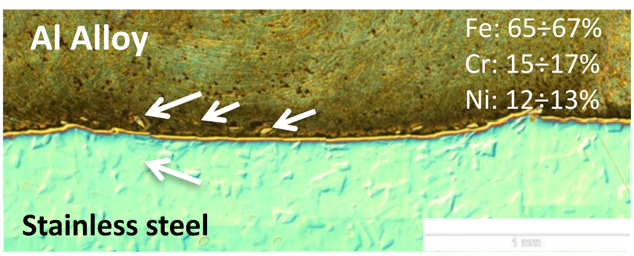

Figure 3: Elements composition measured in some locations of Al alloy and stainless steel parts (shown with arrows) of welding seam area.

The appearance of such particles is mainly associated with the mechanical deformation of the upper layer of stainless steel when the welding tool is touched. Similar structure observed also in [1, 2]. The size and distribution of those particles is evidently depends on some welding parameters such as rotation speed of welding tool and/or speed of feed.

The concentrations profiles of the main elements done by means of SEM/EDX at the welding interface between Stainless steel and Aluminium Alloy show slight mutual diffusion (See Fig. 4). These profiles show particularly the diffusion of stainless steel components Fe, Ni, Cr in deep of Al alloy part up to 2 µm, the diffusion of Al in stainless steel is ca. 1 µm. This difference in diffusions depths could be connected with local temperature, difference in diffusion coefficients of base metals and also the ratio of solubility one component in each other. The similar diffusion behaviour is also observed in [1, 7, 8].

3D MICROSCOPY

To investigate the internal structure of welding seam in details by means of 3D Microscopy the aluminium alloy and stainless steel's parts of samples #1, 2 were mechanically separated from each other.

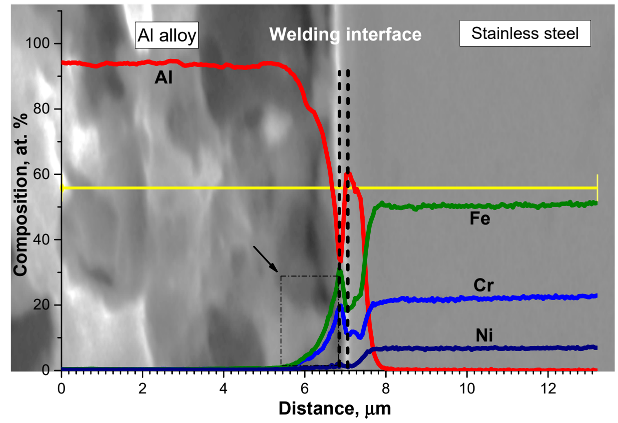

Figure 4: Concentrations profiles of Fe, Ni, Cr and Al across the EDX analysis line at the welding interface between Al alloy and stainless steel.

The circle-like structure observed in welding seam area after separation on sample #2 (Fig. 5) and stripes-like structure on sample #1 (Fig. 6) by means of 3D Microscopy.

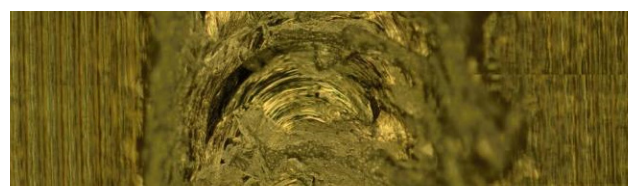

Figure 5: The microstructure of WS area of sample #2.

The circle-like structure in welding seam area of sample #2 show the traces of touching of welding tool of stainless steel partner by welding tool feeding. The welding seam area of sample #1 looks different and consists itself of two different regions: the stripe structure (circle-like structure for sample #2) (mainly in the middle of welding seam) and areas where the diffusion Al – Stainless steel can take place. The stripe structure is similar to base surface of the sample (outside of welding joint) and obviously didn't mechanically deform by welding tool. It can be assumed that the roughness of the stainless steel surface and the penetration depth of the welding tool play an important role. The mutual diffusion takes place only in edge areas and partly in the middle of welding seam area. For example the analysis of chemical composition done in the top of welding seam area (marked by orange circles, see also Fig. 6) by means of SEM/EDX confirms the diffusion of main base components in each other. Also the element analysis by X-Ray fluorescence performed on some locations inside and outside the welding seam area also confirms the diffusion: in location marked with green squares the amplitude (concentration) of base stainless steel components has maximum while in locations marked with red squares the amplitude has significantly lower magnitude (see Fig. 6).

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-TUPH15

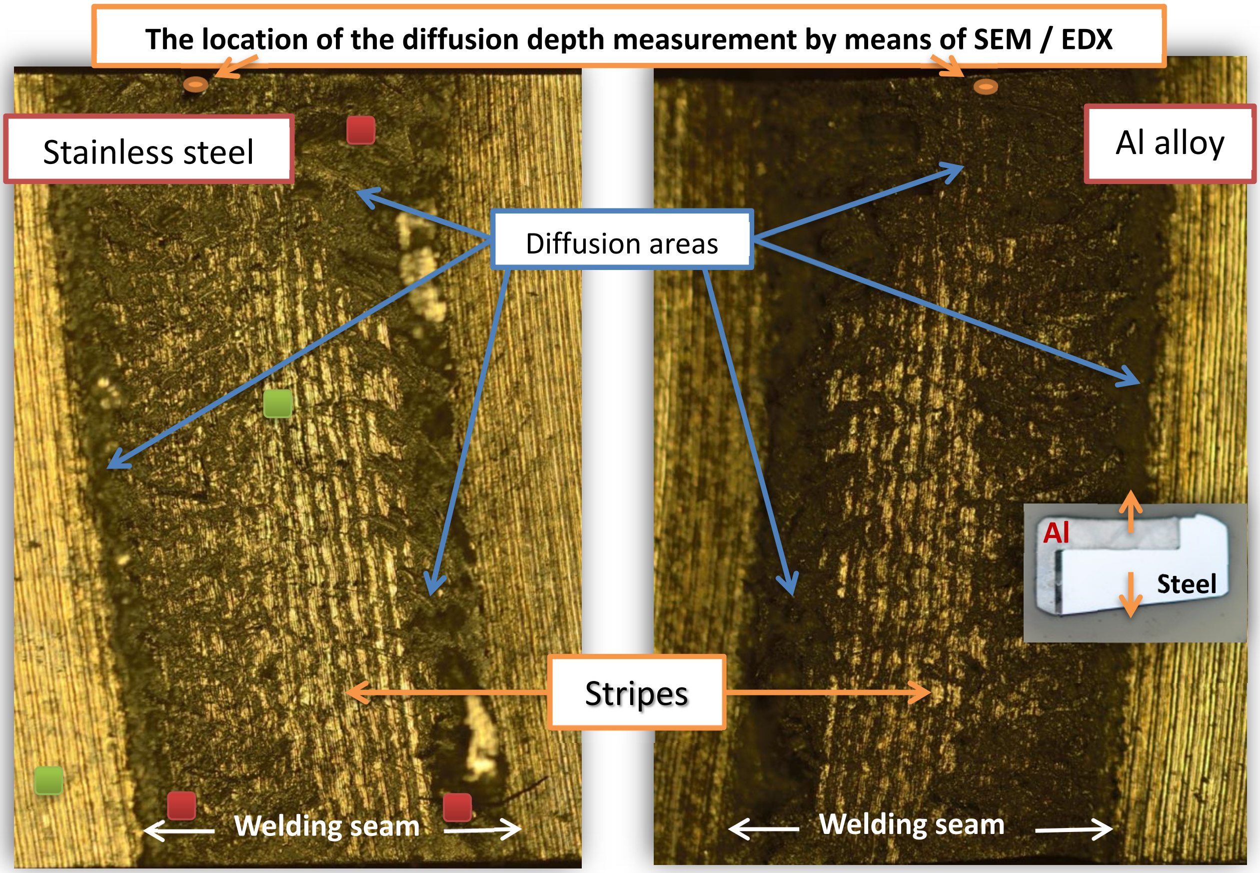

Figure 6: Mirror display of two opposite surfaces of the interface joint of sample #1. The green and red squares show the location of measurements of chemical composition.

CONCLUSION

The obtained results show the hardening of stainless steel partner and softening of Al allow in area close to interface joint most likely due to the local temperature treatment/mechanical deformation. The welded seam has a non-homogeneous structure and mutual diffusion obviously occurs only in some regions, mainly along the edges. Obviously, the parameters of welding, the material thickness and the roughness of the surface of stainless steel are highly important.

ACKNOWLEDGEMENTS

We would like to thank Fa. Riftec GmbH (Geesthacht, Germany) for the provided samples of welded joints for investigation [9, 10].

REFERENCES

[1] H, Uzun, C. D. Donne, A. Argagnotto, T. Ghidini, C, Gambaro, “Friction stir welding of dissimilar Al 6013-T4 to X5CrNi18-10 stainless steel”, *Materials and Design,* vol. 25, issue 1, Feb. 2005, pp. 41-46.

[2] A. Elrefaey, M. Gouda, M. Takahashi, and K. Ikeuchi, “Characterization of aluminum/steel lap joint by friction stir welding”, *Journal of Materials Engineering and Performance*, vol. 14, March 2004, pp.10-17.

[3] Z. Shen a, Y. Chen b, M. Haghshenas b, *, A.P. Gerlich, “Role of welding parameters on interfacial bonding in dissimilar steel/aluminum friction stir welds”, *Engineering Science and Technology, an International Journal*, vol. 18, issue 2, June 2015, pp. 270-277.

[4] M. Dehghani, A. Amadeh, S. A. A. Akbari Mousavi, “Investigations on the effects of friction stir welding parameters on intermetallic and defect formation in joining aluminium alloy to mils steel”, *Material and Design*, vol. 49, August 2013, pp. 433-441.

[5] K. Kimapong, T. Watanabe, “Lap Joint of A5083 Aluminum Alloy and SS400 Steel by Friction Stir Welding”, *Materials Transactions*, Vol. 46, No. 4, 2005, pp. 835-841.

[6] K. Kimapong, T. Watanabe, “Effect of Welding Process Parameters on Mechanical Property of FSW Lap Joint between Aluminum Alloy and Steel”, *Materials Transactions*, Vol. 46, No. 10, 2005, pp. 2211-2217.

[7] W.-B. Lee, M. Schmuecker, U. A. Mercardo, G. Biallas, Seung-Boo Jung, “Interfacial reaction in steel-aluminum joints made by friction stir welding”, *Scripta Materialia*, vol. 55, issue 4, August 2006, pp. 355-358.

[8] M. Mazar Atabaki, M. Nikodinovski, P. Chenier, J. Ma, M. Harooni and R. Kovacevic, “Welding of Aluminum Alloys to Steels: An Overview”, *J. Manuf. Sci. Prod.*, vol.14, issue 2, July 2014, pp. 59 – 78.

[9] EN ISO 25239-1:2012: Friction stir welding-Aluminum-Part 1: Vocabulary

[10] Riftec GmbH, Geesthacht, Private Communications

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.