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

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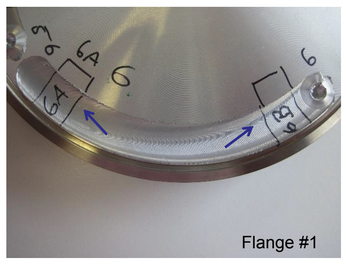
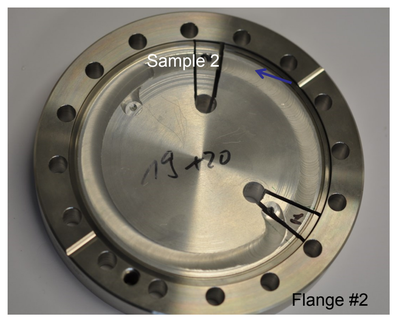
Abstract

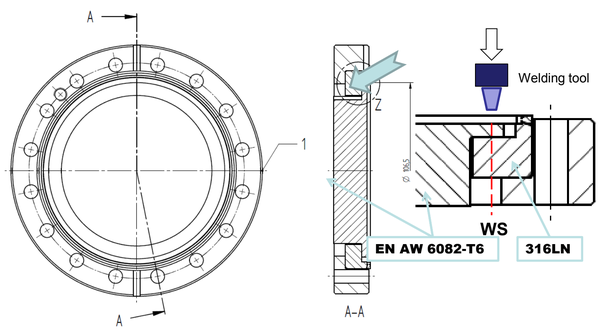
At DESY in Hamburg an investigation was started to join aluminium chambers with stainless steel flanges by friction stir welding. First results will be presented.
It will be shown that there is only a small effect of hardening in the contact zone at the stainless-steel side, a small amount of particles 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.

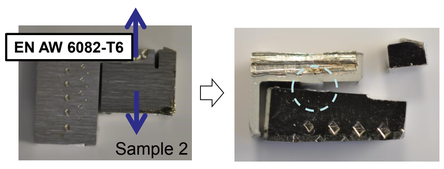
Objects for Investigation



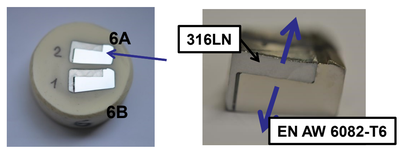


Flange NW100 (316LN) with Insert from Al alloy (EN AW 6082-T6).





Welding joint for 3D Microscopy



Welding joint for Hardness, X-Ray fluorescence, SEM/EDX & 3D Microscopy

Chemical composition of base metals

%	Si	Fe	Cu	Mn	Cr	Al	Ni	Mo	C
EN AW 6082-T6	0.7-1.3	max. 0.5	max. 0.1	0.4-1	max. 0.25	Bal.	-	-	-
316LN	max. 0.75	Bal.		max. 2	17-19	-	13-15	2-3	max. 0.03

Hardness measurements

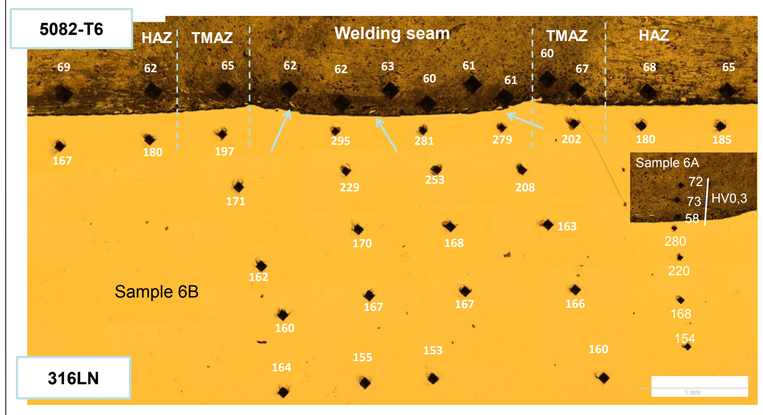


Figure 1: Distribution of HV1 hardness values measured along welding seam area and TMAZ/HAZ areas of sample 6A/6B. Arrows show the small particles of stainless steel fraction mixed by welding with Al alloy. Insert shows the hardness of sample 6A.

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 also shows the hardening of material in welding seam area close to joint interface. It is reasonable to assume that hardening of material can be caused by at least 2 factors: one of them is deformation or pressure from the side of welding tool coming from Al, temperature influence or the building of associated phases. 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 by us in stainless steel part close to joint interface is in average ca. 285HV1. This hardness level can be attributed most likely to surface mechanical deformation the stainless steel.

Welding seam microstructure / X-Ray fluorescence

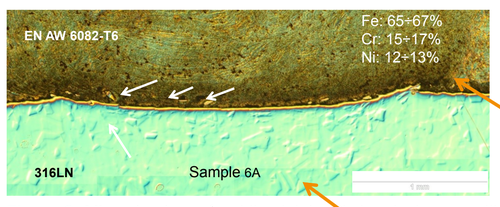
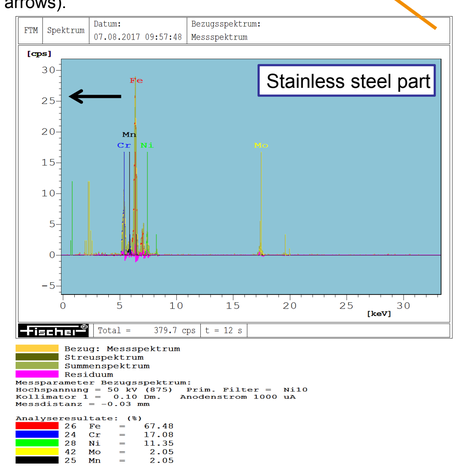
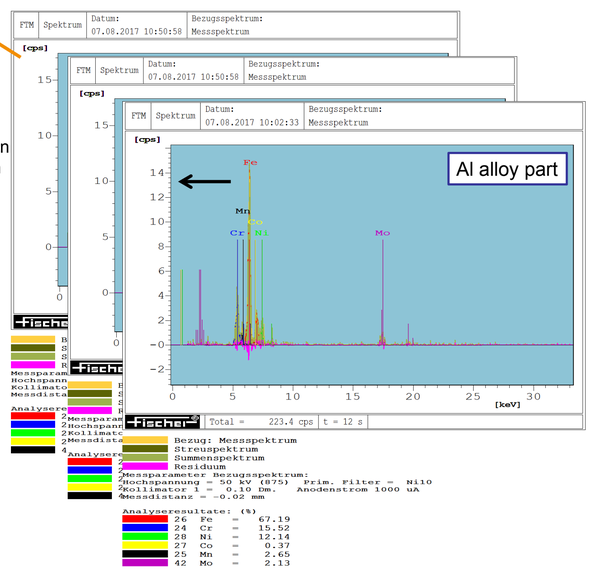


Figure 2: Microstructure of welding joint and chemical composition in some locations of Al allow and stainless steel parts (shown with arrows).





The appearance of small particles of stainless steel fraction in narrow band in Aluminum alloy part close to joint interface is observed (some visible particles are marked with arrows on Fig. 2). 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 one location in stainless steel. 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.

Welding seam microstructure / SEM/EDX

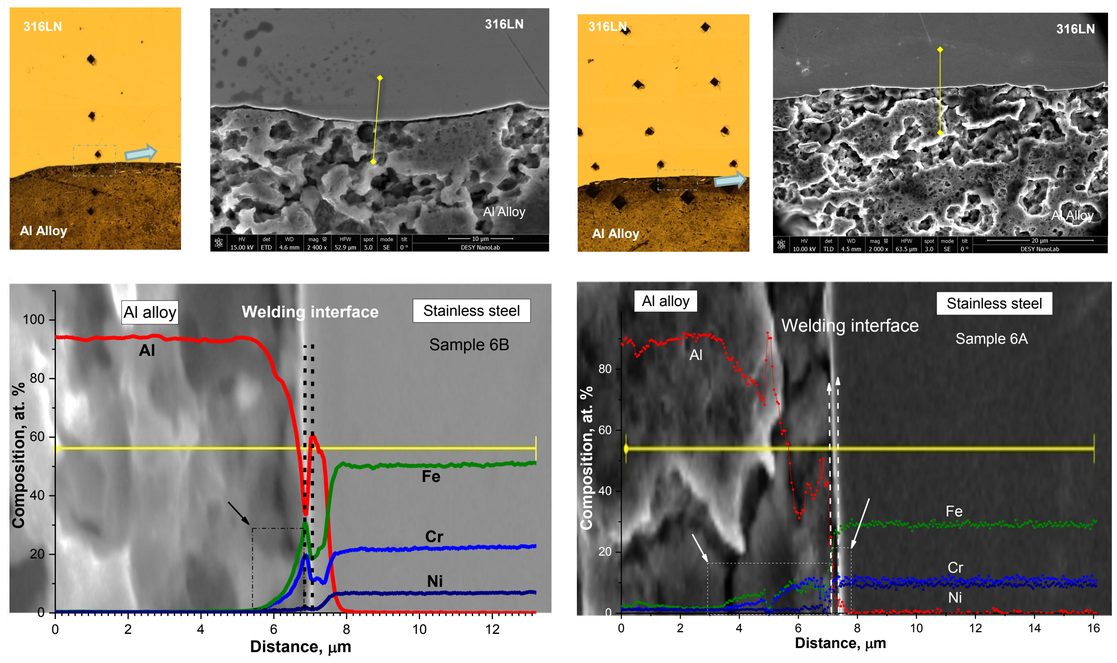
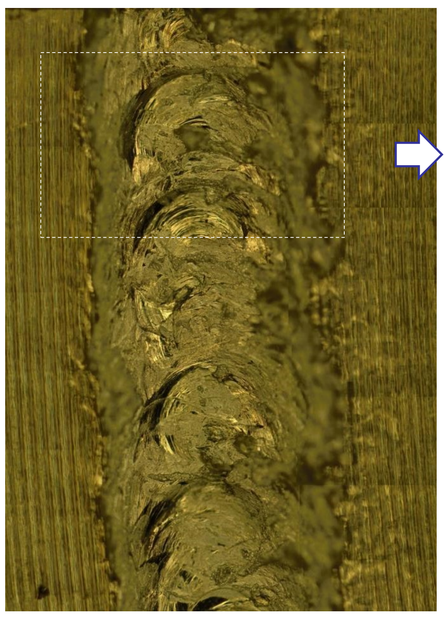


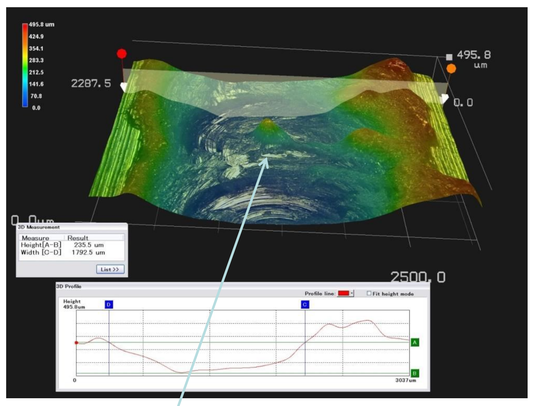
Figure 3: Concentrations profiles of Fe, Ni, Cr and Al across the EDX analysis line at the welding interface between Al alloy and stainless steel.

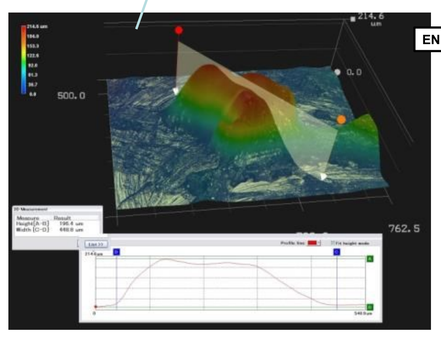
The concentrations profiles of the main elements done by means of SEM/EDX at the welding interface between Stainless steel and Aluminum Alloy show slight mutual diffusion (See Fig. 3). These profiles show particularly the diffusion of stainless steel components Fe, Ni, Cr in deep of Al alloy part up to 4 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].

Welding seam / 3D Profile

Sample #2







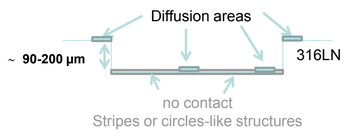


Figure 4:. Structure and 3D Profile of welding seam of sample #2.

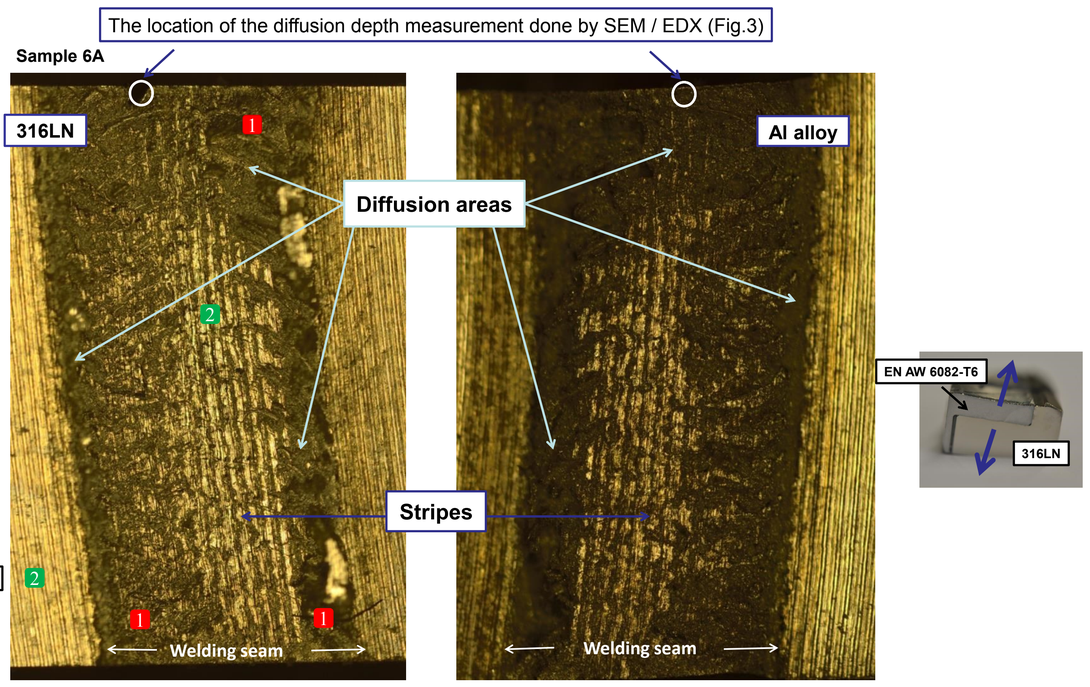


Figure 5:. Structure of welding seam of sample 6A. Mirror display of two opposite surfaces of the welding joint of sample 6A. The green and red squares show the location of measurements of chemical composition by X-Ray fluorescence.

The circle-like structure in welding seam area of sample #2 (Fig. 4) shows the traces of touching the stainless steel by welding tool feeding. The welding seam area of sample 6A (Fig. 5) has a stripe-like structure (mainly in the middle of welding seam) and areas where the diffusion Al alloy – 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. The mutual diffusion takes place obviously only in edge areas and partly in the middle of welding seam area. The analysis of chemical composition in locations (marked by white-out circles) by means of SEM/EDX confirms that (see Fig. 3). Also the element analysis by X-Ray fluorescence performed on some locations inside and outside the welding seam area shows the high amplitude of main components of base stainless steel in comparison with amplitude measured in locations marked with red squares.

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.

MEDSI MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

PARIS 2018

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