Investigation of Root Flaws in Friction Stir Welds

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Introduction

Friction Stir Welding (FSW) is a solid state welding process especially suitable for light weight metals. It was invented by The Welding Institute in 1991 [1]. The present investigation is focused on a possible welding flaw termed *root flaw*. The occurrence of a *root flaw* is associated with the oxide surface layer, which is always present on aluminium, and is stirred into the weld during the welding process [2, 3]. In the case of a *root flaw*, the material at the joint has undergone a thermomechanical process caused by the welding tool motion, but the material is only partially joined in the root region of the weld. It is necessary to investigate the probability of cracks initiating at the *root flaw* while a welded component is loaded mechanically. Therefore, it is necessary to characterize the three-dimensional structure of the *root flaw* throughout the weld, which is associated with the welding parameters. Since the *root flaw* is a very small feature, with dimensions of only a few hundred microns, microtomography is most suitable for the investigation of it's three-dimensional structure throughout the weld.

Experimental procedure

Three aluminium friction stir weld samples were prepared. In all three, a *root flaw* was created intentionally by a preoxidation treatment. The preoxidation treatment was applied to the edges of the aluminium plates before welding. In this way, natural aluminium surface layers of different thicknesses were formed. During the welding process, the surface layers were stirred into the welds, causing *root flaws*. One *root flaw* was very pronounced in the sample with a thick surface layer. The *root flaws* were less pronounced on the remaining two samples, because the surface layers were thinner. 1 x 1 x 20 mm^3 microtomography samples were prepared containing the *root flaw* region of the welds. The microtomography measurements were carried out at beamline BW2 using monochromatic photons of 24 keV. Projection data of 1536 x 1024 pixels with a size of 1.5 µm enabling a spatial resolution of 4.1 µm. Of each sample, a length of about 3 mm was investigated by performing 2 tomographic scans at different sample height. Each scan consisted of 720 projection equally stepped between 0 and π.

Results

Of the three investigated *root flaws*, only the most pronounced one could be imaged. The structures of the two less pronounced *root flaws* were below the spatial resolution of the current setup. Figures 1 and 2 show slices of the *root flaw*. The slice in Figure 1 is taken from a plane that corresponds to a cross section of the weld. The slice in Figure 2 lies in a plane parallel to the axis of the weld. The dark lines in the images represent the course of the *root flaw* throughout the weld. A sufficient number of slices was obtained to reconstruct the three-dimensional extension of the *root flaw* along the weld. Work is ongoing to extract a three-dimensional surface representation of the *root flaw* from the volume data.

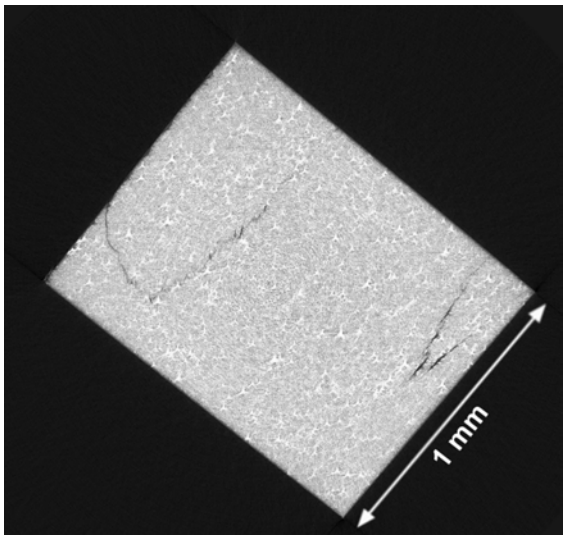

Figure 1: Cross section of the root flaw in a plane perpendicular to the welding direction.

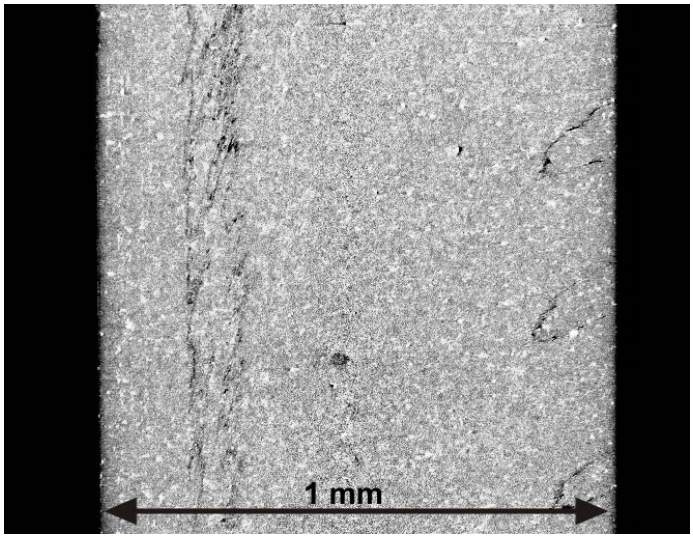

Figure 2: Cross section of the root flaw in a plane parallel to the welding direction.

References

[1] W. M. Thomas, E. D. Nicholas, J. C. Needham, M. G. Murch, P. Temple-Smith, C. J. Dawes, "Friction stir butt welding", International patent application No. PCT/GB92/02203 and GB patent application No. 9125978.8

[2] T. Vugrin, M. Schmücker, G. Staniek, Friction Stir Welding and Processing III, 277, proceedings of TMS Annual Meeting, San Francisco, California, Feb. 13-17, 2005

[3] Y. S. Sato, F. Yamashita, Y. Sugiura, S. H. C. Park, H. Kokawa, Scripta Mat., 50, 365 (2004)