Investigation of material flow in friction stir welds using high energy synchrotron radiation at HARWI II

T. Donath, R. Zettler, F. Beckmann, J. Fischer[1], J.F. dos Santos, D. Lohwasser[2], and A. Schreyer

GKSS-Research Centre, Max-Planck-Str. 1, 21502 Geesthacht, Germany
[1] Hannover Medical School, Anna-von-Borries-Str.1-7, 30625 Hannover, Germany
[2] Airbus Deutschland GmbH, Germany

The friction stir welding (FSW) process invented and patented by The Welding Institute of Cambridge [1] essentially relies on frictional heating and plastic deformation brought about by a rotating and non-consumable tool that is plunged into and then traversed along the join line of two abutting workpieces. In FSW the joining occurs at temperatures below that of the melting point of the materials being joined. This has demonstrated many advantages. Among these are the production of high quality joints with little preparation of the joint surfaces or post-weld dressing, relatively fast production i.e. joining speeds, high fatigue strengths, the ability to joins dissimilar alloys and the fact that distortion is relatively low when compared to conventional fusion welding processes.

To date there is no model capable of predicting the influence FSW tool geometry and welding parameters have on the formation of the joint and subsequent mechanical properties. Hence there is still a significant amount of work to do, in order to characterize and understand the process of joining and bonding. X-ray computed microtomography (µCT) was initially applied for the investigation of material flow for the FSW of an AA2024 alloy. In addition to the classical probes: macrographs, micro-hardness, strain and stress measurements, µCT delivers volume information of the 3-dimensional structure of the weld. Contrast is obtained by a marker material, which is implanted into the workpieces before welding. The welding process is then rapidly interrupted using a stop action technique which embeds the tool in the marker region of the workpieces whereby the redistribution of the marker around and behind the tool is studied.

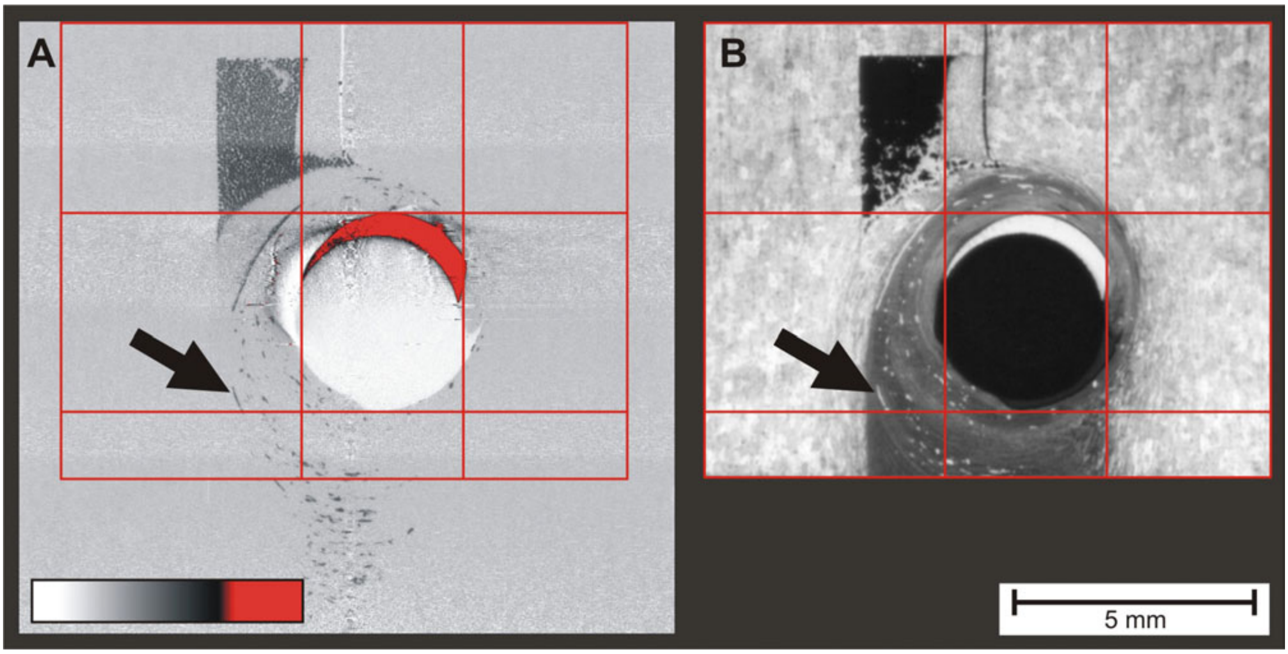

Figure 1: Tomographic cross section (A) and macrograph (B) of the same plane of a FSW sample. The Ti-marker shows up dark in the tomographic cross section and white in the macrograph. A small remainder of the pin is visible in both images. The arrow points towards the same streak of marker in both images.

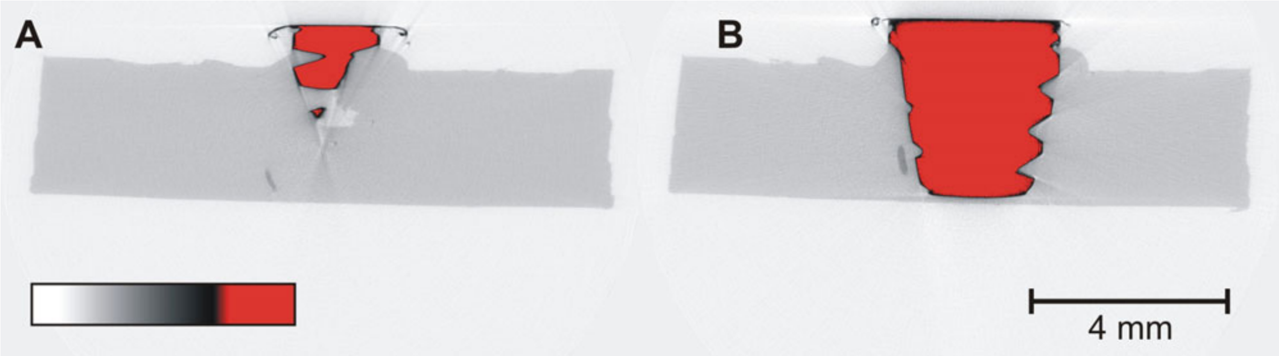

Figure 2: Tomographic cross sections (A, B) of the first friction stir weld measured at HARWI II. Using high energy X-rays of ~80 keV reconstruction of the FSW sample is possible without prior pin removal.

Investigations into marker flow commenced in 2003 on 4 mm thick cold rolled 2024-T351 aluminum sheets friction stir welded at the GKSS-Research Center, Geesthacht. Welds produced by different welding tools and varying welding parameters were studied at beamline W2 at 60 keV photon energy [2,3]. Figure 1 shows a µCT cross section in comparison with a macrograph of approximately the same plane of a weld. The shank of the pin was cut after welding and the threaded portion of the pin remaining in the workpieces carefully removed from the sample by means of spark erosion. This was necessary to avoid reconstruction artifacts caused by the strongly absorbing pin.

The project has now been continued at the refurnished beamline W2 (HARWI II). Data for a total of seven FSW samples has been recorded during the first measurement period after the beamline upgrade. Preliminary results are shown in Figure 2. High quality microtomographic reconstructions could be obtained, which allow for the segmentation of the Ti-marker. At the now available energy of above 80 keV removal of the pin from the weld is no longer necessary, as can be seen from Figure 2. This not only simplifies sample preparation, but also avoids reconstruction artifacts caused by incomplete pin removal.

We would like to thank B. Reime for assistance at the "old" HARWI beamline.

References

[1] W.M. Thomas, E.D. Nicholas, J.C. Needham, M.G. Church, P. Templesmith, C.J. Dawes: International Patent Application No. PCT/GB92/02203 and GB Patent Application No. 9125978.9, (1991).

[2] T. Donath, F. Beckmann, R. Zettler, J. dos Santos, D. Lohwasser, T. Lippman, Clemens H., and A. Schreyer: In AIP Conf. Proc. 705: SRI 03 San Francisco, 1312, (2004).

[3] R. Zettler, T. Donath, J.F. dos Santos, F. Beckmann, T. Lippmann, D. Lohwasser and A. Schreyer, Advanced Engineering Materials, accepted for publication 2005.