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Crystallographic texture of dissimilar laser welded Al5083-Al6013 sheets

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Abstract. Dissimilar welded components joined with any kind of welding technologies gain an increasing interest due to significant improvements in engineering structures by using new materials (alloys) or new materials combinations. The present paper deals with laser welding of Al5083-H111 and Al6013-T6 and the characterization of the crystallographic texture. Fine grained Al5083 was joined with coarser grained Al6013.Whereas Al6013 is strongly oriented, dominated by a strong cube component and a much lower Goss component, the finer grained Al5083 shows a week deformation texture. The welding seam itself has a moderate cube texture with a minor <100> fiber texture in welding direction. A small texture variation about the texture strength and the volume fraction of the fiber component was observed along the weld. Results were obtained by neutron, hard X-ray and electron diffraction.

Introduction

Contrary to traditional engineering load-carrying components and structures made from a single material, combining various engineering materials helps tailoring a structure locally to meet the required performance and cost-efficiency in specific regions of a global structure. This principle of local engineering with multi-material systems can push weight and cost reduction beyond the limits of traditional design. Particular candidates for these light-weight advanced multi-material systems are combinations of Al-alloys and ceramic reinforced Al/Al-alloys or Al-alloys and Mg-alloys. Fabrication of these multi-material systems obviously requires novel joining techniques which can consider the specific features of the materials with respect to weldability and microstructure, stress, distortion evolution at the joint area. Therefore, three main joining processes, namely; Friction Stir Welding (FSW), Friction Welding (FW) and Nd: YAG laser beam welding (LBW) shall be investigated, since these processes have capacity to produce advanced multi-material components for novel applications.

Materials characterization by material testing (stress strain curve, micro hardness) has to be accompanied by residual stress measurements, texture analysis and description of phase constitutions. Open questions are heterogeneity in distributions of phase volume fractions, grain sizes, crystallographic texture and residual stress which results in very challenging tasks for diffraction analyses. Due to the specific materials properties of the basic material, the grain size distribution and the joining technology, different requirements for the local resolution have to be combined with a sufficient grain statistics. Local crystallographic textures [1] have been studied using individual grain orientation measurement (BKD) in the SEM. Global textures were measured by high energy X-ray diffraction [2] and neutron diffraction

[3] due to the coarse grained Al6013. This work is part of an intense study to improve LBW, FW and FSW for different materials combinations in close contact to industrial applications. One of the first candidates was LBW of Al5083-H111 with Al6013-T6. Most of the existing work on materials characterization of LBW was focused on microstructure investigations, only some dealing with the crystallographic texture [4, 5]

Sample description

The basic materials were a 3.2mm thick Al6013-T6 alloy sheet and a 2.0mm Al5083-H111 alloy. Laser beam welding (LBW) was carried out with an Al 4047 alloy as weld metal deposit. The chemical composition of these three alloys is given in table 1. The whole test sample has a length of 320 mm and a width of 240 mm (length of the welding seam). Microstructure investigations gave an average grain size of Al5083 of 7-8 µm, of Al6013 of 80-100µm and in the weld of 100-150µm.

Elemente	Al5083	Al4047	Al6013
Si	≤ 0.40	11.0 – 13.0	0.60 –1.00
Fe	≤ 0.40	≤ 0.80	≤ 0.50
Cu	≤ 0.10	≤ 0.30	0.60 – 1.10
Mn	0.40 – 1.00	≤ 0.15	0.20 – 0.80
Mg	4.00 – 4.90	≤ 0.10	0.80 – 1.20
Cr	0.05 – 0.25	-/-	≤ 0.10
Zn	≤ 0.25	≤ 0.20	≤ 0.25
Ti	≤ 0.15	-/-	≤ 0.10

Table 1: Chemical composition of the three Al-alloys used in this study

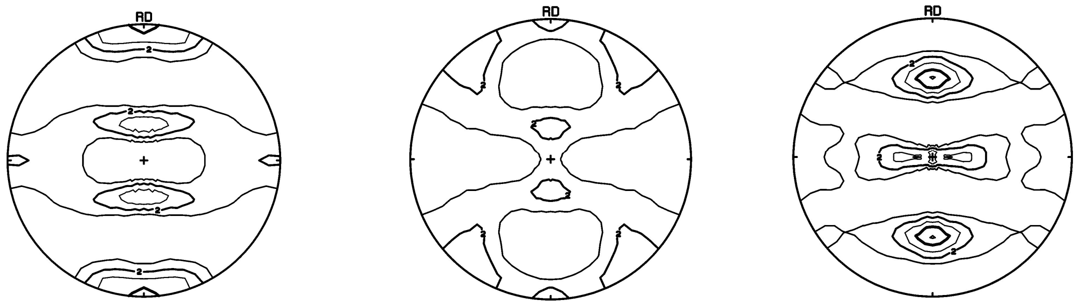
The welding process was performed with a laser power of 3.3 kW under helium atmosphere and different speeds of the robot between 1.8m/min and 2.6m/min. Geometrically the weld was characterized by a depth of 3.1965mm and a width of 3.645mm (top), 2.215mm (bottom) and 1.633mm in the tail. Some pores were found particular for high speed welding. Nevertheless, it was demonstrated that the combination of Al5083 and Al6013 is weldable by LBW. It has to be noticed that Rp02 and Rm values are different for Al5083 and Al6013 (Rp02:125 MPa versus 385 MPa; Rm: 275 MPa versus 400 MPa). The results of the crystallographic texture we present here are focused on 1.8m/min LBW.

Experiments

Complete pole figures were measured using neutron diffraction at five position of each welding experiment. In order to describe the basic material two positions in each sheet 4mm outside the welding seam and far away from the welding seam were measured. One reason to choice neutron diffraction was the grain size in Al6083, which is much coarser than the fine grained Al5083. Samples of 10x10x10 mm³ were cut from the basic material. This sample volume guarantees a sufficient grain statistics and gives an average texture of a representative sample volume. The welding seam itself was characterized at three positions using smaller sample cubes of 1.5 x 1.5 x 1.5 mm³ (volume - 3.4mm³). A documentation of the texture variation along the welding seam indicates the quality of the welding. In order to look more in detail on the welding seam and on the heat affected zone orientation microscopy (OM) was performed using the electron back scattering diffraction (EBSD). Moreover, high energy X-rays were carried out to describe the stress profile over the welding seam and to investigate local textures of 1mm³ volumes. These measurements were done at the high-energy beamline BW5 at HASYLAB (DESY-Hamburg). Stress results will be published elsewhere.

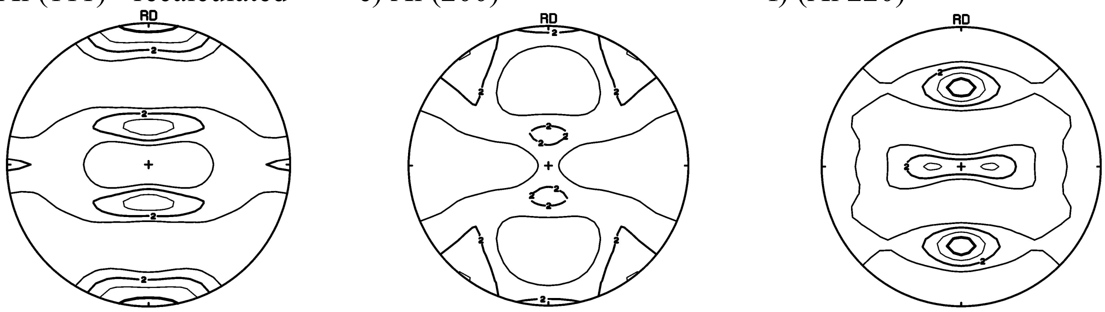
As an example the three measured complete pole figures of sample Al5083-H111 are shown in figures 1a-c. It has to be noticed that without background correction no other corrections were necessary. The measurements were carried out at TEX-2 the materials science texture diffractometer at the FRG-1 (http://genf.gkss.de) [6]. Thereafter, the orientation distribution function (ODF) was calculated using the iterative series expansion method [7]. In figures 1 c-d an excellent agreement between measured and recalculated pole figures expresses the high quality of neutron texture analysis. One main advantage of neutron diffraction is that complete pole figures were measured independent if the angular dispersive method or the energy dispersive method is preferred.

a) Al (111) - measured b) Al (200) -measured c) (Al 220) -measured



Pmax = 1.8 mrd Pmax = 1.5 mrd Pmax=2.0 mrd

d) Al (111) - recalculated e) Al (200) f) (Al 220)



Pmax = 1.9 mrd Pmax = 1.5 mrd Pmax=1.9 mrd

Fig. 1: Measured pole figures of Al5083-H111; sample position 4mm outside the welding seam (counting levels: 1.00, 1.25, 1.5, 1.75, 2.00 mrd)

Texture results

Figure 2 shows phi2=0° and phi2=45° sections. Al5083-H111 has a relatively weak texture with the brass (BS) component {110} <112 > and the Cu component {112} <111> as majority. A much softer cube component {001} <100> is also available. There was no texture variation 4mm outside the welding seam (figures 2b and 2f) compared to the basic material (figures 2a and 2e). The crystallographic texture of Al 6013-T6 with larger grains is much sharper than the Al5083 texture. Strong cube {001} <100> and Goss {110} <001> components indicate the recrystallization of this material. Smaller BS and G/B components complete the crystallographic texture of Al6013. 4mm outside the welding seam we detect the identical texture as far away from the welding seam.

The crystallographic texture in the welding seam has a moderate orientation degree and is characterized by a cube {001} <100> < component and a <100> fiber component, see figure 3. Comparing two different positions along the welding seam (position 1 - beginning of the joining process; position 2 - in the middle) one can see that the maximum degree of orientation (Fmax) varies between 3.2 mrd and 2.9 mrd. In middle part of welding seam the fiber component is a little stronger (figure 3a) as at the beginning of the joining process (figure 3b). This is only a small effect but the fiber component might be connected to the joining direction.

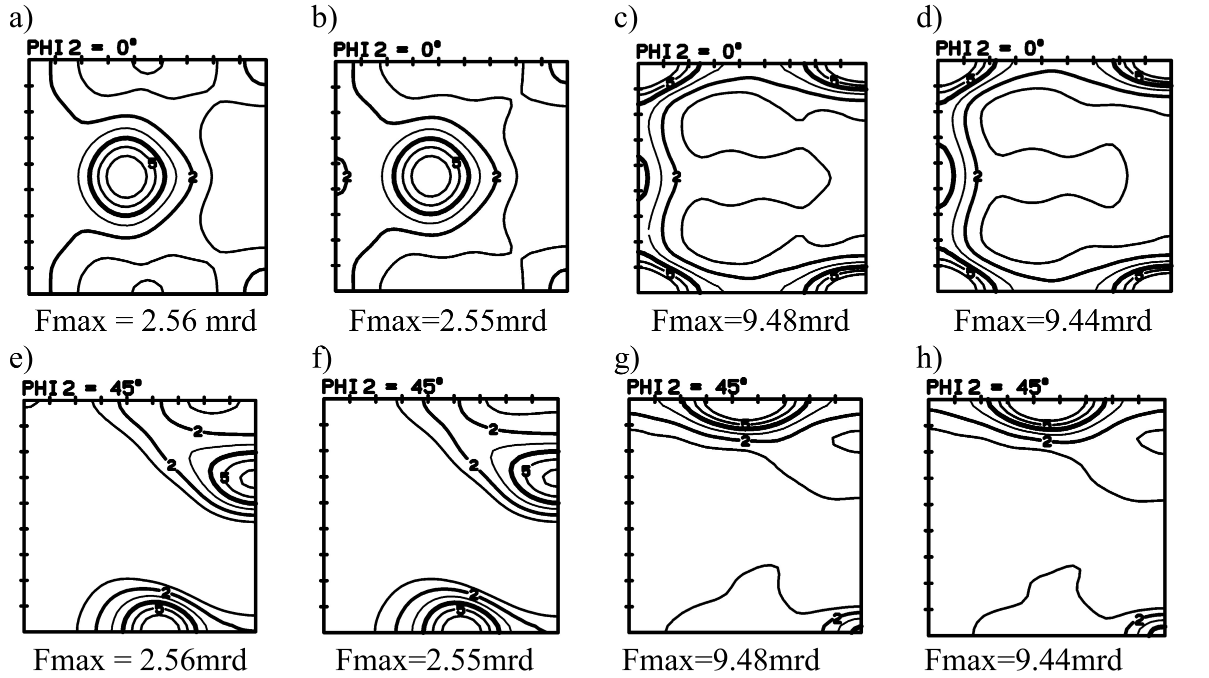


Fig. 2: Crystallographic texture in the two basic materials presented as phi2=0° and phi2=45° sections (a and e: Al5083 far away from the welding seam; b and f: Al 5083 close to the welding seam; c and g: Al6013 far away from the welding seam; d and h: Al6013 close to the welding seam) (counting levels: a,b,e and f – 1.00, 1.25, 1.5, 1.75, 2.00, 2,25 mrd; c,d,g and h – 1.00, 2.00, 3.00, 4.00, 5.00, 6.00 mrd).

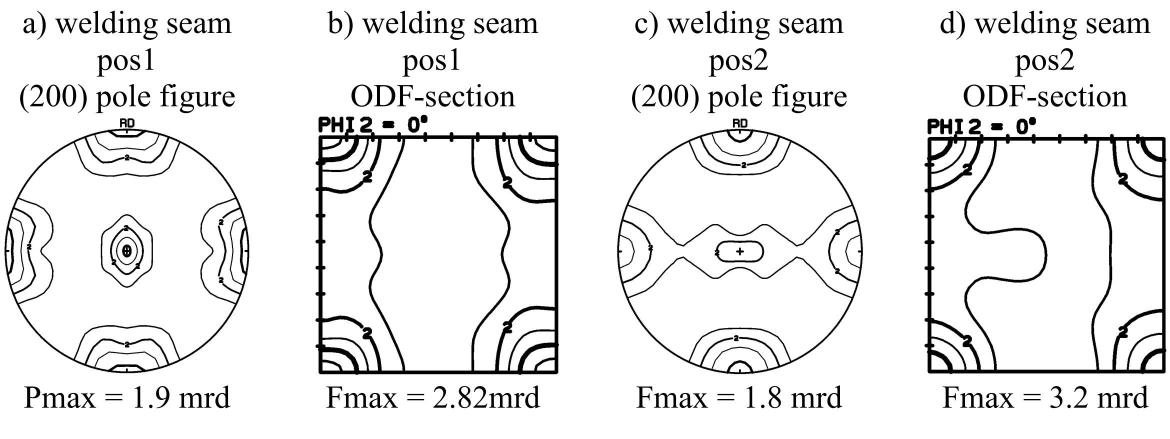


Fig. 3: Crystallographic texture of the weld; a and b at the of the joining process; c and d at the middle part of the joining (counting levels for the ODF-sections: 1.00, 1.50, 2.00, 2.50, 3.00, 3.50 mrd; counting levels for the pole figures: 1.00, 1.25, 1.50, 1.75 mrd)

In the case of the high energy X-ray diffraction the texture of Al5083 was nearly identical with a little higher error because of the grain statistics, but in the case of the coarse grained Al6013 and the welding seam the grain statistics were to bad for a quantitative texture result.

In the OM-pattern shown in figure 4 one can see clearly the two basic materials, the fine grained Al5083 and the coarse grained Al6013. The central part of the weld consist of large nearly round grains while the boundary between the basic material and the weld has large elongated grains from the basic material into the weld. Especially in the transition zone most of the grains show cube orientations or an orientation close to the cube orientation (red-red in (hkl) [uvw]. The central part has not such a strong cube orientation which agrees with the low orientation degree obtained with neutron diffraction (figure 3). For a calculation of the orientation distribution the grain statistics is too pure, but there is a good correlation between the neutron data and the EBSD-data.

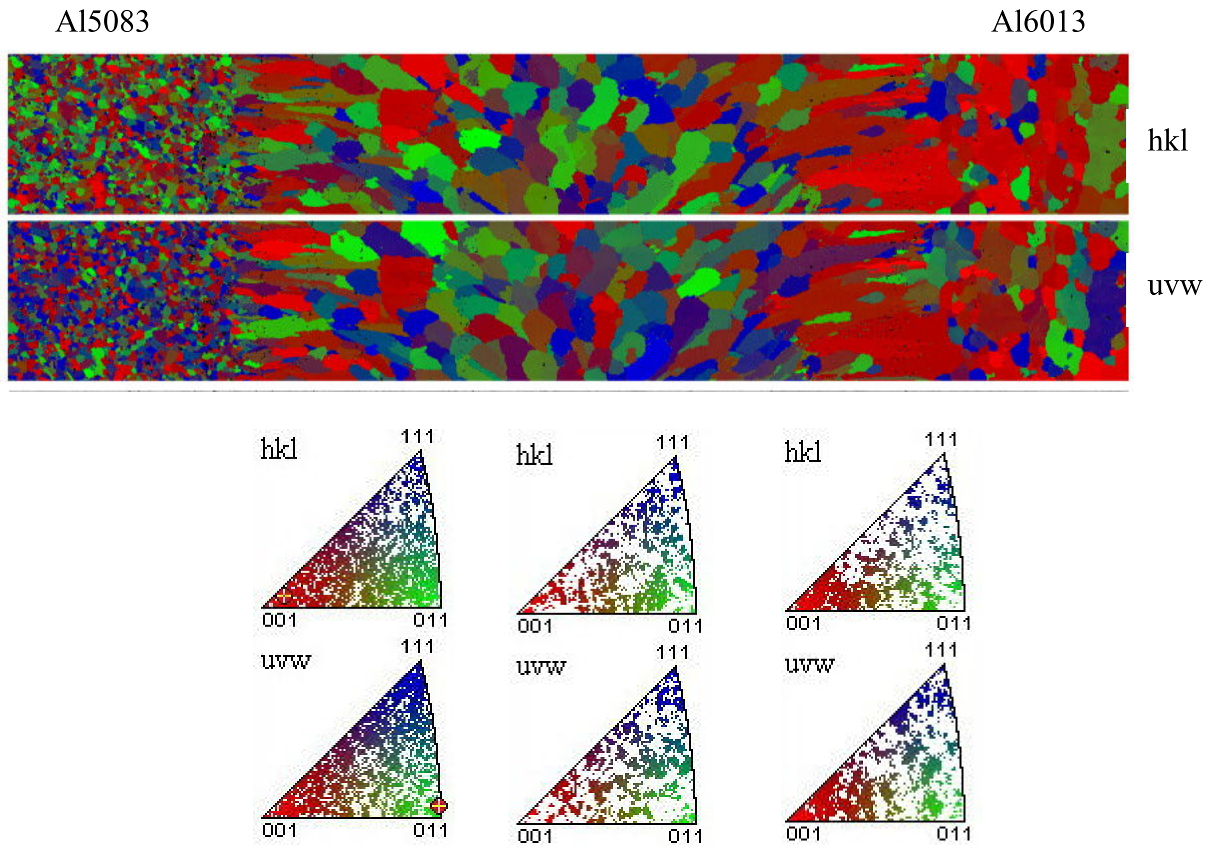


Fig. 4: Orientation Mapping over dissimilar laser beam welded Al5083-Al6013

Conclusions

Firstly, one can conclude, that it is possible to join Al5083 and Al6013 using laser beam welding technology, which is compared to other joining techniques a fast joining. Secondly, a combination of neutron diffraction and electron diffraction gives an excellent overview of the crystallographic texture in the two different basic materials and in the welding seam. Particular the combination of a fine grained and a coarse grained material needs a combination of analyzing methods. The crystallographic textures of the two basic materials are as expected and can be described as a combination different ideal texture components (Al5083 – brass, copper and cube; Al6013 – cube, Goss, BS and G/B). The welding seam is dominated by cube and <100> fiber>. Looking on the texture sharpness Al6013 shows a strong orientation degree. The other areas in the welded plate are more or less weakly orientated.

Acknowledgement

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