2012

Microstructure and microtexture development during friction stir processing of nickel aluminum bronze

Menon, S.K.; McNelley, T.R.

Microscopy Society of America

S.K. Menon, T.R. McNelley, "Microstructure and microtexture during friction stir processing of nickel aluminum bronze," Microscopy Microanalysis, v. 18 (Supp. 2), 2012, pp. 1662-1664.

http://hdl.handle.net/10945/55354

1662
doi:10.1017/S1431927612010161
Microsc. Microanal. 18 (Suppl 2), 2012

Microstructure and Microtexture Development during Friction Stir Processing of Nickel Aluminum Bronze

S. K. Menon and T. R. McNelley
Department of Mechanical & Aerospace Engineering,
Naval Postgraduate School, Monterey, CA 93943

In this investigation the results of orientation imaging microscopy analysis of the mechanisms of microstructure evolution during friction stir processing (FSP) of an as-cast NiAl bronze material will be reported. FSP is an allied technology of friction stir welding (FSW), a solid-state joining technology developed at The Welding Institute [1] to circumvent problems of solidification cracking of Al alloys during conventional fusion welding. Subsequently, FSW has been sucessfully employed in joining of alloys of Mg, Cu, Fe, Ni and Ti [2]. In FSW, sheets or plates of material to be joined are abutted with one another and placed on an anvil. A non-deforming, cylindrical tool with a projecting, centric pin is rotated while the pin is plunged into a location along the faying surfaces of the materials. A combination of frictional and adiabatic heating softens the materials and allows the pin to penetrate until the tool shoulder comes in contact with the surfaces. A plastcized column of material forms around the pin and enables coalesence of material as the tool is traversed along the faying surfaces, leaving the weld 'nugget' in its wake

In FSP, the tool may be traversed in a pattern across the surface of a single work piece of arbitrary thickness in order to process a volume of material defined by the tool pin profile and traversing pattern. Overlap of the pin profile on successive passes is necessary to assure uniform microstructures and properties in the resulting 'stir zone' (SZ). The use of this term reflects that the material in the SZ has experienced multiple passes while a weld nugget generally experiences only a single pass. A transverse section through the outermost passes of a multipass FSP treatment of a cast NiAl bronze (nominally Cu-9.4Al-5.0Ni-4.0Fe) plate is shown in Fig. 1 [3-5]. Here, the tool pin was in the shape of a truncated cone 12.7mm in length, 15mm in base diameter and 4.5mm in tip diameter. The base metal is to the right-hand side in this montage of images; dark-etching consituents are apparent in the thermomechanically affected zone (TMAZ) and a refined microstructure is evident in the SZ.

Further details of microstructure refinement from the as-cast base metal microstructure into the SZ are shown in backscatter electron images in Fig. 2. The base metal comprises coarse grains of primary α (fcc) embedded in a eutectoid transformation product formed from a high-temperature β (bcc) phase that decomposes into lamellar κ_{iii}(NiAl) and α. The κ_{iv}(Fe_3Al) phase is dispersed as fine particles in the primary α and the κ_{ii}(also Fe_3Al) as coarse, globular particles in the eutectoid. The TMAZ in the second image shows dissolution of the fine κ_{iv} and formation of a substructure in the primary α. With futher deformation, the κ_{iv} dissolves completely and new grains become apparent in the primary α as seen in the third image, while fine grains containing straight annealing twins are intermingled with refined transformation products of β formed by heating during FSP.

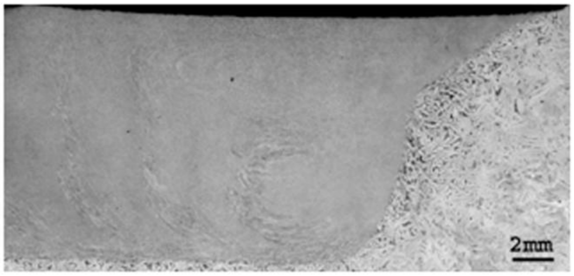

Figure 1. A montage of images from the edge of the SZ in a cast NiAl bronze plate after multi-pass FSP

Inverse pole figure (IPF) maps were obtained from the same regions depicted in Fig. 2 using orientation imaging microscopy (OIM) methods. These maps reveal the transformation from a coarse, as cast material (Fig. 3a) by, initially, deformation accompanying dissolution of the κ_{iv} (Fig. 3b), followed by formation of fine α grains in the TMAZ (Fig. 3c) that persist into the SZ (Fig. 3d). The OIM data were also represented in the form of discrete pole figures as shown in Fig. 4. The discrete pole figures at the left show mainly one orientation from a region in the base metal. In the TMAZ (the center pole figures), the arcs of orientations reflect the formation of a B-type shear texture under the influence of tool rotation. However, such a texture does not persist into the SZ. Instead, a random texture is seen (the pole figures at right). This suggests a change in deformation mechanism during the large-strain deformation of FSP, from slip processes in the TMAZ to grain/phase boundary sliding into the SZ. Further evidence for such a transition will be subsequently presented.

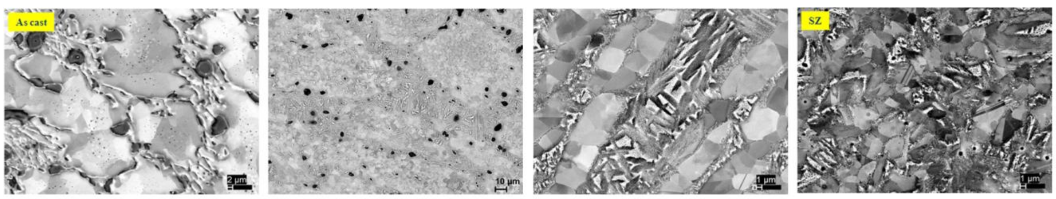

Figure 2. Backscatter electron images showing progressive refinement of microstructure from as-cast (left) to SZ (right)

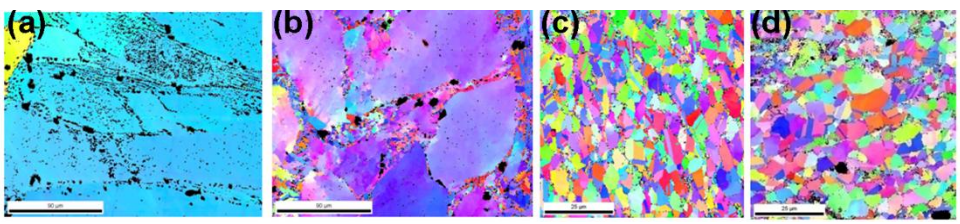

Figure 3. IPF maps from as-cast (a), into the outer TMAZ (b), the inner TMAZ (c) and on into the SZ (d). Refined, equiaxed grains are apparent in the SZ.

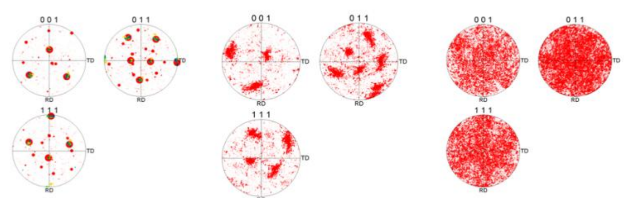

Figure 4. Discrete pole figures from as-cast material (left), into the TMAZ (center) and on into the SZ (right). The texture becomes random in the SZ despite the very large deformation.

References

1. W. M. Thomas, E. D. Nicholas, J.C. Needham, M. G. Murch, P. Templesmith and C. J. Dawes: G. B. Patent Application No. 9125978.8, Dec. 1991; U. S. Patent No. 5460317, Oct. 1995.
2. R.S. Mishra and Z.Y. Ma: *Mater. Sci. Eng. R*, 2005, vol. 50, pp. 1-78.
3. K. Oh-ishi and T. R. McNelley: *Metall. Mater. Trans. A*, 2004, vol.35A, pp 2951-2961
4. K. Oh-ishi and T. R. McNelley: *Metall. Mater. Trans. A*, 2005, vol. 36A, pp. 1575-1585
5. S. Swaminathan, K. Oh-Ishi, A.P. Zhilyaev, C.B. Fuller, B. London, M.W. Mahoney and T.R. McNelley: *Metall. Mater. Trans. A*, 2010, vol. 41A, pp. 631-640.