Discussion

Discussion of “Fatigue Crack Initiation Mechanism for Cast 319-T7 Al Alloy”*

J. CAMPBELL

DOI: 10.1007/s11661-009-0095-8

© The Minerals, Metals & Materials Society and ASM International 2009

Jang and co-workers present interesting results for fatigue tests taken from a gravity sand cast aluminum alloy cylinder block casting. They find a wide spectrum of failure modes, including zero failure (fatigue runouts), initiation from pores, and observations of extensive coarse transgranular facets on the fracture surfaces. They conclude that the transgranular facets are slip planes, and the oxides observed in places on these planes are the result of fretting damage during crack propagation.

I would like to draw the attention of the authors to the fact that facets on fracture surfaces of tensile and fatigue specimens are common on many kinds of cast alloys, including Al alloys, cast irons, and Ni-base superalloys.^[1] The mechanism is simply that of straightening oxide bifilms (the necessarily double oxide films caused by surface turbulence during casting) by the advance of the dendrites during solidification. This dendrite pushing process creates large planar areas, which are separated by the planar unbonded interface between the two films, thus forming extensive transgranular, and sometimes intergranular, cracks. The transgranular cracks exhibit the accurately planar crystallography defined by the dendrites, whereas the bifilms pushed into intergranular planes exhibit the typical curved surfaces of grain boundaries. Critically, Cox and co-workers^[2] only observed facets on the fracture surfaces of Ni-base superalloys that had been cast turbulently. Those that had been cast with carefully designed filling systems that avoided the entrainment of the oxide from the liquid surface were free from facets.

The observation by the authors of oxides in some patches of the facets but not in others is typical of oxide films entrained into the bulk metal from the liquid surface. Such films are irregular and messy, thick in places, but often so thin (perhaps 20 nm) as to be difficult to detect by conventional microanalysis.

If the facets had been the result of a slip band mechanism, some evidence of extrusions and intrusions

might have been expected, but none are seen. Furthermore, if failure was the result of such a metallurgical phenomenon, why were facets not seen on every fracture since the relatively fine grain size would be expected to allow this.

Conversely, entrained bifilms, subsequently straightened by dendrite advance, are to be expected in practically all turbulently poured cast metals and alloys (bars cast of pure gold would be an exception). Furthermore, because the action of turbulence is random, bifilms will be expected of different thicknesses and different areas, and would be randomly distributed, appearing in some fractures but not others. Among the casting community, it is well known that turbulence during pouring creates scattered results, whereas quiescently filled molds yield high and reproducible mechanical test results.

The early work from this laboratory by Nyahumwa *et al.*^[3] observed facets and attributed them to slip planes. However, the bifilm straightening phenomenon was not known at that time. Closer inspection of the reported images indicates that these were probably bifilm products. The planar facets observed by Cox^[2] are a series of planes intersecting from three mutually perpendicular directions, making a slip plane origin impossible, but easily explained as a bifilm phenomenon.

A further incidental observation relates to the porosity in cast metals. Porosity is often, if not always, part of a more extensive bifilm (the pore is merely a local region where the bifilm has opened because of residual entrapped air, inward diffusion of hydrogen, tensile stress due to shrinkage, *etc.*). Thus, it is to be expected that cracks will nearly always appear to initiate from pores, not necessarily as a result of the presence of the pore, but because the pore indicates that its surroundings are likely to be an extensive precracked area formed by its associated bifilm. Such “pore extensions” have not been investigated so far. They are not expected to be present in every case and are not expected to be easy to see even if present. Where straightening has occurred, the bifilm is clearly revealed, creating a facet. However, if they have not received the benefit of dendrite straightening, only extremely careful observation will reveal them.

REFERENCES

1. J. Campbell: *Mater. Sci. Technol.*, 2006, vol. 22 (2), pp. 127–45; 2008, vol. 24 (7), pp. 875–81.
2. M. Cox, M. Wickins, J.P. Kuang, R.A. Harding, and J. Campbell: in *Castings*, 2nd ed., J. Campbell, ed., Elsevier, New York, NY, 2003, pp. 57–61.
3. C. Nyahumwa, N.R. Green, and J. Campbell: *Metall. Mater. Trans. A*, 2001, vol. 32A, pp. 349–58.

J. CAMPBELL, Emeritus Professor of Casting Technology, is with the Metallurgy and Materials Department, University of Birmingham, B15 2TT, United Kingdom. Contact e-mail: jc@campbelltech.co.uk

*Y.H. JANG, S.U. JIN, Y.I. JEONG, and S.S. KIM: *Metall. Mater. Trans. A*, 2009, vol. 40A, pp. 1579–87.

Discussion submitted July 28, 2009.

Article published online October 29, 2009