EUROPEAN SYNCHROTRON RADIATION FACILITY

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Application for beam time at ESRF – Experimental Method

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Title of the project

Measuring short fatigue crack growth rates in aluminium alloy 7075 by in situ high resolution synchrotron x-ray microtomography.

Aims of the experiment and scientific background

There is an urgent request to obtain reliable short fatigue crack growth data (crack size from ~10μm to 0.3 mm) in aluminium alloy 7075, one common aircraft material used in the Royal Australian Air Force (RAAF). It is well known that the growth of such short cracks can constitute a significant proportion of the aircraft total component lifetime (~ 50 to 90%). Therefore, the accurate prediction of short fatigue crack growth is essential for the safe and cost effective operation of aging aircraft within the RAAF fleet. Crucially such data to be obtained could also be used to predict component fatigue lives and assess and improve crack growth prediction models and tools. The short crack growth models to be assessed by the data are the blocked slip decohesion and the crack closure with the notch-plasticity mechanisms. In order to achieve these goals, the Defence Science and Technology Organisation (DSTO) have been tasked to conduct a range of scientific experiments and studies, including short fatigue crack growth behaviour in aircraft structures and components.

Although there are several techniques available for the measurement of small fatigue crack length such as plastic replicas and fractography, they all have serious limitations for the above-mentioned short fatigue cracks. For instance, the replicas are time consuming process with the difficulties to locate fatigue initiation and measure short crack propagation when the crack is very small. Also the obscurity of the crack front caused by other material microstructuctual features severely limits the usefulness of the replicas. Fractography is a post failure process to decode the information left on fractured surface after fatigue test. Its accuracy is critically dependent on the quality of encoded information during fatigue test such as the formation and visibility of fatigue crack growth micro features. Unfortunately, it has been found that the fractured surface near the initiation site is often contaminated and obscured so that reliable short crack growth data is hard to obtain by the fractography. In recent years, in situ high resolution synchrotron x-ray microtomography has been developed at the European Synchrotron Radiation Facility (ESRF) [i, ii, iii]. The small coupons can be loaded by the ESRF in-situ loading device (INSA de Lyon) under the synchrotron radiation with the various load frequency and different stress ratios. This would provide a valuable opportunity to gain insight into the mechanisms of crack growth at the micro level with a uniquely complete three dimensional microtomographic imaging description of fatigue crack growth behaviour near crack tip. Using this technology, the details of fatigue crack behaviour during loading and unloading can readily be observed in-situ and the corresponding two- and three-dimensional microstructural characterisation can be also visualised in conjunction with the fatigue crack growth behaviour. Therefore, the objectives of this project will be as follows:

(1) to seek a better understanding of the mechanisms of short fatigue crack growth in an aircraft material using in-situ high resolution synchrotron x-ray microtomography; and
(2) to obtain short fatigue crack growth rate data in aircraft material aluminium alloy 7075 under constant amplitude loading and overload conditions.

As the above-mentioned experimental technology is neither currently available nor planned for in the near future at the Australian Synchrotron facility, there is a requirement to access the overseas synchrotron facility at ESRF. The justification for three persons for the experiments is that the beamtime is allocated for the 24/7 operational basis and three 8-hour shifts are required to keep the experiments underway continuously and effectively.

Experimental method

In this experiment, small pre-cracked single-edge notched (SEN) coupons of AA7075 will be used because the material is widely used for airframes. A tiny corner slit (~10.0μm) will be induced in the surface-polished coupon by focused ion beams. The final dimension of the test section is 1.0x1.0x5.0 mm.

The small coupons will be loaded by the ESRF in-situ loading device (INSA de Lyon) with the load frequency of 10Hz. The fatigue crack growth tests will be conducted under constant-amplitude loading for 3 different R-ratios (0.1, 0.3 and 0.6), as well as under single overload condition. The short fatigue crack growth data (crack size vs cycles) will be measured by in-situ high resolution synchrotron x-ray microtomography at beamline ID-19 of the European Synchrotron Radiation Facility (ESRF). The experimental set-up at ID19 will consist of the ESRF high resolution CCD camera (2000x2000) pixels that will provide resolution of 0.7 μm. The crack size will be detected by a 3D microtomographic mapping (taking about 20min each mapping) at pre-defined regular intervals [iv].

Results expected

The results to be obtained are

(1). short fatigue crack growth data in aircraft material AA7075 under constant amplitude loading with 3 R-ratios and overload conditions.

(2). The observations of effect of overloads on short fatigue crack growth and assoiciated mechanism of short fatigue crack growth (crack size from ~10μm to 0.3 mm).

Concluding remarks

Although the Australian Synchrotron with a 3 GeV radiation facility in Melbourne has came online in 2007, the beamline of high resolution microtomographic imaging is neither currently available nor planned for in the near future. There is a requirement to access the overseas synchrotron facility at ESRF.

References

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ii. **Toda, H., Sinclair, I., Buffiere, J-Y, Maire, E, Connolley, T., Joyce, M., Khor, K.H. and Gregson, P.,** Assessment of the fatigue crack closure phenomenon in damage-tolerant aluminium alloy by in-situ high-resolution synchrotron x-ray microtomography. *Philosophical Magazine*, Vol. 83, No. 21, pp.2429-2448, 2003.

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