An automated approach to crack-tip tracking using thermoelastic stress analysis

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Introduction

Monitoring of the initiation and propagation of fatigue cracks is important for a wide range of industrial applications, often in environments where access is not simple [1]. Thermoelastic stress analysis (TSA) is a non-destructive measurement technique which maps the surface stresses in a transiently loaded material by measuring the temperature variation of that material using an infrared camera [2]. The distribution of these surface stresses can be used to determine the presence and position of a crack [3], and TSA has been shown to be extremely sensitive to the initiation of cracks before they are visible by other methods [4]. Here, we use TSA to monitor the initiation and propagation of cracks in coupon specimens under constant amplitude loading.

Methods

Two distinct geometries of specimen were investigated: a simple one-hole coupon, machined from a single sheet of Aluminium alloy 2024-T3 (thickness 1.6 mm); and a double-lap joint with external plates machined from the same sheet of Aluminium alloy 2024-T3, and the internal plate from Aluminium alloy 6082-T6 (thickness 6.35 mm) that were held together by two nut and bolt pairs. The simple specimen was coated with an aircraft primer paint, and the bolted specimen was painted with a matt black paint (*Plasti-kote 23101 Premium Spray Paint, matt black*).

Coupons were then cyclically loaded in an Instron 8501 servohydraulic testing machine (*Instron, Buckinghamshire, UK*) at a load of 5.28 ± 4.32 kN, 19 Hz (simple specimen) and 16.577 ± 13.563 kN, 13 Hz (bolted specimen). TSA data were collected during loading and subsequent crack growth using a DeltaTherm 1780 system (*Stress Photonics, Madison, WI*).

TSA data were processed *ex situ*, using an automated algorithm. This algorithm compares consecutive maps of TSA signal magnitude, and determines the position of the crack tip based on changes in the signal magnitude as the crack initiates and grows.

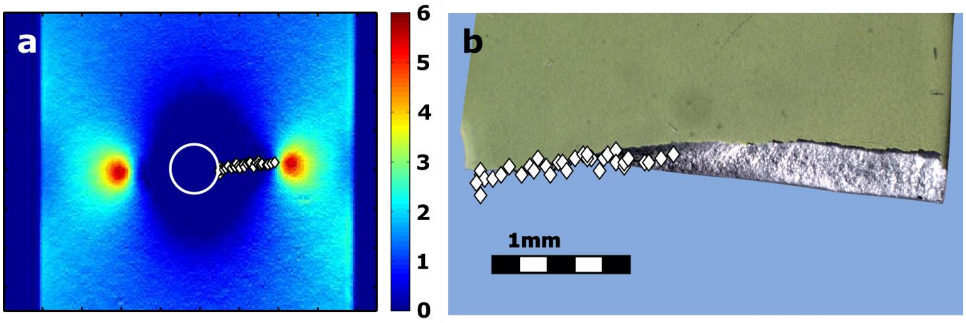

Fig 1. Crack tip positions in the simple coupon mapped using the automated algorithm: a) overlaid on final normalised TSA signal magnitude data (specimen width 40 mm); b) overlaid on final crack morphology (inset of right side of specimen).

Results and discussion

Results from the tracking algorithm for the one-hole coupon are shown in Figure 1. These results show that the automated tracking algorithm indicates the initiation of the crack at sub-mm lengths, and that the propagation is mapped within 1 mm of the final crack morphology.

Figure 2 shows a comparison of TSA data and visible light images of the bolted joint during loading. Changes in TSA signal magnitude (indicative of crack initiation) are present before the crack extends beyond the bolt-head and is seen in the visible light image. This result demonstrates that TSA can be used to indicate crack initiation before the crack would be observed by an inspector using visual observations alone.

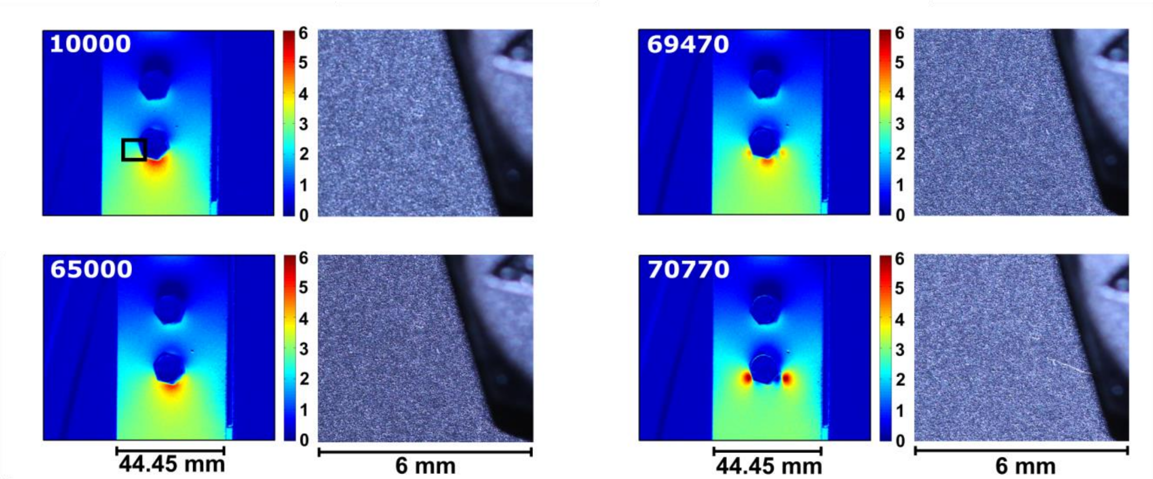

Fig 2. A comparison of normalised TSA signal magnitude data (left) with visible light images (right) for the inset box shown in the top left dataset at given cycle numbers (white).

Conclusions

We find that TSA will indicate crack initiation before it is observable by visible light methods. Our automated algorithm can detect crack initiation at sub-mm lengths, and the mapped crack paths match the morphology of crack surfaces imaged after failure.

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