Residual stress measurements on novel XFINE AA2124-SiC$_p$ composites using the contour method

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Abstract. The contour method was used to measure the residual stresses in forged plates made of novel composite materals XFINE217 and XFINE225, composed of aluminium alloy AA2124 reinforced with respectively 17 and 25 vol.% of 0.7 μm diameter silicon carbide particles in three different heat treatment conditions: cooled down from forging temperature (T1), quenched in cold water then aged (CWQ T6) and quenched in 25 vol.% polyglycol solution then aged (PGQ T6). Results from T1 samples showed negligible residual stresses, while CWQ T6 samples presented significantly higher residual stress levels than PGQ T6 plates.

Introduction

The measurement of macro residual stresses (type I) [1] on AA2124-SiCp composites is an important step to their characterization because, due to the heat treatable nature of their aluminium alloy matrix, quenching is usually required to reach optimum performance [2]. However quench residual stresses can lead to distortions or even premature failure of components made of such composites. These residual stresses can be measured by non-destructive techniques, such as neutron diffraction [3] and synchrotron X-ray diffraction [4], as well as destructive techniques, such as hole drilling and the contour method.
In this paper, we describe contour method residual stress measurements on forged plates made of novel composites XFINE217 and XFINE225 composed of aluminium alloy AA2124 reinforced with respectively 17 and 25 vol.% of silicon carbide particles in three different heat treatment conditions: cooled down from forging temperature (T1); quenched in cold water then aged (CWQ T6); and quenched in 25 vol.% polyglycol solution then aged (PGQ T6).

Materials and methods

Residual stresses were measured in forged plates of a composite made of aluminium alloy AA2124 matrix reinforced with different concentrations of silicon carbide particles: samples **A**, **B** and **C** with 17 vol.% (XFINE217), and samples **D**, **E** and **F** with 25 vol.% (XFINE225). The nominal diameter of the particles is 0.7μm and the production route of the composites was a Materion proprietary process. Plates **A** and **D** were tested in the T1 condition, i.e. cooled from forging temperature in air at room temperature. Samples **B** and **E** underwent a heat treatment consisting of a two hour soak at 505°C (778K), followed by cold water quenching, then ageing at 150°C (423K) for one hour (CWQ T6). Samples C and F also underwent a T6 heat treatment, however they were quenched in a 25 vol.% polyglycol solution (PGQ T6), being all other parameters identical to the treatment of samples B and E.
For the contour method, the plates were cut using an Angie Charmilles FI 440 ccS with a 0.15 mm diameter uncoated hard brass wire at a cut feed rate of 10 mm·min^{-1}. All cut surfaces were measured using a Zeiss Eclipse coordinate measurement machine (CMM) equipped with a TP8 Renishaw touch-trigger probe and an ILD2210 Micro-Epsilon laser triangulation probe, with a resolution of 1 μm. The axes of the CMM are controlled via a PC using the Inspect 3D software version 4.00r.

Results and discussion

The maps of normal residual stresses (σ_{zz}) measured on each of the samples are presented as residual stress colour-maps on the *x-y* plane (see figure 1), all using the same colour scale for easy comparison. Recall that on samples **A**, **D** and **E** there are regions affected by detrimental cutting artefacts which must be disregarded. Therefore, the corresponding areas are shown faded in the residual stress colour-maps.
Quench residual stresses are known to follow nearly parabolic profiles through the thickness of plates [3]. The through thickness profiles presented in figure 2 suggest that the contour method is suitable for measuring residual stresses on XFINE composites. The quality of the wEDM cuts was extremely good,

although some artefacts were present near the start and end of the cut. Therefore, the results are suppressed in these regions.

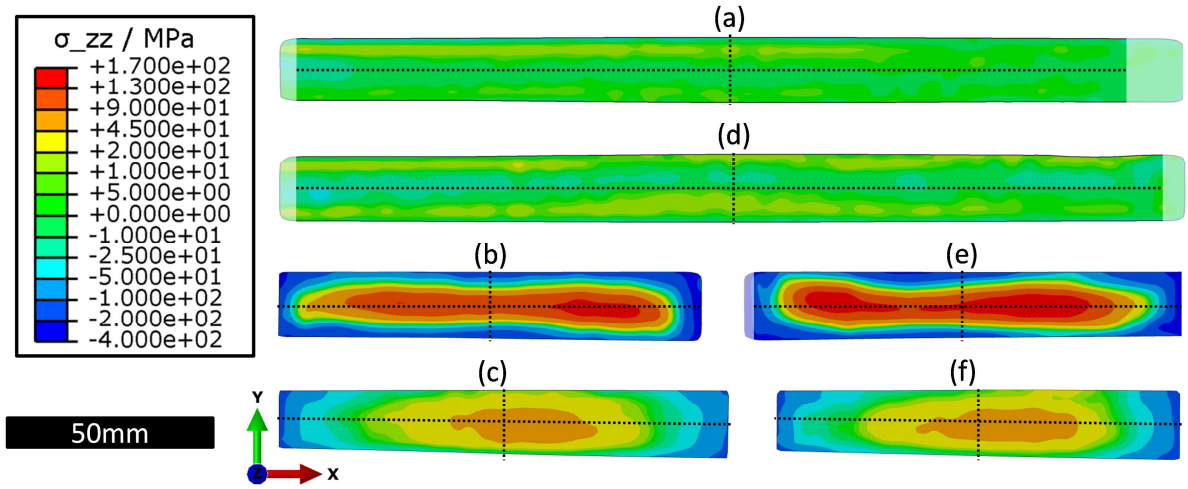

Figure 9 – Normal (σ_zz) residual stress map from sample **A** (a), sample **B** (b), Sample **C** (c), sample **D** (d), sample **E** (e) and sample **F** (f). Note that the regions affected by the cut artefacts were faded, since RS results in these regions should be disregarded. Additionally, dotted lines show the location from where RS plots were extracted.

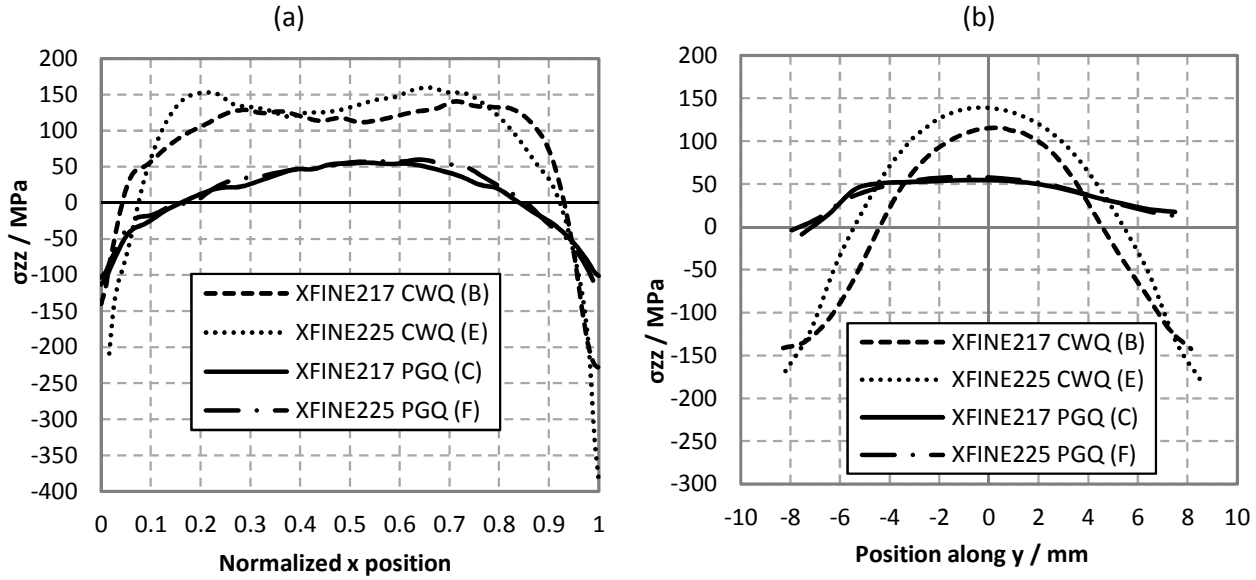

Figure 1 – (a) Normal (σ_{zz}) residual stress profiles along the normalized x axis at mid-thickness of CWQ and PGQ T6 samples and (b) through the thickness in the centre of CWQ and PGQ T6 samples.

Conclusions

The contour method can be successfully applied to measure residual stresses on ~15 mm thick plates of composites made of AA2124 reinforced with 17 and 25 % of SiC particles. Residual stresses in the composite in the T1 condition (cooled after forging at room temperature air) are negligible. T6 treatment comprised of a quench in cold water (CWQ T6) introduces more residual stress than when a 25 % solution of polyglycol (PGQ T6) is used in this operation. Finally, PGQ T6 introduces nearly the same amount of residual stress on ~15 mm thick plates of XFINE217 and XFINE 225.

References

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