CMMT(MN)002

Standardisation of High Temperature Tensile Tests for Discontinuously Reinforced Metal Matrix Composites

Recommendations

Reliable and consistent measurements of tensile properties require the standardization of heating profiles prior to testing. Strain rate has a significant effect on stress/strain response and must be reported with the test result

Background

There is an increasing market pull, particularly from the automotive sector, for discontinuously reinforced metal matrix composites (MMC) in a wide range of components, both to save weight and to improve performance. MMC brake rotors, for example, have about half the weight of conventional cast iron rotors and the increased performance comes from improvements in strength and stiffness over a range of temperatures. Accurate values for mechanical properties are required for preliminary design studies particularly for assessing the effects of thermal exposure and the mechanical properties at high temperatures. There are currently no recognised international standards for these measurements for MMC, although NPL has developed recommended test procedures for measuring strength and stiffness at ambient temperatures [1,2].

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November 1996

High Temperature Tensile Testing

This measurement note is concerned with the extension of the recommended room temperature testing procedures to elevated temperatures, particularly for aluminium alloy matrix MMC.

Following the methodology adopted during the development of the ambient temperature testing procedure, an international intercomparison exercise was conducted through VAMAS on a SiC whisker-reinforced Al alloy MMC at 200°C [3].

Significant differences in properties were obtained in tests conducted by the participating organisations because the heating profiles, ie time to temperature and time at temperature before testing, were markedly different.

Ambient Testing Procedures

Validation exercises were conducted to underpin the ambient temperature tensile testing procedure [1]. These inter-comparisons formed the basis of new guidelines [2] which recommend specific testpiece dimensions, testing rates, methods of gripping and strain measurement techniques. The guidelines also define methods for measuring Young's modulus, proportional limit, proof stress, tensile strength and elongation to failure. The procedure contains a recommended proforma for a test report in anticipation of future database requirements. From these validation exercises the uncertainties associated with the measurement of mechanical properties following this procedure were:

Young's Modulus	±2% +
Proportional Limit	±20% ++
Elongation to Fracture	±25(10) +++
Proof Stress	±2%
Tensile Strength	±4%

+ Potentially better than ±1% with the tangent/secant method of analysis and strain gauges with accurately known gauge factors.

++ Could be reduced further by specifying a plastic strain of less than 0.01.

+++ For all tests, (±10% for tests failed in gauge length).

VAMAS Intercomparison

Four tensile testpieces were circulated to each participating organisation in the USA, Europe and Japan. The material was a discontinuously reinforced SiCw / Al alloy supplied from the USA and machined into testpieces by NRIM, Japan. NPL coordinated the testing, collated the data and produced a report [1]. All participants were asked to conduct the tests at 200°C, but following the recommended ambient test procedure where possible.

Each participant was given no instructions on the appropriate heating profile to adopt prior to testing nor on the strain rate to use other than that specified in the ambient testing procedure (ie greater than 0.001 s^{-1} in the plastic range). The heating profiles adopted by the participants were as follows:

Organisation	**Time to temp. min**	**Dwell at temp. before test min**
NPL	30	10
NASA	40	15
Univ Bordeaux	40	15
Clausthal	30	20
INSAMET	20-40 (plus 12h at 200°C prior to test)	30
NRIM	40	5
DLR	10	10

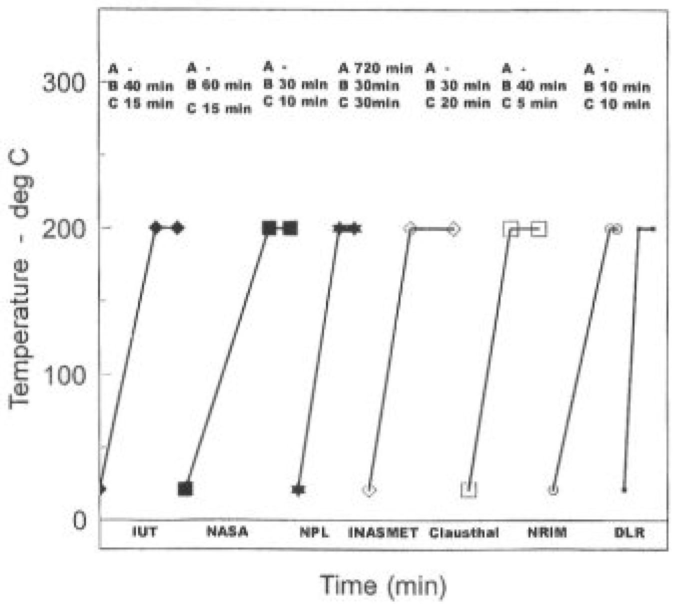

Figure 1 Schematic heating profiles

The effects of using these different heating profiles can be seen in the variation of tensile strength, Fig 2.

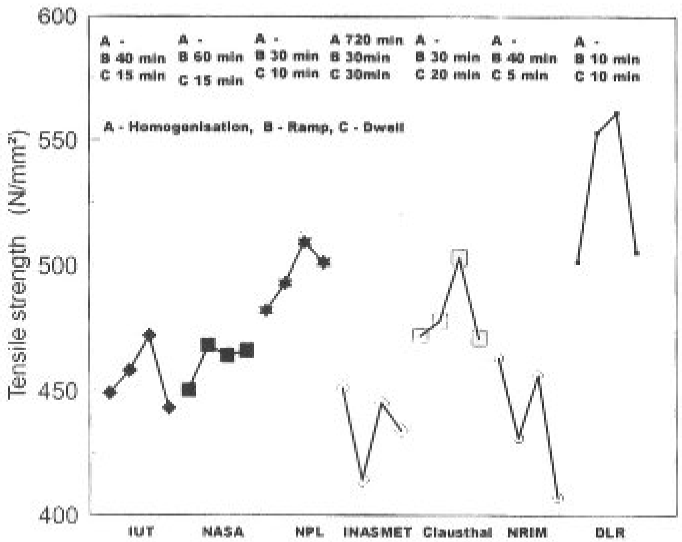

Figure 2 Effect of heating profile on tensile strength - VAMAS 200°C intercomparison.

These differences result from the use of a heat treatable Al alloy matrix. The metallurgical condition is not stable at 200°C - it overages and softens appreciably.

Due to this variation, it is clear that a standard procedure for testing MMC at temperature must include either recommended constraints on heating profile or mandatory instructions to give specific details in the test report.

Effect Of Strain Rate

Strain rate is an important variable when testing conventional materials at elevated temperatures. This is also the case for aluminium alloy based MMC. Typical effects of changes in strain rate in tests at 200°C on 2000 series Al alloy /SiCp MMC are shown in Fig 3. Clearly, for standardisation purposes, it will be necessary either to specify a strain rate to be used in a standard test or to record the strain rate used in the test in a formalised test report.

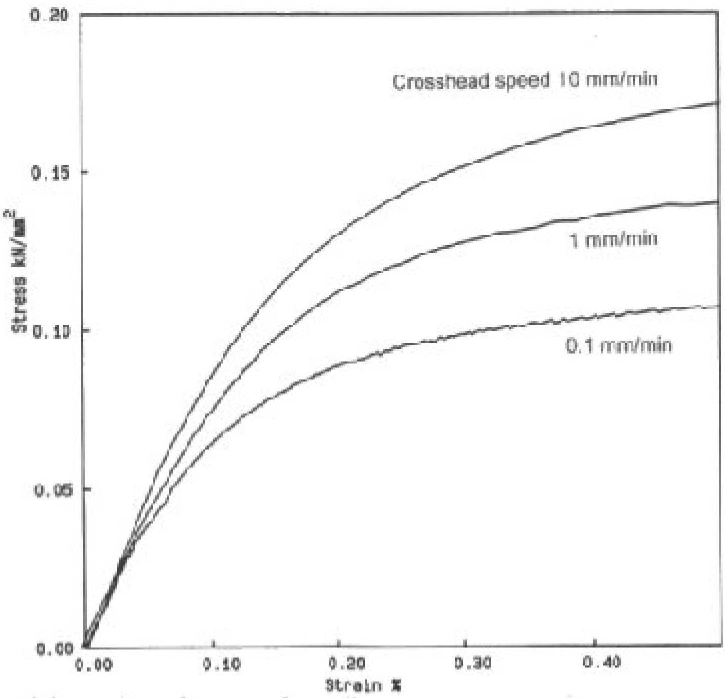

Figure 3 Effect of changes in strain rate on the tensile stress/strain curves of a representative discontintlously reinforced MMC at 200°C.

Conclusions

In the interlaboratory exercise a choice of different heating profiles prior to testing resulted in significant differences in tensile strength.

Strain rate has a large effect on stress/strain flow curves in tests at elevated temperatures on Al alloy MMC.

Acknowledgements

The work at NPL was supported by the DTI EAM division through the Materials Measurement programme. VAMAS participants are thanked for their contribution to interlaboratory testing.

References

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