Creep of Al and Al-Al_4C_3 Materials

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Properties of the dispersion strengthened alloys Al–Al_4C_3 in simple tension have been investigated at room and elevated temperatures [1-5], shear creep of several composite materials was analyzed in [6-11]. In the present work the alloy Al–Al_4C_3 is tested in shear at elevated temperatures ranging from 523 K to 773 K under creep conditions in comparison to standard pure aluminum specimens. The selected specimen geometry and testing machine is able to provide pure shear conditions (i.e. with zero normal stress) in the central region (gauge area) of the specimen.

The geometry and particularly the central (gauge) area of the shear specimens (80 x 20 x 6) used for the shear tests in pure aluminum and Al–Al_4C_3 are composed of a smooth U –groove in the shear plane and a ramp waste profile in the transverse (out of the shear plane) direction. The specimen is loaded with the pair of opposite forces on the outer pin-holes. These externally applied forces along with the pair of reactions developed on the inner stationary pins generate pure shear loading (i.e. with no tension or bending) along the gauge area of the specimen.

The testing machine is a single axis servo-hydraulic one that is capable of applying shear forces up to 15 kN at the central region of the above – presented shear specimen. In order to verify that a pure shear field is developed in the gauge area of the specimen, numerical analysis using FEM was carried out using tetrahedral isoparametric finite elements in the elastic domain. The loading of the shear specimen was modeled as a uniformly distributed load on the load bearing inner surface of the outer pinholes and the inner pins were modeled as supports allowing free rotation but no linear motion. The successful technique employed was to engrave a grid of conical holes about ∅50μm x 50 μm deep directly onto the specimen using a suitable carbide indentation tool. The image processing is carried out on the Autodesk MAP 2004 GIS image processing software platform. On each hole a polygon is drawn by the user along its boundaries and the centroid of this polygon is calculated automatically by the software.

Six specimens from pure aluminum and one specimen from aluminum matrix carbide alumina produced by mechanical alloying were tested in comparison under different shear loading and temperature. On all specimens the aforementioned grid of holes was engraved and the changes of the grid pattern were recorded at successive time intervals using an optical long distance observation microscope. From image analysis the strain maps were produced and the creep rates were calculated. All pure Al specimens exhibited the classical three – stage creep behaviour, i. e. a linear stage I, where the creep was advancing rapidly, a stable stage II wher the rate is constant and a rapidly increasing final stage which led them to failure, Fig. 1.

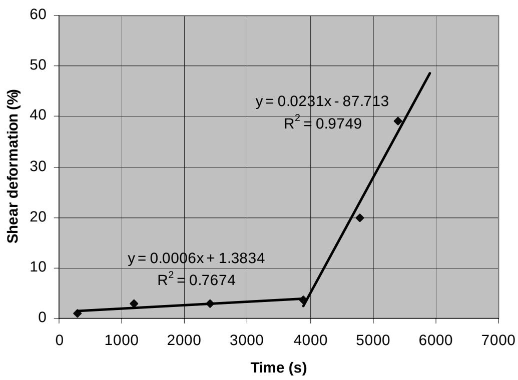

Fig. 1

The composite Al–Al_4C_3 was in the beginning tested at 25 MPa and 573 K. It was decided that since its shear creep properties have never been described in the bibliography the temperature and/or stress would be raised progressively depending on the observed behaviour of the material. After 60 min of loading at 573 K and 25 MPa with negligible deformation the temperature was increased to 623 K while maintaining the same stress level for another 60 min. The temperature was further increased to 673 K for 45 min and 723 K for another 45 min and after 22 minutes of loading at 723 K and 25 MPa some surface cracks appeared in the gage area (center) of the specimen where the uniform pure shear field is developed. These cracks had a tendency to appear and re-appear as the scale was removed, leading to the assumption that they were not deep cracks running inside the material but rather surface cracks of the oxide layer formed as the substrate was deforming due to creep. As the specimen did not show accelerated creep behaviour, the temperature was further increased to 773 K and the loading was kept at 25 MPa for another 60 min.

Dependences of shear stress on creep rate of Al and Al–Al_4C_3 specimens at various temperatures are shown in Fig. 2.

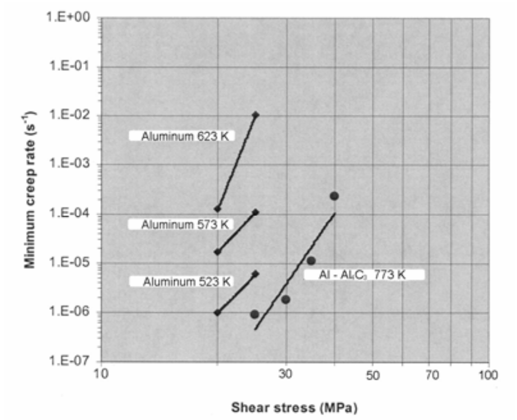

Fig. 2

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