

Extrudability of Particle-reinforced Aluminium Metal Matrix Composites at Warm working Temperatures (0.3-0.5 T_m)

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This work evaluates the warm temperature extrudability of aluminium Metal Matrix Composites (MMCs) and Metal Matrix Nano Composites (MMNCs) produced by powder metallurgy. Green and sintered compacts were produced by blending 2124-Al with Al₂O₃ (5 or 10 vol. %) or SiC (10 or 15 vol. %) powders in a high energy ball mill, cold *i.e.* ambient temperature compaction and sintering at 490°C for 1 hr. The deformation behaviour of unreinforced 2124-Al, MMC and MMNC green and sintered compacts was studied by performing uniaxial compression tests using a Gleeble 3500[®], within the warm working temperature range (170 - 280°C). Strain rates of 0.01 and 5 s⁻¹ were used and the total strain of 0.3 was kept constant. The Abaqus Finite Element modelling (FEM) programme was used to simulate an extrusion process using the results from the uniaxial compression tests as input data. The uniaxial compression test results and the FEM analysis were used to design a warm temperature extrusion process. These results were then validated by performing a laboratory scale extrusion experiment.

A more uniform distribution of reinforcing particles in the 2124-Al alloy matrix was achieved in the Al₂O₃ reinforced MMNCs than SiC reinforced MMCs. Cold compaction of the 2124-Al with 10 vol. % Al₂O₃ powder was unsuccessful as green compacts pressed from this powder fractured. This fracturing was attributed to poor bonding and plastic flow due to the higher density of Al₂O₃ particles on the surface of the 2124-Al powder. Alternate consolidation techniques, such as spark plasma sintering (SPS), were recommended for the 10 vol. % Al₂O₃ powder. Deformation behaviour improved significantly when sintered MMC compacts were uniaxially compressed at 280°C, a strain rate of 5 s⁻¹ and a soaking time of 20 minutes. The best deformation, *i.e.* good ductility which is shown by a large plastic region and high flow stress, was achieved in the 2124-Al with 10 vol. % SiC MMC, as it plastically deformed at the highest stress (~153 MPa) up to the maximum strain of 0.3.

Extrudability of the unreinforced 2124-Al was good, while the 5 vol. % Al_2O_3 reinforced MMNC and SiC reinforced MMCs had poorer warm temperature extrudability, which was attributed to a lack of lubrication during extrusion. The MMCs and MMNC were more difficult to extrude than the unreinforced 2124-Al alloy because they have a higher resistance to deformation as a result of the harder, stiffer reinforcing particles which do not deform easily. The lack of lubrication could have made deformation of MMCs and MMNCs more difficult due to higher friction (increased resistance to deformation) and reduced material flow. The desired good distribution of Al_2O_3 in 2124-Al achieved in blending was not maintained by cold compaction, uniaxial compression and extrusion. This indicated that an alternate processing route is required for the Al_2O_3 reinforced MMNCs. Distribution of SiC particles in 2124-Al with 10 vol. % SiC improved slightly due to uniaxial compression. It was observed that in some areas, SiC particles were reasonably dispersed inside slightly deformed 2124-Al grains; illustrating that deformation influenced the distribution of SiC particles in the aluminium alloy matrix. Analysis of small extruded portions of SiC reinforced MMCs showed that extrusion has the potential to improve distribution of SiC particles in 2124-Al grains. However, higher deformation is required to optimise the SiC distribution.