Journal & Proceedings of the Royal Society of New South Wales, vol. 154, part 2, 2021, pp. 239–240. ISSN 0035-9173/21/020239-02

Thesis abstract

Effects of filler and matrix materials on the properties of metal syntactic foams

Kadhim Al-Sahlani

Abstract of a thesis for a Doctorate of Philosophy (Mechanical Engineering) submitted to the University of Newcastle, Australia

Metal matrix syntactic foams (MSFs) are lightweight materials manufactured by embedding hollow or porous lightweight particles in a metal matrix. Recently considerable attention on developed MSFs has been established because of their potential to replace a wide range of ceramics, metallic and foams polymeric because of their unique properties.

To tailor MSFs, there are many parameters to control. Most important of these are the filler and matrix materials properties, which directly affect the mechanical and structural properties of MSF. So far, there has been limited application of such foams because of the low cost-efficiency, relatively high density and unsteady deformation behaviours of MSFs.

This study aimed to investigate various combinations of inexpensive fill and matrix materials to manufacture low-cost MSF with a high strength-to-weight ratio using simple manufacturing processes. Various low-cost, lightweight particles were analysed and classified according to their production. Inexpensive expanded perlite (EP) has the lowest bulk density (0.18 g/cm^3) of particles used to produce low-price, low-density MSFs. Expanded glass (EG) particles (with internal porosity ≥84%) are another innovative and cost-effective filler. EG has superior mechanical and physical characterisation, for example, low density (only 0.23 g/cm^3), spherical shape and reasonably high crushing strength, and particles are available in a wide size range (0.1–8.0 mm). EG is manufactured from recycled glass, which makes it a sustainable resource.

Counter-gravity, pressure-assisted infiltration was successfully used in the current research to manufacture novel EG-metal syntactic foams subsequently called EG-MSFs. One study addressed the particle morphology effect on the mechanical properties of foams using A356 alloy as a matrix. A novel method for controlling EG shrinkage was successfully created and used to produce novel inexpensive EG-MSFs with a range of densities: 1.05–1.17 g/cm^3. The same approach was employed to characterise the effect of particle size on the MSF properties. Three different EG particle sizes were embedded within an A356 alloy matrix to produce MSF samples. A further study was conducted to investigate the effect of thermal treatment and ductility of the matrix of MSFs at cryogenic temperatures. The alloys A356 and ZA27 were compared for their compressive properties under such conditions. The density of Al-EG foams was close to 1 g/cm^3, and a higher density of approximately 1.85 g/cm^3 was obtained for

zinc-EG foams. The mechanical behaviour of the MSFs was investigated and analysed by careful monitoring of the spread of the plastic deformation areas.

The particle strength and matrix ductility of MSFs was also investigated. To this end, pure aluminium (Al) and ZA27 were used to manufacture four groups of foams with embedded sodium chloride (NaCl) particles. In half of the samples, the NaCl particles were leached out. This allowed isolation of the particle strength effect while maintaining similar matrices.

Structural, microstructural and mechanical analyses of the manufactured foam samples were conducted for a comprehensive characterisation of the material. The stress-strain curves of all foams contained three distinct regions: an elastic region, a plateau region, and densification. Mechanical foam properties including 1% offset yield stress, energy absorption, plateau stress, unloading modulus, energy efficiency and plateau end strain were analysed following the ISO 13314 standard. The results identified promising materials for lightweight structural applications and energy absorption.

Finally, a comprehensive comparison of the current results with previously reported data was made, considering mechanical foam properties including yield stress, plateau stress, absorption energy capacity, absorption energy efficiency and plateau strain. Each of these mechanical properties was plotted to create an inclusive diagram comparing MSFs made from various fillers and matrices. The results of this investigation are likely to be valuable in regard to applications of MSF for weight saving and energy absorption. The compressive mechanical characterisation of MSFs is the principal object of this thesis. The outcomes of the current work therefore allow prediction of the mechanical properties of MSFs that undergo compressive loading in industrial applications. This study contributes to increasing the knowledge base regarding MSFs and will help material designers to tailor the properties of MSFs by controlling matrix and filler properties. This will enable the development of novel materials that are optimised for a given application.

Dr Kadhim Al-Sahlani
School of Engineering
University of Newcastle
Callaghan NSW 2308
AUSTRALIA

E-mail: Kadhim.Al-Sahlani@uon.edu.au