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Effect of Plasma Electrolytic Oxidation coating on the specific strength of open-cell aluminium foams

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Plasma Electrolytic Oxidation (PEO) coating treatment is applied to open celled aluminium foams with different structures, aiming to enhance the mechanical performance of the composite material. The mechanical properties of the coated foams produced are assessed experimentally, both in tension and compression. From experimental results, yield stress is found to increase initially with increasing PEO coating thickness, though this trend is not maintained with thicker coatings. This is caused by the transformation of greater quantities of metal to ceramic with thicker coatings (leading to more flaw-sensitive behaviour), and higher defect density in the surface layer (reducing the strength of the coating material). The specific strength of the samples (the yield strength per unit weight for a fixed volume) is shown to initially increase with coating thickness, although, due to the diminishing mechanical benefit and constant weight increase, the effect of substantial coatings is less beneficial. The optimum coating thickness appears to be in the region of 13 μm for the low porosity replicated foams tested in compression, and a value between 18 and 50 μm for the high porosity investment cast foams tested in tension.

1. Introduction

Metal foams have many interesting and unusual properties that make them candidates for innovative designs. These include structural applications, making use of the high specific mechanical properties of foams. These properties could potentially be increased for open cell foams (where pores are connected together and to the outside environment), by treatments affecting their large surface area. This has been shown to be the case with a thin surface coating (of the order of hundreds of nanometres, being a reaction layer on aluminium foam processed by replication, formed during the dissolution step [1]), and also with thicker coatings applied by electrodeposition (e.g. Ni, Ni–Fe and Ni–W alloy on aluminium foams to thicknesses of 25–400 μm) [2–4].

These improvements can be explained by considering the common assumption that deformation occurs by bending of foam struts. As the coating is at the beam surfaces (where the strain is highest) even a thin film can have a significant effect, provided that the coating material has a high strength and modulus, and the deposition mechanism allows strong and uniform adhesion [2]. In electroplating processes, the inner struts receive less coating compared to the outer region (attributed to the foam structure inhibiting the passage of charge and altering the electric field distribution in the electrolyte penetrating the pores), though this is less of a disadvantage where resistance to bending is required for the whole sample [4].

Foams can be produced from many different metals, using many processes [5]. Amongst these, good control of the structure may be achieved in investment casting-based routes and the replication process [6]; both of these give open celled foams, but with very different structures [6–8]. In this work we examine the effect of the Plasma Electrolytic Oxidation process on the mechanical behaviour of aluminium foams with low and high levels of porosity processed by these methods.

2. The Plasma Electrolytic Oxidation process

The Plasma Electrolytic Oxidation (PEO) process has been examined on dense metals in a wide range of structures [9], but its application to metallic foams has not been systematically investigated. PEO is a plasma-assisted electrochemical surface treatment that is used to convert surfaces of light metals, e.g. Al, Mg and Ti, into hard and well-adhered oxide layers [10]. The process operates at high anodic potentials (typically several hundreds of volts) that trigger numerous microdischarge events at the metal–electrolyte interface, generating high instantaneous temperatures and pressures. Excursions to these extreme conditions alternated with rapid cooling by the surrounding electrolyte significantly affect coating morphology, phase composition and stress state [11] leading to the

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