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Analysis of the rheological behavior of copper metal injection molding (MIM) feedstock

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Abstract

Metal Injection Molding (MIM) technique allows for the production of highly porous metallic foams with porosity levels up to 90%. It makes use of the pressure built up by the decomposition of a foaming agent which is incorporated in a foamable precursor copper material obtained by powder compaction. Rheological is one of the key factors to ensure the successful of MIM technique and to predict failure, whether due to the binder component and compositions, powder loading or unsuitable process parameters. The balanced ratio feedstock contains of 63 vol.% of copper powder, different percentage of potassium carbonate; Batch 1 (0.4 vol.%), Batch 2 (0.5 vol.%) and Batch 3 (0.6 vol.%), and the remaining volume percentage of binder system has been mixed to form copper feedstock. The rheological behaviors were investigated using a capillary rheometer (CFT-500D, Shimadzu) at various temperature and loads. From the experiments, it was concluded that the MIM feedstock exhibit a shear thinning or pseudo-plastic behavior based on the trend of graph which is suitable for MIM process. This result is within the ideal range of viscosity theoretical for MIM feedstock which is in the range of between 10 Pa.s to 1000 Pa.s at all temperature tested. The viscosity of a pseudo-plastic substance decreases as the shear rate increases (shear thinning). This could be due to particle orientation and ordering with flow as well as breakage of particle agglomerates released together with the binder.

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Keywords: Copper; rheology; feedstock

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1. Introduction

Metallic foams or cellular materials are unique materials with controlled pore structure and properties that can be applied to various applications; such as low density, high stiffness in conjunction with very low specific weight and high gas permeability combined with high thermal conductivity. Many metals have been researched and developed to produce metallic foam such as aluminium, copper, titanium and so on. Copper foam has been used in various industrial applications, such as thermal conductors, catalysts, and batteries[1,2].

Many different methods have been used to manufacture copper metal foams, among which, the methods that use metal powders are the most widely used. These methods have a good control over the cell shape, cell size and porosity distribution. Some investigators have used the Sintering and Dissolution Process (SDP), and recently, the Lost Carbonate Sintering (LCS) process[3,4]. This research aims to produce the copper foam by using MIM as this process has the ability to produce complex shaped powder parts with near net shape at high production capacity.

In MIM process, the molding stage is a critical step for the fabrication of sound parts without cracks and distortions. Non-homogenous flow and powder-binder separation can produce defects during molding, resulting in cracking and warpage during debinding and sintering, and ultimately poor physical and mechanical properties of the final MIM component[5]. So this step requires specific rheological behavior; viscosity, density, thermal properties and pseudoplastic behavior of a feedstock that determine its performance for successful manufacturing process.

With reference to recent results on the development of copper foam for MIM[6,7], the present study is specifically focus on investigation of the rheological behavior and stability of Copper feedstock. The data can be used not only to predict the flow behavior during injection molding and to determine viscosity, but also to reveal the stability and homogeneity of feedstock and the extent of powder-binder separation.

Nomenclature

μm	micrometer
vol.%	volume percentage
°C	degree Celcius
s-1	per second
Pa.s	Pascal second

2. Experimental Procedure

A commercially available Copper spherical shape powder as shown in Fig. 1 is provided by Guangzhou Jiechuang Trading Co. Ltd., China and its characteristics is tabulated in Table 1. The 22 μm particle size distribution was determined using a Cilas particle size analyzer and it can be seen that the powder had a relative wide particle size distribution which is desirable for efficient particle packing.

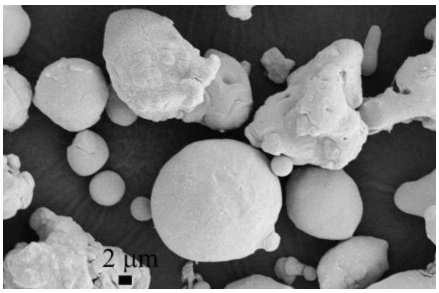

Fig. 1. A scanning electron micrograph of Copper powder.