DENSIFICATION AND DEFORMATION BEHAVIOUR OF SINTERED POWDER METALLURGY COPPER-7% TUNGSTEN COMPOSITE DURING COLD UPSETTING

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ABSTRACT

Studies were conceded out to evaluate the initially preformed density and initial aspect ratio on the densification behavior of sintered Copper 7% Tungsten composite. The preform possessed 0.85 is the initial theoretical density. Aspect ratio varied from 0.4, 0.6 and 0.8. Properties of Copper Tungsten composites with respect to linear strain, lateral strain and true stress were evaluated and plotted. Studies exposed that higher stress and higher strain values are obtained in composite when compared to the Tungsten powder. The composite of Copper 7%W obtained at 750\(^\circ\)C. The Composite obtained at lower aspect ratio acquired the highest stress and strain when compared to the composites preforms obtained at other aspect ratio.

KEYWORDS: Powder Metallurgy, Metal Matrix Composites, Preform, Sintered Copper-7% Tungsten Composite, Nano Structure.

1. INTRODUCTION

The term “composite” broadly refers to a material system which is tranquil of discrete constituents (the reinforcement) distributed in a continuous phase (the matrix). It derives its individual characteristics from the properties of its ingredients, from the geometry and architecture, and also from the properties of the restrictions (interfaces) of its different constituents. Composite materials are usually classified on the basis of physical or chemical nature of their matrix phase, like polymer matrix, metal-matrix and ceramic composites etc. Among the materials that are extended to an increasing scope of metal matrix composites. The space industry was the first sector captivated in the usage of these materials. Another fragment of even superior fiscal importance for the development of new metal matrix composites (MMC’s) is the automotive industry. The suppleness allied with MMC’s in
tailoring their physical and mechanical properties as compulsory by the users have made them suitable candidates for a gamut of applications related to automobile and aeronautical sectors. The preface of fine dispersed particles into the metal matrix has crucial reinforcing effects when maintained at prominent temperatures. Powder forging technique is conventional as the most inexpensive and efficient procedure leading to aperture elimination and superior mechanical strength. Although a number of processes are available for producing MMC's, the powder metallurgy technique was found to be the most appropriate because it yields better mechanical properties. Research on dispersion strengthened materials points out the implication of the properties of the starting metallic powders and also the importance of the preliminary structure in preserving the structure of the concluding manufactured goods. A very important aspect of scattering strengthening is the even allotment of tungsten particles, their fine distribution, especially in nanometer scale, and the introduction of a possible amount of dispersed particles into the volume of the base metal. The powder metallurgy sintered parts possesses 20-40% porosity which can be advantageously used, but the mechanical properties of the component are adversely effected by the presence of porosity. Therefore, the parts intended for dynamic applications, the final compaction should be close (up to about 1.5-2%) to that of fully dense material.Forging of the sintered preforms result in a precision component with the reduction or elimination of porosity. The lessening in porosity during forging, results in a decrease in preform volume. The compliant of porous materials, thus, does not follow the laws of number constancy. Further, the “material parameters” (such as, modulus of elasticity and modulus of rigidity) are functions of density of the buckling body and as such the “material parameters” also feel a variation along with a change in porosity (density). Initially, there had been some experimental, semi-experimental or analytical looms using slab method for obtaining the density of porous formed metal parts. Thereafter, several researchers studied the forging of porous materials and garrison by using finite element method taking material to be rigidly plastic. A challenge to use numerical method for the analysis of powder metal forging operation has also been studied by various researchers using a unyielding plastic approach. Rigid plastic approach could be adequate for large deformation by excluding the effect of resilient behaviour of the material. Subsequently, there have been some attempts to develop elastic-plastic approach to study the deformation of porous materials. The aim of the present work is to study the mechanics of cold forging of powder metal preforms taking into account its plastic strains as the work material which undergoes deformation. The model developed was applied to study the forging of an axis symmetric short frozen cylindrical part under simple upsetting. The analysis was carried out for the press forging with slow rates of deformation where inertia and temperature effects were negligible. The total results predicted the densification pattern of the work material and the loads required to produce the desired deformation.

2. PROBLEM FORMULATION

Present exploration focused on the densification behavior of sintered copper 7% tungsten powders when taken in varying quantities. Frictionless compression tests are used to find out the fundamental plastic flow characteristics of porous metals. Studies expose that the deformation was uniform with barreling of cylindrical surfaces. The proposed study also carries out to evaluate the initial preformed density and initial aspect ratio on the densification behavior of sintered copper 7% tungsten composites. The preform obsessed 0.85 as initial density and three aspect ratio varied from 0.4, 0.6, and 0.8. Four performs, each
of different aspect ratio were taken for each temperature. A critical literature survey reveals that several attempts have been made in producing components through powder metallurgy route, which may contain one or the other type of impurifier. These perhaps could not be verified during the course of several investigations as the fine dispersion of self oxidized material in the component perchance induced enhanced properties. A wide variety of research in the area of elemental powder and its own oxide composite has been carried out. But earlier investigations have shown that extruding the sintered preform containing the self oxidized dispersions in different proportions on extrusion may encourage improved mechanical properties. It is well established that in the metal forming operations the deformation is never sternly homogeneous and therefore pores present on the surface of the component can never be closed either due to the predominance of tensile forces or due to hydrostatic forces present in the dead metal zones. Therefore, it is more likely that the particulate structure will be customary at the surface of the component irrespective of preform design for any upsetting test. For studying the behavior of copper 7% tungsten composite during cold upsetting, mechanical properties should be given precedence. In most of the methods adapted for studying the strengthening of the composite, strengthening metal must have higher melting point than matrix metal. In this method, we have developed tungsten as a strengthening component, but it possesses higher melting temperature than Copper (matrix metal). The basic advantage of dispersion strengthened materials is that it does not improve yield strength at ambient temperature or work hardening rate. The present investigation on composite carried out at temperatures of 750°C with three aspect ratios of 0.4, 0.6 and 0.8.

3. EXPERIMENTAL PROCEDURE

3.1. Materials Required:
The materials required for this investigation are: Copper and Tungsten powder for composite preparation, graphite for using as lubricant, high carbon die steel punch and die, two flat plates heat treated to Rc 53 to 56 and tempered to Rc 46 to 49, a stainless steel tray, and an electric muffle furnace.

3.2. Preparation of Copper-7% Tungsten Composite:
Copper and Tungsten powders were used in the present investigation. These powders were purchased from M/s. Metal Powder Company (P) Ltd., Tirumangalam, Madurai, Tamilnadu, India. Electrolytic copper and atomised tungsten were obtained with 100% and 99.73% purity respectively. The individual powders were pulverized in a high energy ball mill (Fritsch, Germany - Pulverisette - 6) for four hours after that it was mixed on weight basis with 7% Tungsten and rest Copper powder. These composite powders were pulverized in a high energy ball mill and after 10 hours milling, the obtained particle size was approximately below 400nm. SEM was used for evaluation of morphological changes of the particles after milling and is shown in Fig. 1(a-c). Fig. 1(a) shows the SEM image of the Cu particles at 9500X magnification and has a structure of a cluster of tiny particles and like small flattened flake particles due to severe plastic deformation of copper, micro-welding and fracture of the large flakes due to typical mechanical milling. Fig. 1(b - c) shows the SEM image of the W powders at 6000X and 2000X magnification respectively, It is in the formation of flattened particles with pancake structure. Fig. 1(d) shows the SEM image of the Cu-7%W Powder Composite at 8000X particles. It shows the morphological changes of Cu-7%W powder mixture after 10 hours milling. No significant difference between the Cu morphology in the composite and the monolithic W powder is observed at low milling times; that means the fine
W elements distributed throughout the Cu matrix and represents the particle size in the range between 200-400nm.

![SEM micrograph after ball milling](image1.png)

![SEM micrograph after ball milling](image2.png)

Fig. 1 SEM micrograph after ball milling (a) Cu powder 9,500 X (b) W powder 6,000X

3.3. Characteristics of Oxidized Powder:
The characteristic of the copper and Tungsten powder is shown in Table 1 (a-b). The individual powders were pulverized in a high energy ball mill (Fritsch, Germany - Pulverisette - 6) for four hours after that it was mixed on weight basis with 7% Tungsten and rest Copper powder.

<table>
<thead>
<tr>
<th>Test Standard</th>
<th>ASTM B-417</th>
<th>ASTM B-213</th>
<th>ASTM E-194</th>
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</thead>
<tbody>
<tr>
<td>Sieve analysis, %</td>
<td>Apparent density (g/cc)</td>
<td>Flow rate Sec(50g⁻¹)</td>
<td>Acid Insoluble</td>
</tr>
<tr>
<td>+75µm</td>
<td>+45µm</td>
<td>-45µm</td>
<td></td>
</tr>
<tr>
<td>EC/86 Grade</td>
<td>0.42</td>
<td>5.43</td>
<td>94.24</td>
</tr>
</tbody>
</table>

Table 1 Characteristics of powder

(a) Copper Powder

(b) Tungsten Powder

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Test Standard</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve analysis : - 45 µm</td>
<td>ASTM D-185</td>
<td>99.00</td>
</tr>
<tr>
<td>Average Particle Size, Fisher Number</td>
<td>ASTM B-330</td>
<td>3.92</td>
</tr>
<tr>
<td>Oxygen Content (Hydrogen Loss)</td>
<td>ASTM E-159</td>
<td>1.85</td>
</tr>
<tr>
<td>Other Impurities Purity</td>
<td>AAS</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>97.93</td>
</tr>
</tbody>
</table>
3.4. Compaction of Zinc-Zinc Oxide Powder:
Cylindrical compacts of 20 mm diameter with an aspect ratio of 0.40, 0.60 and 0.80 were prepared. The compacts were prepared using ball milled Cu-7% W composite. The composite powders were compacted by using suitable punch and die set assembly on a Universal Testing machine having 1 MN capacity. Compacting pressure was applied gradually and it was 1.2 GPa for three aspect ratios. Graphite was used to lubricate the punch, die and the butt. When preparing the compacts, the initial density and aspect ratio were maintained by precisely controlling the mass and accurately monitoring the compacting pressure employed.

3.5 Sintering
After the compaction, the compacts were immediately taken out from die set assembly and loaded into the furnace for sintering. To prevent oxidation, the green compacts were initially covered with inert argon atmosphere in the furnace. The sintering was carried out in an inert gas circulated electric muffle furnace at 750°C for a holding period of one hour. As soon as the sintering schedule was over, the sintered preforms were cooled inside the furnace itself to the room temperature. After the completion of sintering, the preforms were cleaned by using a fine wire brush.

3.6 Cold Deformation Experiments
Deformation experiments were carried out by using flat faced dies and a hydraulically operated compression testing machine of having 1MN capacity. The flat dies were machined and tempered. Flat faces of the dies were ground after heat treatment in a grinding machine, in order to obtain the final dimensions and surface quality and its hardness was measured as 90 HRB after tempering. Graphite was well applied as lubricant on the ends of preforms and contacting surfaces of flat dies, which created a situation for almost frictionless ideal deformation. In general, each compact was subjected to an incremental compressive loading in steps of 50kN until the appearance of visible cracks on the free surface. Immediately, after the completion of each step of loading, the height, the contact diameters at the top and bottom, the bulged diameter and the density were measured for each of the deformed preforms. The density measurements were carried out using Archimedes principle. Experimental measurements were also used to calculate the various parameters namely the stresses, the Poisson’s ratio, density ratio and the strain.

4. RESULTS AND DISCUSSIONS
The sintered P/M Copper-7% W composite was made under the temperatures of 750°C. Cylindrical preforms of three different aspect ratios were employed in the compression tests. Plots were drawn for copper-7% W between the hoop strain and the axial strain to compare with different aspect ratios. The rate of change of hoop strain with respect to axial strain was not the same for all aspect ratios. This indicates that each aspect ratio had different slope and the hoop strain increased with axial strain. Among the three aspect ratios, sintered preforms oxidized at aspect ratio of 0.8 had more strain values. Similarly, the aspect ratio of 0.8 also had high strain values when compared with others. From the plots it was also evident that the strain increased with higher aspect ratios. The deformation of the composites under lower aspect ratio is less. Due to the low value of hoop and axial strain, composites have the low ductile property. This composite is more suitable for the compressive load applications. Plots between the true stress and true strain are shown in figure 3. It is observed that the true axial stress increases rapidly as the true axial strain is increased, followed by a gradual
increase in the true axial stress with further increase in the axial strain. Further, it is found that the 0.80 preform improved load bearing capacity compared to that for other aspect ratios, while the initial fractional density remains constant.

5. CONCLUSION

The major findings of this investigation include the rate of change of hoop strain with respect to the axial strain indicated high values for higher aspect ratios. The rate of change of true stress with respect to true strain was different for different aspect ratios. Higher aspect ratio had the maximum value of both true stress and true strain than lower aspect ratio.
REFERENCES