Investigation of the Deflection Behavior of CZ3000 Prealloyed Powder Beam Using In-situ Bending Technique

M. Mousapour[1]   M. Azadbeh[2]*

A. Mohammadzadeh[3]

1- Introduction
The formation of a liquid phase during sintering is a common technique to enhance densification. A variant to traditional liquid phase sintering (LPS) is to use prealloyed powders, which are heated to a temperature between the liquidus and solidus. The liquid forms inside the particles and spreads to the particle contacts during heating, resulting in capillary force acting on the semisolid particles. This process is termed supersolidus liquid phase sintering (SLPS). Full density or near full density products using coarse prealloyed particles can be obtained via SLPS. A beam bending technique to measure the macroscopic apparent viscosity of semisolid Cu-10Sn prealloyed powder was first used by Lal and German. During this test, they plotted the measured mid-point deflection versus sintering time and found that the slopes of curves (deflection rates) are constant and apparently independent of time. This means that the deflection is a linear function of the sintering time. Investigation on boron doped stainless steel 316L sheets showed different results. Here, the response of the deflection rate as a function of time was nonlinear. It seems that there are some factors such as thickness, powder preparation conditions and even type of alloy which directly affect the deflection behavior. In order to investigate the effects of chemical composition and type of material on the deflection behavior, Cu-28Zn (CZ3000) was studied. The chemical composition of the brass alloy is varied by zinc evaporation during sintering. Recently, the influence of zinc evaporation on sintering processes and properties of brass alloys have been shown by Azadbeh et al. In the present work, the effect of sintering time and temperature on zinc evaporation, and microstructure evolution were evaluated using in situ beam bending test.

2- Experimental
Water atomized pre-alloyed brass powder was mixed with 0.75 wt.% lithium stearate as lubricant in a V-

shaped mixer at 65 rpm for a period of 20 min. Rectangular test specimens, $55 \times 10 \times 10$ mm^3 (DIN ISO 5754) in size were fabricated from this mixed powder. Compaction was carried out uniaxially in pressing tools with floating die at a pressure of 600 MPa.
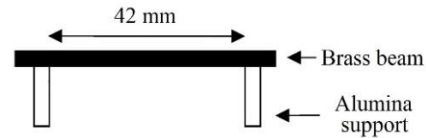

Fig. 1 Schematic view of the bending beam on supports

The compacted samples were used as beams for beam bending test, the initial geometry during the tests is shown in Fig. 1. The setup which consists of rectangular beams on alumina support (95% purity) with the span length of 42 mm, was placed in a horizontal tube furnace (TFS/25-1250). In order to monitor beam bending during sintering, a glass window with 10 mm thickness was applied to the entrance of furnace, and the in-situ images from the samples were taken by a digital camera (Canon: Power shot ELPH 135). The samples were heated at the rate of 20 K/min from room temperature to 540 °C and dwelled at this temperature for 30 min for lubrication removal. Brass beams were then heated at 10 K/min to the sintering temperature ranging from 910 to 950 °C, and the isothermal soaking time range from 0 to 90 min. A flow of N$_2$ gas (technical quality) of 2 l/min, was maintained throughout the entire cycle. All of the compacts were quenched after sintering by quickly pulling out the alumina support and dropping them into the water to preserve the microstructure.

The midpoint deflection of the beams at various sintering temperatures and times was calculated by Screen Ruler 2D software. The sintered specimens were sectioned in parallel to the pressing direction, polished and etched (8 g FeCl$_3$, 25 ml HCl, 50 ml H$_2$O). Microstructural examination of the etched specimens was conducted using an optical microscope (PMG3). In order to show the alloying element content in the microstructure, point analysis of the samples was performed using a SEM (CAM SCAN MV2300) equipped with an energy dispersive X-ray (EDX) micro-analyzer. In order to measure the mass loss, equation (1) was used:

Mass loss = $[(M_g - M_s) / M_g] \times 100$ (1)

where, M_g and M_s are the mass of green and sintered compacts, respectively.

3- Results and Discussion
The in-situ bending images of the brass beam at 920°C and various times are shown in Fig. 2. Beam bending occurred during sintering since the liquid

[1] Department of Materials Engineering, Sahand University of Technology, Tabriz, Iran.

[2] *Corresponding Author, Department of Materials Engineering, Sahand University of Technology, Tabriz, Iran.
Email: azadbeh@sut.ac.ir

[3] Young Researchers and Elite Club, Ahar branch, Islamic Azad University, Ahar, Iran.

volume fraction of the beams increases with increased temperature, which lowered the viscosity and rigidity of the samples. For the most common alloys, the beams failed at high temperature and short time due to high fraction of liquid volume, but for the brass, this did not occur even at high temperature and long time. In fact, despite high deflection of the brass beam which indicates high liquid phase content, failure did not occur.
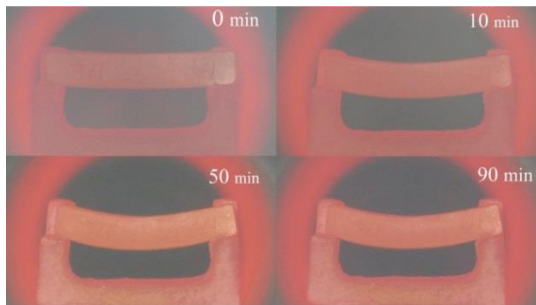

Fig. 2 In situ bending images showing beam deflection at 920 °C and various times

The mid-point deflection of the beam as a function of time and various temperatures is shown in Fig. 3. The deflection increased with sintering time while the deflection rate decreased at constant temperature. This reduction continued until a specific time and after that, deflection rate changes were negligible (slope tends to zero). This behavior can be attributed to zinc evaporation which directly affects the chemical composition of the brass samples. It seems that changes in the chemical composition due to zinc evaporation influence the liquid volume fraction in various zones of the brass beam which involves viscosity of the sample. For better illustration of Zn evaporation, the samples can be divided into: (a) core region and (b) outside thin wall (rim) region.

In order to investigate both surface and core regions, point analysis at the surface and core zones of the samples (sintered at 920 °C for 50 min and sectioned at mid-point of the beam) are shown in Fig. 4. Zn content in the surface zone is less than that in the center zone due to zinc evaporation. According to the phase diagram and lever rule, liquid volume fraction decreases with increasing time and zinc evaporation, and so causes an increase in viscosity and rigidity, which finally reduces the mid-point deflection.
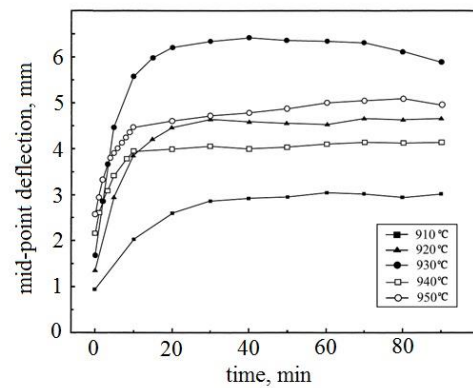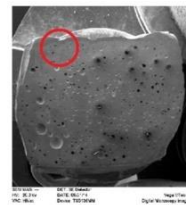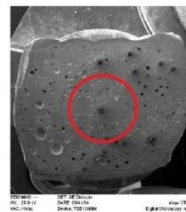

Fig. 3 Mid-point deflection versus time during sintering at various temperatures

Elements	Intensity	Weight %	Atomic %
Cu K	0.9824	92.70	78.83
Zn K	0.9843	1.36	1.12
O K	1.2380	5.94	20.05
Total		100.00	

(a)

Elements	Intensity	Weight %	Atomic %
Cu K	0.9984	65.73	66.01
Zn K	1.0010	34.09	33.28
O K	1.1462	0.18	0.71
Total		100.00	

(b)

Fig. 4 Point analysis from a) surface and b) core areas of Cu-28Zn beam at 920°C for 50 min

4- Conclusion

Mid-point deflection of brass beam shows a non-linear behavior with sintering time. The fracture did not occur for brass beams even at high temperature and long time periods.

The different deflection behavior of the brass beams can be attributed to zinc evaporation. Changes in chemical composition due to zinc evaporation influence the liquid volume fraction in various zones of the brass beam which affects the viscosity of the sample, a more rigid "case" being formed at the surface.