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Influence of fluidity and Hausner's ratio in the process behaviour of P/M of Al -% wt Cu Composite

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Abstract

The term 'P/M' covers the art of producing objects from metal powders or without adding any non metallic constituents and without completely melting material. In order to produce engineering material one should study the flow of the powder. Because the powders may be pressed to the desired form in a suitable die and subsequently heated to produce a welded alloyed or coalesced mass. The wide spread use of powders in the P/M industry has generated a variety of methods for characterizing the powder flow. Hence this paper describes the role of flow rate and fluidity of the powder composition which is taken for the investigation purpose. The study helps the material may then be suitable for immediate use or may be further worked by conventional methods. Because the strength of finished engineering product depends on the flow rate of the powder. Moreover the fluidity offers best article production with unique properties which is not obtained by other methods. The best example is bearings and filters with controlled porosity. For investigation purpose various compositions of Al-Cu powder is used. With small variation the result is obtained. It is understood that the composition of Al –Cu is neither pyrophoric nor toxic in nature.

Key word: Apparent density, Compact, flow rate and sintering.

1 Introduction

Aluminium is best known for its light weight characteristics. When it is cold worked, the material strengthens by double. But it does not oxidize quickly in air due to its microscopic oxide coating on the surface. Any addition of a small quantity of various elements to aluminium vastly improves the mechanical properties and prevents the tearing which is so common when machining the pure metal. The most important manufacturing properties are bulk density, fluidity and compactability and commonly reported methods for testing powder flow are angle of repose, compressibility index or Hausner's ratio, flow rate through an orifice. A quantity of copper is added with aluminium and it is subjected to heat treatment in order to get a good result. The flow chart in Fig: 1 shows the direction of the process which is adopted for the proposed investigation.

2. Metal Powders

Much attention is given on the selection of the powder before going in to the mixing operation because mixing is an important operation of P / M. Ideally , powders for use in the powder –metallurgy method should be nearly spherical in shape, with a minimum of fine dust and no large particles (S.P.Nayak, 1977). Care is taken on the selection of the powder that they should not have internal porosity, high bulk density but should have the ability to flow readily. Commercially available powders do not have all these specifications but exhibit various particle shapes i.e. spherical, angular, dense and porous structures. But the properties of the final product and the techniques used for the production of the finished product depend to a great degree upon the characteristics of the powder and also the type of the method used for manufacturing where it influences the other parameters.

3. Powder Mixing

The fine aluminium powder which is obtained from M / S Metal Box Company Ltd is sintered in Muffle furnace for 1 ½ Hours at an elevated temperature of 550 ^{0} C. The fine copper powder is also heated at the same temperature at the same duration in order to get effective result. During sintering moisture is evaporated and a thin coating of alumina is formed on the surface of the powder particle. Oxidized copper is mixed with sintered alumina at different proportions like 3 %, 5 %, 7%, 9%, 11%, 13%, 15% and 17 % in a pot mill for 4 hours in order to get a homogeneous mixture. Aluminium is having good mechanical properties and when it is added with the second alloying element copper in series, further the strength of the alloy is improved. Because copper is a nobler metal and it flows during sintering and fills the cavity of alumina (R.S Khurmi and R.S Sedha, 1991). It is well known that the SAP (Sintered aluminium powder) belongs to the category of dispersion strengthened alloys**.**

4. Powder Characteristics

The theoretical density, apparent density of the above said combination is studied and tabulated in the Table: 1. The related graph: 1 showing good increase in the theoretical density and apparent density. In general this value is very much appreciable for further process.

4. 1 Flow Rate

The flow rate measures the ability to be transferred. It is the property of the powder by which it flows readily and fills the mould cavity. Therefore during the compaction process the die must be filled rapidly with powder to achieve high rate of production and economy. It also governs the time required to fill a mould and the rate of production (P.Polukhin et. al, 1970). Hence the flow rate is influenced by the shape of the particles, coefficient of friction and size of the particle.

The flow rate as well as the flow ability is measured and shown in Table: 2. The related Matlab graph is shown in graph: 2

Before finding out the flow rate of the powder, the different composition of the powders sintered in the muffle furnace for 1 ½ hours. Because the survey says all powders contain considerable amount of gases. So during sintering the gases will be burnt and it will be getting ready for the process. From the readings it is understood that the powder flow is slightly sluggish and that may be due to the bulk density of the particle.

It is well known that copper is one of the most important additions to Al. It has appreciable solubility and substantial strengthening effect through the age hardening characteristics it imparts to Al. Many alloys contain copper either as major addition 2XXX or 2XX.X series or as an additional alloying element, in concentration of 1 to 10 % (Joseph. R.Davis, 2000). Although there are some variations in the method of determining the compressibility index and Hausner's ratio, the basic procedure is to measure,

(1) The unsettled apparent volume, $V_{o,}$

(2) The final tapped volume $V_{f,}$ of the powder after tapping the material until no further volume changes. The related compressibility index and Hausner's ratio are also determined using equations (1) and (2) and they are recorded in the Table: 3

Compressibility Index = $(V_o - V_f) / V_o$ -------- equation (1)

Hausner's Ratio = V_o / V_f ---------- equation (2)

The values recorded in the Table: 3 are showing good result and Hausner's ratio is neared to the value of the theoretical density. The compressibility is having on an average of 59.69 %.This is a good index parameter for further operation.

5. Result and Discussion

- Though different concentrations of Cu and Al are used the theoretical density of each composition is showing effective value and according to the increase in Copper concentration the theoretical density is showing an increase order which is tabulated in Table: 1 and the corresponding graph (graph: 1) is showing promising increase in its value.

- The apparent density is depending on the physical properties of a powder (S.M.Tang, et.al., 1997) which include particle shape, size, specific surface and pyconometric density.

- Bulk density which is the apparent density of the powders is the loose state is showing slight variation even though different proportions of Al and Cu powders are added. The minimum packed volume thus achieved depends on a number of factors including particle size distribution, theoretical density, particle shape, cohesiveness due to surface forces including moisture.

- The table 2 is showing the sluggish nature of the powder. During sintering the temperature influenced the bonding of the metallic particle (Hailong Wang, et al, 2008). Though the gas is liberated during sintering a thin alumina is formed on the surface layer which is influencing the dispersion strengthen of the powder and that weight age may be the cause for sluggishness of the flow of the powder. But the fluidity is better for various proportions of the powder.
- The measure of the compressibility and Hausner's ratio are remarkable and fair. But the measurement is not the intrinsic properties of the powder, i.e., they depend on the methodology used. An increase in value is proportional to adhesion and friction properties of the powder.

6. Conclusion

From the above results it can be concluded that copper is having an added advantage over aluminium and it is having effective fluidity over various concentrations of Al- Cu powder. More over the flow rate of the material depends upon many factors, some of which are particle related and some are related to the type of process. It is evident from good index ratios the best compact density will be obtained. Copper based ceramic composites can offer excellent strength properties at elevated temperature because ceramics are thermodynamically stable at elevated temperature. Application for such materials involves aerospace devices, fusion reactors and etc.

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Table: 1 Density Measurements

Composition of Al-Cu	Theoretical density ρ_{the} gm / mm^3	Apparent density ρ_{app} gm/ mm^3
97+3 %	2.755	0.846
95+5 %	2.786	0.817
93+7 %	2.818	0.881
91+9%	2.850	0.871
89+11 %	2.883	0.898
87 +13 %	2.918	0.919
85+ 15 %	2.953	0.909
83+17 %	2.989	0.777

Table: 2 Flow rate of Powder composition

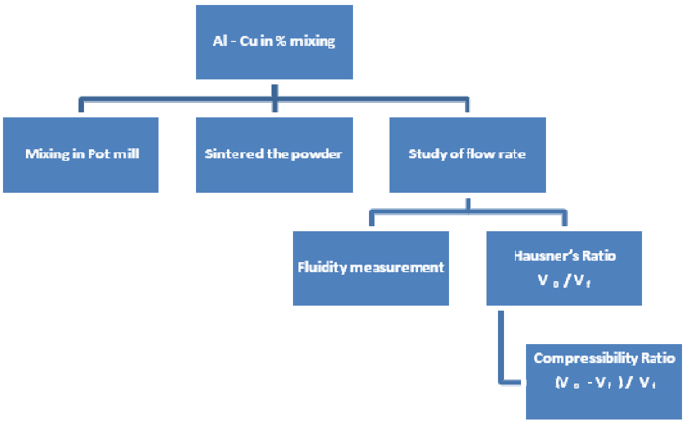
Composition of Al-Cu	Flow rate in Secs	Fluidity Gm/sec
97+3 %	221	0.226
95+5 %	152	0.329
93+7 %	93.8	0.533
91+9%	102.1	0.489

89+11 %	**149**	**0.335**
87 +13 %	**86**	**0.581**
85+ 15 %	**102**	**0.490**
83+17 %	**121**	**0.413**

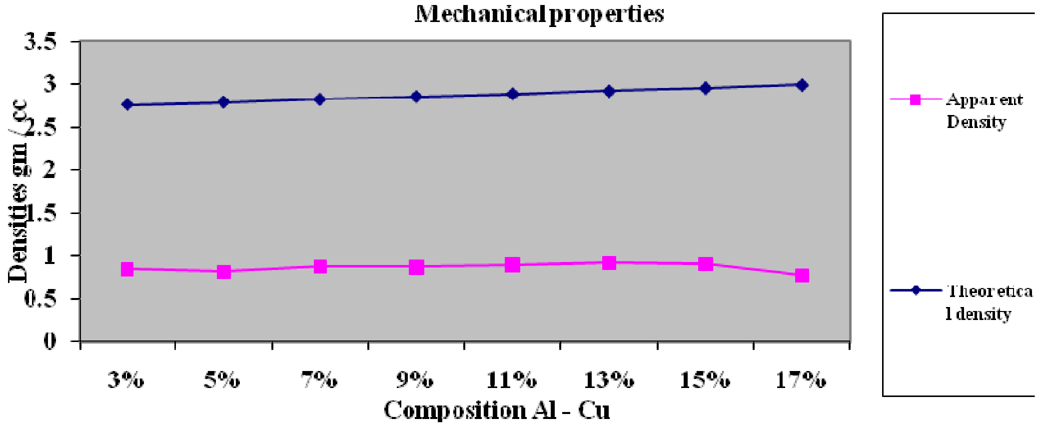
Table 3: Compressibility Index and Hausner's Ratio

Composition % Cu in Al	Compression Index %	Hausner's Ratio
3%	58.07	2.3851
5%	65.24	2.8711
7%	58.64	2.4183
9%	65.49	2.8979
11%	57.97	2.3795
13%	55.84	2.2646
15%	58.05	2.3836
17%	58.28	2.3979

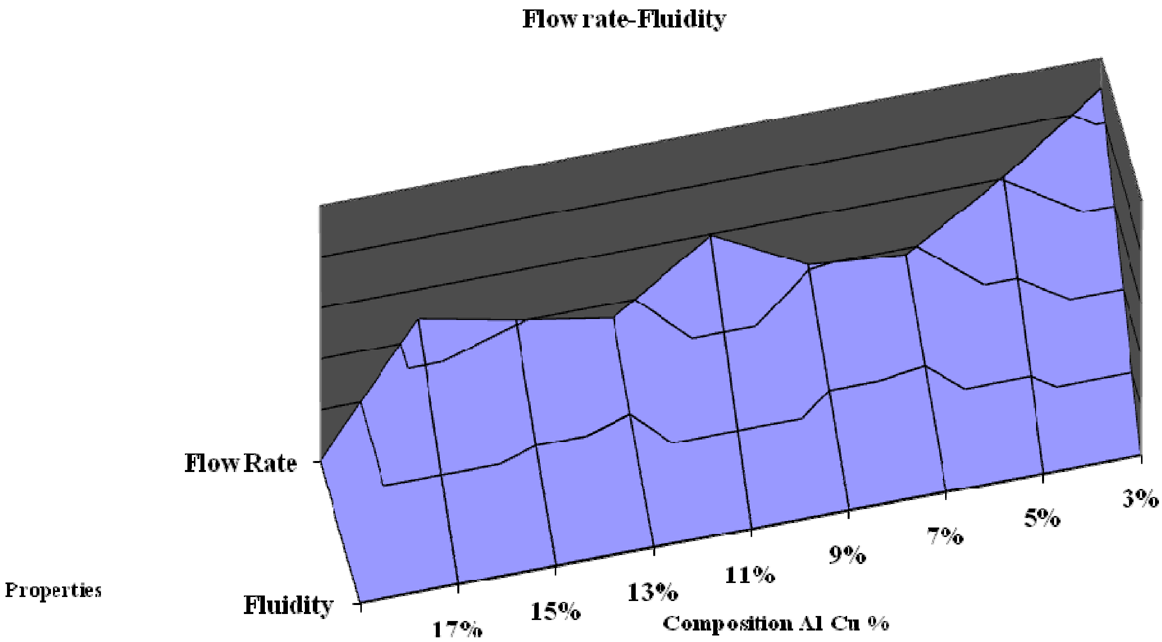
Fig: 1 Flow chart representation of the process



Graph: 1 **Property vs. Densities**



Graph: 2 Mat lab 3 D representations for Flow rate Vs. Fluidity



Graph: 3 Compressibility Index and Hausner's Ratio for different Al-Cu Composites