

## **Development and strengthening of aluminium alloy (Al-Cu) by mechanical working and heat treatment**

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### **Abstract**

Understanding the mechanical properties of materials is one of the most difficult tasks faced by the solid –state physicist and progress in this direction has not been as great as in the case of the electrical, thermal and magnetic properties. For the purpose of discussion it is convenient to classify the mechanical properties as elastic or plastic and as structure – sensitive or structure insensitive. Elastic properties are the appropriate elastic constants, while plastic properties include the strength properties and the creep, fatigue and fracture characteristics. Modern cutting tools, gadgets, aerospace parts made from hard alloys have caused a real revolution in this field and they depend on the above properties. The finished parts are produced without machining and for an example, in the manufacture of gears by P/M, the technological process consists of simple and labour saving operations, obtaining the powder pressing, sintering and sizing. Based on the above fact the project is undertaken and keen interest is shown on the development and strengthening of aluminium alloy (Al- Cu Composites) by mechanical working and heat treatment.

**Key words:** Powder Compact, Densification, Extrusion, Composites

### **1. Introduction**

The properties of metals are the most important factor as far as their use is concerned. On the other hand service conditions require that metals resist a great variety of stresses without undergoing appreciable deformation. Keeping

in mind the investigation is carried out for different composition of aluminum and copper and their characteristics studied at stages and the results recorded are discussed.

## 2. Stages of Experiment

The principal stages of powder metallurgy process therefore include:

- a) Obtaining the metal powders in a suitable degree of fineness & purity (H.F. Fischmeister, 1983)
- b) Subjecting them to a sufficient pressure in a suitable mould to cause cohesion (G.A.J.Hack, 1984)  
to occur among the particles.
- c) Sintering the compacted mass (Karl Sieber, 1971) at a temperature high enough to cause  
diffusion & inter granular crystal growth to occur.
- d) Finishing sizing & inspecting the product.

### 2.1 Advantages and Limitations

An alloy is a macroscopically homogeneous substance which possesses good metallic properties. The products of semi finished and finished are produced using alloys by the process of casting, forging, rolling and extrusion. The products produced also have desired mechanical and physical properties (K.A.Natarajan , 1977), so, before put to use they are subjected to heat treatment and tested.

### 2.2 Preparation of Powder Composition

The first step of the PM process is mixing of the metallic powder in the proportions needed for the final properties of the product. The important task of mixing is to achieve a homogeneous mixture to avoid porosity and to get good plasticity of the material. The plastic deformation of a given metal or alloy is influenced by the following:

- a) Alloy composition b) Grain size c) Segregation of alloying elements. The smaller the Grain size of a metal, the greater will be the cohesive force of the metallic structure , therefore, smaller grain size means ( Fig : 1 ) greater tensile strength and greater hardness( Niels Hansen , 1967 ) .

### 2.3 Powder Mixing

Powder mixing is an important operation. When two or more varieties of powders are used as shown in (TABLE: 1), these powders should be mixed well and in an efficient way in order to obtain a homogeneous mixture. For this purpose electrically operated double cone apex mixer is used. When powders are not properly mixed segregation is likely to occur.

#### *2.4 Physical Properties of Powder*

The powder as it is produced is loose and there is considerable swell when compacted in the die and it is reduced in volume as most of the voids are filled up due to interlocking of the grains. The compression ratio 'r' is the ratio of the density of the compact to the apparent density of the powder is also studied. In practice it varies from 2: 1 to 3: 1. This factor is very important and should be taken into consideration while designing the compaction die (Niels Hansen , 1969), as the final shape and size of the components which are produced on a mass scale which should be uniform. The apparent density (Table: 1), theoretical density and also the tap density of the above mentioned powder composition is studied.

#### *2.5 Tap Density or Load Factor*

This is the apparent density after the powder has been shaken down or consolidated by vibration and the related information is shown in (TABLE: 1). The tap density is sometimes used as a basis of die design, and it is increasing with the increase in number of taps and the characteristics curve is shown in the (GRAPH: 1) and the observations are recorded in the Table: 2.

#### *2.6 Alloy Composition*

The development of mass production of sintered items from Al Powders is currently a top priority task. Al is readily compacted and consolidated at pressures which are considerably lower than those used in iron powder pressing practice. Because, the powder compaction is a popular route for the production of light engineering components and it is suitable for automobile parts. So keeping this point in mind 3% weight of copper is added with aluminium and compacted at a pressure of 174 MPa. The Compact is sintered at a 550 °C in order to burn the lubricant and also to increase the strength. It is known that the particle size influences mould strength, density of the compact permeability flow (J.D Talati ,1982) etc. The particle size distribution is specified by undertaking the sieve analysis in studying the flow rate and fluidity for the above composition.

### 3. Porous Products

By controlling the particle size and distribution and the pressure during compaction, the percentage of porosity can be controlled within narrow limits. If high porosity is required the powders are mixed with substance which produces foam. Foam exerts a pressure on the individual particles during sintering and tries to separate them. Ultimately the foams will be burnt during sintering process. Ideally metal powders for use should be spherical in shape with a minimum of fine dust and no larger particles. They should not have internal porosity, high bulk density and the ability to flow readily into the die. But powders like angular, flake like, dendrites and irregular shape both dense and porous structure depend on a great degree upon the characteristics of the powder which in turn influence by the method used for manufacturing the powder . Further the compacts are extruded.

### 4. Extrusion

After studying the green density, sintered density and % growth, the compacts are extruded to understand the extrusion process and inter relationship between process variables and forces involved. The tensile specimens are prepared which is shown in figure: 2, and the properties measured are indicated in Tables: 3 & Table: 4 and the corresponding Graphs: 2 and Graphs: 3 are drawn.

## 5. Results and Discussion

The above mentioned readings are of initial stage of proposed composition. The project is a long process and more findings are there. Tap density is increasing with respect to number of taps and it is well obtained and it is shown in the Graph: 1. The results show good densification behavior of the composition. It is evident that the coarse pores get closed earlier than the smaller pores.

Aluminium alloy composites are becoming potential engineering materials offering excellent combination of properties such as high specific strength, high specific stiffness good degree of deformation. The degree of deformation is decreased with the increase in copper content in aluminium. The plasticity, strain hardening and densification parameter are some how similar irrespective of the copper addition in aluminium alloy. From the tables 3 & 4 it is evident that a thin layer of alumina is formed and the addition of copper in alumina is becoming sintered aluminium product, SAP.

## 6. Conclusion

Sintered Aluminium Product is dispersion strengthened alloy and it consists of fine dispersion of alumina. The industrial manufacture of items from aluminium base powders has been organized in several countries and its scale may exceed in future than the production of iron - base items.  $Al_2O_3$  would have been dispersed into a poly crystalline Al matrix. The presence of II phase may give interesting properties as that may be helpful to strengthen the material. Till date the air craft industry throughout the world is still dependant in the production of Al alloys of greater strength.

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TABLE 1 Different composition of Powder of Al-Cu

Composition	Al Powder gm	CuO gm	Duration	Apparent Density gm/cc	Sintering Temperature
3%	970	30	1 Hr 30 min	.84628	550 <sup>0</sup> C

5%	950	50	1 Hr 30 min	.81752	550 <sup>0</sup> C
7%	930	70	1 Hr 30 min	.8816	550 <sup>0</sup> C
9%	910	90	1 Hr 30 min	.87192	550 <sup>0</sup> C
11%	890	110	1 Hr 30 min	.898	550 <sup>0</sup> C
13%	870	130	1 Hr 30 min	.91992	550 <sup>0</sup> C
15%	850	150	1 Hr 30 min	.9092	550 <sup>0</sup> C
17%	830	170	1 Hr 30 min	.77752	550 <sup>0</sup> C

Table: 2 Tap Density VS. Number of Taps for 3 % Cu in Alumina

Number of Taps	Tap Density gm /cc
0	1.1708
4	1.2169
8	1.2363
12	1.2988
16	1.3088
20	1.3477
24	1.4275
28	1.5082
32	1.5436

Table: 3 Mechanical Properties of Al-Cu

Die Diameter: 12 mm

Temperature: 350<sup>0</sup> C and 450<sup>0</sup> C

Composition	% Elongation	% Reduction	% Elongation	% Reduction
3%	2.47	12.13	1.04	20.08
5%	4.72	4.40	18.04	3.96
7%	11.26	6.99	6.58	1.81
9%	8.88	0.44	21.88	7.78

Table: 4 Mechanical Properties of Al –Cu composites at 350<sup>0</sup> C

Composition %	% Degree of Deformation $\theta$	Plasticity $\phi$	Strain hardening $\eta$	Densification Parameter $\rho$	Poisson's Ratio $\nu$
3%	5.61	0.5017	0.711	3.8789	0.358
5%	4.8	0.333	0.467	2.6144	0.3215
7%	1.1	2.745	0.523	2.887	0.4015
9%	0.38	0.2872	0.454	3.3164	0.3926

Figure: 1 Grain Size in Al-Cu Composite

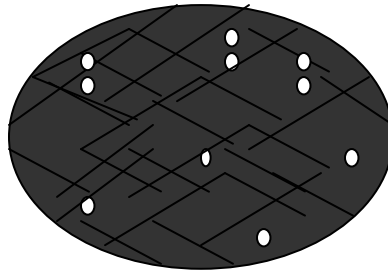
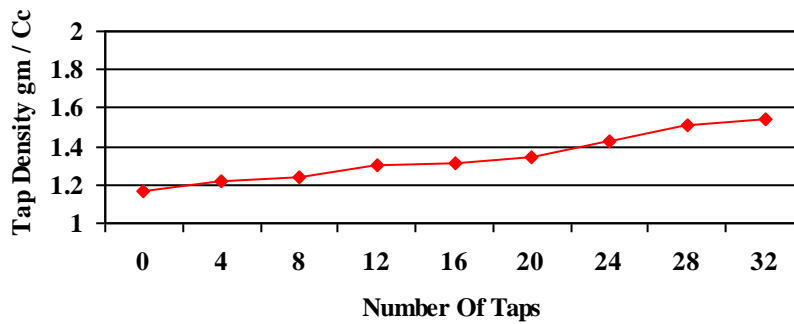


Fig 1: Smaller Grain Size

Figure: 2 Tensile Specimens of Al-Cu Composites

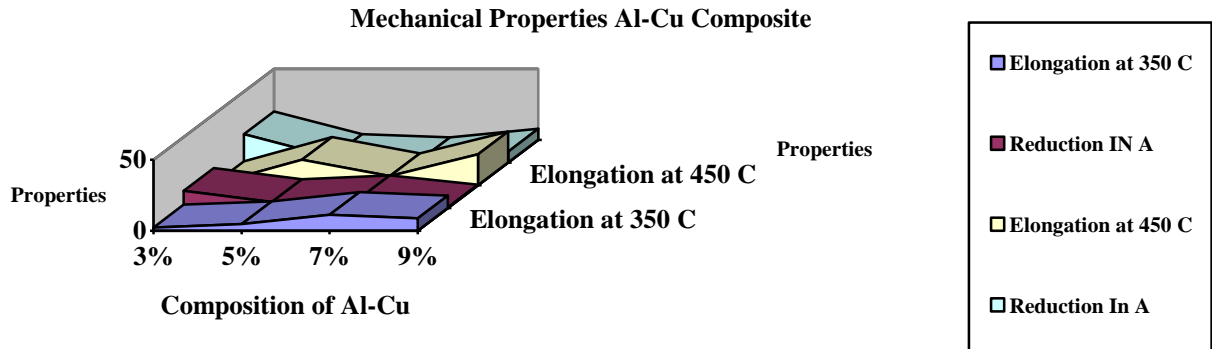


Graph :1 Tap Density VS.Number of Taps

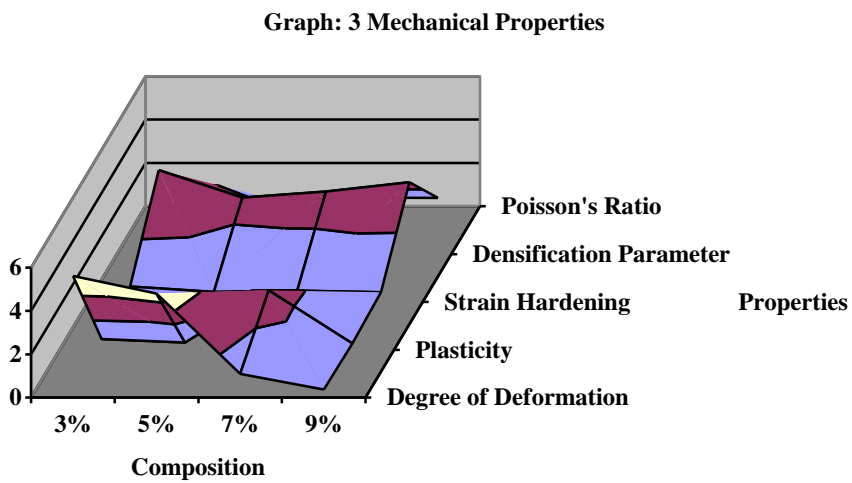




**Graph: 2 Mechanical Properties of Al-Cu**



**Graph: 3 Mechanical Properties of Al –Cu composites at 350<sup>0</sup> C**



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