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Effects of copper addition on Thermal behaviour of P/M iron metal

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ABSTRACT: Powder metallurgy is the science of procuring powder, consolidation into required shape and sintering it to obtain final product. The final density of the product depends upon the compaction pressure and sintering temperature. Thermal conductivity is a property to measure the heat conducting ability of the material. It depends upon the composition and porosity of the material. In this study, the thermal conductivity of Fe-Cu powder is studied and compared with plain iron powder prepared at the same density. Finely powdered metal powders are compacted in a die using an UTM machine. The disc obtained is sintered in a furnace to improve its strength. The thermal conductivity of Fe-Cu Powder alloy is found to be greater than that of plain iron powder because of the addition of copper, which has higher thermal conductivity. The Rockwell hardness value is also studied for the influence of hardness on thermal conductivity. The material developed can be used in various thermal applications like cooking ovens, clutch plates, and other industrial applications.

KEYWORDS: Powder metallurgy, Thermal Conductivity, Powder iron, Fe-Cu alloy, sintering.

1 INTRODUCTION

Powder Metallurgy is a process of mixing single or different powders, compacting the mixture using a die, heating in a controlled furnace to create metallurgical bonds to improve its strength. PM process enables manufacturers to make products that are consistent and predictable in their behaviour across a wide range of application. It is an old technology used as early as 3000 BC. Yet, it has gained its importance only recently. Powder metallurgy involves four steps that are as follows. 1) Powder manufacturing, 2) Blending of powders, 3) Compaction, 4) Sintering. Powders are manufactured by physical, chemical or mechanical methods depending upon the application. Blending is done to obtain a homogeneous mixture generally using a ball mill. Compaction involves application of pressure on the powder mixture to get the desired shape. Compaction done in room temperature is called cold compaction. At elevated temperatures, it is known as hot compaction. Die compaction is the most common method of compaction. Sintering is a process of heating the compacts in a furnace to improve its density and strength. Air, nitrogen, argon, ammonia are some of the sintering atmospheres. Air is the cheap and common one. Post-sintering operations are done in some cases to improve its properties. Powder metallurgy is advantageous over the conventional manufacturing process because of the ability to produce complicated shapes with high utilization.Some of the advantages of powder metallurgy route is net shape obtainability, and high utilization of materials.But cost and part size acts as a limitation. Nowadays, its vastly used in automobiles and cutting tools.

Johnson and Gennan [[i]] has revealed in their studies that die compaction method is suggested as a good way of compacting powder metallurgical parts over other processes. Koh and Fortini [[ii]] concluded that the thermal conductivity and electrical resistivity can be related to the solid material properties and the porosity of the porous matrix regardless of the matrix structure.Vincent et al. [[iii]] studied that the thermal conductivity and porosity behavior showed three distinct domains. In all the domains the thermal conductivity decreases as volume fraction of porosities increases. Molina et al. [[iv]] found that the thermal conductivity of tested composites gradually increases with the applied infiltration pressure because of the inherent reduction in porosity of the material. Kononenko et al. [[v]] observed that, the thermal conductivity decreases with increasing porosity. This is due to the fact that, as the size of the air gap between adjacent particles increases, the surface area of contacts between the particles decreases. Kurt and Ates [[vi]] studied that thermal conductivity decreases with porosity rate in PM materials. Change of the thermal conductivity in PM materials due to porosity is also discussed. Wilson Nunes dos Santos [vii] inferred that addition of glass phase decreases the thermal conductivity of material. Pia and Sanna [viii]concluded that the thermal conductivity reduces as the range of pores present gets reduced. Hadas et al. [ix] cooling rate improves with decrease in porosity. Fathy et al. [x]studied that slight improvement in density dramatically increases the mechanical properties of the material.

1.1 FORMULATION OF PROBLEM STATEMENT

Iron powder has always been used in many applications because of its cost and availability. Powdered iron can be used to prepare clutch materials in automobile industry. The heat gets accumulated in the clutch due to friction caused by engagement and disengagement. With higher thermal conductivity, the material can dissipate heat more efficiently to the surroundings. The aim of this project is to develop an alloy of iron that has higher thermal conductivity than the iron keeping in mind the weight factor. The samples are prepared by powder metallurgy route. In this study, copper powder is chosen for alloying with iron powder, because of its higher thermal conductivity compared to that of iron powder and compared with pure iron of same theoretical density**.**

2 EXPEREMENTAL WORK

2.1 POWDER PROCUREMENT

Copper (Metal) Powder Electrolytic 99.5% of mass 500 g are procured from a Scientific supplier. Tightly sealed iron powder which was already available is made use of in this work.

2.2 MIXING OF POWDERS

Mixing is done to combine different materials to yield homogeneous powder of the alloy. The iron-copper alloy powder is taken in a cleaned glass jar. The addition is done alternatively using a funnel. Ceramic balls are added along with the powders inside the jar and sealed to prevent losses. The jars are loaded into a ball mill. The sides of the ball mill are cushioned using soft clothes and crushed papers. This is to prevent breakages during rotation of the mill. The ball mill is allowed to run for 10 hours to give it a thorough mix. Rotation is carried out at constant low speeds to get a homogeneous mix. Homogeneous mixing of powder is essential for obtaining even properties throughout the mass of the final product.

2.3 COMPACTION

The powder, after mixing is weighed and mass of powder required for one piece is found. That quantity of powder is separately stored in an air tight cover. Same procedure is carried out for other pieces. Then the powder is poured inside a circular die of diameter 50 mm and height 7mm.The disc, die and the punch are lubricated with graphite oil. Graphite oil is useful particularly in high loads. An universal testing machine operates the punch and a load of 180 kN is applied to get the green specimen. The green specimen is given an aluminium paint to prevent oxidation from happening on the surface.

2.4 SINTERING

Sintering of the coated and dried samples was done in a 3.5 kW muffle furnace at a temperature of 1000 ˚C for a period of 120 minutes.

2.5 THERMAL CONDUCTIVITY TEST

Thermal conductivity test was carried out using a heater placed between the specimens that are stationed on either side. Thermocouple sensors, six in number are inserted in various locations of the setup to obtain the temperature values on both the heated and non-heated sides of the specimen. The different layers of the setup are clamped tightly by a nut-bolt mechanism to minimize the air gap that decreases the accuracy of thermal conductivity measurement.

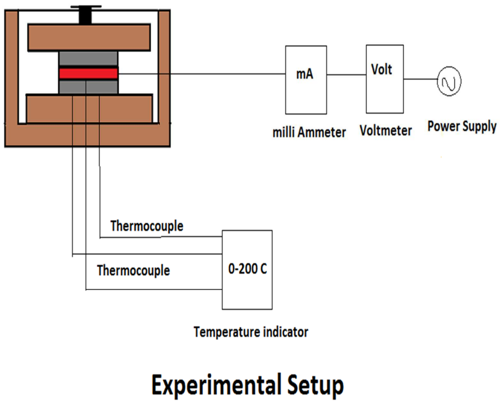

Fig. 1 Schematic diagram of thermal conductivity setup

2.6 Rockwell hardness test

The Rockwell hardness test is carried out to find the Rockwell hardness number. This is to study the relationship between hardness and thermal conductivity values.

2.7 Microstructure

The microstructure is looked at to find out the microscopic science behind the observed phenomenon.

3 Results And Discussion

3.1 Thermal conductivity test:

TABLE I. THERMAL CONDUCTIVITY OF IRON AND IRON-COPPER P/M ALLOY

Specimen	Voltage (V)	Heat Flux(W/m^2)	Thermal Conductivity (W/mK)
Fe	50	1401.02	2.46
	60	2123.42	3.64
	70	3283.64	6.06
	80	4290.62	7.35
	90	5253.82	12.20
Fe- Cu	50	4073.50	7.13
	60	6123.05	7.14
	70	8311.60	11.63
	80	10827.62	15.15
	90	13285.01	15.49

- The thermal conductivity value increases with increase in voltage
- The thermal conductivity of Fe-10%wtCu is found to be higher than that of plain iron of same percentage theoretical density as copper has higher conductivity.

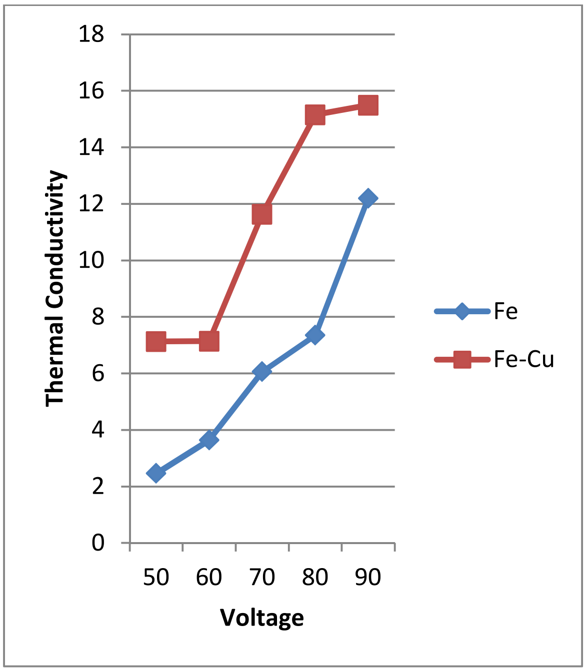

Fig. 2 Voltage vs Thermal Conductivity

3.2 Rockwell Hardness Test

The Rockwell hardness number of the two samples are determined and the Fe-10%wtCu material is found to show higher value of hardness. The reason behind higher value is because of the presence of copper. Copper has higher density compared to iron, hence leads to greater hardness value of the sample.

TABLE II. ROCKWELL HARDNESS VALUE

S.No	P/M Material	Rockwell Hardness number(R.H.N) B-SCALE
1	Fe	68.6
2	Fe-10%wt Cu	104.12

3.3 Microstructure

The microstructure of the Fig.4 shows pearlitic grains in ferrite matrix. Fig. 3 shows copper being homogenously distributer in iron matrix. The two figure shows the microstructure of the two samples at a magnification of 100x. The presence of copper which is shown as orange particles in the image, is the driving factor for higher thermal conductivity of Fe-10%wtCu.

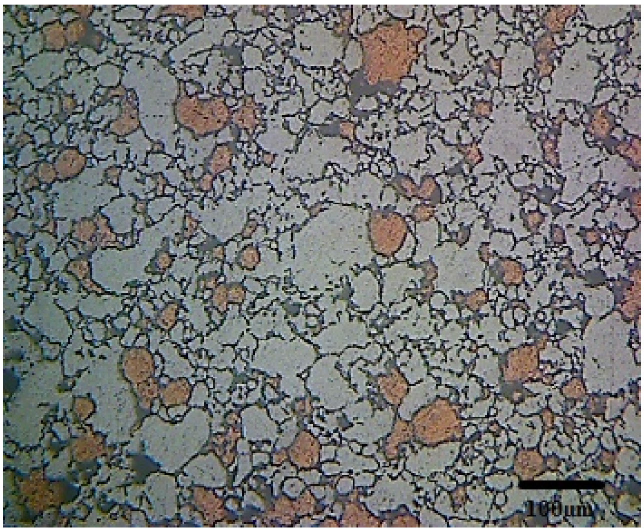

Fig. 3 Fe-10%wtCu at 100x magnification

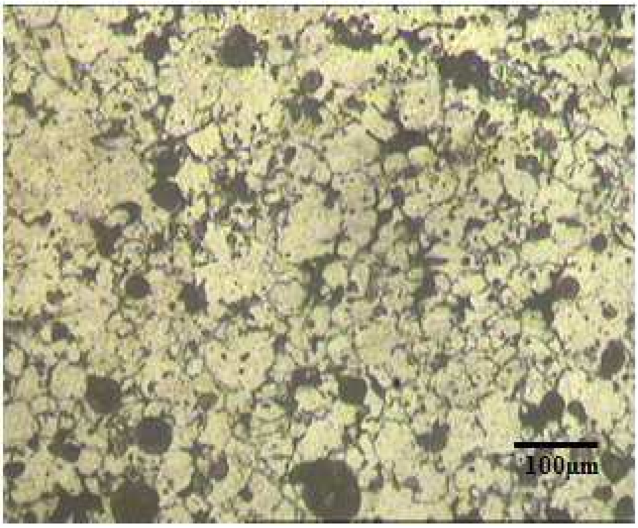

Fig. 4 plain Fe at 100x magnification

4 Conclusions

- Thermal conductivity of the material improves with increase in heat flux.
- Introducing higher thermal conductivity material in the matrix leads to improve the thermal conductivity of the alloy.
- Addition of copper (Cu) to the iron material enhances the hardness apart from the thermal conductivity.

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