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JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY

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MECHANICAL PROPERTIES AND MICRO-STRUCTURAL STUDY OF SINTERED ALUMINIUM METAL MATRIX COMPOSITES BY P/M TECHNIQUE

Rajesh Kumar Behera[1]*, Sarat Chandra Panigrahi[2], Birajendu Prasad Samal[3], Pramod Kumar Parida[4]

*Correspondence

rajesh.mle@oec.ac.in

[1]Biju Patnaik University of Technology, Rourkela, Odisha, India.
rajesh.mle@oec.ac.in
[2]IIT Kharagpur, Prof and Head R&D, R.E College, Bhubaneswar, India.
[3] Departments of Mechanical Engineering, Orissa Engineering College, Bhubaneswar, Odisha, India.
[4] Department of Mechanical Engineering, College of Engineering and Technology, Bhubaneswar, Odisha, India.

Articles Info:
Received **19 June 2019**
Received in revised form **17 September 2019**
Accepted **29 September 2019**
Available Online **30 September 2019**

Keywords:
Powder Metallurgy, Sintering, Aluminium Metal Matrix Composite, Microstructure, Mechanical Properties

ABSTRACT

Material world requires a strong research to produce a new class of materials having light weight, higher strength and better performances. This has been leads to investigate for high strength light weight alloy. The main objective in developing aluminium metal matrix composites is to provide enhanced characteristic performances and properties above the currently available materials. Preparation of AMMC by P/M technique is a low cost efficient method. Mechanical properties of the composite by adding silicon carbide may obtain better microstructure and mechanical properties of the composite. A per the literature a new type of aluminium composite has been tries to develop which will offer attractive mechanical properties such as high strength, easy machinability, appreciable density, and low manufacturing cost etc. Aluminum powders of 99.55% purity and 325 mesh sizes are mixed with alloying metals like Copper, Magnesium, Silicon and Silicon Carbide powders in a precisely controlled quantity. During the process of powder metallurgy (P/M) product preparation, it was minutely observed to attain the maximum efficiency and accuracy. Aluminium (Al) is a light weight material but doesn't possess a good strength. To achieve this, Copper (Cu), Silicon (Si), Magnesium (Mg) & Silicon Carbide (SiC) powders were blended with it at required proportions. The compaction was carried out with help of a C-45 steel die by power compaction press with a load of 150KN to 250KN. The obtained green products were sintered in a Muffle furnace to produce the final Aluminium Metal Matrix Composites (AMMCs) product.

INTRODUCTION

Based upon AMMC the prospective present paper evaluate the various potentials like application of AMMC, the percentage of various reinforcements, processed methodology, microstructure and mechanical behaviors e.g. strength, wear ,corrosion etc. and its effects are discussed. Si-C reinforcement in

Al-composites in different weight percentages will affect the clustering of particles and particle cracking in weak matrix-reinforcement bonding. Aluminium metal matrix composites are better and high performance materials for industrial applications due to its appreciable properties over the traditional aluminium or its alloys [1-4]. It is applied in the fabrication of different components in automobile, electronics, aerospace, nuclear defence, architectural applications, window frames, irrigation tubing, petroleum and chemical industries at lower cost. The composites have unique properties than the individual metal elements. Researchers are focused upon the exceptional materials like Aluminium composite for its better advantages. Aluminium metal matrix composites (AMMCs) are helpful towards fabrication of different fields in engineering applications. AMMCs including copper, silicon, magnesium, silicon carbide and aluminium shows better stiffness, hardness and tensile strength [5-7]. The Interfacial relations between matrix, its reinforcement and nature of bonding determine the structure and properties of the composites [8-10]. Powder metallurgy (P/M) is such a technique used for its special attributes like lower sintering temperature, cost effective and homogeneous distribution of reinforcements within matrix [11-15]. Al composite Preparation by powder metallurgy process can effectively avoid the unfavorable interfacial chemical reaction at low temperatures, the product quality is adequate and the volume fraction of particles in the composite is easy to control.

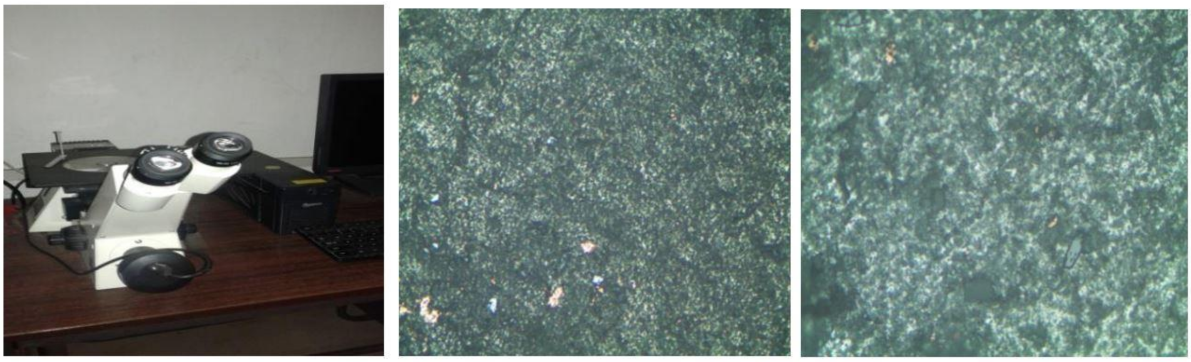
METHODOLOGY

In the present experiment, the powder metallurgy (P/M) [16-20] method was adopted for processing of AMMCs and the reinforcement of metal powders were added into the matrix. The Cu powder of particle size 325 meshes with purity 99.77%, Si powder of particle size 325 meshes with purity 99.87%, Mg powder of particle size 100 meshes with purity 99.80% and SiC powder of particle size 325 meshes with purity 99.55% are mixed and blended with Al powder of particle size 325 meshes with purity 99.55%. In this composite material, the volume fraction of SiC particles 5% and 10% were added separately with Al-Cu-Si-Mg [21] in a volume fraction of 91.5% - 2.5 - 0.5% - 0.5% respectively. The mixed/blended powder was compacted in digital compression testing machine with a rate of loading 0.208KN/sec and up to 250KN (521.02MPa). The green compacted specimens were removed and sintered in a muffle furnace. The sintering temperature was 6200C and was annealed for 24hours.

RESULT AND DISCUSSION

Microstructure Test

The examination of micro-texture was investigated the shape morphology, grain size and distribution of Aluminium, Copper, Silicon, Magnesium and especially silicon-carbide particles.



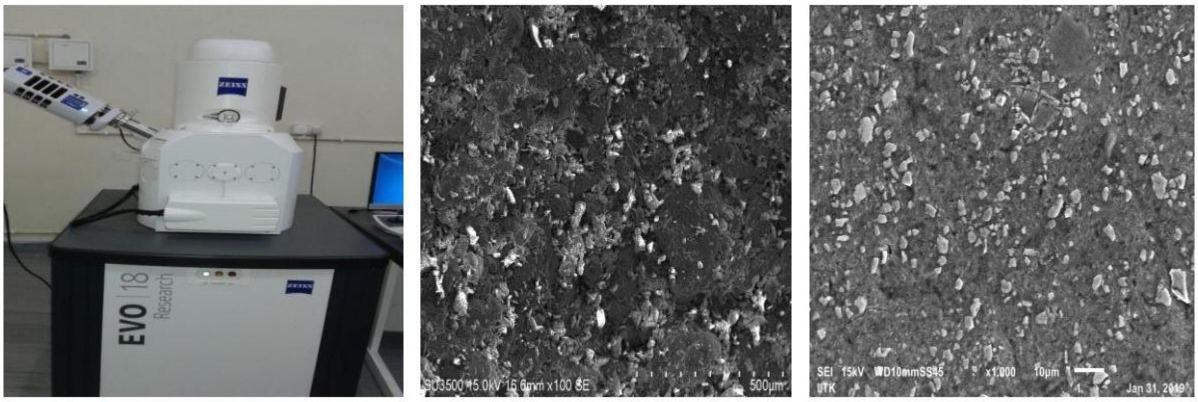
Metallurgical Microscope 5% SiC in AMMCs 10% SiC in AMMCs

Fig.1 Microstructure of Al-composite with Cu, Si, Mg and SiC

The microstructures of the composite were studied by using inverted metallurgical microscope and scanning electron microscope. The microstructures show the nearly uniform distribution of silicon carbide particles in aluminium composite and some clustering of silicon carbide arise reinforcement in it.

The composite microstructures decreased with decrease in compact load. The degradation in microstructures was more pronounced for the under-load microstructure than the peak-load microstructures. Also it indicates increasing the load ratio resulted in higher fatigue strength. The composite materials may be useful for remarkable lightweight materials in automobile parts. Experimentally it was found that in addition with SiC reinforcement particles, the composite shown lower wear rate compared to other Aluminium composites. The improved distribution of the Si-C reinforcement in matrix will improve more tensile strength and cohesive force of the cluster.

Silicon carbide distributions in the composites are affecting directly the performance of the materials. This observed that very few particles of silicon are heterogeneously nucleated on the particle of SiC. If the separation of SiC occurs between the particles due to contact with each other, it will result the formation of porosity in the material. The microstructure of the composite is shown in Fig. 1 and Fig. 2. SiC particles are also considered to avoid the possibility of particle fracture and de-bonding under severe stress at the interface of particulate-matrix. Due to high pressure during the compaction process, a dense microstructure was obtained which was helpful for the improvement of material strength and heat conduction capacity.



Scanning Electron Microscope　　5% SiC in AMMCs　　10% SiC in AMMCs

Fig. 2 Microstructure of Al-composite with Cu, Si, Mg and SiC

XRD Test

Figure3 shows the XRD pattern of composite materials. It can be seen that the phase product are Al, Cu, Si, Mg and SiC phase. The sintering did not produce other phases; there are no interface products and other chemical reactions. But the randomness or aggregation of the reinforced particles in the metal matrix is difficult to ensure the higher tensile properties because of brittle phase. The particle distribution at the interfacial bonding of the matrix is directly affects the tensile strength of the composite. In this present study is trying to explore a low thermal expansion and good mechanical properties composites.

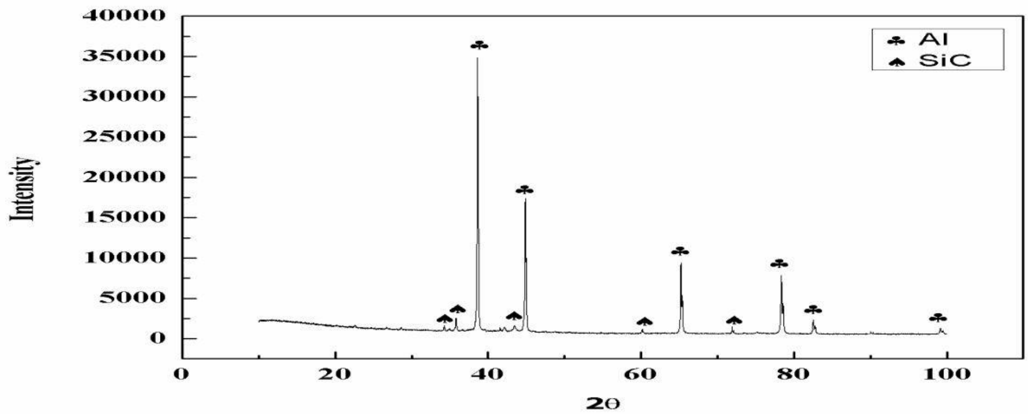


Fig. 3 XRD pattern of Al-SiC

doi: 10.1016/j.eng.2018.07.020

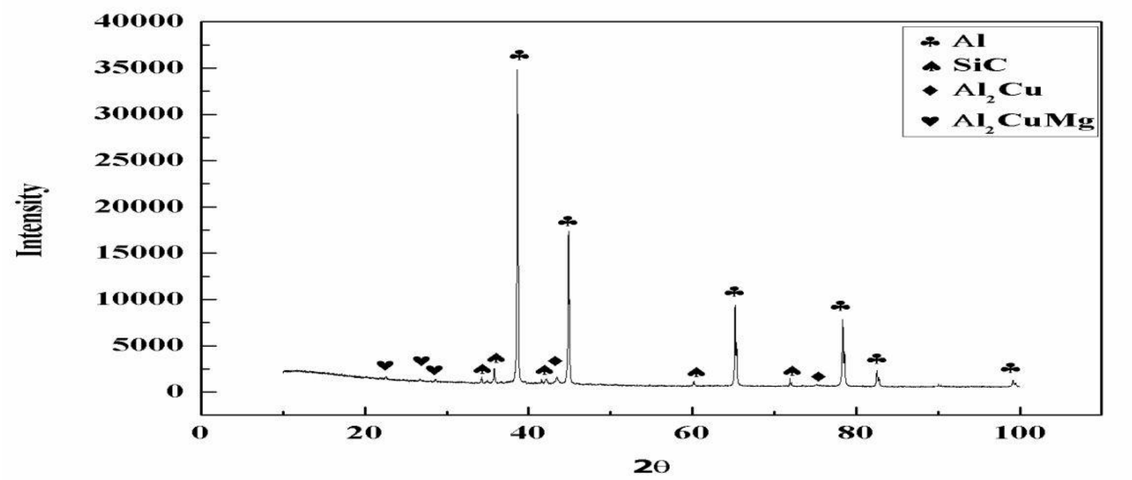


Fig. 4 XRD pattern of Al-composites

Material Characterization

Hardness Test (Rockwell)

XRD Test Figure3 shows the XRD pattern of composite materials. It can be seen that the phase product are Al, Cu, Si, Mg and SiC phase. The sintering did not produce other phases; there are no interface products and other chemical reactions. But the randomness or aggregation of the reinforced particles in the metal matrix is difficult to ensure the higher tensile properties because of brittle phase. The particle distribution at the interfacial bonding of the matrix is directly affects the tensile strength of the composite. In this present study is trying to explore a low thermal expansion and good mechanical properties composites.

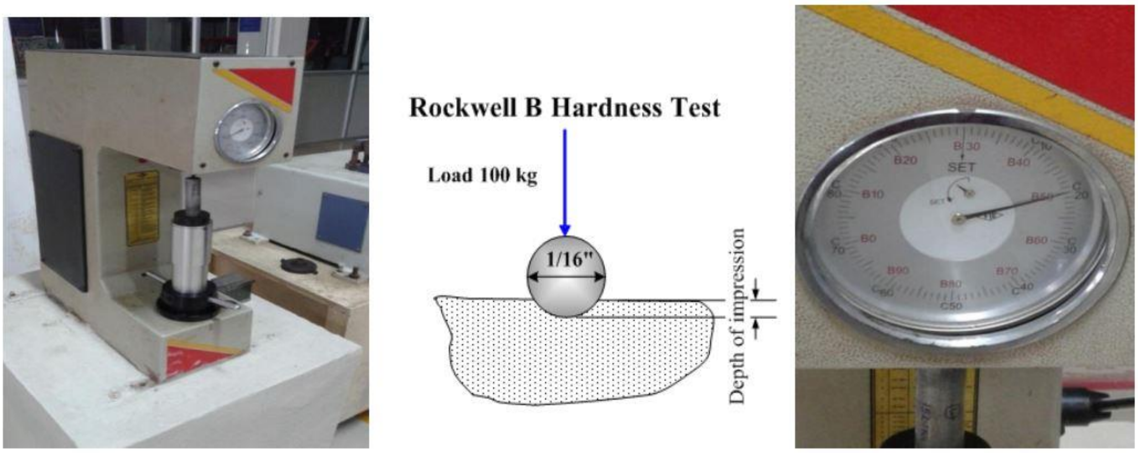
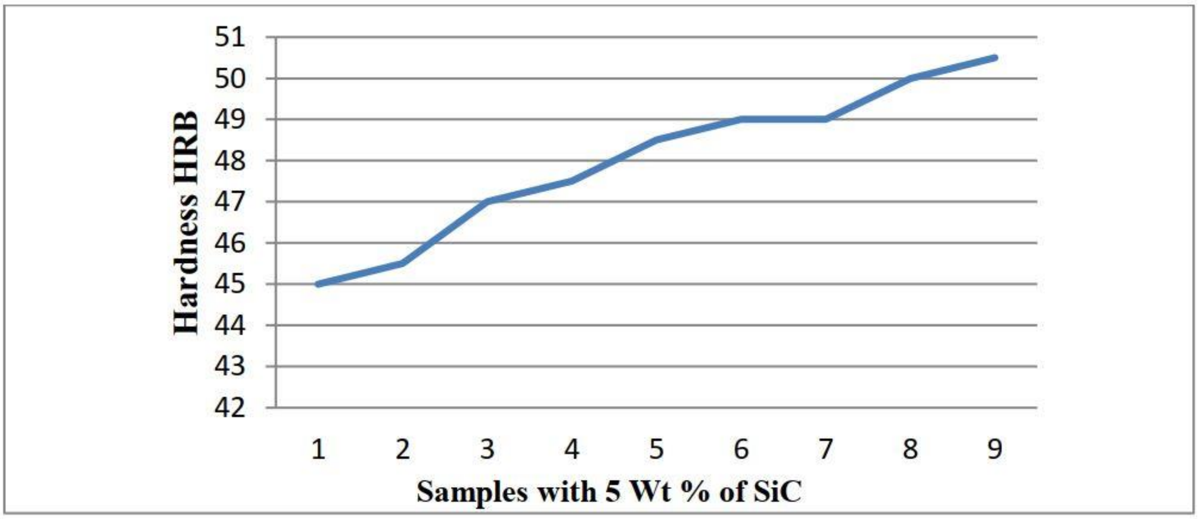


Fig.4.Rockwell Hardness Tester

The major advantages of Rockwell hardness test is its ability to display hardness values directly and the determination of hardness of a material involved by the application of a minor load followed by a major load.

Table 1 Sample-I for 5% SiC reinforcement

Sl. No.	Compacted Samples (Aluminium-91.5 wt %, Copper- 2.5 wt%, Magnesium- 0.5 wt%, Silicon- 0.5 wt% and Silicon Carbide- 5 wt%) x= SiC wt%	Hardness Test (HRB)
1	5	45.0
2	5	45.5
3	5	47.0
4	5	47.5
5	5	48.5
6	5	49.0
7	5	49.0
8	5	50.0
9	5	50.5

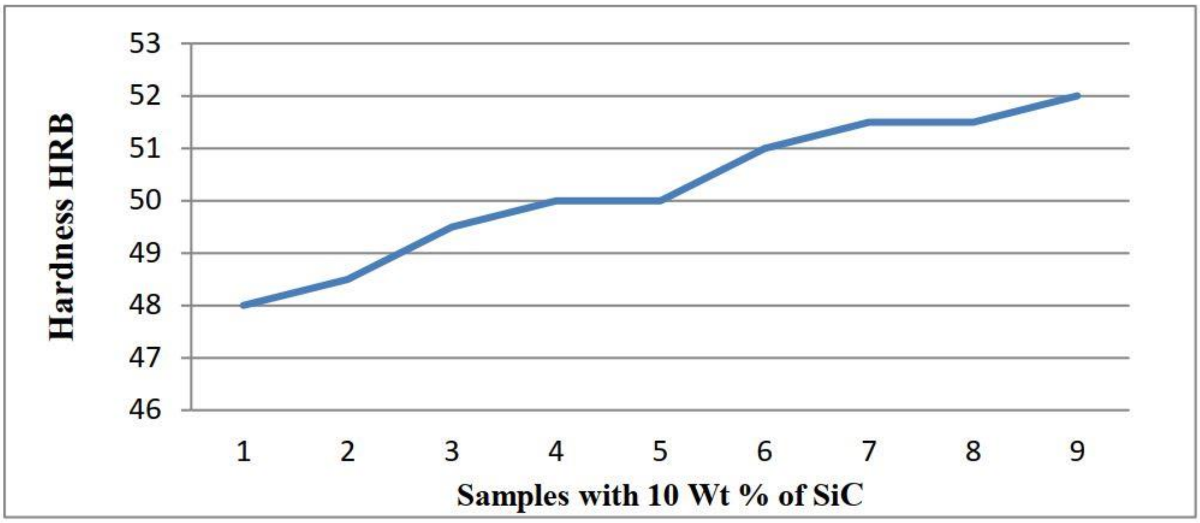


Graph 1 Samples Vs Hardness

Table 2 Sample –II for10% SiC reinforcement

Sl. No.	Compacted Samples (Aluminium-91.5 wt %, Copper- 2.5 wt%, Magnesium- 0.5 wt%, Silicon- 0.5 wt% and Silicon Carbide- 10 wt%) x= SiC wt%	Hardness Test (HRB)
1	10	48.0
2	10	48.5
3	10	49.5
4	10	50.0
5	10	50.0
6	10	51.0
7	10	51.5
8	10	51.5
9	10	52.0

doi: 10.1016/j.eng.2018.07.020



Graph 2 Samples Vs Hardness

As the adding of higher weight percent of silicon carbide in AMMCs, it shows higher the BHN value. Then the research will continue to find out different machinability aspects of sintered products.

Density and Porosity Test

Aluminium used as a main raw material known as matrix material and was reinforced with Cu, Mg, Si, SiC. The composite material was developed with the process starting with selection of metal powders, weighing, mixing/blending, compacting and sintering. The AMMCs was reinforced with 5% and 10% SiC weight basis separately. The calculation of sintered density by application the law of 'rule of mixture' is shown below.

Table 3 Sample 1 of 5% SiC reinforcement

Raw Metal Powders	Atomic Number	Density (ρ) in gm/cm^3	Weight Percentages (%) in mixture (x)	Rule of Mixture ($\rho \times x$) in gm/cm^3
Aluminium (Al)	13	2.70	91.5	2.4705
Copper (Cu)	29	8.96	2.5	0.224
Magnesium (Mg)	14	1.738	0.5	0.00869
Silicon (Si)	12	2.329	0.5	0.011648
Silicon Carbide (SiC)	-	3.21	5	0.1605
Total			100	2.875338

Table 4 Sample II of 10% SiC reinforcement

Raw Metal Powders	Atomic Number	Density (ρ) in gm/cm^3	Weight Percentages (%) in mixture (x)	Rule of Mixture ($\rho \times x$) in gm/cm^3
Aluminium (Al)	13	2.70	86.5	2.3355
Copper (Cu)	29	8.96	2.5	0.224
Magnesium (Mg)	14	1.738	0.5	0.00869
Silicon (Si)	12	2.329	0.5	0.011648
Silicon Carbide (SiC)	-	3.21	10	0.321
Total			100	2.900838

CONCLUSION

AMMC produced by powder metallurgy technique is a low cost efficient method. The mechanical properties of the composites are improved as the silicon carbide particles obtain higher volume fractions in the composites. Both industrial and academic researchers have displayed their interest in AMMCs and this has increased the survey of literature on microstructure and mechanical properties of the composites. It has been observed that the hardness is increased with increasing the amount of reinforcements.

1. Hardness of AMMC shows the best results when Si-C is reinforced at 5% and 10% weight percent.
2. Hardness increases with the increase in silicon carbide but decreases with the decreases in silicon carbide. To obtain an optimum hardness the reinforced material can be used in proper proportions.
3. Reinforcing the matrix with silicon carbide very negligible pores will obtain if the mixing is done properly.
4. The AMMC shows prominent results in increasing the wear resistance.
5. Uniform distribution is apparently found in AMMC. 6. Apart from mechanical properties the XRD pattern shows the Si-C present in the matrix at different intensities where the further research may concentrate.

Appendix

The density of sample-I:

D = Diameter of Sample = 2.0 cm

R = Radius of Sample = 1.0 cm

H = Height of Sample = 7.5 cm

V = Total Volume of the Sample = $\pi r^2 H$

$= \pi \times (1.0)^2 \times 7.3$

$= 22.942\ cm^3$

So, Density of Sample (ρ) = Mass/Volume

$= 59.59\ gm / 22.942\ cm^3$

$= 2.597419\ gm/cm^3$

Porosity can be calculated by using the following equation:

The theoretical density of the material = $2.875338\ gm/cm^3$

The actual/experimental density of the material = $2.597419\ gm/cm^3$

$$\text{Porosity} = \frac{\rho_{(\text{Theoretical})} - \rho_{(\text{Experimental})}}{\rho_{(\text{Theoretical})}} \times 100 = \frac{2.875338 - 2.597419}{2.875338} \times 100$$

$= 9.66\ \%$

The density of sample-II:

D = Diameter of Sample = 2.0 cm

R = Radius of Sample = 1.0 cm

H = Height of Sample = 7.1 cm

V = Total Volume of the Sample = $\pi r^2 H$

$= \pi \times (1.0)^2 \times 7.1$

$= 22.314\ cm^3$

So, Density of Sample (ρ) = Mass/Volume

$= 60.0\ gm / 22.314\ cm^3$

$= \mathbf{2.688894}\ gm/cm^3$

Porosity can be calculated by using the following equation:

The theoretical density of the material = $2.900838\ gm/cm^3$

The actual/experimental density of the material = $2.688894\ gm/cm^3$

$$\text{Porosity} = \frac{\rho_{(\text{Theoretical})} - \rho_{(\text{Experimental})}}{\rho_{(\text{Theoretical})}} \times 100 = \frac{2.900838 - 2.688894}{2.900838} \times 100$$

$= 7.306\ \%$

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