“A Study of Density Calculation For Composite Materials Aluminum Alloy 6063 Reinforced WithTiO$_2$ And B$_4$C Hybrid MMC’s’’

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Abstract **— Material science is the field of applying the properties of material of different ranges of science and Engineering. This field examines the connection between the structure of materials and properties developed by dispersion of two or more components to matrix components. In materials science, a common rule of mixtures is a weighted design is used to predict various properties of a composite material. It gives a theoretical upper- and lower-bound on variables such as the elastic modulus, mass density, ultimate tensile strength, thermal conductivity, and electrical conductivity. A composite material consists of two or more physically and chemically different phases that have better properties when compared to the individual components. Reinforcements are typically mixed with continuous matrix components. If the matrix is metal, the composite is known as metal matrix composite (MMC).**

One of the major purposes for the establishment of the performance of mass density calculations by Archimedes’s principle is it gives us a clear idea on the concept of buoyancy. When we immerse an object in any fluid, there is some force acting upwards on the object. This upward force acting on the object is called the buoyant force or buoyancy. This experimental project is focused on the application of forces applied to an metal matrix when it is submerged in fluid. Aluminum 6063 is best choice as a matrix material to prepare MMCs and aluminum is gaining importance and popularity in several fields of materials science and engineering that is widely used in research for having characteristics like low density, improved wear resistance, excellent strength and enhanced thermal properties and option of modification of the strength of composites by adding reinforcements. . TiO2 ceramic particles and B4C particles contains excellent hardness with good wear resistance & better anti-friction characteristics. It has been well established that mixing of TiO2 and B4C in the matrix alloy has improvement in mechanical properties. A new hybrid composite is produced using the aluminum (6063) alloy and the reinforcements TiO2 (Titanium Dioxide) and B4C (Boron Carbide) by Electromagnetic Stir Casting Process.

Keywords— Composite Materials, Engineering, Rule of mixtures & Archimedes’s principle Metal Matrix Composite (MMC).

I. INTRODUCTION

A materials structure composed of two or more physically different phases whose proportions produce properties that are different from those of its constituents. (or) Two or more chemically distinct materials which when combined have improved properties over the individual materials. The reason why composite materials have increased its place from decades is due to its combined characteristics of materials and properties like light in weight, cost effective and stronger as compared to other common materials.

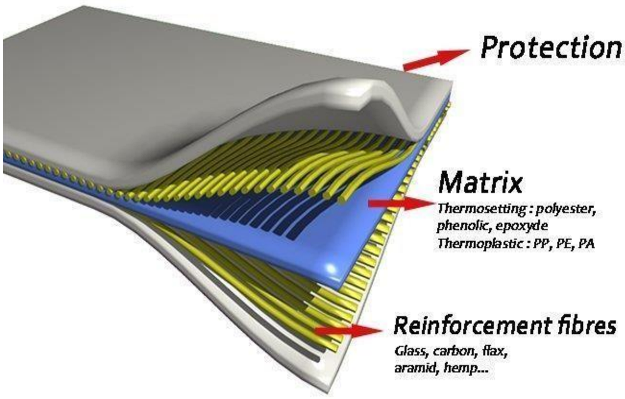

Figure. 1.1 Composite Material (Source: Wikipedia)

a) Metal Matrix Composites (Mmc):

It consists of a metal and one or more other materials typically a ceramic or organic compound. They have goodstrength fire resist, strength to weight ratio etc.

b) Reinforcement:

The action of strengthening a material is called as reinforcement. These are commonly used to increase the mechanical properties of a composite like strength, grain size. Reinforcements typically distributed over continues matrix.

c) Overview Of Composites:

With knowledge of the various types of composites, as well as an understanding of the dependence of their behaviors on the characteristics, relative amounts, geometry/distribution, and properties of the constituent phases, it is possible to design materials with property combinations that are better than those found in the metal alloys, ceramics, elastomers glasses and polymeric materials. Increase in the performance requirements of materials for aerospace and automobile applications has led to the development of numerous structural composite materials. Some of these composites are particle-reinforced metals-matrix composites, ceramic particle reinforced composites. These composites by virtue of their higher specific strength and stiffness, improved elevated performance, have become important and necessary materials used in various industrial applications. Therefore the mechanical properties of these composites have received much attention. Some of the techniques used for the development of these composites are stir casting, powder metallurgy and squeeze-casting. In modern automotive industry, metal matrix composites (MMC) play a vital role due to their lightweight. If more than one reinforcement material is added, then those are called Hybrid Metal Matrix composites

Materials for Preparing the Hybrid Metal Matrix Composite Matrix Material In the present research work, Al6063 has been chosen as the matrix material for preparing the hybrid metal matrix composite as it finds enormous application in the construction, automotive, marine, etc. industries due to characteristics such as moderate strength, good corrosion resistance, and toughness compared to other aluminum alloys. Reinforcement Materials In this work, with particulates, namely B_4C, TiO_2, have been employed as reinforcement materials to make the proposed hybrid MMC. In the present work Al6063-TiO_2/B_4C Metal Matrix Composites are used for experimental investigation and analysis of various cross sections of components formed by this new composite were evaluated to explore their suitability for various applications.

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II. OBJECTIVES

A. The research aimed to fulfill the following objectives:

- To study Metal Matrix Composites
- To prepare the AAMMCs of AA6063, reinforced B4C and TiO2. To determine the mechanical property Density Analysis of AMMCs.
- Common uses of Hybrid Metal Matrix Composites
- Future applications of this new composite were evaluated to explore their suitability for various applications.
- Density calculation

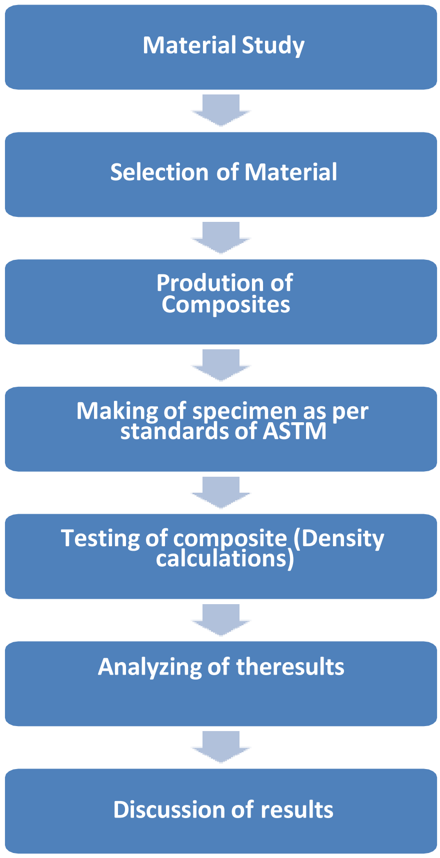
III. METHODOLOGY

a) Experimentalprocedure

The steps that are involved to complete the process of the project is divided into two stages:

1. Preparation of composite material by the stir casting process
2. Study of density calculations based on Archimedes principle. The total process of the project is shown below with a clear flow chart.

The methodology that involved in the project is discussed below. This methodology gives the overall concept of the project and the methods like selection of material, production of composite, process used to make the material. The below flow chart gives the detailed steps line by line from starting to ending. And also discussed the detailed explanation of each process



b) Material Study:

The 1st step of these process is that we undergone for the research about the materials that are widely using in the present era in the industries. After researching that we came to a conclusion that the composite materials are mostly using by the industries due to its high benefits. so in this project we used the hybrid composite materials.

c) Selection Of Material:

In this step after the researching of various materials and also the deep study of their properties and the applications of their materials we selected the materials. And after selecting the materials we went on to found various advantages and disadvantages and applications of Aluminum with that of other materials. So after that due to the vast advantages of Aluminum we decided to go further into the project by adding the reinforcement materials with the help of Boron carbide and Titanium di oxide . Along with these the project has divided into various stages to perform and complete the project in time.Due to all the efforts of our team we gone into a good researching part of project work.

d) Production Of Composites:

After studying of materials, we started to prepare the AAMMC of AA6063, reinforced with B4C and TiO2 with the help of stir casting process. We used the Stir casting method for the continuous process with fewer defects and also to avoid the bubbles during the casting process. In this we used different composition percentage ranging from Aluminum (100%), Boron (1%, 3%, 5%) and Titanium (1%, 3%, 5%). And also divided the composition percentage into 3 different ratios based on the reinforcement material.The composition percentage of different materials is shown below in the table that we made using the stir casting process.

Table .3.1. Composition of hybrid metal matrix composite

Sample No	Aluminum (AA6063) % Wt.	Titanium dioxide (TiO_2) %Wt.	Boron carbide (B_4C) %Wt.
Sample No 1	100%	0%	0%
Sample No 2	98%	1%	1%
Sample No 3	96%	3%	1%
Sample No 4	94%	5%	1%
Sample No 5	96%	1%	3%
Sample No 6	94%	3%	3%
Sample No 7	92%	5%	3%
Sample No 8	94%	1%	5%
Sample No 9	92%	3%	5%
Sample No 10	90%	5%	5%

e) Testing of composites:

In this project we intended to do the density calculations for hybrid composite aluminum alloy 6063 combination with B_4C and TIO_2. By the help of Archimedes principle in experimental and by the role of mixture the density is calculated theoretically. First measure the weight of the specimen in air then insert the specimen into the liquid now measure the weight of the specimen this weight is equal to weight of liquid displaced from the jar. And this is equal to the volume of the specimen. Now by the help of the volume and weight of the specimen we can find the density of the specimen.

IV. RESULTS AND DISCUSSION

The results for the current project are the objectives that we discussed in the previous chapters. As per the objectives and the methodology, we have done the project and achieved our project aims. The result for the mass density calculations by Archimedes’s principle is done on Digital Density Meter and finally calculated the density of metal matrix component. Those are discussed below.

a) Composition And Fabrication Of Composite:

We prepared the Hybrid Composite materials by taking the aluminum (Al) as a matrix metal, combined with boron carbide (B4c) and titanium dioxide (TiO2) reinforcement. These three materials combined and produced as Hybrid Composite Material. We use Stir Casting method due to the availability and effectiveness to produce the composite material. The chemical composition of alloys along with the product produced by the stir casting.

b) Machining And Specimen Preparation:

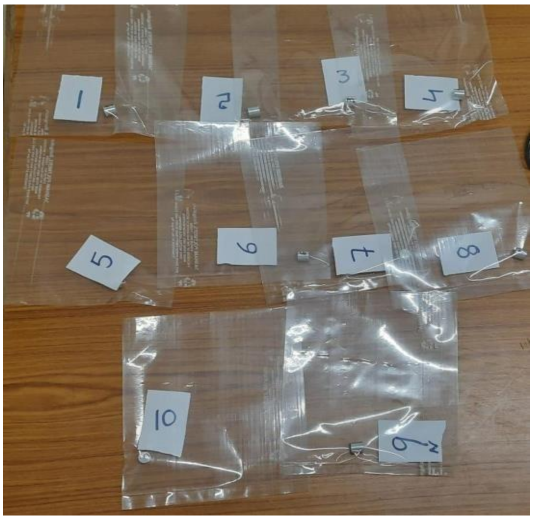


Figure. 4.1. Specimen Samples

After the fabricating of alloy by using stir casting, the composite materials are machined and produced as per the American Society for Testing and Materials (ASTM) Standards. The whole machining process has been done using the Lathe Machine. The specimen diameters are 10mm length and 10mm diameter. Totally for 10 different compositions are machined by using the Turning, Facing, and Parting Operations. The Specimens which are prepared after the machining as given below:

4.1 *The Testing Of The Specimens:*

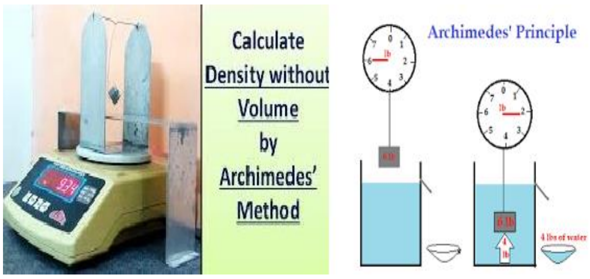


Figure. 4.2. Digital Density Meter Specimen measurement in air & Specimen measurement in water

The Testing of the specimens are done by using Archimedes's principle. The arrangement of the digital density meter is shown below. The mass density calculation has been done for the various composite combinations in air and water. The outputs for the experiment have been plotted and results for the tests that we conducted as shown below:

c) TESTING READINGS:

The Mass Density calculation test for the hybrid composite on digital density meter setup has been done and the results for the various specimen compositions have given below by varying composition. Along with the readings the graphs obtained by the testing is attached below.

TABLE .4.1. TEST READINGS

TiO2		B4C		Al 6063		Density of Composite (rc)
Vol. Fraction of TiO2 V TiO2	Density of TiO2 V TiO2 (g/cm3)	Vol.Fraction of B4C VB4C	Density of B4C VB4C (g/cm3)	Vol. Fraction of 6063-Al V6063-Al	Density of 6063-Al V6063-Al (g/cm3)	
0	4.23	0	2.52	1	2.69	2.69
0.01	4.23	0.01	2.52	0.98	2.69	2.7037
0.03	4.23	0.01	2.52	0.96	2.69	2.7345
0.05	4.23	0.01	2.52	0.94	2.69	2.7653

a) Calculations:

Rule of mixture:

$$\rho_c = V_r * \rho_r + (1-v_r) * \rho_m$$

$$\rho_c = V_t * \rho_t + V_B \rho_B + (1-V_t-V_B) * \rho_a$$ **Where,**

- **ρ_c = Density of Composite**
- **V_r = Volume Fraction of Reinforcement**
- **ρ_r = Density of Reinforcement**
- **ρ_m = Density of Metal Matrix**
- **V_t = Volume Fraction of Titanium Dioxide**
- **ρ_t = Density of Titanium Dioxide**
- **V_B = Volume Fraction of Reinforcement**
- **ρ_b = Density of Boron Carbide**
- **ρ_a = Density of Aluminum**

1) $\rho_c = 0 * 4.23 + 0 * 2.52 + (1-0-0) * 2.69$
Density of composite (ρ_c) =2.69

2) $\rho_c = 0.01 * 4.23 + 0.01 * 2.52 + (1-0.01-0.01) * 2.69$
Density of composite (ρ_c) =2.7037

3) $\rho_c = 0.03 * 4.23 + 0.01 * 2.52 + (1-0.03-0.01) * 2.69$
Density of composite (ρ_c) =2.7345

4) $\rho_c = 0.05 * 4.23 + 0.01 * 2.52 + (1-0.05-0.01) * 2.69$
Density of composite (ρ_c) =2.7653

TABLE .4.2. TEST READINGS

TiO2		B4C		6063-Al		Density of Composite (rc)
Vol. Fraction of TiO2 VTiO2	Density of TiO2VTiO2 (g/cm3)	Vol. Fraction of B4C VB4C	Density of B4C VB4C (g/cm3)	Vol. Fraction of 6063-Al V6063Al	Density of 6063-Al V6063-Al (g/cm3)	
0	4.23	0	2.52	1	2.69	2.69
0.01	4.23	0.03	2.52	0.96	2.69	2.7003
0.03	4.23	0.03	2.52	0.94	2.69	2.7311
0.05	4.23	0.03	2.52	0.92	2.69	2.7619

b) Calculations:

1) $\rho_c = 0 * 4.23 + 0 * 2.52 + (1-0-0) * 2.69$
Density of composite (ρ_c) =2.69

2) $\rho_c = 0.01 * 4.23 + 0.03 * 2.52 + (1-0.01-0.03) * 2.69$
Density of composite (ρ_c) =2.7003

3) $\rho_c = 0.03 * 4.23 + 0.03 * 2.52 + (1-0.03-0.03) * 2.69$
Density of composite (ρ_c) =2.7311

4) $\rho_c = 0.05 * 4.23 + 0.03 * 2.52 + (1-0.05-0.03) * 2.69$
Density of composite (ρ_c) =2.7619

TABLE .4.3. TEST READINGS

TiO_2		B_4C		6063-Al		Density of Composite (rc)
Vol. Fraction of TiO_2VTiO2	Density of TiO_2V TiO2 (g/cm3)	Vol. Fraction of B_4CVB4C	Density of B_4CVB4C (g/cm3)	Vol. Fraction of 6063-Al V6063 Al	Density of 6063-Al V6063 Al (g/cm3)	
0	4.23	0	2.52	1	2.69	2.69
0.01	4.23	0.05	2.52	0.94	2.69	2.6969
0.03	4.23	0.05	2.52	0.92	2.69	2.7277
0.05	4.23	0.05	2.52	0.9	2.69	2.7585

c) Calculations:

1) $\rho_c = 0 * 4.23 + 0 * 2.52 + (1-0-0) * 2.69$
Density of composite (ρ_c) =2.69

2) $\rho_c = 0.01 * 4.23 + 0.05 * 2.52 + (1-0.01-0.05) * 2.69$

Density of composite (ρ_c) =2.6969

3) $\rho_c = 0.03 * 4.23 + 0.05 * 2.52 + (1-0.03-0.05) * 2.69$

Density of composite (ρ_c) =2.7277

4) $\rho_c = 0.05 * 4.23 + 0.05 * 2.52 + (1-0.05-0.03) * 2.69$

Density of composite (ρ_c) =2.7585

TABLE .4.4. TEST READINGS

Sample	Composition
HC1	6063Al
HC2	6063Al-1wt.%B_4C-1wt.%TiO_2
HC3	6063Al-1wt.% B_4C -3wt.% TiO_2
HC4	6063Al-1wt.% B_4C -5wt.% TiO_2

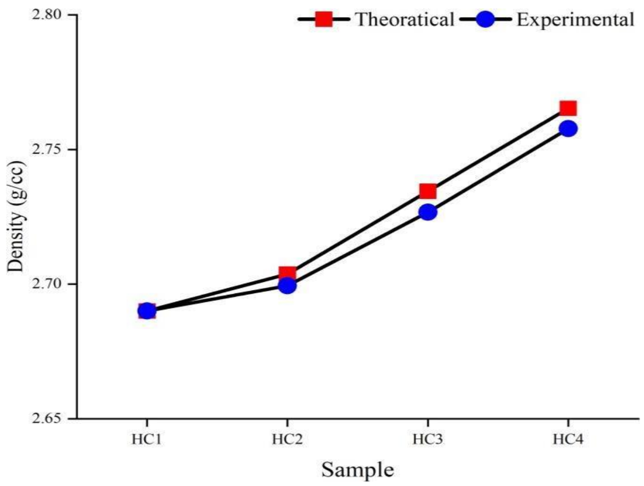


Figure. 4.3. Graph showing Variation between Theoretical and Experimental

TABLE .4.5. TEST READINGS

Sample	Composition
HC1	6063Al
HC2	6063Al-3wt.%B_4C-1wt.%TiO_2
HC3	6063Al-3wt.%B_4C-3wt.%TiO_2
HC4	6063Al-3wt.%B_4C-5wt.%TiO_2

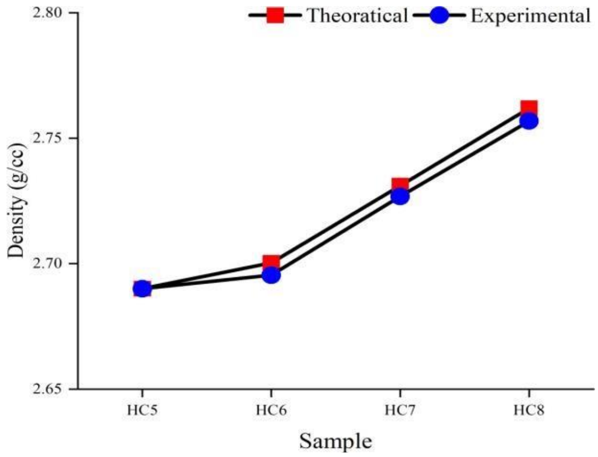


Figure. 4.4. Graph showing Variation between Theoretical and Experimental

TABLE .4.6. TEST READINGS

Sample	Composition
HC1	6063Al
HC2	6063Al-5wt.%B_4 C-1wt.%TiO_2
HC3	6063Al-5wt.%B_4 C-3wt.%TiO_2
HC4	6063Al-5wt.%B_4 C-5wt.%TiO_2

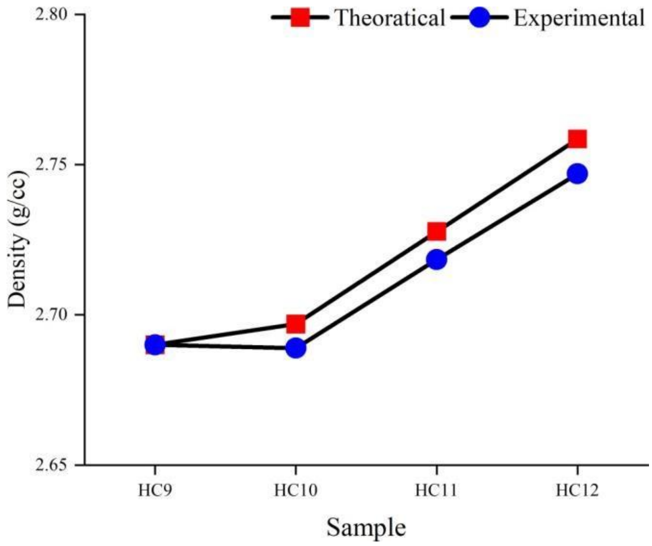


Figure. 4.5. Graph showing Variation between Theoretical and Experimental

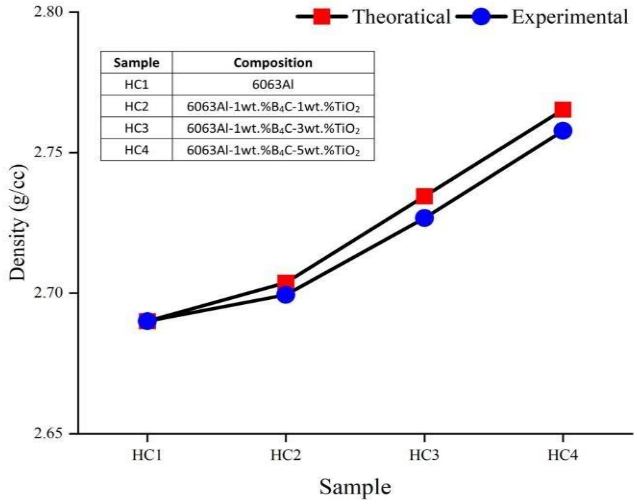


Figure. 4.6. Graph showing Variation between Theoretical and Experimental

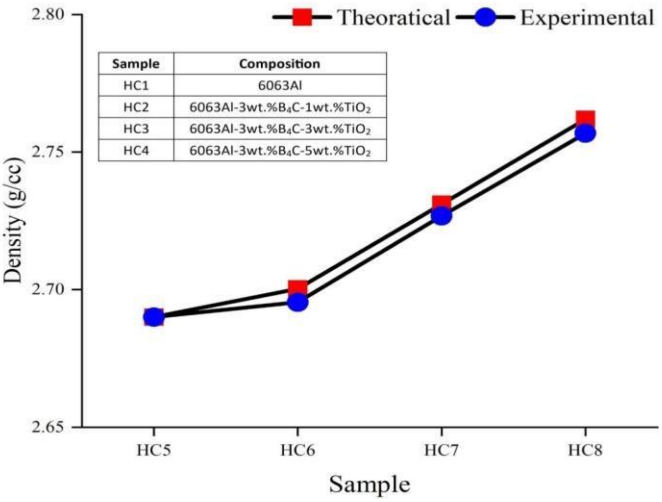


Figure. 4.7. Graph showing Variation between Theoretical and Experimental

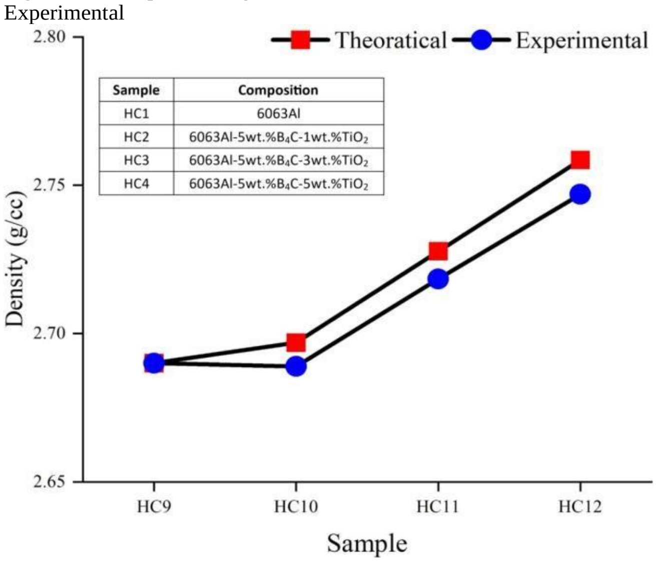


Figure. 4.8. Graph showing Variation between Theoretical and Experimental

CONCLUSION:

The hybrid composite aluminum alloy (Al 6063) with born carbide (B_4C) and titanium oxide (TIO_2) had observed a major increasing the density of the aluminum alloyas we made an observation during performing the experiment that there are significant changes while we are increasing the percentage of the boron carbide (B_4C) and titanium oxide ($Ti0_2$). That is when the first composition which is aluminum (100%) and the second composition which is aluminum (99%) and boron carbide and titanium oxide (1%) will have slightly small changes in the density values. As we increasing the percentage of the boron carbide (B4c) and titanium oxide (TiO2) the values of the density have increased highly.

SCOPE FOR FUTURE STUDY

As of now we had performed the test on the density calculations and seen the drastic changes in the values of density for adding the boron carbide (B4C) and titanium dioxide (TIO2) with the aluminum alloy. The future scope on the hybrid composite materials that we can perform the different tests on different properties like mechanical properties , thermal properties which helps to use the composite materials effectively and efficiently .not only in experimental way we can apply this in practically after seeing the results of the tests.

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