# A STATISTICAL ANALYSIS ON MECHANICAL PROPERTIES OF GRAPHENE AND S-GLASS REINFORCED Al-6061 METAL MATRIX COMPOSITES USING ANOVA.

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***Abstract:*** In recent days nanotechnology has turn out to be one of the maximum exquisite escalating technology in the subject of engineering and scientific areas. During the last decade there are numerous experimental evaluation become completed with the aid of using many scholars on nanoparticles. This research work was carried out through different samples with varied composition of the hybrid composite materials and the results were found on the optimization of machining parameters of AL-6061-S-GLASS-graphene hybrids. The machining parameters of the hybrid composite was made by stir casting process and analysis of variance (ANOVA) was used to analyze data and find the most influencing factor. To optimize the wt.% of reinforcement and matrix to get maximum mechanical properties by Response Surface Methodology. Confirmatory examinations were also performed for the purpose of validation after obtaining the optimized results. From the results it was found that the addition of graphene, Better bonding between the particles and good neck formation was observed at Al-0.5%G/1%S-Glass % composite. On the other hand, the agglomeration was determined at Al-2%G/5%S-Glass.

***Index Terms* - Al 6061, Graphene, S-Glass fiber, Statistical Analysis, ANOVA.**

## I. INTRODUCTION

In this research paper we study the variation of corrosion rate of different compositions of the hybrid composites, material preparation for the test, test the specimen, results and conclusion. Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al – matrix. They are usually reinforced by Al2O3, SiC, C but SiO2, B, BN, B4C, AlN may also be considered.

Ever since the evolution in aerospace and nuclear industry, there has been tremendous demand for the development of advanced engineering materials for various applications ranging from transportation to military applications. Many of the engineering application in the world today require materials with unusual combination of properties that cannot be met by the conventional metal alloys, ceramics or polymers. This is especially true for the materials that are needed for aerospace and transportation Applications.

In this preview, Researchers all over the world have been involved in development of a large range of super alloys, heat resistance materials which are light in weight but possess very high strength. Frequently, materials having high strength have relatively high density, also increasing the strength of stiffness results in a decrease in impact strength. Engineers around the world have been in search of better combination of properties in materials. With the rapid progress in material processing and manufacturing technology, it is therefore desired to develop a new generation of composite materials having low density, light weight, high strength stiffness and hardness. The Aluminum Metal Matrix composites are one such option which can yield us the desired properties.

Composite materials in general are materials which are engineered combination of two or more materials tailored to get the desired properties. The matrix phase and reinforcement phase with significantly different physical and chemical properties, which are constitute of any composite material when compared produce a material with characteristics different from the individual components. Various types of engineered composites are prevalent in industry, which include polymer matrix, ceramic matrix and metal matrix composites.

Metal Matrix composites (MMCs) are made of a continuous metallic matrix and one or more discontinuous reinforcing phases. The reinforcing phase may be in the form of fibers, whiskers or particles. In particular, Particle – reinforced aluminium alloys have the potential to be used in the wide range of engineering applications due to their higher stiffness and strength when compared with conventional aluminum alloys. For these composite materials, Graphene, a commercially pure material, has become the main type of reinforcement used. And most of the research work carried out on aluminium based composite materials involved in silicon carbide as its reinforcing material. Hence forth it is essential to look for the possibilities of fabricating aluminium based composite materials using alternative materials such as S– glass.

Metal matrix composites are produced economically by stir casting techniques, with substantial increase in the stiffness, hardness and strength to weight ratio of cast MMCs; but however there is reduction in ductility. It has been observed that some improvements in strength and ductility can be achieved with the application of plastic forming processes i.e. forging of the cast composites. The forged MMCs in general have better mechanical properties compared to cast MMCs, such as it improves density, hardness and tensile strength etc. The forging process also avoids the use of secondary operation like machining.

## II. Methodology And Specimen Preparation

### CASTING

- **Fabrication of Test Specimens**

  Stir casting technique of liquid metallurgy is used to prepare Al 6061 Hybrid composites.It consist of resistance Muffle-furnace and a stirrer assembly was used to synthesize the composite.

- **Preheating of reinforcement**

  Muffle furnace was used to preheat the particulate to a temperature of 700° C. It was maintained at the temperature till it was introduced in to the Al 6061 alloy melt.

Fig. 1 Furnace setup

- **Melting of matrix alloy**

  The melting range of Al 6061 alloy is of 700-800°C. A known quantity of Al 6061 ingot wear pickled in 10% NaOH solution at room temperature for 10 min. The smut formed was removed by immersing the ingots for 1 min mixture of one part nitric acid and one part water followed washing in methanol. The cleaned ingot after drying in air were loaded into the graphite crucible of the furnace for melting. The melt was super-heated to a temperature of 800°C and maintained at that temperature. The molten metal was then degassed using Hexa-Chloro ethane tablets for about 8 min.

Fig. 2 Melting Ingots

- **Mixing and Stirring**

  Alumina coated stainless steel impeller was used to stir the molten metal to create a vertex. The impeller was of centrifugal type with three blades welded at 45° inclinations and 120° apart. The stirrer was rotated at a speed 300-400 rpm and a vertex was created in the melt. The depth of immersion of impeller was approximately one third of the height of the molten metal. From the bottom of the crucible. The pre-heated particulates of Graphene and short S-Glass fiber were introduced into the vertex at the rate of 120 gm/min. Stirring was continued until interface interactions between the particles and the matrix promoted wetting. The melt was degassed using Hexo chloro ethane tablets and after reheating to superheated temperature (800°C) it was poured into the preheated die.

Fig. 3 Mechanical Stirrer in action

- **Pouring of Molten Metal into dies**

  Then after few minutes of stirring, the liquid metals with reinforcements are poured into the dies to get the required castings. The dies were are preheated and coated additives to ease the process of removing the casting.

Fig. 4 Pouring of metal

Fig. 5 Casted Specimen in the die

**SPECIMEN PREPARATION**

The casted specimens are withdrawn from the mould and machined to required dimension according to ASTM for conducting corrosion, and hardness tests and lathe is used for this purpose.

Fig. 6 Corrosion test specimens

The percentage of reinforcements used in different specimens is as shown in table 1

**Table 1: Percentage Of Reinforcements**

| Specifications | % Graphene | % S-Glass Fiber | % Al-6061 |
|---|---|---|---|
| A0.5G1S | 0.5 | 1 | 98.5 |
| A0.5G3S | 0.5 | 3 | 96.5 |
| A0.5G5S | 0.5 | 5 | 94.5 |
| A1G1S | 1 | 1 | 98 |
| A1G3S | 1 | 3 | 96 |
| A1G5S | 1 | 5 | 94 |
| A1.5G1S | 1.5 | 1 | 97.5 |
| A1.5G3S | 1.5 | 3 | 95.5 |
| A1.5G5S | 1.5 | 5 | 93.5 |
| A2G1S | 2 | 1 | 97 |
| A2G3S | 2 | 3 | 95 |
| A2G5S | 2 | 5 | 93 |

**DESIGN OF EXPERIMENT METHOD**

Nowadays, DOE has been more widely used in quality control, manufacturing, and system engineering disciplines for design or development of a new product and redesign of an existing product [14]. Due to the highly competitive global industry, companies need to understand the impact of both operational and environmental variables and their interactions on system or product performance. Therefore, mathematical model–based optimization employing DOE is a powerful design technique for use by system analysts, engineers, and designers. Compared to many methods, DOE is a more efficient method among optimization models in terms of number of required experiments. Its applications and computations are also more time efficient [15].

**RESPONSE SURFACE METHODOLOGY AS AN APPROACH.**

Generally, the procedure that could be used to find the optimum parameters is response surface methodology RSM [17] is defined as a group of statistical and mathematical techniques useful in modelling, improving, and optimizing processes. The general approach of RSM for process optimization [18] includes: Conducting screening experiments; moving the experimental region near the optimal point. The best condition from this step is called “the near-optimal condition”; developing a model within a relatively small region around the optimal point; and finding the optimal settings for process parameters that maximize or minimize the objective function. Due to few studies have been carried out by using the RSM technique for modelling and optimization of matrix and reinforcements for maximum mechanical properties, therefore, the RSM technique was used in the present study to model and optimize wt.% of reinforcements and matrix to obtain excellent mechanical characteristics.

## III. Results And Discussion

**Development and Optimization of Mechanical Property of Hybrid Composites. (Response Surface Methodology)**

Table 1. Design Matrix of Responses

| StdOrder | RunOrder | wt% of Al 6061 | wt% of G | wt% of S-Glass | Tensile Strength $N/mm^2$ | Compressive Strength $N/mm^2$ | Hardness BHN |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 98.5 | 0.5 | 1 | 380.26 | 556.45 | 40.26 |
| 2 | 2 | 96.5 | 0.5 | 3 | 360.23 | 660.96 | 42.55 |
| 3 | 3 | 94.5 | 0.5 | 5 | 372.44 | 496.88 | 43.22 |
| 4 | 4 | 98 | 1 | 1 | 373.78 | 709.9 | 41.3 |
| 5 | 5 | 96 | 1 | 3 | 375.22 | 560.52 | 45.23 |
| 6 | 6 | 94 | 1 | 5 | 375.48 | 526.23 | 41.3 |
| 7 | 7 | 97.5 | 1.5 | 1 | 405.22 | 419.88 | 45.61 |
| 8 | 8 | 95.5 | 1.5 | 3 | 390.65 | 665.91 | 46.22 |
| 9 | 9 | 93.5 | 1.5 | 5 | 395.26 | 547.79 | 49.22 |
| 10 | 10 | 97 | 2 | 1 | 350.12 | 447.23 | 44.22 |
| 11 | 11 | 95 | 2 | 3 | 320.55 | 524.45 | 47.05 |
| 12 | 12 | 93 | 2 | 5 | 300.45 | 383.82 | 48.3 |
| 13 | 13 | 100 | 0 | 0 | 310 | 495.4 | 35 |

**Analysis of Variance(ANOVA)**

Table 2 ANOVA for tensile Strength

### Analysis of Variance

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value |
|---|---|---|---|---|---|---|
| Model | 5 | 10713.1 | 81.86% | 10713.1 | 2142.6 | 6.32 |
| Linear | 2 | 159.6 | 1.22% | 865.3 | 432.7 | 1.28 |
| wt% of Al 6061 | 1 | 0.0 | 0.00% | 557.7 | 557.7 | 1.64 |
| wt% of G | 1 | 159.6 | 1.22% | 848.6 | 848.6 | 2.50 |
| Square | 3 | 10553.5 | 80.64% | 10553.5 | 3517.8 | 10.38 |
| wt% of Al 6061*wt% of Al 6061 | 1 | 4298.4 | 32.85% | 491.2 | 491.2 | 1.45 |
| wt% of G*wt% of G | 1 | 5688.9 | 43.47% | 5012.2 | 5012.2 | 14.78 |
| wt% of S-Glass*wt% of S-Glass | 1 | 566.2 | 4.33% | 566.2 | 566.2 | 1.67 |
| Error | 7 | 2373.4 | 18.14% | 2373.4 | 339.1 | |
| Total | 12 | 13086.4 | 100.00% | | | |

| Source | P-Value |
|---|---|
| Model | 0.016 |
| Linear | 0.337 |
| wt% of Al 6061 | 0.240 |
| wt% of G | 0.158 |
| Square | 0.006 |
| wt% of Al 6061*wt% of Al 6061 | 0.268 |
| wt% of G*wt% of G | 0.006 |
| wt% of S-Glass*wt% of S-Glass | 0.237 |
| Error | |
| Total | |

Full mathematical model has been checked for adequacy by calculating F-value and P-value at 95% significant level. P-value for regression model (0.001<0.05) and R2 value for tensile strength is 81.8% greater than predicted value(51.56%).

### Regression Equation in Coded Units

Tensile Strength $N/mm^2$ = 387.65 + 17.1 wt% of Al 6061 + 20.5 wt% of G
- 37.8 wt% of Al 6061*wt% of Al 6061 - 71.0 wt% of G*wt% of G
+ 32.6 wt% of S-Glass*wt% of S-Glass

*Uncoded coefficients are not available with non-hierarchical model.*

Table 3 ANOVA for Compressive Strength.

### Analysis of Variance

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value |
|---|---|---|---|---|---|---|
| Model | 5 | 66678 | 59.66% | 66677.9 | 13335.6 | 2.07 |
| Linear | 2 | 12758 | 11.42% | 5688.2 | 2844.1 | 0.44 |
| wt% of Al 6061 | 1 | 4502 | 4.03% | 587.1 | 587.1 | 0.09 |
| wt% of G | 1 | 8256 | 7.39% | 4542.2 | 4542.2 | 0.71 |
| Square | 3 | 53920 | 48.24% | 53919.8 | 17973.3 | 2.79 |
| wt% of Al 6061*wt% of Al 6061 | 1 | 25512 | 22.83% | 4381.1 | 4381.1 | 0.68 |
| wt% of G*wt% of G | 1 | 8671 | 7.76% | 12965.6 | 12965.6 | 2.01 |
| wt% of S-Glass*wt% of S-Glass | 1 | 19737 | 17.66% | 19736.8 | 19736.8 | 3.06 |
| Error | 7 | 45086 | 40.34% | 45085.8 | 6440.8 | |
| Total | 12 | 111764 | 100.00% | | | |

| Source | P-Value |
|---|---|
| Model | 0.185 |
| Linear | 0.660 |
| wt% of Al 6061 | 0.771 |
| wt% of G | 0.429 |
| Square | 0.119 |
| wt% of Al 6061*wt% of Al 6061 | 0.437 |
| wt% of G*wt% of G | 0.199 |
| wt% of S-Glass*wt% of S-Glass | 0.123 |
| Error | |
| Total | |

Full mathematical model has been checked for adequacy by calculating F-value and P-value at 95% significant level. P-value for regression model (0.001<0.05) and R2 value for tensile strength is 59.66% greater than predicted value (38.14%).

### Regression Equation in Coded Units

Compressive Strength N/mm² = 650.7 - 17.5 wt% of Al 6061 - 47.4 wt% of G
+ 113 wt% of Al 6061*wt% of Al 6061 - 114.2 wt% of G*wt% of G
- 193 wt% of S-Glass*wt% of S-Glass

*Uncoded coefficients are not available with non-hierarchical model.*

Table 4 ANOVA for Compressive Strength.

### Analysis of Variance

| Source | DF | Seq SS | Contribution | Adj SS | Adj MS | F-Value |
|---|---|---|---|---|---|---|
| Model | 5 | 151.480 | 86.11% | 151.480 | 30.2960 | 8.68 |
| Linear | 2 | 141.256 | 80.30% | 146.059 | 73.0297 | 20.92 |
| wt% of Al 6061 | 1 | 99.400 | 56.51% | 19.735 | 19.7353 | 5.65 |
| wt% of G | 1 | 41.857 | 23.79% | 22.343 | 22.3428 | 6.40 |
| Square | 3 | 10.224 | 5.81% | 10.224 | 3.4079 | 0.98 |
| wt% of Al 6061*wt% of Al 6061 | 1 | 4.638 | 2.64% | 0.951 | 0.9506 | 0.27 |
| wt% of G*wt% of G | 1 | 1.621 | 0.92% | 2.458 | 2.4582 | 0.70 |
| wt% of S-Glass*wt% of S-Glass | 1 | 3.965 | 2.25% | 3.965 | 3.9651 | 1.14 |
| Error | 7 | 24.433 | 13.89% | 24.433 | 3.4904 | |
| Total | 12 | 175.913 | 100.00% | | | |

| Source | P-Value |
|---|---|
| Model | 0.007 |
| Linear | 0.001 |
| wt% of Al 6061 | 0.049 |
| wt% of G | 0.039 |
| Square | 0.456 |
| wt% of Al 6061*wt% of Al 6061 | 0.618 |
| wt% of G*wt% of G | 0.429 |
| wt% of S-Glass*wt% of S-Glass | 0.322 |
| Error | |
| Total | |

Full mathematical model has been checked for adequacy by calculating F-value and P-value at 95% significant level. P-value for regression model (0.001<0.05) and R2 value for tensile strength is 86.11% greater than predicted value (60.28%).

## Regression Equation in Coded Units

Hardness BHN = 44.39 - 3.22 wt% of Al 6061 + 3.32 wt% of G
+ 1.66 wt% of Al 6061*wt% of Al 6061 - 1.57 wt% of G*wt% of G
- 2.73 wt% of S-Glass*wt% of S-Glass

*Uncoded coefficients are not available with non-hierarchical model.*

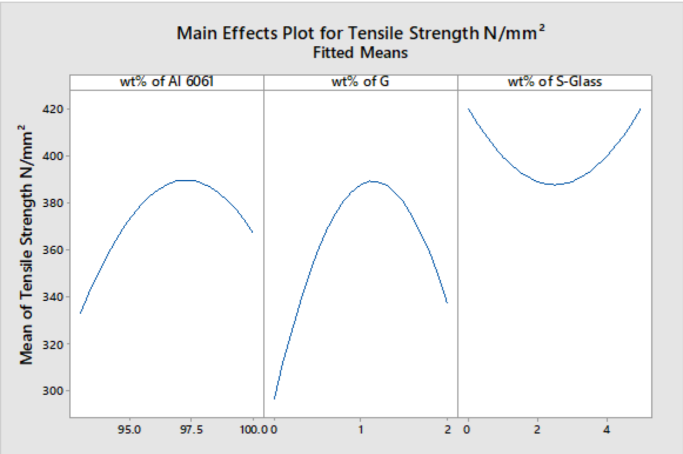


Figure: 7.Main effects Plot for tensile Strength

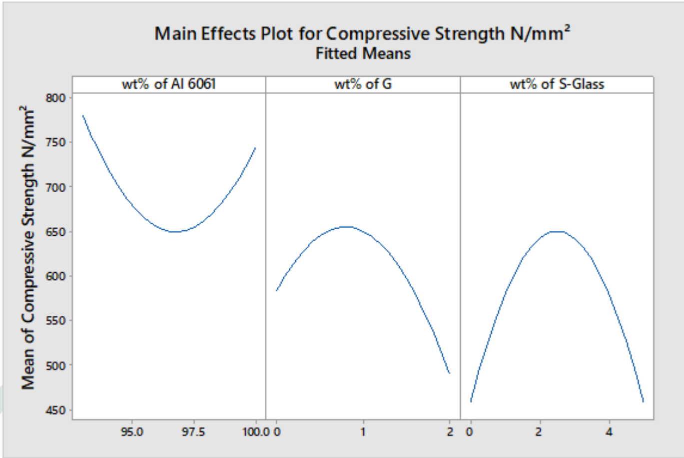


Figure: 8.Main effects Plot for Compressive Strength

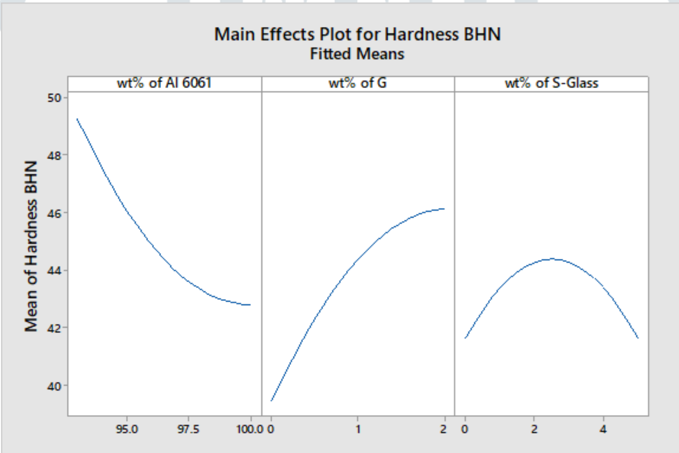


Figure: 9 Main effects Plot for Hardness.

Figure:7 shows the main effects plot of tensile strength, Wt Al6061 and Graphene is concave and wt.% of S-glass is convex that represents the slope of curve increases and decreases. As rise in wt.% of Al6061 and Graphene up to peak lead to increase in tensile strength after that decreases, whereas in the case of S-Glass, curve is convex, initially tensile strength decreases till 2.5 wt.% of S-class and sudden rise.

Figure:8 shows the main effects plot compressive strength. % Al6061 is convex and wt.% of Graphene & S-glass is concave that represents the slope of curve decreases and increases. As fall in wt.% of Al6061 decreases and rise in wt.% of reinforcements increases the compressive strength.

Figure:9 shows the main effects plot of hardness. Wt.% Al6061 is convex, hardness decreases with increases in wt.% of Al6061 whereas wt.% of graphene and S-Glass is concave, hardness increases with

Increase in Wt.% of Graphene and till 2.5 wt.% of S-Glass.

**Optimization of Mechanical Properties**

The numerical optimization was carried out by using Minitab 19 software to obtain the optimum combinations of parameters. This optimization was based on the data from the predicted models for mechanical properties, in term of wt .% of Al 6061,Graphene and S-Glass. Table lists the design summery for the 3 factors and 3 responses showing that the models of mechanical characteristics are quadratic model. To modify the predicted models, desirability, as an objective function, allows to properly combining all the goals. Desirability was therefore evaluated reaching to be maximized through a numerical optimization, which ranges from zero to one at the goal. In this optimization, both weight and importance were selected to be constant (i. e, weight =1 and importance =1), since the bead characteristics have the importance and are not in conflict within each other. The aim of this optimization is to determine a good set of conditions that will meet all the goals. The ultimate goal of this optimization was to obtain the maximum response that simultaneously satisfied all the variable properties.

Table 5 Response Optimization of tensile, Compressive Strength and Hardness

## Response Optimization: Hardness BHN, Compressive ... rength N/mm²

### Parameters

| Response | Goal | Lower | Target | Upper | Weight | Importance |
|---|---|---|---|---|---|---|
| Hardness BHN | Maximum | 35.00 | 49.22 | | 1 | 1 |
| Compressive Strength N/mm² | Maximum | 383.82 | 709.90 | | 1 | 1 |
| Tensile Strength N/mm² | Maximum | 300.45 | 405.22 | | 1 | 1 |

### Solution

| Solution | wt% of Al 6061 | wt% of G | wt% of S-Glass | Hardness BHN Fit | Compressive Strength N/mm² Fit | Tensile Strength N/mm² Fit | Composite Desirability |
|---|---|---|---|---|---|---|---|
| 1 | 94.4848 | 1.13131 | 2.52525 | 47.1985 | 689.958 | 366.756 | 0.798802 |

### Multiple Response Prediction

| Variable | Setting |
|---|---|
| wt% of Al 6061 | 94.4848 |
| wt% of G | 1.13131 |
| wt% of S-Glass | 2.52525 |

| Response | Fit | SE Fit | 95% CI | 95% PI |
|---|---|---|---|---|
| Hardness BHN | 47.20 | 1.78 | (42.98, 51.42) | (41.09, 53.31) |
| Compressive Strength N/mm² | 690.0 | 76.6 | (508.8, 871.1) | (427.6, 952.3) |
| Tensile Strength N/mm² | 366.8 | 17.6 | (325.2, 408.3) | (306.6, 427.0) |

### Optimization Plot

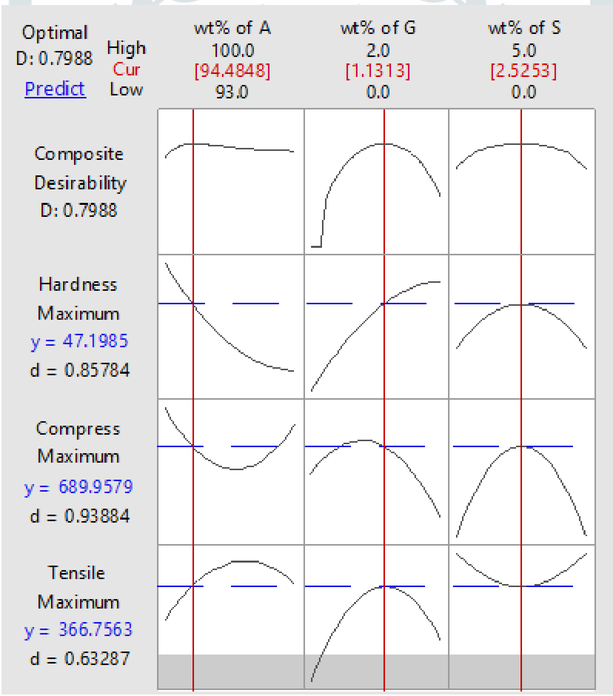


Figure:10. Response Optimization Plot

The optimization of mechanical properties like tensile strength, compressive strength and hardness is done with Response surface methodology design experiment approach. The optimal factor value of composite consists of 94.48 wt.% of Al 6061,1.13 wt.% of Graphene and 2.52 wt.% of S-Glass that showed the Tensile, Compressive strength and hardness values of 366.76 MPa,689.95 and 47.19 BHN.

It is obviously specified the desirability of the mechanical properties and composite. The obtained desirability value is more than 0.5.if we look into individual desirability of responses like Hardness, Compressive Strength and Tensile strength, values are 0.857,0.938 and 0.6328 that is fallen in the class of Excellent, Excellent and Good. The overall desirability value of the composite is 0.7988 which is satisfactory.

So we can conclude that the optimized response values are acceptable due to satisfactory desirability value.

## CONFIRMATION TEST

In order to validate the methodology, confirmation tests should be performed for DOE, parameters to verify predicted results. If the predicted results are confirmed, the suggested optimum working conditions will be adopted

Table 6. Confirmation test of Tensile Strength

| Specimen Designation | Experimental Tensile Strength N/mm² | Predicted Tensile Strength N/mm² | % Error |
|---|---|---|---|
| A0.5G1S | 380.26 | 385.14 | -1.267071714 |
| A0.5G3S | 360.23 | 367.86 | -2.074158647 |
| A0.5G5S | 372.44 | 378.71 | -1.655620396 |
| A1G1S | 373.78 | 379.48 | -1.502055444 |
| A1G3S | 375.22 | 380.05 | -1.27088541 |
| A1G5S | 375.48 | 381.56 | -1.593458434 |
| A1.5G1S | 405.22 | 410.96 | -1.396729609 |
| A1.5G3S | 390.65 | 394.82 | -1.056177499 |
| A1.5G5S | 395.26 | 401.67 | -1.595837379 |
| A2G1S | 350.12 | 355.74 | -1.579805476 |
| A2G3S | 320.55 | 327.39 | -2.089251352 |
| A2G5S | 300.45 | 306.11 | -1.849008526 |
| 100Al | 310 | 316.88 | -2.171168897 |

Table 7. Confirmation test of Compressive Strength

| Specimen Designation | Experimental Compressive Strength N/mm² | Predicted Compressive Strength N/mm² | % Error |
|---|---|---|---|
| A0.5G1S | 556.45 | 661.84 | -15.92378823 |
| A0.5G3S | 660.96 | 667.21 | -0.93673656 |
| A0.5G5S | 496.88 | 504.28 | -1.467438725 |
| A1G1S | 709.9 | 717.17 | -1.013706653 |
| A1G3S | 560.52 | 564.22 | -0.655772571 |
| A1G5S | 526.23 | 533.97 | -1.449519636 |
| A1.5G1S | 419.88 | 427.81 | -1.85362661 |
| A1.5G3S | 665.91 | 672.47 | -0.975508201 |
| A1.5G5S | 547.79 | 551.77 | -0.721315041 |
| A2G1S | 447.23 | 450.14 | -0.646465544 |
| A2G3S | 524.45 | 529.61 | -0.974301845 |
| A2G5S | 383.82 | 386.87 | -0.788378525 |
| 100Al | 495.4 | 498.61 | -0.643789735 |

Table 8. Confirmation test of Hardness

| Specimen Designation | Experimental Hardness BHN | Predicted Hardness N/mm² | % Error |
|---|---|---|---|
| A0.5G1S | 40.26 | 42.47 | -5.203673181 |
| A0.5G3S | 42.55 | 43.74 | -2.720621856 |
| A0.5G5S | 43.22 | 452 | -90.4380531 |
| A1G1S | 41.3 | 42.96 | -3.86405959 |
| A1G3S | 45.23 | 47.05 | -3.868225292 |
| A1G5S | 41.3 | 42.87 | -3.662234663 |
| A1.5G1S | 45.61 | 46.32 | -1.532815199 |
| A1.5G3S | 46.22 | 47.21 | -2.097013345 |
| A1.5G5S | 49.22 | 51.17 | -3.810826656 |
| A2G1S | 44.22 | 46.33 | -4.554284481 |
| A2G3S | 47.05 | 48.69 | -3.3682481 |
| A2G5S | 48.3 | 49.71 | -2.836451418 |
| 100Al | 35 | 36.76 | -4.78781284 |

Confirmation test was conducted for responses like tensile strength, compressive strength and hardness to validate the experimental or observed value vs Predicted value. It is clearly seen that % error has fallen within ± 10%. So it is acceptable. The experimental values are found to be very close to predicted values.

## IV. Conclusion

The developed composite has improved properties compared to the basic alloy. The inclusions of the Graphene and S-glass fibers have extended their good properties to the alloy which acts as the matrix alloy

- The optimization of mechanical properties like tensile strength, Compressive strength and hardness is done with response surface methodology. The optimal factor value of composite consists of 94.48 wt.% of Al 6061,1.13 wt.% of Graphene and 2.52 wt.% of S-Glass that showed the Tensile, Compressive strength and hardness values of 366.76 MPa,689.95 and 47.19 BHN
- Confirmation test was conducted for responses like tensile strength, compressive strength and hardness to validate the experimental or observed value vs Predicted value. It is clearly seen that % error has fallen within ± 10%. So it is acceptable. The experimental values are found to be very close to predicted values, Better bonding between the particles and good neck formation was observed at Al-0.5%G/1%S-Glass % composite. On the other hand, the agglomeration was determined at Al-2%G/5%S-Glass.
- Al 6061 reinforced with S-Glass fiber and Graphene hybrid composite with high specific stiffness and high strength can be used in long-term applications in which saving weight is an important feature, such applications include and automotive engine parts and aerospace industry.
- In automotive industry, it can be used for making supporting parts, rear axle, differential housing Brake disc etc. The developed hybrid metal matrix composites in aerospace industry for interior parts like seat structure and dash boards, because of low density and better mechanical properties.

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