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# Interrelating the Breaking Strength of Novel Nano Tungsten Carbide Reinforced Aluminium Alloy Composites with Al-Mg-Cr Alloy

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## Abstract

**Aim:** In the present study an effort was made to synthesise Al-Mg-Cr alloy reinforced with nano WC tungsten carbide (WC) ceramic strengthening particles by stir casting was investigated, and it was compared to as-cast aluminium alloys in terms of compressive strength. **Materials and Methods:** Al-Mg-Cr alloy and 2wt% of novel nano tungsten carbide of particle size <50 nm was melted in a resisting heating furnace at 850°C with stirring speed of 500 rpm and stirring time 10 min respectively. The Al-Mg-Cr alloy nanocomposite was manufactured in two groups (Experiment =1 and Control Group =1). Sample sizes for each group were 20 with pre-test power of 80%, beta=0.05%, and CL 95%. **Result:**The Compressive strength and Yield strength of fabricated composites were analyzed from the results of the experiments and compared to the properties of as-cast Al-Mg-Cr alloy. The significance between the synthesized composites and the as-cast alloys was p=0.001(p<0.05). **Conclusions:** Within the limitations of this study, It was revealed that the compressive strength and yield strength of synthesized novel nano tungsten reinforced Al-Mg-Cr alloy composites significantly increased from 59.45% and 28% respectively owing to reduction in porosity and enhanced grain refinement between the intermixtures.

**Keywords:**Aluminium metal matrix composite,Al-Mg-Cr alloy, Novel Nano Tungsten Carbide, Stir-casting, Compressive Strength, Yield Stress.

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## INTRODUCTION

Metal matrix composites (MMCs) are becoming more popular due to their ability to customize characteristics with the addition of certain reinforcements (Anbuchezhiyan et al. 2021). Owing to the low density, high strength to weight ratio and enhanced stiffness metal matrix composites play a significant role in the automotive, aerospace and marine industry. Nevertheless, ceramic particle distribution plays an important role in determining such characteristics. In the literature investigation, it was found that it is particle damage mechanism that causes metal matrix composites to exhibit reduction in physical properties when micron scaled ceramic reinforcement is added (Anbuchezhiyan et al. 2017). This can be overwhelmed with the incorporation of nanoceramic fortifying particles in the network alloy (Pugazhenthi et al. 2021). The consideration of nano ceramic particulates in the lattice amalgam shows improved mechanical properties over micron-sized composites. Anyway these composites show low wettability between the matrix and ceramic strengthening particles is a significant drawbacks of synthesizing such nanocomposites. In request to defeat this issue, we suggest adding a little level of nano reinforcing particulates, just as an interaction boundary equipped for moderating these impacts. It was induced that because of their low density and upgraded execution, these nano metal grid composites can be used for automobile components, aerospace components, and consumer goods (Gowayed and Ojard 2020).

There are around 150 and 231 research papers distributed with regards to novel nano tungsten carbide supported unique aluminium compounds in Google Scholar and Science Direct, respectively. In the Stir casting method, the mechanical properties of WC enhanced aluminium alloy composites were considered by changing the weight extents (1%,2%,,3%and 4%) of the support particles (Ali et al. 2021). It was found that the Compressive strength was significantly increased because of a decrease somewhere far off between the hard support particulates and the matrix alloy (Fenghong et al. 2019). The mechanical properties of built up aluminium composites including Si3N4 were concentrated on utilizing stir casting method. It was noticed that

the ductility of the synthesized composites decreased because of the additional reinforcements.Stir casting method was used to achieve uniform particle distribution for the novel nano tungsten carbide reinforced AZ31 MMC (Gaaz et al. 2017).The expansion of support altogether expanded the compressive strength while reducing the tensile strength. The investigation of Al7075 alloy based metal matrix reinforced with differing measures of novel nano tungsten carbide was completed to concentrate on the mechanical properties like hardness, compressive strength, and impact strength (Abis 1989). As a consequence of the increment in weight percent of WC, hardness, rigidity, and impact strength are improved is considered to be closely related article to this work (Narasimham et al. 2020).Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021)

It was found that a couple of studies have been led on synthesizing novel WC supported Al-Mg-Cr alloy using bottom pouring stir casting method. The use of novel nano tungsten carbide in composites has not yet been synthesized and assessed and by thinking about this as the space of exploration hole, a work has been made to blend such composites and dissect both their Compressive strength and extension rate. Research conducted in this study was aimed at designing and fabricating metal matrix nanocomposite materials, and theoretical and experimental knowledge about these materials was illustrated.

## Materials And Methods

This study was carried out in the campus of Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences. No ethical approval was required since this project is regarding fabrication of Metal matrix composites.Sample sizes for each group were 20 with pre-test power of 80%, beta=0.05%, CL 95% and the significance value p=0.001 was obtained (Gaaz et al. 2017).

In order to fabricate Al-Mg-Cr alloys nano composites, necessary amounts of aluminum alloy were used for matrix materials and novel WC of a particle size of 50 nm was utilized for reinforcement. The chemical composition of AL-Mg-Cr alloys are shown in Table 1.Stir casting setup with bottom pouring was used to fabricate aluminiumnanocomposites.A resistance heating furnace was preheated to $450^0$C and then the required components of alloys were added.The alloy was heated to $750^0$C and allowed to melt.

To ensure that the molten metal was thoroughly melted, the stirrer was rotated at 400 rpm.Observations revealed that the aluminium alloy was melted at $785^0$C, and that 2wt% nano-WC particles of size 50 nm were introduced into the molten metal by an external sprue.The stirring speed was increased to 500 rpm and the stirring time was maintained at 10 minutes to achieve homogeneous reinforcement distribution in the matrix alloy.A temperature increase of $800^0$C was carried out before pouring the molten slurry into the mould to increase its viscosity.To remove porosity in the matrix material, the die (120 x120 x 25 mm) was preheated at 250°C.The stirring speed was increased to 550 rpm and the molten slurry was poured into the dia and allowed to cool at room temperature.

Synthetic composites are machined according to ASTM standards in order to assess their performance. The Compressive strength and Yield stress values of Al-Mg-Cr alloys nano composites were investigated using ASTM E8 as shown in Fig 1.

The Universal Testing Machine (UTM) was used to determine the compressive strength of synthetic composites (TFUN-400). The SCM-3000 programme provided test data for real-time testing. To align the load pointer, the initial setting knob was set to zero. The diameter of the test piece was measured with vernier calipers at several points, and the mean value was calculated. The test specimen was clamped between the machine's crosshead jaws and gradually loaded, with the elongation of the composite being measured until it broke.

**Statistical Analysis**

The analysis was carried out using SPSS 26 software. Multiple comparison table, and G graph were generated by integrating novel nano WC reinforced Al-Mg-Cr alloy composites and percent of elongation as independent variables (Pugazhenthi et al. 2021).

## Results

In present study used a novel nano WC reinforcement as reinforcement, while Al-Mg-Cr alloys were used as base materials for developing aluminiumnanocomposites using the stirring casting technique. Fig. 1 shows compressive strength of Al-Mg-Cr alloys nano composites samples that were synthesized using the stir casting process and machined to ASTM specifications. Fig. 2-3 shows an SPSS bar graph of produced aluminiumnanocomposites. Tables 2 and 3 indicate the chemical composition of the Al-Mg-Cr alloy, as well as

the ultimate tensile strength and % elongation values derived from produced composites. Table 4 shows the average, mean, and standard deviation. Table 5 illustrates the independent sample test for Compressive Strength of Al-Mg-Si alloy and 2 wt% of $TiO_2$ reinforced Aluminiumnanocomposites respectively.

## Discussion

The present study observed that the compressive strength and Yield stress of synthesized aluminium alloy nanocomposites improved considerably when compared to the as-cast Al-Mg-Cr alloy as shown in Fig. 2. It's because the nano WC ceramic reinforcing particles are equally dispersed throughout the matrix alloy, with no evidence of residual pores as inferred in the literature (Tjong 2007). Furthermore, between the intermixture, the load distribution between the matrix and reinforcement is significant, resulting in increased tensile strength (Mazahery and Ostadshabani 2011). The Orowan mechanism states that the addition of nano ceramic WCs inhibits dislocation mobility in aluminium matrix alloys owing to the impact of grain refinement (Fenghong et al. 2019). Stir casting was also used to develop aluminium composites, and it is well known that this process reduces the porosity of the composite above the maximum and enhances grain refinement, both of which contribute considerably to the composite's compressive strength, as inferred in the literature (Aynalem 2020)

The limitation of the recent study inferred that inclusion of nano ceramic particulates (WC) in Al-Mg-Cr alloy was developed using stir casting method and its breaking properties was analysed.It was observed that the properties of developed composites significantly improved due to grain refinement by forming an intergranular structure and enhancing grain boundaries, leading to an increase in ductility of nanocomposites and a significant increase in the Yield stress of developed nanocomposites. In further it is decided to analyze the grain boundaries and dislocation motion of incorporating a higher percentage of nano reinforcement in matrix alloy as future scope of present study.

## Conclusion

Within the limitations of present study, nano WC reinforced Al-Mg-Cr alloys were synthesized using the stir casting process, and their compressive strength and yield stress were evaluated and compared to monolithic Al-Mg-Cr alloys as part of the research. Nano Aluminum composites improved Al-Mg-Cr alloys due to their uniform distribution of ceramic strengthening particles, reduced porosity, and enhanced grain refinement, permitting them to be used in functional applications.

**DECLARATION**

**Conflict of interest**

The authors declare that there is no conflict of interest in this manuscript.

**Authors Contribution**

Author AJ was involved in data collection, data analysis, Manuscript writing. Author GA was involved in conceptualization, data validation, and critical review of the manuscript.

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## TABLES AND FIGURES

**Table 1**. Chemical composition of Al-Mg-Cr alloys

| **Concentration of wt%** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cr | Cu | Fe | Mg | Mn | Si | Cr | Zn | Al |
| 0.28 | 0.1 | 0.4 | 2.6 | 0.1 | 0.25 | 0.35 | 0.1 | Balance |

**Table 2.** Comparison of compressive strength of Al-Mg-Cr alloys with Al-Mg-Cr Alloy + 2wt% of nanoWC

| **Exp No** | **Al-Mg-Cr Alloy** | **Al-Mg-Cr Alloy + 2Wt% of nanoWC** |
|---|---|---|
| 1 | 94.43 | 242.879 |
| 2 | 94.38 | 243.13 |
| 3 | 94.35 | 242.82 |
| 4 | 94.41 | 242.85 |
| 5 | 93.92 | 242.81 |
| 6 | 94.37 | 242.79 |
| 7 | 94.28 | 242.84 |
| 8 | 94.42 | 242.52 |
| 9 | 94.37 | 241.92 |
| 10 | 94.39 | 241.98 |
| 11 | 94.28 | 242.63 |
| 12 | 93.91 | 242.76 |
| 13 | 94.44 | 242.8 |
| 14 | 94.36 | 242.61 |
| 15 | 94.4 | 242.78 |
| 16 | 94.33 | 242.17 |
| 17 | 94.42 | 242.38 |

| | | |
|---|---|---|
| 18 | 94.38 | 242.72 |
| 19 | 94.31 | 242.79 |
| 20 | 94.44 | 242.91 |

**Table 3**. Comparison of yield stress of Al-Mg-Cr alloys with Al-Mg-Cr Alloy + 2Wt% of nanoWC

| **Exp No** | **Yield stress of Al-Mg-Cr Alloy** | **Yield stress of Al-Mg-Cr Alloy + 2Wt% of nanoWC** |
|---|---|---|
| 1 | 5.2 | 69.78 |
| 2 | 4.85 | 69.82 |
| 3 | 5.19 | 69.85 |
| 4 | 5.21 | 69.76 |
| 5 | 5.18 | 69.82 |
| 6 | 5.21 | 69.77 |
| 7 | 4.95 | 69.69 |
| 8 | 4.98 | 69.81 |
| 9 | 4.96 | 69.78 |
| 10 | 5.15 | 69.83 |
| 11 | 5.18 | 69.74 |
| 12 | 5.22 | 69.75 |
| 13 | 5.17 | 69.7 |
| 14 | 5.19 | 68.92 |

| | | |
|---|---|---|
| 15 | 5.14 | 68.96 |
| 16 | 5.23 | 69.12 |
| 17 | 5.21 | 69.57 |
| 18 | 5.2 | 69.63 |
| 19 | 5.18 | 69.84 |
| 20 | 5.19 | 69.62 |

**Table 4.** Average compressive strength and yield stress of as cast Al-Mg-Cr alloy and 2 wt% of WC reinforced Aluminiumnanocomposites

| **S.NO** | **TYPES OF MATERIAL** | **AVERAGE COMPRESSIVE STRENGTH (MPa)** | **AVERAGE OF YIELD STRESS (MPa)** |
|---|---|---|---|
| 1. | Al-Mg-Cr alloy | 94.3295 | 5.1395 |
| 2. | Al-Mg-Cr alloy + 2wt% of nanoWC | 242.65445 | 69.6384 |

**Table 5.** Independent Sample Test for Compressive Strength of Al-Mg-Si alloy and 2 wt% of $TiO_2$ reinforced Aluminiumnanocomposites.

| **Independent Samples Test** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Levene's Test for Equality of Variances** | | **t-test for Equality of Means** | | | | | | |
| | | **F** | **Sig.** | **t** | **df** | **Sig. (2-tailed)** | **Mean Difference** | **Std. Error Difference** | **95% Confidence Interval of the Difference** | |
| | | | | | | | | | **Lower** | **Upper** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Compression | Equal variances assumed | 6.581 | 0.001 | -10.9 | 37 | 0.00 | -16.304 | 1.325 | -20.50 | -12.10 |
| | Equal variances not assumed | | | -10.9 | 31 | 0.00 | -16.304 | 1.325 | -20.524 | -12.10 |

**Fig. 1.** Compressive strength composites samples of Al-Mg-Cr alloy reinforced nano WC ceramic particulates

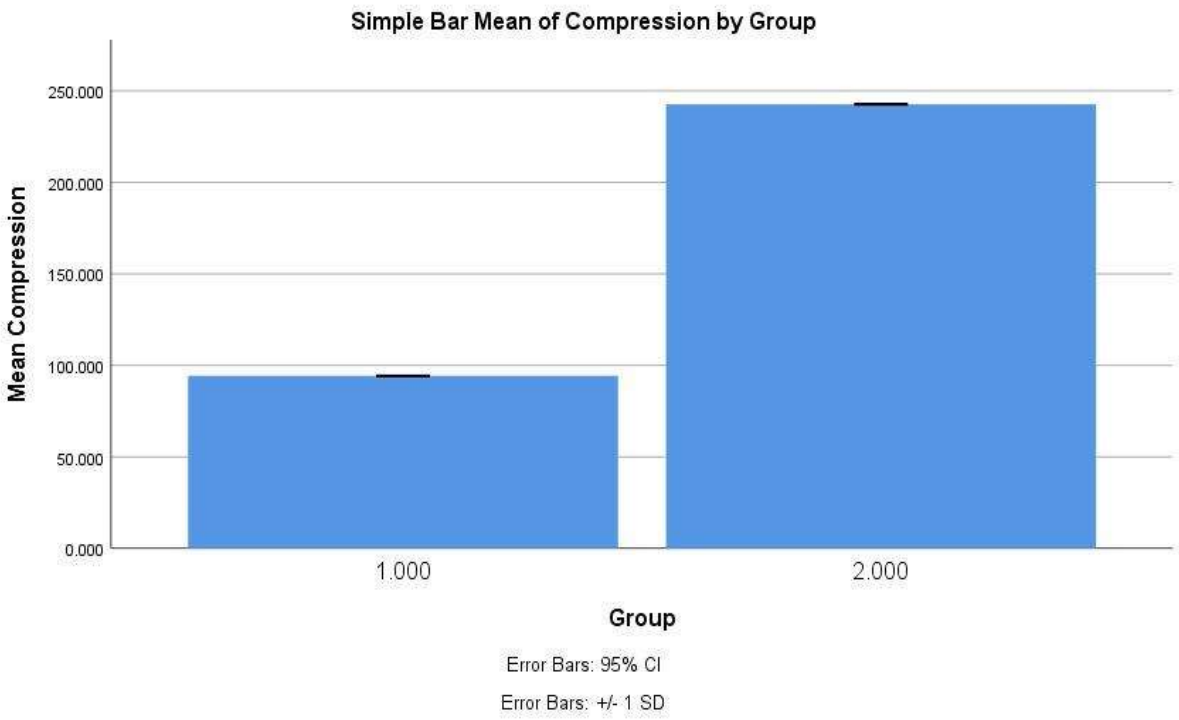


**Fig. 2.** Bar graph shows the comparison between the compressive strength of Al-Mg-Cr alloys with 2wt% of nano WC reinforced aluminiumalloy.The error bars +/- 1 SD was attained.

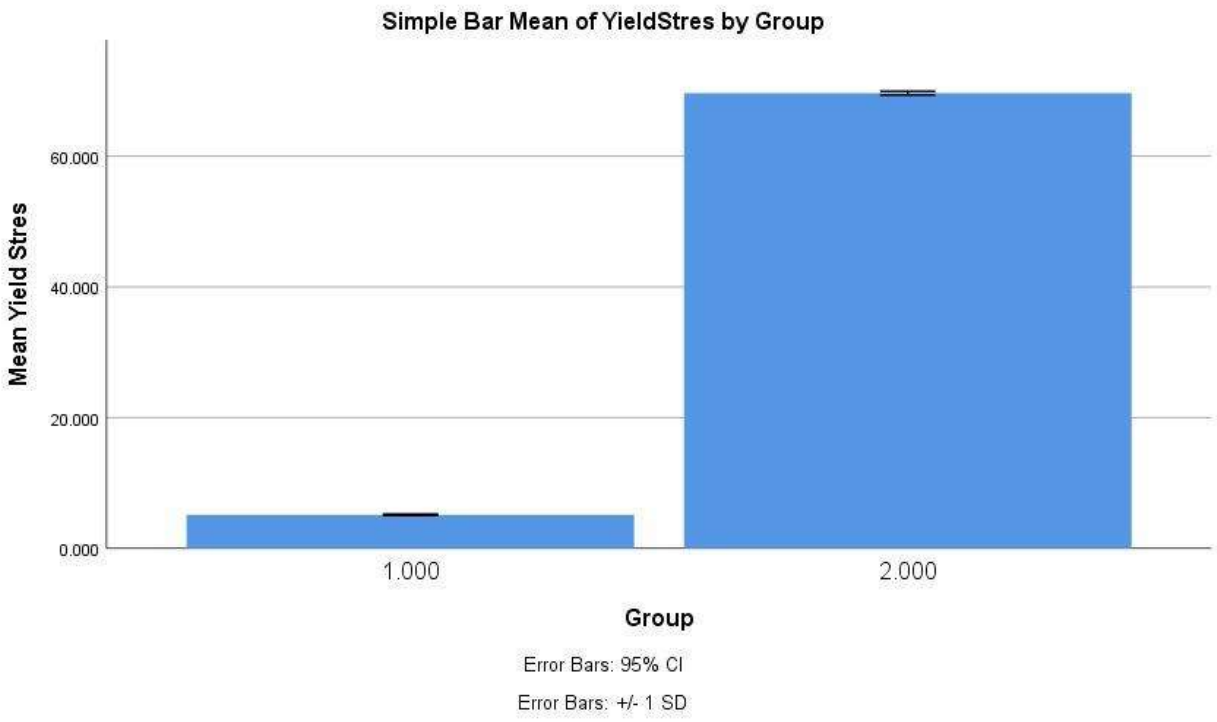


**Fig. 3.** Bar graph shows the comparison between the yield stress of Al-Mg-Cr alloys with 2wt% of nano WC reinforced aluminiumalloy.The error bars +/- 1 SD was attained.