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Tensile Properties of Aluminium/Graphite Composite Through Simulation Analysis

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Abstract: Composite materials are manufactured by the combination of two or more distinct materials. The different materials form the distinct characteristics of the composites. Solid and stiff reinforcement is often inserted into a ductile matrix in aluminium-reinforced composites, which aim to increase mechanical properties, particularly strength, strength-to-weight ratio, etc. This study was focused on the preparation of data on the tensile properties of Al/Gr composites through simulation analysis. The different weight percentages of Al/Gr ratios of 90/10, 80/20, and 60/40 were investigated through tensile properties via simulation analysis. By conducting this simulation analysis, it was found that the different weight percentages of Gr affected the tensile properties of Al. This simulation analysis has been performed through simulation software that has many features and is capable of running testing, which is ANSYS Workbench. Moreover, the designs of the different types of samples are drawn using SolidWorks 2019. Then the results of Al/Gr composites are compared for tensile properties.

Keywords: Aluminium, graphite, composites, tensile, simulation analysis

1. Introduction

Composite materials are created by combining two or more separate materials or phases of the same substance. Compared to its elements, the material has entirely unique, distinct, and better characteristics. The components do not overlap or disappear, but there is an obvious distinction between them [1]. The composites are the foundation (matrix), the content of which is far better than most products and improvements, for example, a substance that obtains the required composite properties. Based on Fig. 1, it is shown that metal, polymer, and ceramic can be the foundation or matrix. On the other hand, whether the content matrix is concrete or not, the composites are metal matrix composites (MMCs).

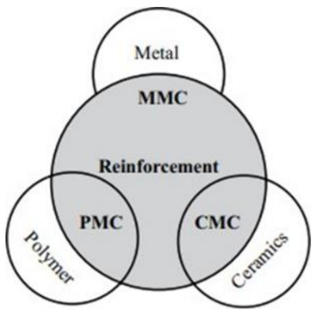

Fig. 1 - Types of composites [1]

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When learning about composites, the terms "matrix" and "strengthening" are also commonly used. Matrix is a comparatively "soft" material with the physical and mechanical basic characteristics of ductility, formability, and thermal conductivity. Fig. 2 shows an example matrix and reinforcement diagram and an actual example of the composite system. Hard reinforcements are incorporated into the matrix, with high power, high rigidity, and low thermal expansion.

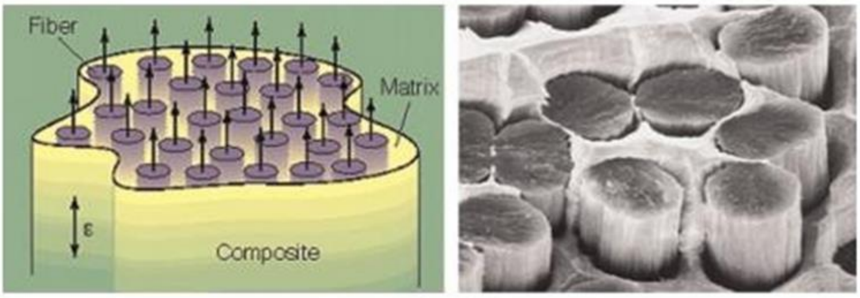


Fig. 2 - Matrix and reinforcement diagram and actual example of the composite system [2]

Other than that, the matrix is intended to bind the reinforcements together in conjunction with their consistent and adhesive properties, to move loads from and to reinforcements, and to shield the reinforcements from environments and exploitation. The matrix generally gives the composite a solid form, which helps with the manufacturing process and is usually needed in a finished component. However, by having an efficient load transition from external forces to reinforcement, the matrix may be utilised to its maximum capacity [2]. Graphite is a type of crystalline carbon that occurs naturally. It is an indigenous mineral element found in rocks that are metamorphic and igneous. Graphite is a mineral that comprises extremes. It is very soft, has a very light pressure cleave, and has a very low specific gravity. It is, on the other hand, highly heat-resistant and almost inert when in contact with almost any other material. Such extreme properties give it a wide variety of metallurgical and industrial applications [3]. Aluminium is a highly electro-negative metal and has a heavy oxygen affinity; this is obvious from the high heat of its oxide formation. For this reason, even though it is among the six metals that are most spread on the surface of the earth, until well into the nineteenth century, it was not separated. The combination matrix steps of aluminium and refurbishment denote aluminium MMC. Due to different characteristics such as low density, improved corrosion resistance, strong abrasion and wear resistance, and high thermal conductivity, composites of extremely specialised modules of aluminium metal matrix are used in many fields such as aeronautics, cars, and marine [4].

For various space applications, graphite and epoxy composite materials are being increasingly used. Because of their favourable mechanical properties, engineers are interested in these materials. mechanical properties such as high strength and stiffness to weight ratio and zero or near-zero thermal expansion coefficient potential [5]. Graphite-epoxy composites are one material scheme of particular interest. Those materials have been used to meet a broad range of design criteria, from minimal weight to high specifications for structural stiffness [5]. The use of graphite/epoxy composites is expected to increase due to their ability to meet many different design requirements simultaneously. Tensile is defined as the mechanical testing of composite structures to achieve parameters such as strength and less rigidity in a given time frame. Processes are time-consuming and sometimes challenging. However, it is a necessary operation, and the testing of simple structures, such as flat coupons, can somewhat simplify it. The data obtained from these tensile tests can then be directly connected to any structural form with varying degrees of simplicity and accuracy [6]. A computational approach for addressing engineering and mathematical physics problems is finite element analysis. The FEM analysis may also be used with dynamic components as an alternative to theoretical approaches. The analogy of theory with the FEM provides a convenient and trustworthy alternative for using the FEM study instead of theory because composite components are more complex than any content and often tricky. The geometry of the design is much more complicated, and the criterion for precision is much greater. comprehension of the physical actions of a dynamic object: strength, heat transfer, and fluid flow. Estimation of design performances and behaviours measurement of the safety margin and precise detection of design failure [7]. ANSYS is a general finite element modelling package for a wide range of mechanical problems to be numerically resolved. These consist of static or dynamic analysis of structures (linear and nonlinear), thermal transfer and fluid difficulties, and acoustic and electro-magnetic difficulties [8].

In general, there are three phases of a finite element solution and a quick fix that can be done by this ANSYS software. The first phase is pre-processing, or, in other words, defining the problem. Other than that, there are several main pre-processing phases, such as determining the key points, lines, areas, and volumes, setting the type of element, material, or geometric characteristics or properties, and determining whether lines, areas, or volumes are requisite to meshing. The requisite quantity of information depends on the size of the analysis, for example, 1D, 2D, and axisymmetrical 3D. The second phase is solution, which is assigning loads and constraints and solving.

2. Samples Preparation for Simulation Analysis

For the preparation of the specimen to simulate, SolidWorks 2019 software was applied to draw the bar and dogbone specimens. SolidWorks 2019 software was applied as a technical drawing software for sketching, designing models, simulating, and drawing details [9]. For this phase, Figs. 3 and 4 show bar and dogbone samples that have been completely drawn in SolidWorks 2019 software before export to ANSYS Software.

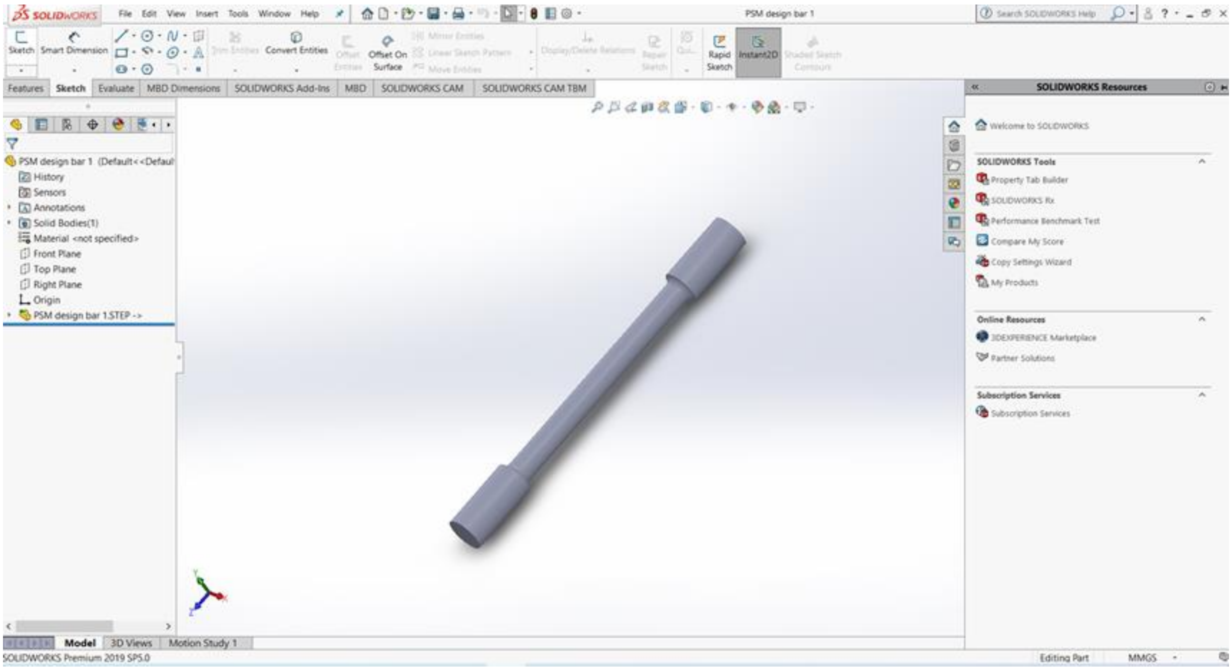


Fig. 3 - Bar specimen in SolidWorks

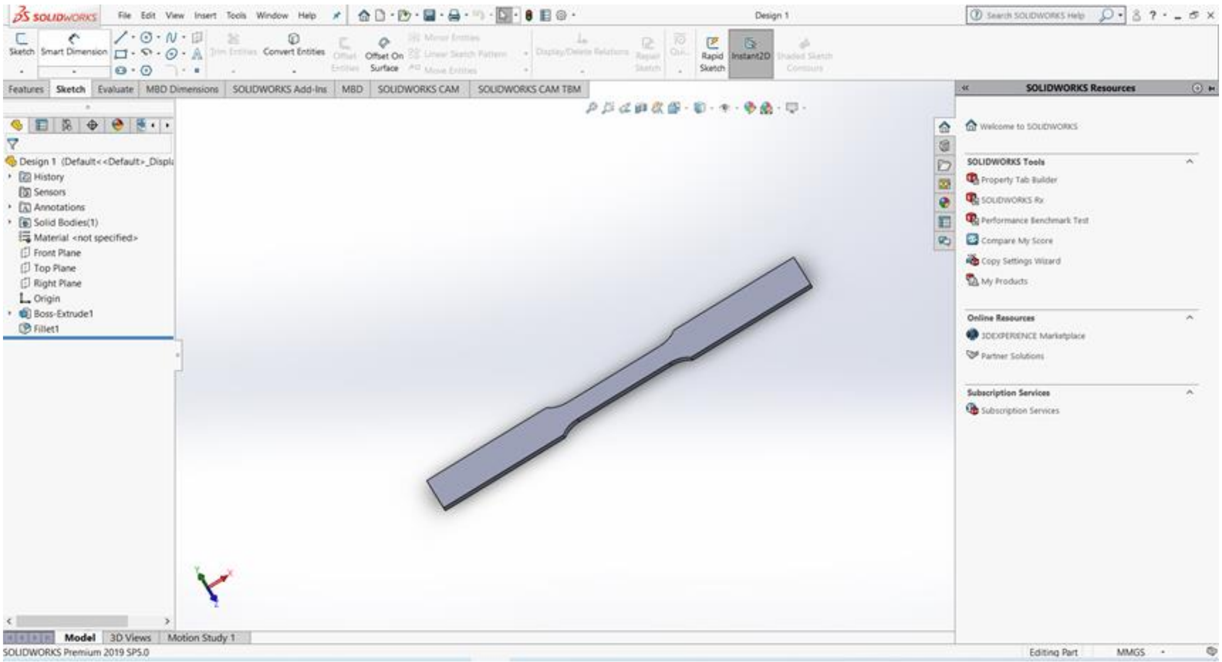
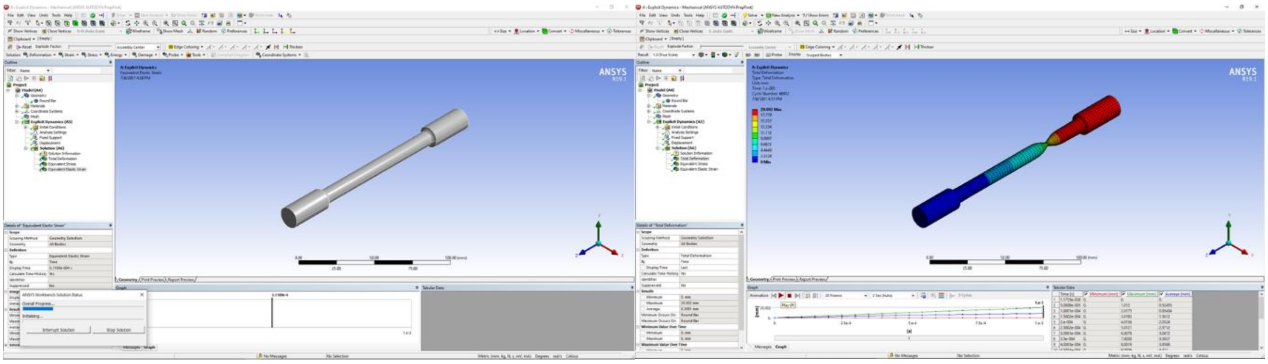


Fig. 4 - Dogbone specimen in SolidWorks

For this simulation study, various running steps are fundamental to simulating the bar and dogbone-shaped specimen. The bar specimen can be ready for testing in this section, as shown in Fig. 5(a). Next, the F5 button needs to be pressed to run the trial. The progress for the trial can be seen in "overall progress," which is located at the bottom left side of the ANSYS software interface. At the bottom of the screen, as shown in Fig. 5(b), the play button is pressed to view the simulation of the tensile test. Moreover, if the specimen does not break, the displacement must be increased by 5 mm, and the simulation must be run again until the specimen breaks.



(a) (b)

Fig. 5 - (a) Progress run test of specimen; (b) tensile test and simulation for specimen to break

3. Results

Fig. 6 shows that the crack started to appear from the point of ultimate value until it separated to become two parts at the fracture point, which is 67.89 MPa. The elongation has reached 19.69%. Thus, the initial specimen length is 160 mm, and the final gauge length is 191.50 mm. 10% Gr has obtained 73.89 MPa as yield strength, which is the point at which the specimen cannot return to its original shape. Moreover, the ultimate strength is obtained at 160.65 MPa.

Fig. 7 shows that the 20% Gr has obtained 206.89 MPa in yield strength. 20% Gr obtained higher ultimate strength compared to 10% Gr. In other words, the ultimate value is the tensile strength for 20% Gr, and the maximum value can be achieved before it goes down, as shown in Fig. 7. The crack started to appear from the ultimate point until it separated to become two parts at the fracture point, which is 200.89 MPa. The elongation has reached 23.91%. Thus, the initial specimen length is 160 mm, and the final gauge length is 198.25 mm.

Fig. 8 shows that the bar specimen has obtained 122.12 MPa of yield strength. 40% Gr shows the highest ultimate strength compared to 10% and 20% of Gr, obtained at 308.57 MPa. In other words, the ultimate value is the tensile strength for 40% Gr, and the maximum value can be achieved before it goes down, as shown in Fig. 8. The crack started to appear from the ultimate point until it separated to become two parts at the fracture point, which is 275.50 MPa. The elongation has reached 29.69%. Thus, the initial specimen length is 160 mm, and the final gauge length is 207.50 mm.

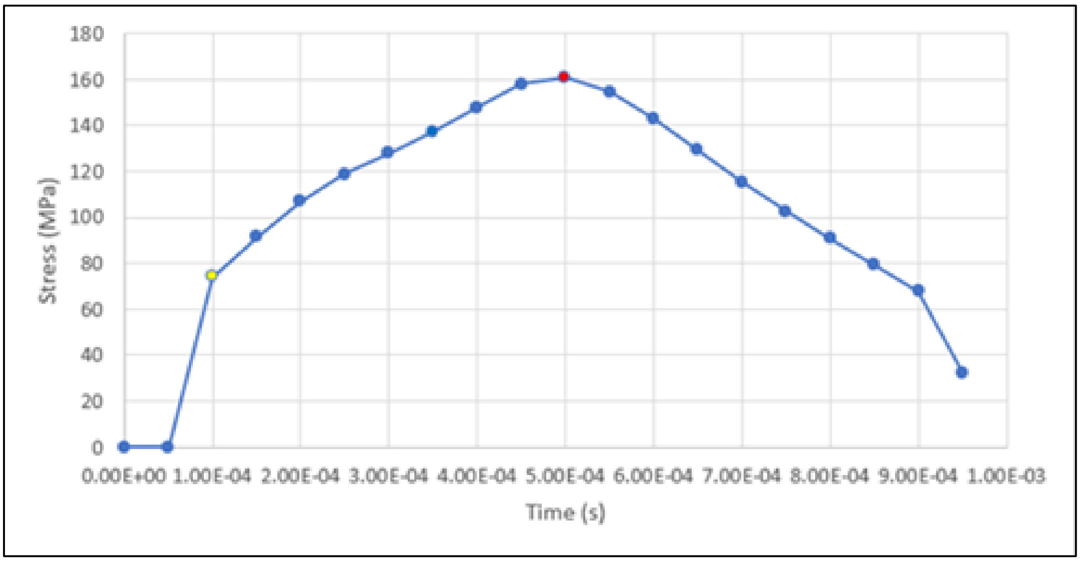


Fig. 6 - Graph plotted of tensile properties for bar specimen (10% Gr)

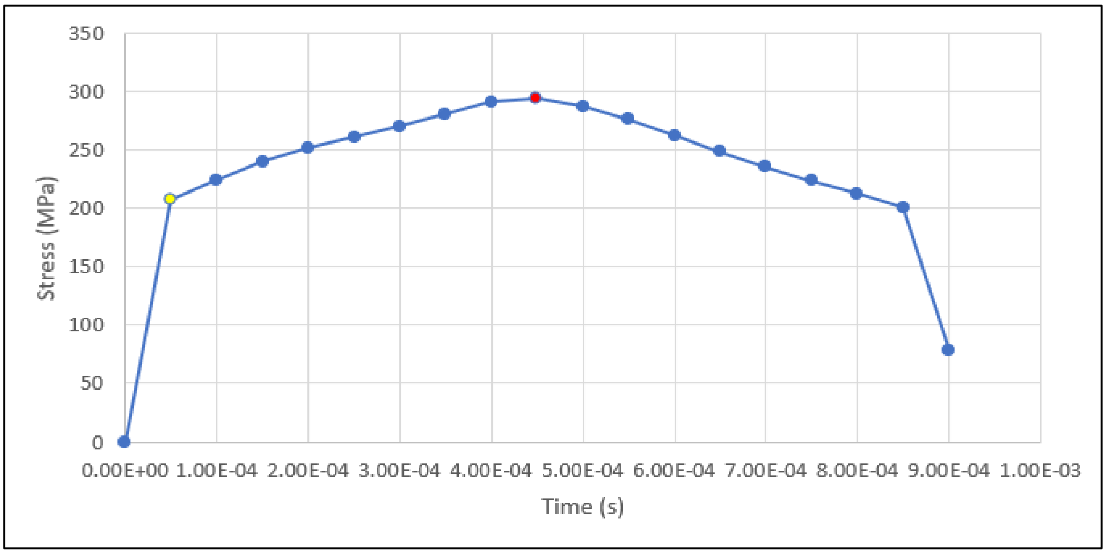


Fig. 7 - Graph plotted of tensile properties for bar specimen (20% Gr)

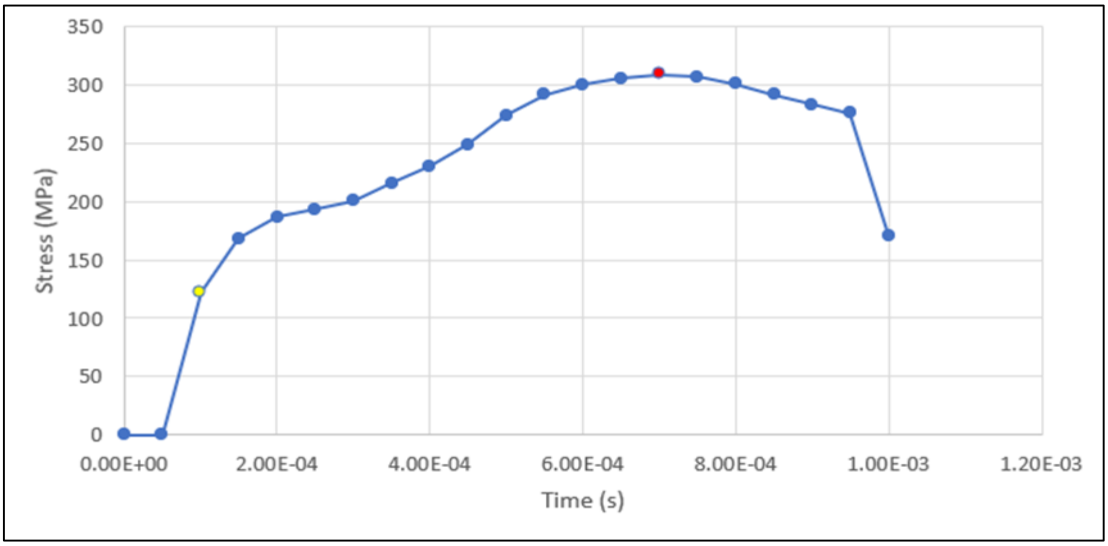


Fig. 8 - Graph plotted of tensile properties for bar specimen (40% Gr)

Fig. 9 shows a graph that displays the trend of the ultimate tensile strength of samples against the different weight percentages of Gr that have been applied. Based on the graph, the blue linear line represents a bar sample, while the orange linear line represents a dogbone sample. In general, composites usually have a higher tensile strength. When the weight percentages of reinforcement were increased, the tensile strength of the composites increased. It was found that the best composite of Al6061 with 6% Gr had a maximum tensile strength of 83.2 MPa in tensile test results. [10]. Based on this simulation, it was found that the best composite of Al-6061 bar specimens with 40% Gr achieved the highest tensile strength, which is 308.57 MPa. Other than that, the simulation for the dogbone specimen achieved the highest tensile strength at 313.94 MPa with 40% Gr, the same as the simulation for the bar specimen.

In addition, based on the previous studies, the composite of an Al-6061 bar specimen with 6% Gr has obtained the minimum value of elongation, which is 2.84%. Hence, the composite Al-6061 bar specimen with 6% Gr can be analysed to determine that it obtained the maximum strength and minimum value of elongation among the 3% and 9% of Gr as reinforcement [10]. However, in this simulation analysis, the minimum value of elongation was obtained by composite Al6061 bars and dogbone specimens with 10% Gr, which are 19.69% and 14.68%, respectively. The Al/Gr composite obtained the minimum value of elongation but not the highest tensile strength.

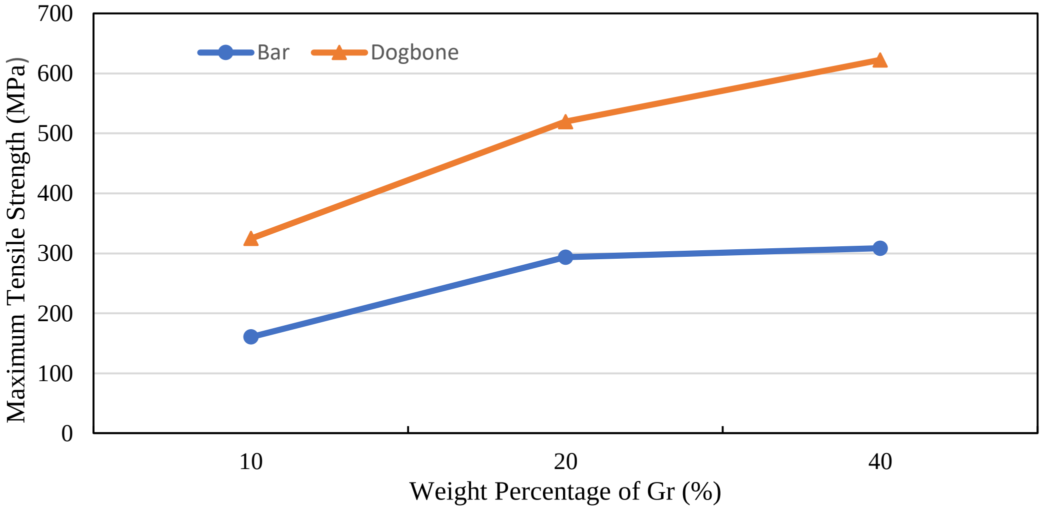


Fig. 9 - Tensile strength of dogbone and bar samples at various weight percentages of Gr/Al

4. Conclusion

In conclusion, the objectives of this simulation analysis have been achieved. The tensile properties of Al/Gr composites have been studied through ANSYS simulation software. Other than that, this simulation analysis shows that when the amount of Gr increased, the yield strength decreased to a certain point, and it became more difficult to return to the original shape. The second objective achieved is to be able to investigate and analyse the outcome of different types of samples based on the ASTM standard on the tensile properties of composites through simulation analysis. When applied to different types of samples, overall analyses have found that the time taken for the bar specimen to fracture and be separated into two parts is longer than the dogbone-shaped specimen. In general, the tensile strength increased with Gr to a maximum strength percentage of 40%. However, the yield strength decreased with Gr at 40%. However, with further and very detailed research of simulation software, it has been proven that ANSYS software has many features needed for this research and is capable of generating the tensile properties of Al/Gr composites.

Acknowledgement

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