



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 6, June 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512



9940 572 462



6381 907 438



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Evaluation of Mechanical Properties of AL7075/TiO₂/Gr Composite Materials

Danappa.G.T¹, R.P.Swamy²

Assistant Professor, Department of Mechanical Engineering, Govt. Engg. College, Huvinahadagali, Karnataka, India¹

Associate Professor, Department of Mechanical Engineering, UBDTCE, Davangere, Karnataka, India²

ABSTRACT: This paper presents the mechanical properties of AL7075/TiO₂/Gr hybrid composites. The fabrication of these composites was carried out using a stir casting process. Various mechanical properties of the hybrid composite viz., modulus of elasticity, ultimate tensile strength, ductility and fracture strain were evaluated for Al-7075 + Gr + by varying nano TiO₂ reinforcement particles with constant 5 wt% Gr in an Al 7075 aluminum alloy. Compared to unreinforced Al-7075 alloy, the mechanical properties of Al-7075 + Gr-7wt. % nano TiO₂ composite is larger. Owing to the brittle nature with increase in TiO₂ reinforcement particles, when subjected to same loads, they undergo catastrophic failure with little or no plastic deformation.

KEYWORDS: AL7075, TiO₂, Gr, Hybrid composites, Mechanical properties.

I. INTRODUCTION

Composites are used in many industries today to enable high-performance products at economic advantage. These industries range from space to sports and include manufactured products for aircraft, transportation, energy, construction, sports, marine, and medical use. There are many material economic and aesthetic advantages to using composites, but a solid knowledge of the physical properties, including the mechanics, tooling, design, inspection & repair, and manufacturing options is required for working in this medium as they are intrinsically linked. Aluminium matrix composites (AMCs) are widely used in aircraft, automobiles and marine field due to the good strength, light weight and low cost. Wear behaviour can be observed in brakes, gears, valves, cam, bearings, clutches and other applications involving sliding contact or rolling contact. AMCs are one of the advanced engineering materials that have been developed for weight critical applications in the aerospace, and more recently in the automotive industries due to the excellent combination of the high specific strength and better wear resistance. Most of the industries demands on materials which has more life in spite of failure. The field of automobiles & aeronautics demands low weight, high strength materials in order to composite with other industries.

Paper is organized as follows. Section II describes Al metal with Al₂O₃, SiC and carbon particles reinforcements, connected mechanical properties evaluation and its performance. After selection of material composition from literature studies, objective of the work is described in Section III. Section IV presents important mechanical properties evaluated from experimental results of AL7075/TiO₂/Gr hybrid composites tested. Finally, Section V presents conclusion.

II. RELATED WORK

In recent years, the composite material of metals has grabbed attention due to their better mechanical properties viz., specific strength, stiffness and hardness. They has also provided an additional advantage as low cost with good cast ability compared to traditional metals and alloys [1]. Due to industrial demand and materials development many researchers are focussed on hybrid metal matrix composite materials having more than two reinforcements in the metal matrix [2]. The particles or materials which are reinforced in the metal matrix composite are due to provide the combination functional properties simultaneously. Thus the material may be used for multi-functional aspects [3]. J Raghu Kumar [4] carried out work on Al7075 metal matrix composite with reinforced Al₂O₃ and B₄C particles into it. They found significant improvement in the wear resistance due to the presence of hard reinforced particles. Kalra et al. [5] conducted wear tests on Al metal with Al₂O₃, SiC and carbon particles by stir casting method. They noticed an improvement in the wear resistance by 64 to 89% as the carbon percentage was increased by 3 to 7.5%. They found that inclusion of Gr particles in the composite matrix reduces the machining difficulties by improving the bulk mechanical properties. Bardeswaran and Perunal [6] have investigated the influence of addition of Graphite on the

wear behavior of Al 7075/Al₂O₃/5wt.% Graphite hybrid composite produced by stir casting. Authors found that the hardness of hybrid composites results in the increased with increasing Al₂O₃ ceramic particulates. Presence of Graphite in hybrid composite has also been able to decrease the coefficient of friction of the composite and this is attributed to release of Graphite which acted as the solid lubricant during the wear process. Sharma et al. [7] Work focuses on the effect of graphite particle addition on the properties of AA 6082 metal matrix composites fabricated by conventional stir casting method. The percentage of reinforcement was varied from 0% to 12% in a step of 3%. The results revealed that with the addition of graphite particles the micro and macro-hardness decreased by 11.11% and 10.44% respectively. The ultimate tensile strength also decreased by 5.88% with a reduction in percentage elongation from 8.7 to 6.8. The density decreased by 4.1% with an increase in porosity from 0.37 % to 2.27 % as the weight percentage of graphite particles increased from 0% to 12 %.

III. MATERIALS & METHODS

Metal matrix composites are widely used in components of various components of industrial equipment because of their superior material properties like high stiffness to weight ratio and high impact strength and fracture toughness while compared to the conventional material. Due to the concepts of high strength to low weight ratio, Al 7075 was extensively applied in aircraft engines and wings. Al 7075 has higher hardness, higher strength, excellent wear resistance, and high-temperature corrosion protection; it is in need of further enhancement of properties for increasing its applicability. Titanium dioxide, also known as titanium (IV) oxide or titanium is the naturally occurring oxide of titanium, chemical formula TiO₂. When used as a pigment, it is called titanium white, Pigment White 6 (PW6), or CI 77891. Generally, it is sourced from limonite, retilite and anatase. It has a wide range of applications, including paint, sunscreen and food coloring. When used as a food coloring, it has E number E171. World production in 2014 exceeded 9 million metric tons. It has been estimated that titanium dioxide is used in two-thirds of all pigments. Both the oxides, TiO₂ and SnO₂ have identical tetragonal crystal structure but different polymorphs. TiO₂ can be crystallized in rutile, anatase or brookite structures. Among these three polymorphs, rutile and anatase have been investigated in detail by many researchers due to its easy preparation and potential industrial applications. The binary metal oxides exhibit a meta-stable crystal form which is different from the original structure when different conditions of pressure and temperature are applied. But it is possible to have this meta-stable state at ambient condition if grain size of these materials reduces to nanometre scale. Among these three phases of TiO₂, rutile is thermodynamically stable at room temperature while anatase is kinetically stable and can be converted to rutile at higher temperature. These polymorphic phases show considerably enhanced surface properties at nanoscale. Graphite has been in use since the 15th century. Pencil marking is formed by sheets of graphite sliding off and settling onto the paper. However, now, graphite has found use in many different applications other than as a writing tool. Graphite is composed of extremely strong fibers made of a series of stacked parallel layer sheets. The material is black in colour and optically opaque. It is inert to weathering and demonstrates softness graded below talc. It is used for applications in paints, carbon additives, electrical brushes, conductive coatings, batteries, dry-film lubricants, lubricating oils and greases thanks to its greasy friction-resistant properties. The objective of this work is to evaluate the mechanical behaviour of Al-7075 + Gr + by varying nano TiO₂ reinforcement particles with constant 5 wt% Gr in an Al 7075 aluminum alloy.

IV. EXPERIMENTAL RESULTS

As per the ASTM E8 standard [9] the tensile test was carried out on the cut specimens using computerised universal testing machines at room temperature to study different properties like modulus of elasticity, ultimate tensile strength, percentage of elongation and failure strain. Figure 1 shows the dimensions of test specimens as per ASTM E8 standards.

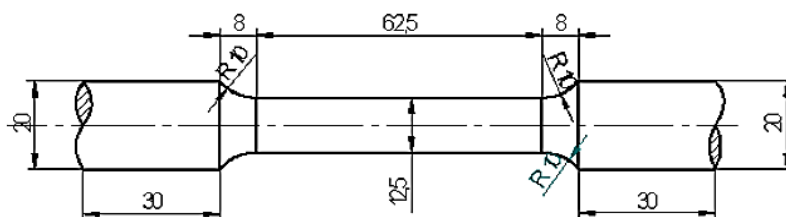


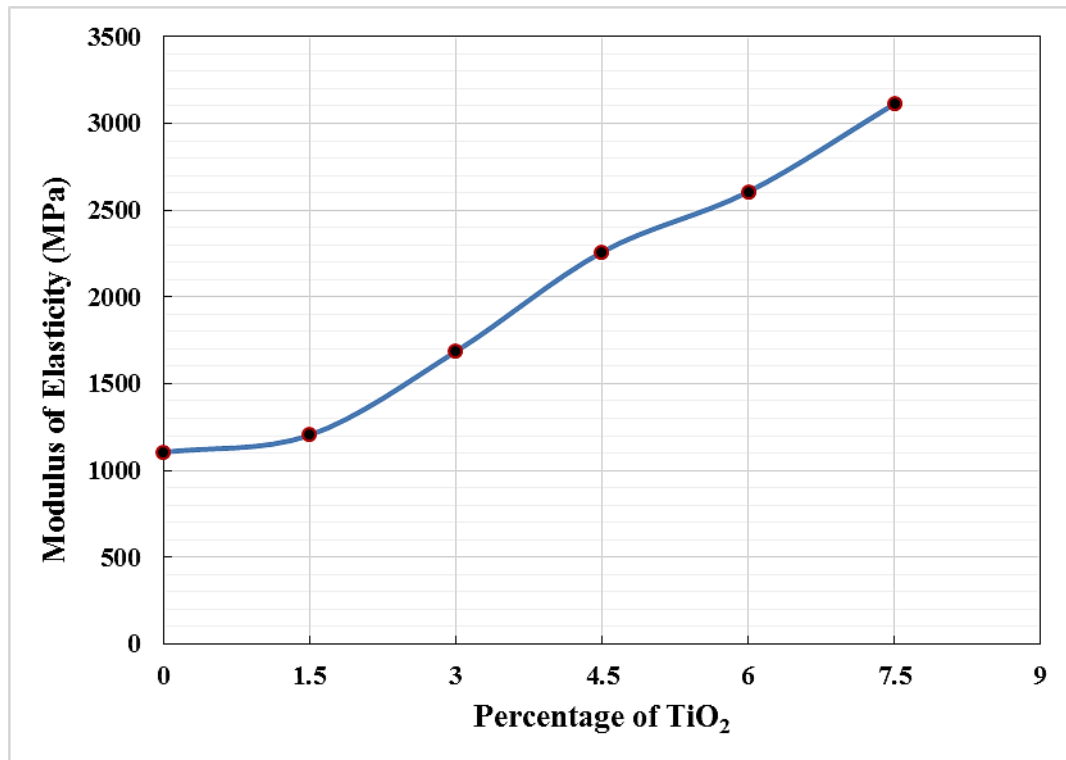
Fig. 1. ASTM E8- Tensile specimen dimensions

The specimen composition selected for this study is given in Table 1.

Table 5: Specimen Composition Details

Sl. No.	Specimen composition	Specimen Code
1	Al 7075 + 5 wt% Gr	[SP]
2	Al 7075 + 5 wt% Gr + 1.5 wt% TiO ₂	[SP-1]
3	Al 7075 + 5 wt% Gr + 3 wt% TiO ₂	[SP-2]
4	Al 7075 + 5 wt% Gr + 4.5 wt% TiO ₂	[SP-3]
5	Al 7075 + 5 wt% Gr + 6 wt% TiO ₂	[SP-4]
6	Al 7075 + 5 wt% Gr + 7.5 wt% TiO ₂	[SP-5]

Figures 1 to 5 show the results of the tensile test. The strain rate selected was 2mm/min to reveal properties like modulus of elasticity, ultimate tensile strength, ductility and failure strain. Figure 2 represents the modulus of elasticity variation from 1.5 to 7 wt. % of nano TiO₂ dispersions in metal lattice composite. When compared to 1.5 wt % of nano TiO₂ composites with 7 wt. % of nanocomposites, there has been an increase of 61.31 % in modulus of elasticity. The increase in modulus of elasticity of the nanocomposite is clear due to the hard nano TiO₂ ceramic particles that contribute to the quality by delectating the aluminum network and bringing about more quality resistance of the composite against the connected ductile load.

Fig. 2. Variation of modulus of elasticity with increase in TiO₂

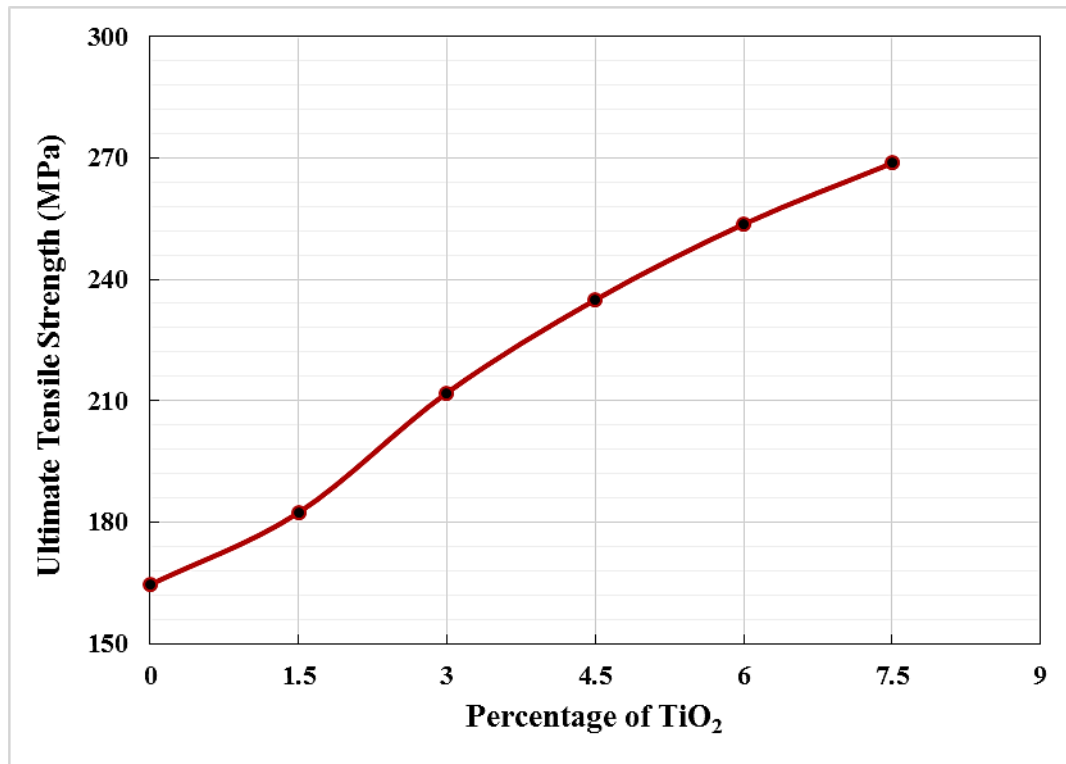


Fig. 3. Variation of ultimate tensile strength with increase in TiO₂

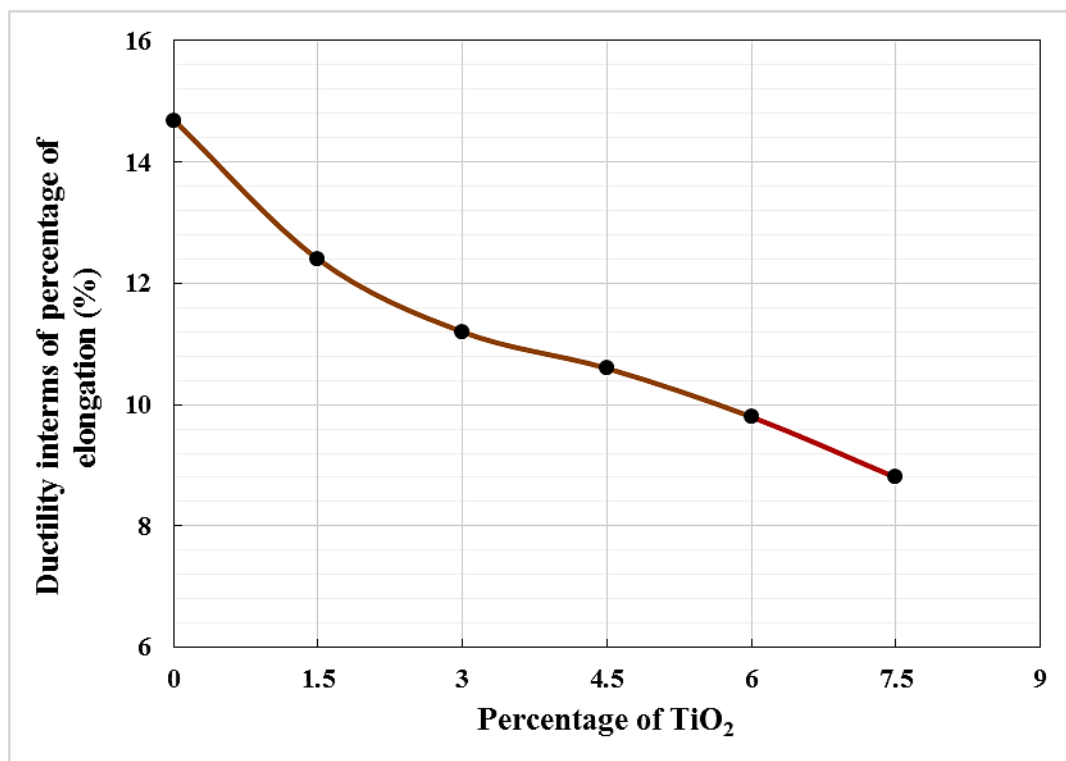


Fig. 4. Variation of ductility with increase in TiO₂

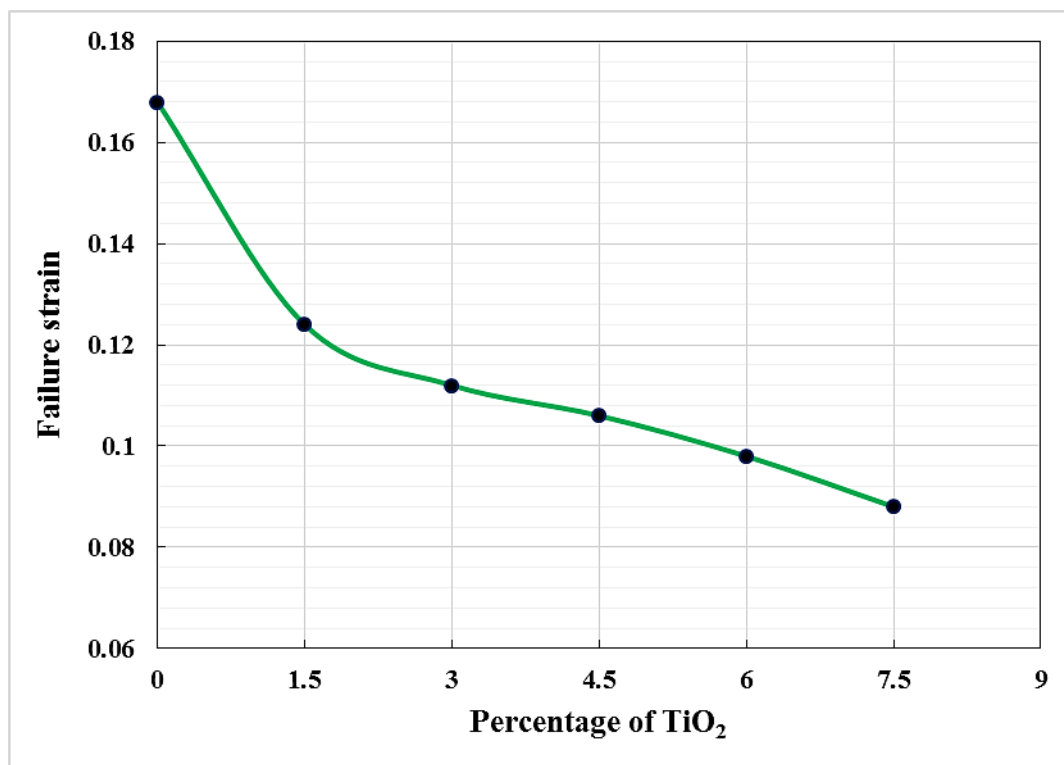
Fig. 5. Variation of failure strain with increase in TiO₂

Figure 3 represents the ultimate tensile strength (UTS) variation from 1.5 to 7 wt. % of nano TiO₂ dispersions in metal lattice composite. When compared to 1.5 wt % of nano TiO₂ composites with 7 wt. % of nanocomposites, there has been an increase of 47.35% in UTS. The improvement in UTS is credited by the hard nano ceramic TiO₂ particulates, which confers quality to the framework mixture, in this way, giving improved solid rigidity. The expansion of these hard-nanoparticles may have offered rise to huge lasting compressive unease generated in accordance with cementing because of the contrast in coefficient of development between flexible matrix and brittle nanoparticles.

Figure 4 denotes the ductility variation (in terms of percentage of elongation) variation from 1.5 to 7 wt. % of nano TiO₂ dispersions in metal lattice composite. When compared to 1.5 wt % of nano TiO₂ composites with 7 wt. % of nanocomposites, there has been a decrease of 29.03% in ductility. This diminishing in rate prolongation in association with the matrix and reinforcement is a most commonly occurring disadvantage in particulate prepared metal matrix composites.

Similarly, figure 5 characterizes the fracture strain variation from 1.5 to 7 wt. % of nano TiO₂ dispersions in metal lattice composite. When compared to 1.5 wt % of nano TiO₂ composites with 7 wt. % of nanocomposites, there has been a decrease of 29.03% in fracture strain. Hence, from these results it was observed that with increase in wt % of nano TiO₂ particles the developed composite material has reduced its ductility. Owing to this brittle nature, when subjected to impact loads, they undergo catastrophic failure with little or no plastic deformation. Further, increase in wt. % of nano TiO₂ reinforcements also leads to increase in void percentage in metal lattice composite.

V. CONCLUSION

In this research, the mechanical behaviour of Al-7075 + Gr + by varying nano TiO₂ reinforcement particles with constant 5 wt% Gr in an Al 7075 aluminum alloy have been evaluated by varying nano TiO₂ reinforcement particles from 1.5 to 7 wt. % of reinforcement. Compared to unreinforced Al-7075 alloy, the mechanical properties of Al-7075 + Gr-7wt. % nano TiO₂ composite is larger. As a result of strain localization, the fracture surface of the composite material consists of small voids. Owing to the brittle nature with increase in TiO₂ reinforcement particles, when subjected to the same loads, they undergo catastrophic failure with little or no plastic deformation.



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