

# Experimental Studies on Mechanical Characterizations of Silicon Nitride and Alumina added Al7075 Hybrid Composite for Various Engineering Applications

T. Karuppusamy, K. Kathir Balaji, Senthil Kumar Madasamy, Beena Stanislaus Arputharaj, Parvathy Rajendran\*, Arunkumar Karuppasamy, Vijayanandh Raja\*

**Abstract:** The present investigation is aimed at studying the influence of alumina and silicon nitride reinforcement particles in addition to the Al 7075 alloy on the hardness, wear, tensile, and impression creep behaviour. Three different composite specimens such as Al 7075 + 5 % alumina, Al 7075 + 5 % Silicon nitride, and Al 7075 + 2.5 % Silicon nitride + 2.5 % Alumina were fabricated using a stir casting process and the prepared composites were subjected to hardness, dry sliding wear test using pin on disc tribometer, tensile testing and impression creep tests. From the results, it was observed that the hardness of the Al 7075 alloy increases with the addition of both silicon nitride and alumina and Al 7075 + 2.5 % Silicon nitride + 2.5 % Alumina exhibited the maximum hardness of the composite specimens. Al 7075 + 2.5 % Silicon nitride + 2.5 % Alumina showed a 75% increase in wear resistance in comparison with the Al 7075 alloy and it also shows an improvement in creep and tensile properties.

**Keywords:** creep; friction; hardness; hybrid aluminium composite; metal matrix composite; tensile test

## 1 INTRODUCTION

Aluminium Matrix Composites (AMCs), a category of lightweight material systems. The unreinforced aluminium metal lacks the strength, rigidity, creep resistance, and wear resistance that the aluminium matrix composites do. Of all the commercial aluminium alloys, 7075 is an incredibly popular choice as a matrix material to prepare metal matrix composites. The addition of reinforcements like silicon nitride in the matrix of Al7075 alloy resulted in improvement in mechanical properties [1-3]. There are studies on the improvement in wear resistance with increase in weight percentage of combination of reinforcements such as TaC+Si<sub>3</sub>N<sub>4</sub>+Ti in the Al7075 matrix alloy [4-6]. A hybrid composite consists of addition of more than one reinforcement particle in the matrix. Al 7075 hybrid composites are widely used in aerospace and automobile industries owing to their higher specific strength. Some of the notable applications include aircraft fuselage, wings, tail section, satellite frames, battery enclosures etc [7-10]. This research work focusses on such Al7075 hybrid composites, its mechanical properties, etc. Al 7075 hybrid composites are manufactured by the addition of 5 % silicon carbide and 2.5 % alumina and were subjected to mechanical property evaluations. It was observed that the addition of secondary particles resulted in finer grain size microstructure and resulted in hardness value improvement [11-14]. Baradeswaran et al. fabricated Al7075 metal matrix composites by the addition of alumina particles in the matrix and studied their properties. From the results, they have concluded that the increase in weight percentage of alumina particles increases the tensile strength of the materials [15]. Moona et al. studied the Al7075 hybrid composite containing 1.5% of aluminium oxide, 1.5% of silicon carbide and 1.5 % eggshell particles and concluded that fatigue strength of such materials is greatly enhanced [16]. From the literature survey, it was found that there exists a significant gap in the research works in the area of silicon nitride and alumina added Al

7075 alloys and the characterization of such fabricated composites. There is minimal work reported in the area of impression creep behaviour of such composites. So, in the current study, silicon nitride and alumina are added to Al7075 alloy to create aluminium hybrid composites, and the mechanical characteristics such as hardness. Tensile, wear, impression creep of these composites are examined [17-20].

## 2 EXPERIMENTAL WORK

The chemical composition of the Al 7075 alloy is given in Tab. 1.

**Table 1** Chemical composition of Al7075 alloy

Element	wt.%
Cr	0.18-0.28
Cu	1.2-2
Fe	0.5
Mg	2.1-2.9
Mn	0.3
Si	0.4
Ti	0.2
Zn	5.1-6.1
Al	Remaining

The silicon nitride and alumina particles are added to the base alloy to improve its strength, hardness, creep resistance, and wear resistance. The compositions of fabricated specimens are shown in Tab. 2.

**Table 2** Fabricated specimen compositions

Sl. No	Compositions (wt.%)
1	Al 7075 Alloy
2	Al 7075 + 5% Silicon Nitride
3	Al 7075 + 5% Alumina
4	Al 7075 + 2.5% Silicon Nitride + 2.5% Alumina

### 2.1 Stir Casting Process

Stir casting process was used for the fabrication of nitride and alumina-reinforced Al7075 alloy hybrid composites. The

stir casting apparatus used for the manufacturing of composites are shown in Fig. 1. Al 7075 alloy is placed in the graphite crucible, and melting of the alloy is done at 720 °C and then mixing of reinforcement particles were carried out using a stirrer coated with graphite. Degassing of molten metal was carried out at 787 °C. Then the stirrer was inserted into the graphite crucible, and it is rotated at 600 rpm for maintaining proper vortex and achieving uniform mixing of the reinforcement particles. The reinforcement particles were preheated at a temperature of about 400 °C for a period of 2 hours and then the reinforcement particles were added to the molten aluminium alloy. Magnesium powders were added in small quantities during stirring to increase the wettability between matrix and reinforcement particles. Mechanical stirring was carried out for 5 minutes, and at the end of mixing, the molten materials were poured into a dried, preheated metallic mould of diameter 30 mm and length 150 mm. Bottom pouring was done to prevent the reaction between the atmosphere and molten composites during pouring. After solidification, the as-cast composites were removed from the die [9-12]. The solidified composite along with the die is shown in Fig. 2.



Figure 1 Stir Casting Apparatus



Figure 2 Solidified composite specimen

## 2.2 Hardness Studies

The hardness studies were carried out using a Rockwell Hardness testing machine at a load of 1 kg for a dwell time of 10 seconds. The hardness tests were performed according to ASTM E-92 standards. Specimens were polished before

taking hardness measurements to remove scratches and surface irregularities using the standard metallographic procedure. Ten readings were taken for each sample to ensure repeatability, and the average values are noted [13].

## 2.3 Wear Studies

A pin-on-disc wear testing apparatus (Model: TE-165-POD Magnum) connected to the data acquisition device was used to conduct dry sliding wear tests, as shown in Fig. 3. The experiments were carried out in accordance with ASTM G99-05 specifications. The experiments were carried out with a steady disc speed of 1 m/s at room temperature. The pin specimen is made to rub against the rotating steel disc for a sliding distance of 1000 m [14-16]. During the tests, the wear loss of the pin specimen is measured using the LVDT transducer with an accuracy of 1.0 µm. During the tests, the wear loss during the tests is continuously recorded in the system. The samples are weighed before and after wear tests manually using an electronic weighing balance to confirm the results obtained using a data acquisition system. The specimen dimensions used for wear testing are of 10 mm diameter and 25 mm length [17-18]. Fig. 4 shows the specimen which is used for wear test.



Figure 3 Pin-on-disc wear testing machine



Figure 4 Specimen used for Wear Test

## 2.4 Tensile Testing

Dark tensile testers are used to evaluate the tensile strength of newly developed composite materials (Model: UTB9052). The samples have been made in accordance with ASTM E-8 standards; Fig. 5 depicts the samples used for tensile testing. The tensile sample has a diameter of 6 mm and a length of 30 mm. The composition of specimens used for tensile studies is given in Tab. 1. The load-displacement data are obtained in the system attached with the tensile tester, and then a plot of stress versus strain is obtained for each specimen [19-20].



Figure 5 Specimens used for tensile testing



Figure 6 Impression creep testing machine

## 2.5 Creep Studies

The creep tests are carried out using impression creep testing machine (SPANKTRONICS). For creep tests, cylindrical specimens of 10 mm diameter and 10 mm height are used. The specimens are polished according to a standard metallographic procedure to remove the scratches present in the surface and the specimen is placed below the indenter. After sample preparation, the specimen is placed beneath the indenter as the first stage. The object is positioned beneath the 1.5 mm diameter tungsten carbide indenter after the lock screw is loosened to raise the furnace. The necessary temperature is established in the temperature controller after adding the small load. At this point, the thermocouple is introduced to measure the furnace's interior temperature. According to the literature study that was done, creep tests are conducted on all examples at a constant temperature of about 200 °C. Before adding significant weight, the sample is kept at this temperature for a 1 hour. Impression depth vs. time graph is collected by the data collection device and displayed on the monitor. The impression creep testing machine is shown in Fig. 6. The impression creep tests are carried out for Al7075 alloy and hybrid composites at a constant temperature of 200 °C and a constant load of 20 kg. The dwell time for carrying out creep tests was 2 hours.

## 3 RESULTS AND DISCUSSION

### 3.1 Hardness Results

Al7075+5% Silicon nitride specimen shows an increase in hardness of about 5% than Al7075 alloy due to the presence of Si<sub>3</sub>N<sub>4</sub> particles in the matrix. Al7075+5% Al<sub>2</sub>O<sub>3</sub> specimen shows an increase in hardness of about 3% than Al7075 alloy due to the presence of Al<sub>2</sub>O<sub>3</sub> particles in the matrix. Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub> specimen shows an increase in hardness of about 14% than Al7075 alloy due to the presence of combination of Si<sub>3</sub>N<sub>4</sub> particles and Al<sub>2</sub>O<sub>3</sub> particles in the matrix. Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub> specimen exhibited higher hardness values of the investigated specimens. The increase in hardness is due to the addition of hard ceramic reinforcements in the matrix of Al7075 which acts as nucleation sites and refines the microstructure and thus resulting in increment in hardness values. The comprehensive hardness behaviour results of various combinations of this proposed aluminium metal matrix hybrid composites are revealed in Fig. 7.

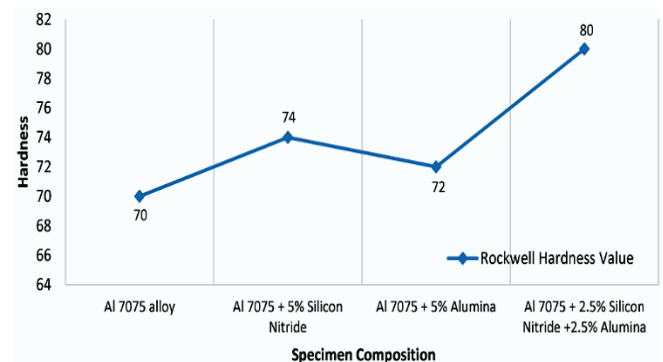


Figure 7 Rockwell Hardness values for Al7075 alloy and its composites

### 3.2 Wear Studies

The wear loss decreases by the addition of both silicon nitride and alumina reinforcements in the matrix. Fig. 8 shows the wear curves of Al7075, Al7075+5% Si<sub>3</sub>N<sub>4</sub>, Al7075 +5% Al<sub>2</sub>O<sub>3</sub> and Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub>. It is observed from Fig. 8, that the wear resistance of Al7075+5% silicon nitride specimen is improved of about 29% than Al7075 alloy. The wear resistance of Al7075+5% alumina specimen is improved of about 44% than Al7075 alloy. The wear resistance of Al7075+2.5%, silicon nitride+2.5% alumina specimen is improved of about 75% than Al7075 alloy. The Al7075 +2.5%silicon nitride+2.5% Alumina showed maximum wear resistance of the investigated specimens. The material loss due to wear for Al7075 + 2.5% silicon nitride + 2.5% Alumina particles at the end of wear test were nearly 50 microns whereas the weight loss due to wear for the Al7075 alloy was found to be 197 microns. The hard nature of silicon nitride particles and alumina particles lowers the wear loss of composite specimens. The higher wear resistance of hybrid composite can be attributed to the presence of hard reinforcement particles like silicon nitride and alumina, which bears the load at the surface and prevent the stress/load concentration on softer Al7075 matrix. The hardness of these ceramic particles is very high and acts as abrasion resistant phases leading to better wear resistance. The losses of material due to wear of all the investigated specimens are given in Fig. 9.

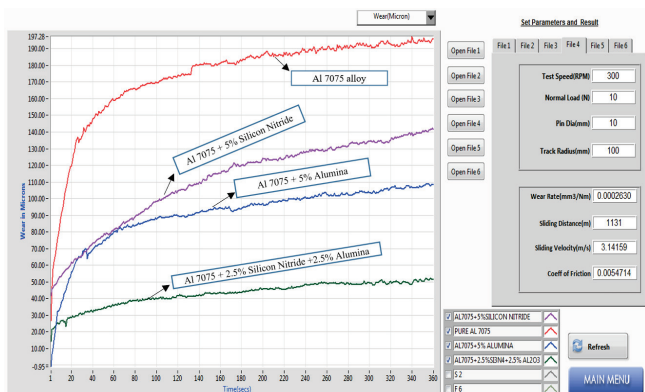


Figure 8 Wear curves of Al7075, Al7075+5% Si<sub>3</sub>N<sub>4</sub>, Al7075 +5% Al<sub>2</sub>O<sub>3</sub> and Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub>

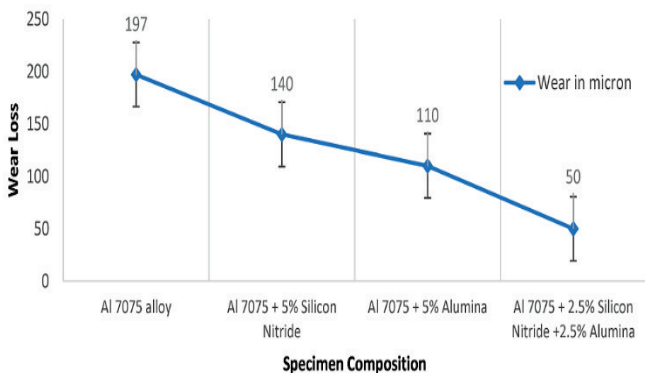


Figure 9 Wear loss (in microns) of Al7075 alloy and composites after wear testing

### 3.3 Frictional Force

Fig. 10 shows the variation of frictional force of Al7075, Al7075+5% Si<sub>3</sub>N<sub>4</sub>, Al7075 +5% Al<sub>2</sub>O<sub>3</sub> and Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub>. From the figure the variation of frictional force varies between 0 to 4.5 N for constant load. The composite specimens showed lower frictional force values due to the presence of reinforcement particles. The unreinforced alloy showed more fluctuation than the composite specimens because of the increasing tangential force between pin and disc surfaces. The lower frictional force values for hybrid composites indicate that the wear loss of the composites was less than the Al7075 alloy. Wear failure of the material will be more in the presence of higher frictional forces between the pin and the disc surface.

When alumina and silicon nitride mixes with Al7075 as reinforcements, the fluctuation of frictional force occurs initially. After it reaches 240 sec, friction reduces, and it is maintained constant.

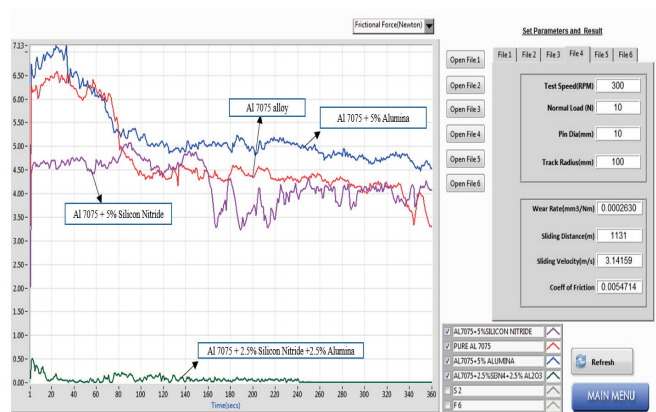


Figure 10 Variation of frictional force of Al7075, Al7075+5% Si<sub>3</sub>N<sub>4</sub>, Al7075 +5% Al<sub>2</sub>O<sub>3</sub> and Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub>

### 3.4 Coefficient of Friction

Fig. 11 depicts the variation in the coefficient of friction of aluminium hybrid composites. The coefficient of friction plays a significant role in many areas of engineering and physics, including the design of brakes, tires, and other frictional components.



Figure 11 Variation in the coefficient of friction of Al7075 composites

From Fig. 11, the coefficient of friction of Al7075 composites varies from 0.03 to 0.5 than the Al7075 alloy. When alumina and silicon nitride mixes with Al7075 as reinforcements, the fluctuation of coefficient of friction occurs initially. After it reaches 240 sec, friction reduces and it is maintained constant.

### 3.5 Creep Studies

Al7075 hybrid composites are subjected to impression creep tests under cast conditions to study the effect of these composites' creep behaviour. Impression depth vs Time graph obtained from the creep tests for the Al7075 alloy is shown in Fig. 12.

The impression depth of Al7075 alloy is found to be 0.361 mm. The creep curves of Al7075+5% Si<sub>3</sub>N<sub>4</sub> is shown in Fig. 13. The impression depth of Al7075 alloy+5% Si<sub>3</sub>N<sub>4</sub> is found to be 0.195 mm. It is observed that the addition of reinforcement particles like silicon nitride can reduce creep deformation with increased creep resistance. The creep deformation of Al7075+5% Si<sub>3</sub>N<sub>4</sub> composite is lower than the creep deformation of Al7075 alloy. The creep curves of Al7075+5% Al<sub>2</sub>O<sub>3</sub> is shown in Fig. 14.

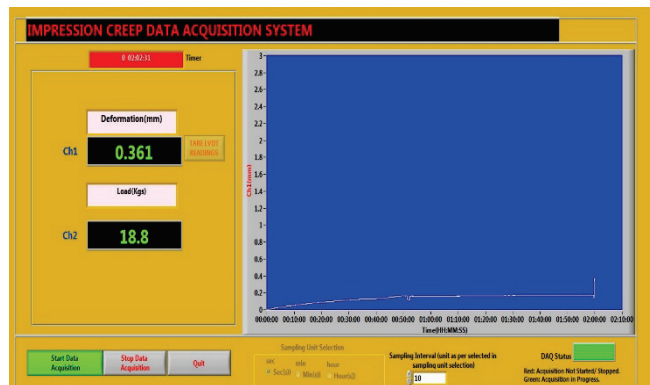


Figure 12 Impression Depth vs. Time graph for Al7075 alloy

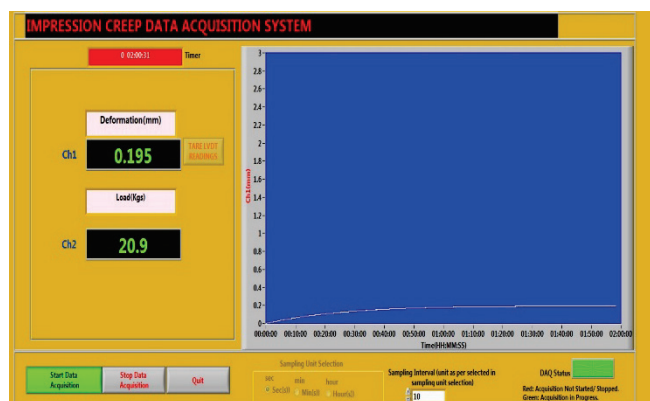


Figure 13 Impression Depth vs. Time graph for Al7075+5% silicon nitride

The impression depth of Al7075 alloy+5% Al<sub>2</sub>O<sub>3</sub> is found to be 0.175 mm. It is observed that the addition of 5% alumina can reduce creep deformation. This is due to the hindrance of dislocation motion by precipitates, present in the matrix. This reduces dislocation motion of creep leading to enhanced creep resistance. The creep deformation of Al7075+5% Al<sub>2</sub>O<sub>3</sub> composite is lower than the creep

deformation of Al7075 alloy. The creep curves of Al7075+2.5% Si<sub>3</sub>N<sub>4</sub>+2.5% Al<sub>2</sub>O<sub>3</sub> is shown in Fig. 15.

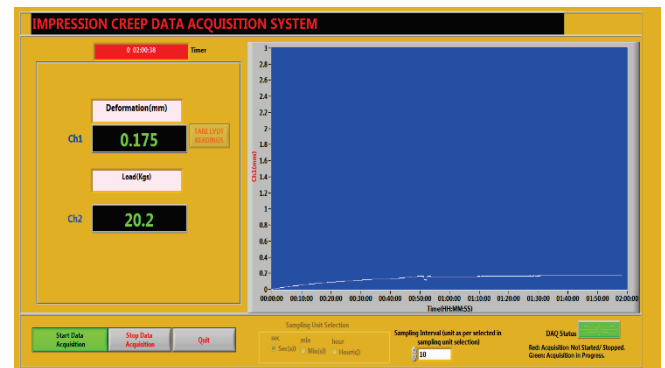


Figure 14 Impression Depth vs. Time graph for Al7075+5% alumina

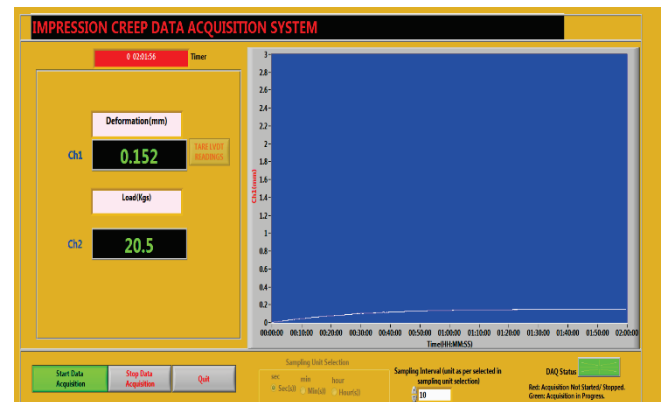


Figure 15 Impression Depth vs. Time graph for Al7075+2.5% Si<sub>3</sub>N<sub>4</sub>+2.5% Al<sub>2</sub>O<sub>3</sub>

The impression depth of Al7075 alloy+2.5% Si<sub>3</sub>N<sub>4</sub>+2.5% Al<sub>2</sub>O<sub>3</sub> is found to be 0.152 mm. In comparison with the fabricated specimens Al7075 alloy+2.5% Si<sub>3</sub>N<sub>4</sub>+2.5% Al<sub>2</sub>O<sub>3</sub> composites exhibit greater creep resistance with less creep deformation. From the Creep deformation graphs, it is evident that the creep resistance of the Al 7075 matrix composite increases. This is because silicon nitride and alumina particle acts as a barrier for dislocation movement. Hence dislocation pile-ups occur and therefore more amount of stress or higher temperature are required for the dislocation to overcome the barrier leading to enhanced creep strength. The comparison of creep curves for all the investigated specimens are shown in Fig. 16.

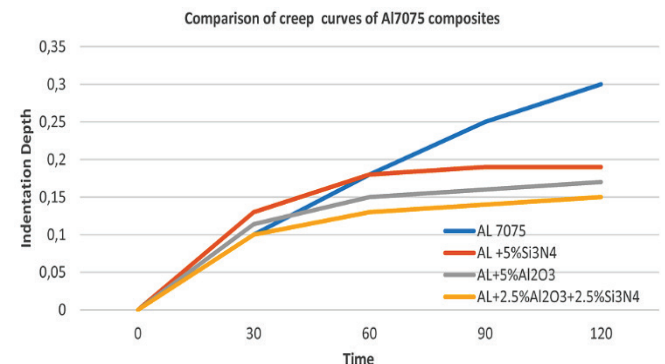


Figure 16 Comparison of creep curves (Indentation depth in mm & Time in minutes) for all the investigated specimens

### 3.6 Tensile Studies

The tensile tests have been performed for both Al7075 alloy and Al7075 hybrid composites. The hybrid composites exhibited higher tensile strength than that of the base 7075 alloy due to the fine grain structure in composite materials that have been obtained during solidification. The presence of reinforcement particles in the molten metal acts as nucleation sites for grain nucleation, and hence it resulted in finer grain size. According to the Hall-Petch relationship, the finer grain size will result in higher tensile strength. The presence of hard reinforcement particles like silicon nitride and alumina hinders the movement of dislocations and hence plastic deformation is restricted, which also contributes to an increase in tensile strength of the composites. The tensile stress values for the tested specimens are shown in Fig. 17.

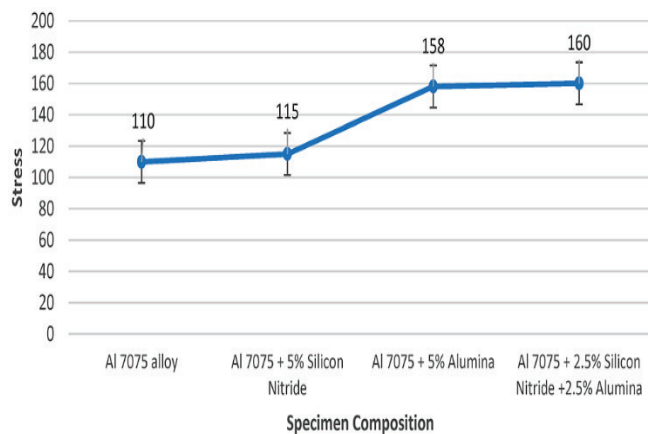


Figure 17 Stress values (MPa) of tested specimen

The tensile strength of Al 7075 alloy was 110 MPa, whereas Al7075 + 5% silicon nitride composite was 115 MPa, there is marginal improvement in tensile strength due to its addition. However, the 5% alumina added Al7075 alloy exhibited significant improvement in tensile strength, which is around 158 MPa. Al7075+2.5% Si<sub>3</sub>N<sub>4</sub> +2.5% Al<sub>2</sub>O<sub>3</sub> exhibits maximum tensile stress of 160 MPa when compared to another composite specimen, due to higher volume fraction of hard ceramic particles in the matrix contributing to Orowan strengthening, dislocation hindering mechanisms and fine grain structures.

### 4 CONCLUSIONS

The major conclusions drawn from the present study on experimental investigations on the effect of reinforcements on mechanical properties of hybrid Al7075 composites are summarized.

- 1) Al7075+2.5% Al<sub>2</sub>O<sub>3</sub>+2.5% Si<sub>3</sub>N<sub>4</sub> exhibits high hardness when compared to other composite specimens.
- 2) The hybrid composite specimen exhibited lower wear loss (50 microns) than all the investigated composite samples and is more suitable for applications demanding higher wear resistance.
- 3) The composite specimens exhibited higher creep resistance than the Al 7075 alloy and Al7075+2.5% Al<sub>2</sub>O<sub>3</sub>+2.5% Si<sub>3</sub>N<sub>4</sub> showed lower impression creep

deformation (0.152 mm) among the fabricated specimens.

### Acknowledgements

Experimental test facilities are been provided by the authors' parent institution, which is Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India. So, all the authors of this article would like to thank all the management of people and higher professionals.

### 5 REFERENCES

- [1] Ahmad, F., Lo, S. H. J., Aslam, M. & Haziq, A. (2013). Tribology behaviour of alumina particles reinforced aluminium matrix composites and brake disc materials. *Procedia Engineering*, 68(0), 674-680. <https://doi.org/10.1016/j.proeng.2013.12.238>.
- [2] Alhaji Ibrahim, M., Sahin, Y., Yusuf Gidado, A. & Said, M. (2019). Mechanical Properties of Aluminium Matrix Composite Including SiC/Al<sub>2</sub>O<sub>3</sub> by Powder Metallurgy-A Review. *Global Scientific Journal*, 7(3), 23-38.
- [3] Natrayan, L. & Senthil Kumar, M. (2018). Study on Squeeze Casting of Aluminum Matrix Composites—A Review. In: Antony, K. & Davim, J. (eds) *Advanced Manufacturing and Materials Science. Lecture Notes on Multidisciplinary Industrial Engineering*. Springer, Cham. [https://doi.org/10.1007/978-3-319-76276-0\\_8](https://doi.org/10.1007/978-3-319-76276-0_8)
- [4] Pradeep Kumar, J., Robinson Smart, D. S. & Selvan, C. P. (2018). Experimental evaluation of strength and wear rate of AA7075/TAC/Si<sub>3</sub>N<sub>4</sub>/Ti nano hybrid metal matrix composite. *International Journal of Mechanical Engineering and Technology*, 9(11), 1690-1698.
- [5] Surappa, M. K. (2003). Aluminium matrix composites: Challenges and opportunities. *Sadhana - Academy Proceedings in Engineering Sciences*, 28(1-2), 319-334. <https://doi.org/10.1007/BF02717141>
- [6] Senthil Kumar M. et al. (2018). Experimental investigations on mechanical and microstructural properties of Al<sub>2</sub>O<sub>3</sub>/SiC reinforced hybrid metal matrix composite. *IOP Conf. Ser.: Mater. Sci. Eng.* 402 012123 <https://doi.org/10.1088/1757-899X/402/1/012123>
- [7] Cui, Y., Wang, L. & Ren, J. (2008). Multi-functional SiC/Al composites for aerospace applications. *Chinese Journal of Aeronautics*, 21(6), 578-584. [https://doi.org/10.1016/S1000-9361\(08\)60177-6](https://doi.org/10.1016/S1000-9361(08)60177-6)
- [8] Pitchayapillai, G., Seenikannan, P., Raja, K. & Chandrasekaran, K. (2016). Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum Disulphide. *Advances in Materials Science and Engineering*, 2016. <https://doi.org/10.1155/2016/6127624>
- [9] Anand Babu, K., Venkataramaiah, P. & Dharma Reddy, K. (2018). Mechanical characterization of aluminium hybrid metal matrix composites synthesized by using stir casting process. *Materials Today: Proceedings*, 5(14), 28155-28163. <https://doi.org/10.1016/j.matpr.2018.10.058>
- [10] Arun Kumar, S., Hari Vignesh, J. & Paul Joshua, S. (2021). Investigating the effect of porosity on aluminium 7075 alloy reinforced with silicon nitride (Si<sub>3</sub>N<sub>4</sub>) metal matrix composites through STIR casting process. *Materials Today: Proceedings*, 39(1), 414-419. <https://doi.org/10.1016/j.matpr.2020.07.690>
- [11] Pratap Singh, A., Senthil Kumar, M., Deshpande, A., Jain, G., Khamesra, J., Mhetre, S., Awasthi, A. & Natrayan, L. (2021). Processing and characterization mechanical properties of

- AA2024/Al<sub>2</sub>O<sub>3</sub>/ZrO<sub>2</sub>/Gr reinforced hybrid composite using stir casting technique. *Materials Today: Proceedings*, 37(2), 1562-1566. <https://doi.org/10.1016/j.matpr.2020.07.156>
- [12] Mistry, J. M. & Gohil, P. P. (2019). Experimental investigations on wear and friction behaviour of Si<sub>3</sub>N<sub>4</sub>p reinforced heat-treated aluminium matrix composites produced using electromagnetic stir casting process. *Composites Part B: Engineering*, 161, 190-204. <https://doi.org/10.1016/j.compositesb.2018.10.074>
- [13] Devegowda, T. M. & Gurupavan, H. R. (2022). Evaluation of Microstructure and Hardness of Al-SiC Metal Matrix. *Composite Material*, 10(10), 14-16.
- [14] Liu, S., Wang, Y., Muthuramalingam, T. & Anbuechziyan, G. (2019). Effect of B<sub>4</sub>C and MOS<sub>2</sub> reinforcement on microstructure and wear properties of aluminum hybrid composite for automotive applications. *Composites Part B: Engineering*, 176, 107329. <https://doi.org/10.1016/j.compositesb.2019.107329>
- [15] Baradeswaran, A. & Elaya Perumal, A. (2014). Study on mechanical and wear properties of Al7075/Al<sub>2</sub>O<sub>3</sub>/graphite hybrid composites. *Composites Part B: Engineering*, 56, 464-471. <https://doi.org/10.1016/j.compositesb.2013.08.013>
- [16] Moona, G., Rastogi, V., Walia, R. S. & Sharma, R. (2020). Microstructure and Wear Study of Al 7075-T6/Eggshell/SiC/Al<sub>2</sub>O<sub>3</sub> Hybrid Composites. *Lecture Notes in Mechanical Engineering*, 471-481. [https://doi.org/10.1007/978-981-15-1071-7\\_39](https://doi.org/10.1007/978-981-15-1071-7_39)
- [17] Paranthaman, V., Sundaram, K. S. & Natrayan, L. (2022). Influence of SiC Particles on Mechanical and Microstructural Properties of Modified Interlock Friction Stir Weld Lap Joint for Automotive Grade Aluminium Alloy. *Silicon*, 14, 1617-1627. <https://doi.org/10.1007/s12633-021-00944-5>
- [18] Suryakumari, T. S. A. & Ranganathan, S. (2018). Preparation and Study the Wear Behaviour of Aluminium Hybrid Composite. *Materials Today: Proceedings*, 5(2), 8104-8111. <https://doi.org/10.1016/j.matpr.2017.11.497>
- [19] Kousik Kumar, R., Somasundara Vinoth, K., Senthil Kumar, M., Beena, S. A., Parvathy, R., Ahmed, H. D. & Vijayanandh, R. (2024). Experimental Studies on Microstructural, Physical, and Mechanical Characterizations of Hybrid Aluminium Metal Matrix Composites Incorporated with Cenosphere and Molybdenum Disulphide. *Journal of Engineering*, 5964256, 15 pages. <https://doi.org/10.1155/2024/5964256>
- [20] David Raja Selvam, J. & Dinaharan, I. (2017). In situ formation of ZrB<sub>2</sub> particulates and their influence on microstructure and tensile behavior of AA7075 aluminum matrix composites. *Engineering Science and Technology, an International Journal*, 20(1), 187-196. <https://doi.org/10.1016/j.jestch.2016.09.006>

#### Authors' contacts:

##### T. Karuppusamy

Department of Mechanical Engineering, Kumaraguru College of Technology,  
Coimbatore - 641049, Tamil Nadu, India  
E-mail: karuppusamy.t.mec@kct.ac.in

##### K. Kathir Balaji, Senior Engineer

Titan Company Limited,  
Bangalore-560100, Karnataka, India  
E-mail: kathirbalaji99@gmail.com

##### Senthil Kumar Madasamy

Department of Aeronautical Engineering, Kumaraguru College of Technology,  
Coimbatore - 641049, Tamil Nadu, India  
E-mail: senthilkumar.m.aeu@kct.ac.in

##### Beena Stanislaus Arputharaj

Department of Research and Innovation, Saveetha School of Engineering,  
SIMATS, Chennai-602105, Tamil Nadu, India  
E-mail: beena2192@gmail.com

##### Parvathy Rajendran

(Corresponding author)  
Department of Mechanical and Aerospace Engineering,  
United Arab Emirates University,  
Al Ain, UAE  
E-mail: aeparvathy@uaeu.ac.ae

##### Arunkumar Karuppusamy

Department of Aeronautical Engineering,  
MLR Institute of Technology, Hyderabad, Telangana, India  
E-mail: arunssksamy@gmail.com

##### Vijayanandh Raja

(Corresponding author)  
Department of Aeronautical Engineering, Kumaraguru College of Technology,  
Coimbatore - 641049, Tamil Nadu, India  
E-mail: vijayanandh.raja@gmail.com