Exploration of the mechanical characteristics of al7075 metal matrix composite enhanced with fe3o4 and pksa

Angadi Seshappa[1*], *Konka* Prudhvi Raj[2], *Bhavanasi* Subbaratnam[3], *Madupoju* Ashok Kumar[4], *B*. Indu Priya[5], *Oleg* Igorevich Rozhdestvenskiy[6]

[1]Department of Mechanical Engineering, KG Reddy College of Engineering and Technology, Hyderabad, 501501, India.
[2]Department of Mechanical Engineering, Mahatma Gandhi Institute of Technology (A),Hyderabad-500075, India.
[3]Department of Mechanical Engineering, Malla Reddy Engineering College and Management Sciences, Hyderabad-501401, India.
[4]Department of Mechanical Engineering, Narsimha Reddy Engineering College, Hyderabad-501401, India
[5]Department of CSE, GRIET, Hyderabad, Telangana, India
[6]Lovely Professional University, Phagwara, Punjab, India.

Abstract. This research primarily focuses on Aluminum hybrid compounds that have extensive applications throughout every realm of manufacturing. Hybrid metal Matrix Composites possess greatly improved physical properties and find extensive utilization across several sectors, including vehicle components and even aviation. The investigation entails using aluminum (Al-7075) as the foundational component and then incorporating iron oxide and PKSA in weight ratios of 3%, 6%, and 9% to fabricate a strengthened Hybrid Metal Matrix Composite. A manufacturing stir-casting technique is being utilized for the fabrication of such compounds. Stirred molding technology is selected because of its advantages, including a very straightforward manufacturing process, cost efficiency, and reliable distribution of reinforcement particles. The inclusion of overall reinforcement grain Fe_3O_4/PKSA is essential to defining technical composite qualities. The current examination indicated enhancements in physical properties, including elasticity, compression, as well as toughness strength. A longitudinal value at a 9% wt. strengthened Fe_3O_4/PKSA is found to be the highest at 342 MPa, while the yield strength is measured at 248 MPa, as equated to a standard Al-7075 alloy. Furthermore, the recently manufactured Al-7075/ Fe_3O_4/PKSA HMMC were subjected to microstructural examinations using SEM and EDS methodologies. The investigations demonstrated a uniform and homogeneous dispersion of Fe_3O_4/PKSA reinforcement particulates inside the mixture matrix.

* Corresponding author: a.seshappa@kgr.ac.in

1 Introduction

Al-7075 is a precipitation-hardened alloy that has remarkable specific strength and stiffness. It also has high fracture toughness, corrosion resistance, and excellent moulding performance. Designated as a super-high-strength deformation aluminium alloy, this material has strong mechanical qualities and resistance to corrosion, rendering it highly adaptable for a wide range of applications [1–4]. Its qualities are governed by aluminium compound particulates, liquid solution particulates, granular construction, as well as dislocations, and it is an essential component of construction in the aeronautical as well as automobile sectors [5–6]. Liquid processing techniques are attractive because they are both cost-effective and capable of producing complex geometric components, unlike solid processing methods. Nevertheless, a notable obstacle in liquid approaches is in attaining a consistent distribution of reinforcement and creating a strong interfacial contact between the reinforcement and the matrix material. Conquering this obstacle is essential for maximising the efficiency of composite materials produced by liquid processing[7]. The strengthening of the Al/Fe3O4 Metal Matrix composite leads to an improvement in both the hardness and tensile strength of the material, but at the price of its ductility in comparison to the base alloy. Furthermore, the composite material in question displays a ductile mode of fracture [8].

Mechanical properties of Fe3O4/ PKSA reinforced with an Al-7075 matrix composite have been the subject of little prior investigation. This experimental investigation makes use of an electric melting furnace to produce Metal Matrix Composites by use of the stir casting process. This technique seeks to address the current lack of knowledge on the mechanical characteristics of the composite and provide useful contributions to the area. Research available regarding the physical characteristics of composites consisting of Fe3O4/ PKSA reinforced with the Al-7075 matrix. The Metal Matrix Composite is produced in the present scientific investigation employing a conventional swirl molding technique inside electrical heating furnaces. This technique seeks to address the current lack of knowledge on the mechanical characteristics of the composite and provide useful contributions to the area.

2 Content Designed Techniques

This research used Al7075 alloy as its foundational metal and a composite reinforcement with Fe3O4 and PKSA at different weight percentages (3%, 6%, and 9% by weight). You can see aluminum's chemical make-up in Table 1. For the Fe3O4/PKSA, 300 Mesh was the selected particle size. Figure 1 shows the casting setup with a stirrer attached to a variable-speed motor, which was used in the manufacturing process as part of the stir casting technique[8]. Fig. 2 illustrates the fabrication process flowchart.

Table 1: Chemical Compositions of Aluminum7075.

Constituent	Cu	Cr	Ti	Mg	Zn	Fe	Mn	Si	Al
Percentage in Wt.	1.8	0.2	0.15	1.9	3.25	0.5	0.4	0.5	Balance

Fig. 1. Squeeze casting setup for MMC processing

Rough castings that met ASTM criteria were machined into tensile and compression specimens with dimensions of 9 mm by 45 mm gauge length. We used a 0.1 mm/min testing rate and an Instron universal testing equipment set to displacement control mode for the experiments. It was necessary to do several experiments before settling on the best average. In order to evaluate the Al7075 alloy and its composites with 3%, 6%, and 9% wt Fe3O4/PKSA, we measured a number of tensile characteristics and percentage elongation. In accordance with ASTM guidelines, the same machine underwent a compression test. The produced composites were analysed microstructurally using a Scanning Electron Microscope. Test samples, which were meticulously polished and had a diameter of 10 to 12 mm, were cut from the castings.

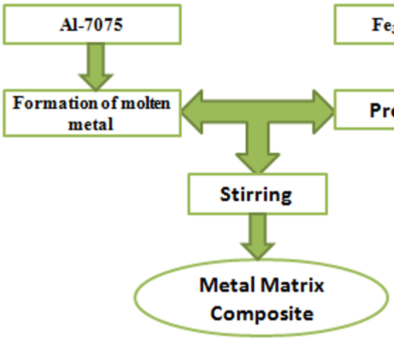


Fig. 2. Flow chart for proposed fabricated process.

- The crucible containing the weighed aluminium alloy 7075 was heated to the necessary temperature of 660 °C by maintaining it in the furnace.
- The iron oxide and PKSA particle weight percentages are 3%, 6%, and 9%, respectively.
- Another step was to warm the moulding dies.
- Incorporate degasifying chemicals to decrease porosity and prevent blowholes.
- Stir the molten metal well at 400 rpm after adding the specified percentages of iron oxide (Fe3O4) and PKSA after the temperature reaches the required value.
- Take slag out.
- After pouring the molten metal into the die, let it cool.

3 Results And Discussions

3.1. Ultimate tensile strength

Figure 3 is a graph that depicts the ultimate tensile strength (UTS) of the material in relation to the various ratios of Fe3O4 to PKSA. With an incremental addition of 0–9% by weight of Fe3O4/PKSA, it is clear that the UTS continuously increases from 190.2 MPa to 361.16 MPa. This is a clear indication of the growth of the UTS. The tensile strength of the composite material has significantly increased as a consequence of this trend, which highlights the effect of the mechanical characteristics of Fe3O4/PKSA particles on the composite composition.

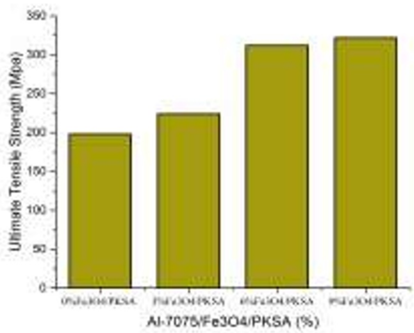


Fig.3. Ultimate Tensile Strength - Al7075 + Fe3O4/PKSA 0 to 9 wt% composite.

3.2. Yield strength

Figure 4 depicts the ratio of yield strength to weight % in a graphical representation. Upon closer inspection, it is evident that the yield strength has increased, going from 103.6 MPa to 262.16 MPa as a result of the incorporation of Fe3O4/PKSA, which ranges from 0% to 9% by weight.

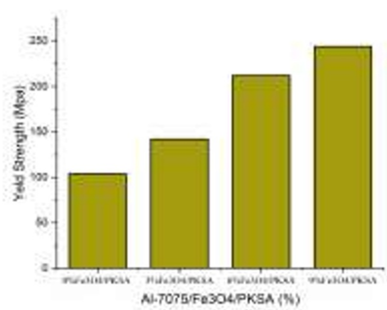


Fig. 4. Yield strength - Al7075/Fe_3O_4/PKSA 0 to 9 wt% composite.

A compact arrangement of Fe3O4/PKSA particles is responsible for the improvement in yield strength. This arrangement imparts molecular strength to the aluminium lattice, which in turn gives the composite material its strength.

3.3. Percentage of elongation

The combination of Fe3O4 and PKSA has a significant impact on the ductility of the composite, as shown in Figure 5. When Fe3O4 and PKSA particles are added in the range of 0 to 9 weight percent, the graph displays a trend that is dropping rather than increasing. Incorporating Fe3O4/PKSA into the composite material resulted in an increase in its strength, which is the cause of this decrease.

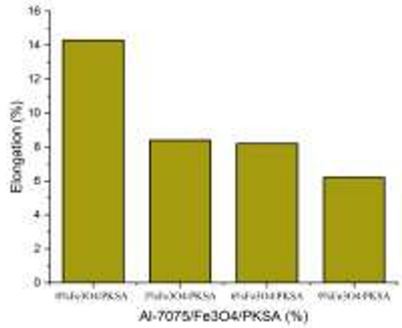


Fig. 5. Percentage Elongation of Al7075 + Fe_3O_4/PKSA 0 to 9 wt% composite.

3.4. Compression test

The ductility of the composite is shown to be affected by the mix of Fe3O4 and PKSA, as shown in Figure 5. With Fe3O4 and RHS particles being introduced in the range of 0 to 9 weight percent, the graph displays a downward trend. The insertion of Fe3O4/PKSA into the composite material resulted in an increase in the material's strength, which leads to this decrease.

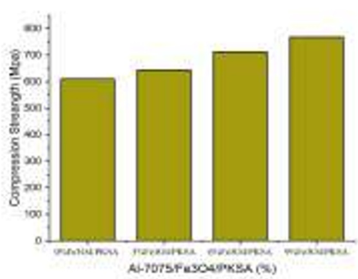


Fig. 6. Compression strength of Al7075/Fe3O4/PKSA 0 to 9 wt% composite

3.5. Hardness study

For the purpose of carrying out indentation testing on the suggested composite of Al matrix alloy, the Brinell hardness tester was used. In order to construct necessary specimens of aluminium 7075 alloy, standard metallographic processes were used. These specimens included 3%, 6%, and 9% of a reinforced Fe3O4/PKSA combination. The tests were carried out with a weight of 250 kilogrammes, a ball with a diameter of 5 millimetres, and a dwell duration of thirty seconds. Recording the values of the indentation load depth in order to determine the hardness of the material. The average data was reported after each specimen was subjected to three independent experiments that were repeated three times. As can be seen in Figure 7, the values that were recorded varied from 65.7 to 108.75 BHN. As a result of the incorporation of hard iron oxide Fe3O4/PKSA, these results demonstrate a progressive rise in the material's difficultness. There is a direct correlation between the incremental reinforcement of Fe3O4/PKSA particles and the proportionate increase in strength values.

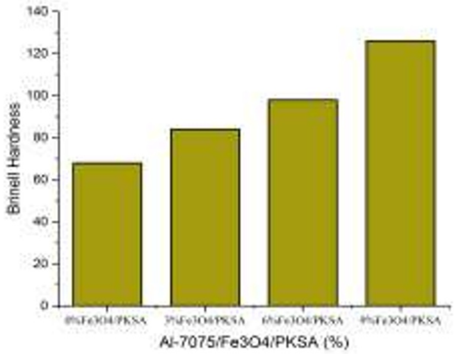
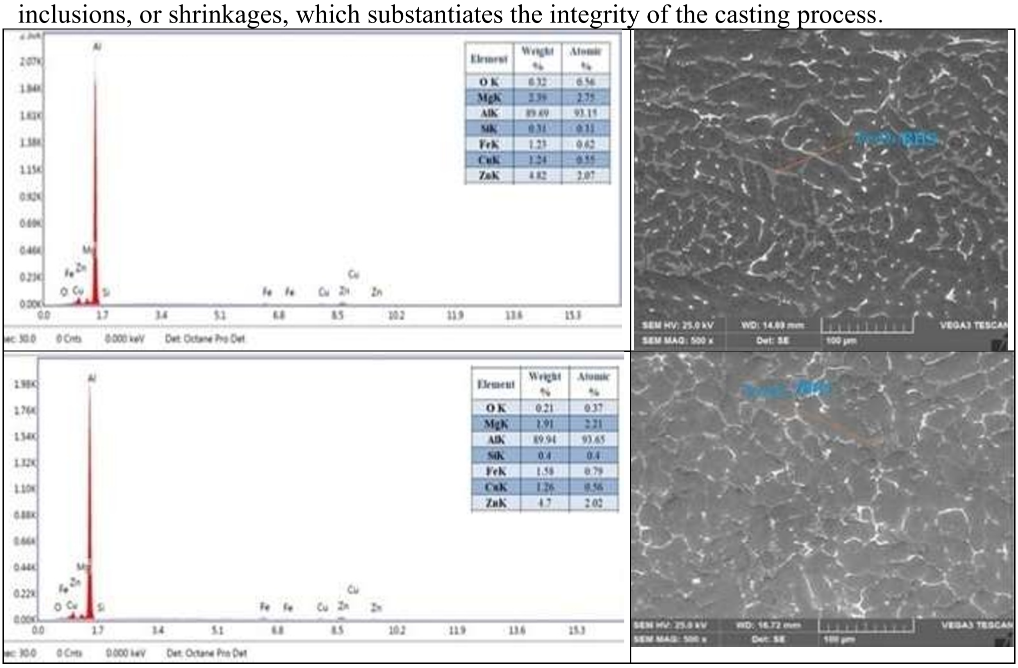


Fig. 7. Hardness of Al7075/Fe3O4/PKSA 0 to 9 wt% composite.

3.6. Microscopic studies (SEM) and energy dispersion X-ray spectroscopy (EDX)

The Tescan Vega Scanning Electron Microscope was used in order to carry out the investigation of the microstructures that were present in the composites that were manufactured. Carefully cut from the castings and then meticulously polished, the test samples had a diameter that ranged from 10 to 12 millimetres. Figure 8 shows three different SEM images of the Al7075/Fe3O4/PKSA particulate composites: a- 3% Fe3O4/PKSA, b- 6% Fe3O4/PKSA, and c- 9% Fe3O4/PKSA combinations.

Figure 8 (a), (b), and (c) illustrate photos that show a consistent distribution of Fe3O4/PKSA particles with minimum agglomeration and segregation, as well as low porosity. Both of these characteristics are present in the photographs. Particularly noteworthy is the absence of any indications of casting flaws, such as fractures, slag inclusions, or shrinkages, which substantiates the integrity of the casting process.



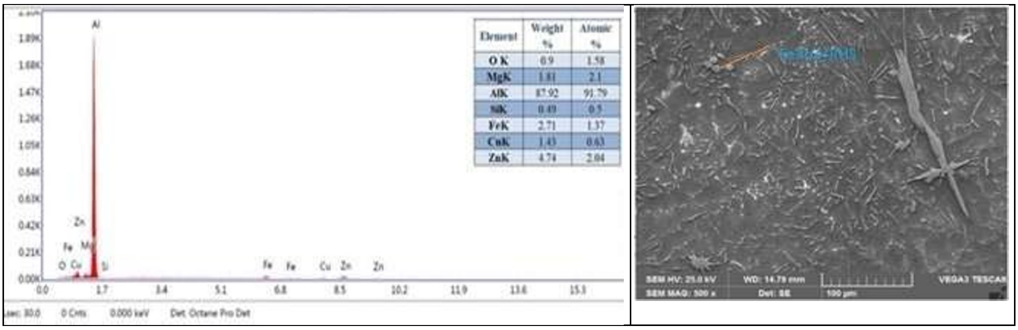


Fig. 8. Distribution of Fe3O4/PKSA particle (a) 3% Fe3O4/PKSA on the Al-matrix and EDX analysis (b) 6% Fe3O4/PKSA on the Al-matrix and EDX analysis (c) 9% Fe3O4/RHS on the Al-matrix and EDX analysis.

4 Conclusions drawn from the present work:

After conducting tensile, compression, and hardness tests, the findings obtained are an average of three different values.

- Using the stir-casting approach, it was possible to successfully create Al7075 metal matrix composites that were reinforced with 3%, 6%, and 9% weight Fe3O4/PKSA. This technique ensured that the matrix included a generally equal distribution of particles.
- When compared to the Al matrix by itself, the introduction of Fe3O4/PKSA particles into the Al7075 matrix has resulted in better mechanical characteristics.
- It is important to note that the BHN value was highest at the 9% Fe3O4/PKSA percentage. This suggests that a larger BHN value is noticed when the percentage of Fe3O4/PKSA is increased.
- In addition, the inclusion of Fe3O4/PKSA in a weight % has shown a linear rise in the density and hardness of the composite, which presents a problem in terms of preserving the essential characteristics of the base metal.
- When seen using a scanning electron microscope, the composites have a reinforcement distribution that is quite consistent.

As a conclusion, this research emphasises the stirring process as an important component that contributes to the effective production of these composites.

References

1. F.Q. Tian, N.K. Li, J.Z. Cui, Development process and direction of strengthening and toughening of ultra-high strength aluminum alloy [J], Light Alloy Process. Technol. 33 (12) (2005) 1–9.
2. A. Seshappa, B. Anjaneya Prasad Characterization and Investigation of Mechanical Properties of Aluminium Hybrid Nano-composites: Novel Approach of Utilizing Silicon Carbide and Waste Particles to Reduce Cost of Material. ISSN Silicon, 1876-990X, 2020, https://doi.org/10.1007/s12633-020-00748-z
3. B. Zhou, S. Lu, K.-l. Xu, C. Xu, Z.-Y. Wang, B.-J. Wang, Hot cracking tendency test and simulation of 7075 semi-solid aluminium alloy [J], Trans. Nonferrous Metals Soc. China 30 (2) (2020) 318–332.

4. J. Ren, R.C. Wang, Y. Feng, C.Q. Peng, Z.Y. Cai, Microstructure evolution and mechanical properties of an ultrahigh strength Al Zn Mg Cu Zr Sc (7075) alloy processed by modified powder hot extrusion with post aging [J], Vacuum 161 (2019) 434–442.
5. J.M. García-Infanta, A.P. Zhilyaev, A. Sharafutdinov, O.A. Ruano, F. Carreño, An evidence of high strain rate superplasticity at intermediate homologous temperatures in an Al Zn Mg Cu alloy processed by high-pressure torsion [J], J. Alloy. Compd. 473 (1-2) (2009) 163–166.
6. Z. Horita, T. Fujinami, M. Nemoto, T.G. Langdon, Improvement of mechanical properties for Al alloys using equal-channel angular pressing [J], J. Mater. Process. Technol. 117 (3) (2001) 288–292.
7. A. Javdani, A.H. Daeisorkhabi, Microstructural and mechanical behavior of blended powder semisolid formed Al7075/B 4 C composites under different experimental conditions, Trans. Nonferrous Metals Soc. China 28 (7) (2018) 1298–1310.
8. J. Hashim, L. Looney, M.S.J. Hashmi, Particle distribution in cast metal matrix composites - part II, J. Mater. Process. Technol. 123 (2) (2002) 258–263, https:// doi.org/10.1016/S0924-0136(02)00099-7.
9. S.K. Pradhan, S. Chatterjee, A.B. Mallick, D. Das, A simple stir casting technique for the preparation of in situ Fe-aluminides reinforced Al-matrix composites, Perspect. Sci. 8 (2016) 529–532, https://doi.org/10.1016/j.pisc.2016.06.011.
10. E. Bayraktar, D. Katundi, Development of A New Aluminium Matrix Composite Reinforced with Iron Oxide (Fe3O4)Journal of Achievements in Materials and Manufacturing Engineering.
11. J. Liu, Y.-S. Cheng, S.W.N. Chan, D. Sung, Microstructure and mechanical properties of 7075 aluminum alloy during complex this extrusion, Trans. Nonferrous Metals Soc. China 30 (12) (2020) 3173–3182, https://doi.org/ 10.1016/S1003-6326(20)65452-8.
12. C.M. Anand Partheeban, M. Rajendran, S.C. Vettivel, S. Suresh, N.S.V. Moorthi, Mechanical behavior and failure analysis using online acoustic emission on nano-graphite reinforced Al6061–10TiB2 hybrid composite using powder metallurgy, Mater. Sci. Eng.: A 632 (2015) 1–13.
13. Trishul M.A, Virupaxayya Hiremath, Shreyas P, Production and Testing of Al- Fe2O3 Particulate Composite. Journal of Achievements In Materials And Manufacturing Engineering.
14. [13] Essam R. I. Mahmoud andMahmoud M. Tash, Characterization of Aluminum-Based-Surface Matrix Composites with Iron and Iron Oxide Fabricated by Friction Stir Processing. Journal of Achievements in Materials And Manufacturing Engineering.
15. EminBayraktar, FayzaAyari, Ming Jen Tan, Ayse Tosun-Bayraktar, And DHURATA KATUNDI, Manufacturing Of Aluminum Matrix Composites Reinforced With Iron Oxide (Fe3O4) Nanoparticles: Microstructural And Mechanical Properties. Journal Of Achievements In Materials And Manufacturing Engineering.
16. F. AyariA, B, D. KatundiB, And E. Bayraktar B, Damage Of Aluminium Matrix Composite Reinforced With Iron Oxide (Fe3O4): Experimental And Numerical Study. Journal Of Achievements In Materials And Manufacturing Engineering.
17. Yi Wang1,2, XiaoLan Song3, Wei Jiang1, Guo-Dong Deng1, Xiao-De Guo1, Hong-Ying LIU1, FengSheng LI1, Mechanism For Thermite Reactions Of Aluminum/Iron-Oxide Nanocomposites Based On Residue Analysis.Journal Of Achievements In Materials And Manufacturing Engineering.

18. Emin Bayraktar, FayzaAyari, Ming Jen Tan, AyseTosun-Bayraktar, And Dhurata Katundi, Manufacturing Of Aluminium Matrix Composites Reinforced With Iron Oxide (Fe3O4) Nanoparticles: Microstructure And Mechanical Properties. Journal Of Achievements In Materials And Manufacturing Engineering.
19. Palani swamy Shanmugha sundaram1, Of Iron Oxide On Tribological Behaviour Of Al- Si Alloy – Iron Oxide Composites – Taguchi Approach. Journal Of Achievements In Materials And Manufacturing Engineering.
20. E. Bayraktar, M.-H. Robert, I. Miskioglu, And A. Tosun Bayraktar, Mechanical And Tribological Performance Of Aluminium Matrix, Composite Reinforced With Nano Iron Oxide (Fe3O4). Journal Of Achievements In Materials And Manufacturing Engineering.