Characterization and Investigation of mechanical properties of aluminium matrix hybrid nano-composite: Novel approach of utilizing waste particles to reduce cost of material

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ABSTRACT

a lightweight metals have risen in significant prominence throughout the modern technological world primarily as a result of their effectiveness as well as sustainability in recent decades. The primary emphasis of this investigation will be on the measures implemented by local governments in the country to manage toxic garbage in a way that is both cost-effective as well as environmentally beneficial. This study aimed to find ways to recycle Al2O3 / silicon carbide nano Particles from solid waste products (PKSA) for utilisation effective reinforcements at low-cost, high-volume automobile parts. Employing an altered injection of gas ultrasound sensor double-stir casting technique, an effort has been undertaken to manufacture aluminum-based nano-composite with various composition proportions of 0% (zero), 3% (three), 6% (six), 9% (ten), and 12% (twelve). When reinforcements % was introduced into aluminum alloys, Micro-hardness, tensile strength, impact resistance, & flexural stiffness comprised some of the various mechanical characteristics tested. Al alloy and aluminium nano-composites were analysed for their dimensions variation and high physical factors including TGA, porosity, and density. XRD and SEM/EDS microstructure analyses have been performed. This research serves as the standard by which other suitable compounds/implants made of metal are evaluated.

Keywords— Solid waste, Mechanical properties,Particle size distribution, Surface morphology, TGA analysis

I. INTRODUCTION

A hybrid substance material consists of a microscopic mixture involving more than one material with a visible connection. Composites, also known were “tailor-made” substances with more than one stage give qualities not available from components alone. Composites include electrical, thermal, tribological, and environmental uses in addition to structural ones[1]. The alloys of aluminum are flexible yet reusable, helping the industry improve innovation. Alloys 2XXX, 6XXX, and 7XXX aluminium alloys are popular hybrid substrate components. Similar to different metals, 7075 has excellent particular durability, stiffness, excellent resistance to corrosion[2]. Nano-composites are popular because they are lightweight, strong, wear-resistant, and fatigue-resistant. More research is being done on aluminium-based nanoparticles for automotive and engineering applications [3]. During these existing subsequent ones, heterogeneous nano-compositions were widely employed in manufacturing mechanical parts that overcome MMC limits. Due to its cheap cost and capacity to make many complex-shaped industrial components, stir casting is the most preferred handling method for aluminium matrix composites. Nano-composite materials including silicon carbides & aluminum oxides were used as either main & additional reinforcements to help optimize characteristics. It includes ensuring homogeneous reinforcement component redistribution within liquid matrices, increasing matrix reinforcement the wettability or bonding, promoting solid solution strengthening via interfacial chemical processes, and minimising porosity [4].

However, increased focus has resulted in an increase in study methods on environmental awareness. The solid waste identified in palm kernel shell ashes (PKSA) is produced in large quantities during the production of raw palm oil[5]. Mechanical and non-structural components may be made lighter and stronger by incorporating palm kernel shell material into their design[6] to produce Al-SiC/Gr nano-composites, and found that up to 12wt.% reinforcement particles may be included in the matrix through liquid metallurgy, thanks to the stir casting approach. Increased wettability from the addition of reinforcement particles improved wear resistance and mechanical characteristics[7] investigated mechanical characteristics using Al matrix and PKSA reinforcement. It was shown that 10% PKSA improves Al matrix mechanical characteristics and homogeneity. In order to achieve outstanding efficiency using lightweight components and use waste as raw materials, the automotive and aerospace sectors have extensively researched aluminum nano-composites. This research aims to enhance Al 7075 alloy mechanical qualities and use waste materials as source materials to reduce costs, preserve the environment, and save materials.

II. EXPERIMENTAL PROCEDURE

The purpose of this study is to investigate the influence that the distribution of reinforcement particles in aluminium alloy has, as well as to determine the mechanical characteristics of the material and various factors, such as the size of the as-cast alloy and the weight of reinforcing materials. The thermogravimetric analysis (TGA), Fourier transform infrared spectroscopy (FTIR), and electron dispersion spectroscopy (EDS) methods were used to anticipate the optimal process parameters that would result in the hybrid nano-composites with the greatest mechanical and physical qualities.

A. Materials ($Al+Al_2O_3+SiC$)

The automobile sector was incentivized to reduce vehicle weight using lightweight materials. Al 7075 alloy is a popular composite material due to its outstanding durability, relatively low coefficient of expansion under heat, enhanced wear strength, and outstanding durability at high temperatures compared to monolithic materials. This piece uses Al 7075 alloy by TradewellFerromet Private Limited, Mumbai, India. Tables 1 and 2 show the chemical formula and physical parameters of the AZ91D alloy.SiC and Al2O3 are widely manufactured to increase component strength, however, all-silicon carbide/aluminum oxides include significant quantities of silica (silicon dioxide, SiO2). Nano Wings Private Limited, Hyderabad, India, supplied SiC and Al2O3 nanopowder for this investigation.

Table 1 Chemical composition of Al 7075 alloy

Element	Magnesium	Zinc	Copper	chromium	Manganese	Iron	Silica	Aluminium
Wt.%	2.1-2.7	4.8-5.6	1.2-2.0	0.18 - 0.23	0.3	0.5	0.4	Bal

Table 2 Physical properties of Al 7075 alloy

Testing Parameters	Physical properties
Density (g/cm^3)	2.81
Melting point (ºC)	530
Thermal Conductivity (W/mk)	78
Coefficient of thermal expansion (µm/mºK)	26.2
Electrical conductivity (%)	14.2
Specific gravity (J/gºC)	2.53

B. Methods

C. Preparation of palm kernel shell into ash

Palm kernel shell (PKS) and oil palm kernel shell (OPKS) are highly agro-waste from crude palm oil processing. Palm kernel shell content increases mechanical qualities by reducing weight and strengthening structural and non-structural components. This work used Palm kernel Shell from Nandi Cashew, Rajahmundry, India. Fig. 1a shows palm kernel shell rinsed with methanol until moisture was fully removed and dried at room temperature. Later, it was pre-heated in a muffle furnace at 300oC for 2 hours to eliminate scent and impurities to make fine powder [8]. The material was squeezed through a 25µm filter following heating. Morphological features including FTIR, EDS, and scanning electron microscopy helped characterise palm kernel shell ash particles. Finally, a chemical solution was developed.

D. Chemical treatment of palm kernel shell ash (PKSA)

The alkaline solution was performed according to [9]. Palm kernel shell ash was chemically treated with 1M NaOH in a shaker water bath at the specified conditions. Fig. 1b shows the pre-heated ash conditioned at 650oC to reduce impulsive and carbonaceous elements. Chemical treatment improves palm kernel shell ash's mechanical and physical qualities.

E. **Fabrication of aluminium metal matrix nano-composites**

MMC manufacturing methods. Fabricating uses powder metallurgy, compo casting, stir casting, diffusion bonding, etc. One of the best ways to improve material qualities at minimal cost and produce attractive forms is stir casting. This work used a modified gas injection ultrasonic probe double-stir casting process to achieve uniform matrix and reinforcement particle distribution. The novel method aims to avoid poor wettability from the graphite crucible bottom and uneven SiC, Al2O3, and PKSA reinforcement particle distribution in the melt.

Primary Stage:

The reinforcement particles were pre-heated at 220oC in a muffle furnace for 2 hours to remove moisture. After charging the aluminium 7075 alloy in a crucible and heating the furnace with argon gas at above liquidus temperature (> 620oC), the ultrasonic probe mechanical stirrer melted entirely. After purging hexachloroethane, argon gas was introduced directly into the furnace at 2cc/min to minimise high-temperature oxidation[10]. After that, an ultrasonic probe stirs the pre-heated aluminium reinforcement particles into the crucible. After stirring, the melt was cooled to 600oC to semi-solidify.

Secondary Stage:

A second 15-minute stirring treatment using an ultrasonic device at 1200 W, 20.20 kHz, and 720°C improved homogeneous distribution between reinforcement particles and aluminium matrix[11]. Ultrasonic probe churning reduces porosity and agglomeration. Finally, the composite slurry was put into a 120-mm-long, 15-mm-diameter mild steel die to solidify (Fig. 2).

F. **Characterization of Physical and Mechanical properties**

G. **Tensile Test**

Tensile testing is widely employed in drug evaluation. Tensile testing determines aluminium nano-composite strength. Tensile testing usually involves holding opposing ends of the object. The load causes elongation and breakage. All formulations were tensile tested according to ASTM E8M-04 standards in this article[12]. Each sample is machined with a 10 mm gauge and 30 mm length on a universal tensile machine at 100 KN. Tensile specimens were constructed for percentage elongation, yield stress, and strength.

H. **Micro-hardness Test**

Hardness is measured by taking a standard load with a magnitude of the indentation (depth or area). There are several testing procedures, but Vickers micro-hardness is popular since it quickly and easily determines material strength. In this investigation, all materials were tested for Vickers micro-hardness. Microhardness was measured at 100 g for 10 s on aluminium alloy and hybrid nano-composites according to ASTM E384 criteria[13]. The evaluation was carried out on samples that had been polished, and measurements were obtained from five distinct locations before calculating the average results.

I. **Impact Test**

Impact testing is done in order to determine the nature of the material (brittle or ductile). When a pendulum is used to hit a specimen, this method also calculates the amount of energy that is absorbed by the material throughout the fracture process. The Charpy test was carried out by measuring the length as 55 millimetres and the diameter as 10 millimetres. Additionally, a Charpy V-notch with a depth of 2 millimetres and a notch radius were constructed[14]. Since the specimen splits into two parts when it is struck, the impact strength of a material may be determined by notching the cross-section of the specimen and using a simple pendulum to take the measurement.

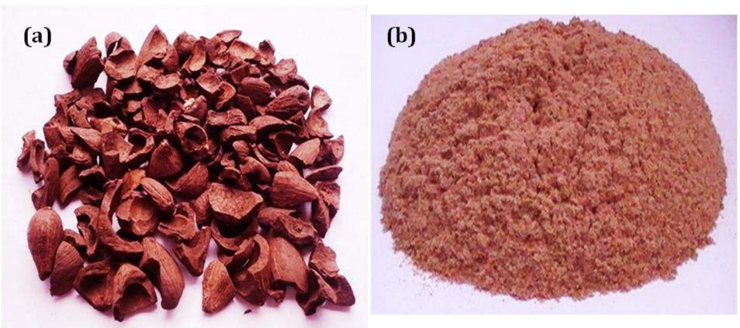

Fig. 1 (a) Palm kernel shell (Before treatment) (b) Palm kernel shell ash (After treatment)

J. **Flexural Test**

The four-point bending test, commonly known as the bending strength test, is the kind of flexure test that is performed the most often. A three-point bend test consists of a two-point specimen that is positioned downwards and a single point of stress that is put on the head of the specimen in order to twist the sample into the shape of a 'V'. The measurements for the samples used in the testing were 3 millimetres by 4 millimetres by 50 millimetres, as required by the requirements of ASTM D790-17[15]. The following equation was used to determine the flexural strength of the material:

$$\mathrm{KIC} = \frac{6Ma^{1/2}}{db^2}\mathrm{y} \qquad (1)$$

Where M represents the moment, d and b represent the breadth and height, and y is the equation that describes the ratio of a to b.

K. **Porosity Test**

Porosity is one of the key basic shaping processes, and it is possible to generate very uniform structures using this method. The amount of porosity in the product must be kept under control throughout the stir casting process. This is the single most critical component in the effective production of the product. In accordance with the requirements of ASTM B962-13, the level of porosity of each sample is determined by using the following equation (2)[16].

$$P = \frac{w_{\mathrm{sat}} - w_{\mathrm{d}}}{w_{\mathrm{sat}} - w_{\mathrm{sus}}} \times 100\% \qquad (2)$$

A saturated weight, denoted by w_{sat}, is contrasted with a dry weight, denoted by w_d, and a suspended immersed weight, denoted by w_{sus}.

L. **Bulk Density Test**

It is usual practice to quantify bulk density in order to identify differences in structural and compositional elements. In addition to this, it may be used to evaluate the quality of raw materials before they are incorporated into a variety of finished products. The Archimedes method is a water incursion technique that is being used in the process of determining the bulk density of various types of materials. In the present study, a technique based on Archimedes' principle was used to investigate bulk density[17] adopting the standards established by ASTM B962-13 for both the aluminium alloy and the hybrid nano-composites. The following equation (3) may be used to get the mass density of the material.

$$Bulkdensity = \frac{\text{Dry weight}}{\text{Saturated weight} - Suspendedweight} Xdensityofwater (3)$$

M. **TGA analysis**

Thermo gravimetric analytics, also known as TGA, is a method of thermal analysis in which the mass of a sample is evaluated over time as changes in the thermal stability of a substance are determined by measuring the changes in weight induced by the constant heating of the specimen. The portion of the substance that is composed of volatile matter is also determined using this method. TGA (Gravimetric instrumentation APA, 220-V, Delhi, India) was used to determine the behaviour of the reinforcement particles. Each sample, which is 20 by 20 by 10 millimeters in size, is subjected to a nitrogen environment that is heated to 400 degrees Celsius at a rate of 10 degrees Celsius per minute[18]. A balancing flow metre is calibrated to 20 psi of synthetic air pressure, and a function of the temperature is used to record any variations in the weight of a material.

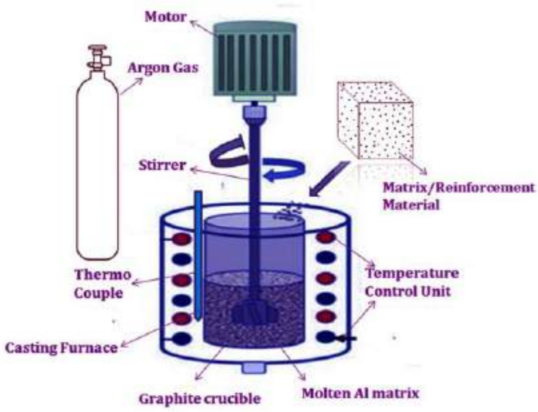

Fig. 2 Modified gas injection ultrasonic probe double-stir casting

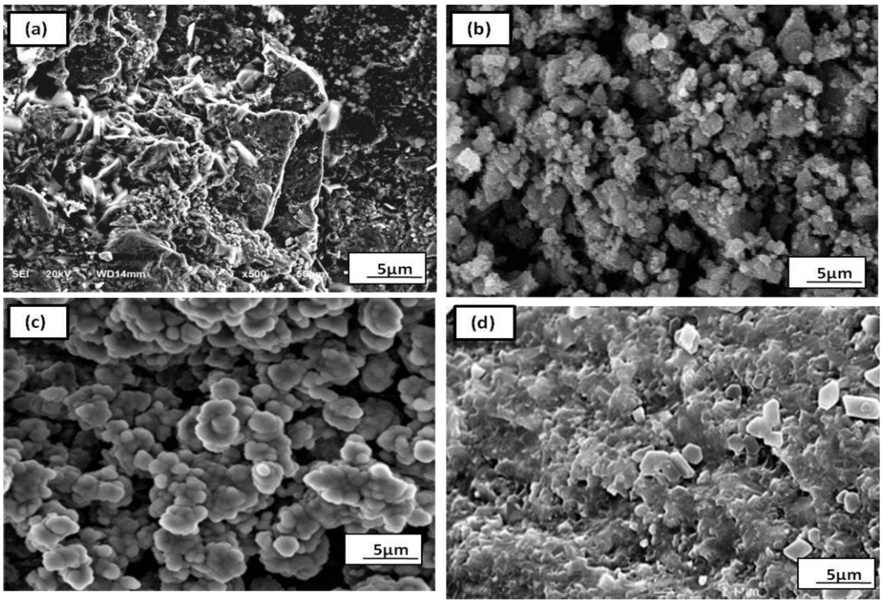

Fig. 3 Initial microstructure of (a) Al 7075 alloy, (b) Silicon carbide, (c) Aluminium oxide (Al_2O_3) and (d) Palm kernel shell ash particles

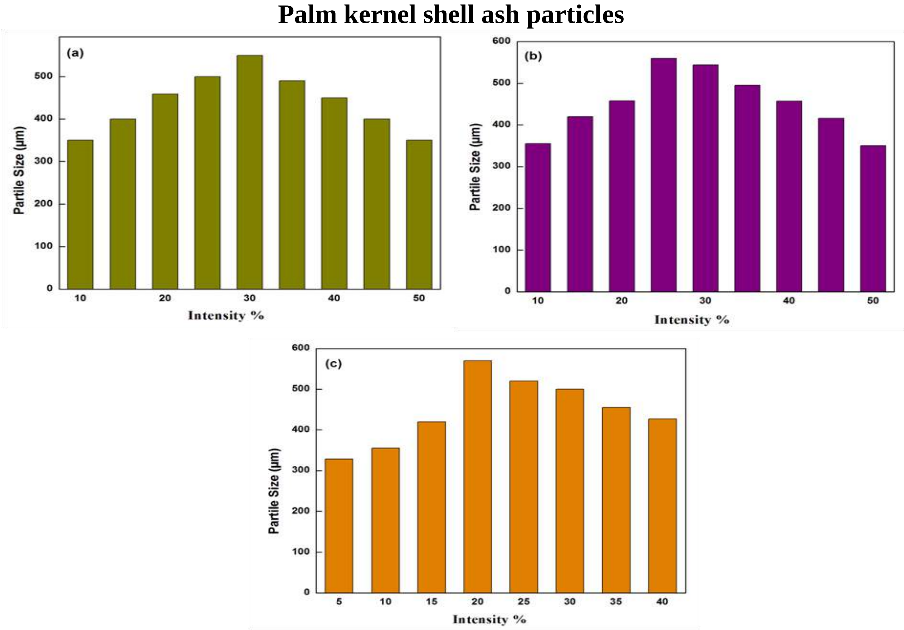

Fig. 4 Particle size distribution of (a) Silicon carbide (SiC), (b) Aluminium oxide (Al_2O_3) and (c) Palm kernel shell ash (PKSA) particles

N. **EDS analysis**

An energy-dispersive X-ray spectroscopy analysis, also known as a JSM-5310BV spectrograph, is a scientific equipment that may be used to investigate the chemical compositions of a sample's surface in the form of an image. The surface of each specimen is raster-scanned by a focused electron beam using a device that consists of a deflection coil to scan the beam. The samples were analyzed inside of a vacuum chamber, after which a photograph was taken and shown as an image on a screen. The primary reason for its peculiarities is the fundamental fact that each variable comprises a unique nuclear structure; as a result, the electromagnetic emission of each variable is characterised by a singular collection of peaks.

O. **XRD analysis**

By analyzing the way in which x-rays scatter off of metal atoms, a technique known as X-ray diffraction, or XRD, may be used to investigate and quantify the crystallite size of various substances. Both the orientation of the specimen and the angle of incidence of the X-rays that are diffracted have a role in determining the intensity of the X-rays that are diffracted. The X-ray diffraction patterns of the aluminium samples were recorded with the use of a diffractometer called an X'PERT PRO (k = 1.5406) that was located at the Mepco engineering college in Coimbatore, Tamil Nadu, India.

P. **SEM analysis**

A scanning electron microscope, often known as a SEM, is a kind of testing procedure that produces a magnified picture for the purpose of examination by scanning the surface of the sample with an electron beam. It is able to concentrate its light on a sizable portion of the sample all at once and generates images with varying degrees of magnification. Prior to the testing, the specimen has to have a coating applied to it in order to boost its conductivity and to limit the high voltage that will be applied to the specimen. The specimens were covered with a very tiny coating of conductive metal, measuring somewhere between 20 and 30 nanometers thick. Mepco engineering college in Coimbatore, Tamil Nadu, India was used as the location for the acquisition of the SEM images utilising the SEM-ZEISS SIGMA instrument.

III. EXPERIMENTAL STUDIES

A. **Initial microstructural analysis**

Vehicle manufacturers may integrate new innovative components by using lighter materials and creating distinctive elements. Al-5.6Zn-2.5Mg alloy is used in aerospace nozzles, notably in SRB space shuttles, to reduce vehicle weight. Starting microstructure of Al 7075 alloy is depicted in Fig. 3a. The first reinforcement material micrograph (Figure 3) displays high-silica SiC particles, PKSA, and Al_2O_3 particles. Using nanoparticles enhances matrix material's unique properties. Solid trash, agro-waste, and synthetic particles may reinforce materials. Agro waste including rice husk ash, coir, bamboo ash, PKSA, and coconut shell ash are promising hybrid nano-composites. Because it is non-toxic and suitable for hybrid manufacturing methods, this research uses waste material like PKSA as reinforcing filler [19]. Synthetic nanomaterials like SiC, Al_2O_3, TiO2, Gr are mostly utilised to improve mechanical and physical qualities. SiC with Al_2O_3 may increase durability, thermal conductivity, and density, saving material costs in building materials, pivots, cargo ships, oil industry, and vehicles. The initial reinforcement particle microstructure is depicted in Fig. 3(b-d).

B. **Investigation of Particle size distribution**

The particle size distribution (PSD) of substances is defined as the powder distribution of those substances. This definition has several major consequences for the properties of a powder and the dispersions. Because of their one-of-a-kind mechanical and tribological qualities, nanoparticles such as silicon carbide (SiC), aluminium oxide (Al_2O_3), and palm kernel shell ash (PKSA) are selected to be used as reinforcing components in composites. As can be seen in Figure 4, the size of SiC and Al_2O_3 particles used in this study ranges from 20-30 m. While PKSA was used as nano-reinforced materials at percentages of 3.0, 6.0, 9.0, and 12 weight percent, the size of the nano-reinforced material was 25-30 micrometres. Therefore, the primary needs for uniform distribution take place in particles of varied sizes and produce a high level of wettability, both of which have a tendency to enhance the quality of a variety of industrially manufactured goods.

C. **Effect of Mechanical and Physical properties**

D. **Tensile Test**

The computerised UTM testing equipment was used to conduct the tensile test on both the Al 7075 alloy and the 7075/(SiC/Al_2O_3/PKSA) hybrid nanocomposite samples. When compared to the base matrix, the hybrid nano-composites exhibit significantly better tensile strength characteristics. Two different samples are analysed for each composition test, and the results are summarised in Table 3, along with their averages[20], improving the material's mechanical characteristics may be credited to adding reinforcement in the form of nano SiC and Al_2O_3 particles at a weight percent range of 0 to 5%. The tensile strength of the Al 7075 alloy may be attained at 222 MPa and climbs to 240 MPa when reinforcing particles are being added. Because of the large quantity of silicon carbide and titanium dioxide (9%), the material has a tensile strength of 255 MPa, which is much greater than average. In addition to an increase in PKSA content, simultaneous improvements were made to the material's elongation percentage and yield strength.

Table 3Tensile Behaviour ofaluminiumhybrid nano-composite

Alloy/Hybrid nano-composites	Yield stress (MPa)	Tensile strength (MPa)	% Elongation
Al 7075 alloy	222	125	13.8
7075/3% (SiC/Al_2O_3/PKSA)	240	133	13.4
7075/6% (SiC/Al_2O_3/PKSA)	242	137	12.8
7075/9% (SiC/Al_2O_3/PKSA)	255	146	10.9
7075/12% (SiC/Al_2O_3/PKSA)	248	142	12.3

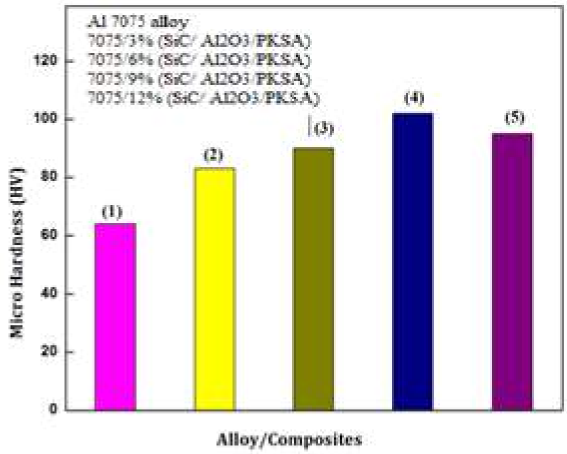

Fig. 5 Micro-hardness of Al 7075 alloy/hybrid nano-composites

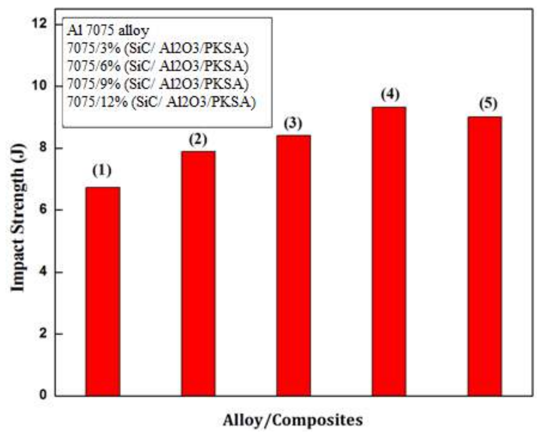

Fig. 6 Impact strength of Al 7075 alloy/hybrid nano-composites

E. **Hardness Test**

The Vickers microhardness test may be used as an alternative to the Brinell hardness test to monitor the capability of the material coming from a standard. This allows the test to be employed on the broadest scale possible in the calculation. On polished specimens, the micro-hardness of the Al 7075 alloy and the 7075/(SiC/ Al2O3/PKSA) hybrid nano-composites is examined. Using a Kroll reagent (50 ml of water, 7 ml of hydrogen fluoride, and 3 ml of hydrogen nitrate), the samples have been dipped by hand and polished with a chemical coating. In order to avoid the possible impacts of Indenter, the analyses are carried out in three different locations, and a total of five analyses are both acquired and reported. Figure 5 illustrates that the presence of PKSA, silica, and titanium dioxide particles contributes to an increase in the hybrid nano-composite's tenacity, which in turn contributes to an enhancement in reinforcing. As a result, the microhardness of the material increases as the percentage of hybrid nano-composite's weight that is increased up to 102 MPa. Because of the creation of a high porosity degree in the matrix, the hybrid nano-composite with a composition of 7075/12% (SiC/ Al2O3/PKSA) showed decreased microhardness. While a low porosity level is usually associated to high hardness and is seen in figure 5, this is not always the case21] It has been shown that the incorporation of 10 weight percent silicon carbide particles into a 7075 alloy using a typical casting method results in an increase in the material's hardness. It was also stated that there was a tendency towards an increase in the hardness of the aluminium alloy while the titanium dioxide particles were strengthening it [22].

F. **Impact**

The Charpy technique, which is commonly used for both notched and un-notched specimens, was chosen for use in the impact testing of composite materials. This approach is also utilised for testing metals. In order to carry out this test, the Al 7075 alloy and the 7075/(SiC/ Al2O32/PKSA) hybrid nano-composites are used, with the weight fractions of the four components being varied. The findings are shown in Figure 6, and it can be seen that the strength of the Al 7075 alloy (6.72 J/mm2) is relatively low. This is because the entire amount of energy consumption was divided into two parts, the first of which led to the highest possible fracture start. Despite this, the strength was increased while the addition of tough reinforcement particles was being made, as can be seen in Figure 6. Because of the high level of silicon-carbide content and the low porosity level, the addition of 9% (SiC/ Al2O3/PKSA) to 7075 alloy results in a greater strength of 10.02 J/mm2, which may be ascribed to the material. The further addition of 12.5% hybrid nano-composite causes a decrease in strength because of significant agglomeration, which in turn causes poor hardness, which ultimately results in a fracture surface[23]. Therefore, the 7075/9% (SiC/ Al2O3/PKSA) hybrid nano-composite demonstrates superior toughness and impact strength in comparison to other alloys and other types of hybrid nano-composites.

G. **Flexural**

The polished specimens of Al 7075 alloy and aluminumnano-composites were put through a flexural testing machine to determine their flexural strength. The results of this testing are shown in figure 7. When compared to aluminium cast alloy, the strength of materials made of aluminium nanocomposites is much greater. In order to minimise the possible impact of a resting applied load on the strong reinforcement sample, two specimens were conducted at each composition, and the average readings are indicated. The alloy with the number 7075 has a flexural strength of 402Mpa. It does so by adding tough reinforcing particles made of silica carbide and titanium dioxide, which causes a rise in content [24]. The flexural strength of the 7075 alloy was increased by 3% and 6% thanks to the inclusion of hybrid nano-composite made of SiC, Al2O3, and PKSA. The new value was 426 MPa. In addition to 9% (439 MPa), the high PKSA content together with the presence of silica and aluminium oxide contributed to the achievement of the maximum flexural strength. If the percentage is increased over 9%, the material has a tendency to become brittle, which raises the risk of fracture and lowers its flexural strength.

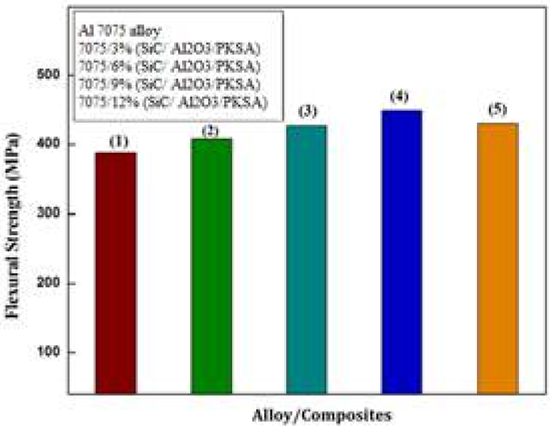

Fig. 7 Micrograph of flexural strength for Al 7075 alloy/hybrid nano-composites

H. **Porosity**

When scientists identified microscopic spaces, pits, and holes in aluminium casting alloys, they discovered that porosity plays a crucial influence in influencing the mechanical characteristics of the material. While reducing the amount of porosity in the material to an acceptable level is required in order to achieve the greatest desired degree of machining efficiency. Equation (2) is what is used to determine the porosity [25]. Figure 8 depicts the porosity of the Al 7075 alloy and the SiC/Al2O3/PKSA reinforcement with 7075 at various weight fractions (0, 3, 6, 9, and 12%). Both the 7075/3% (SiC/ Al2O3/PKSA) and the 7075/6% (SiC/ Al2O3/PKSA) porosities come in at 2.24% and 2.18%, respectively. When compared to base alloy (2.34%) and other hybrid nano-composites, the 9% (SiO2-HA) reinforced 7075 alloy (1.92%) has achieved the lowest porosity level possible. This is proven by the findings that were observed. The results reveal that the inclusion of nine percent has a lower porosity degree owing to the constant distribution between reinforcement and matrix particles; as a result, it enhances the mechanical properties of the composites. In addition, adding 12% leads to an increase in the porosity level, which may be ascribed to the poor wettability and agglomeration of the material. Therefore, porosity is the most important aspect that plays a role in determining the material characteristics of the nano-composites.

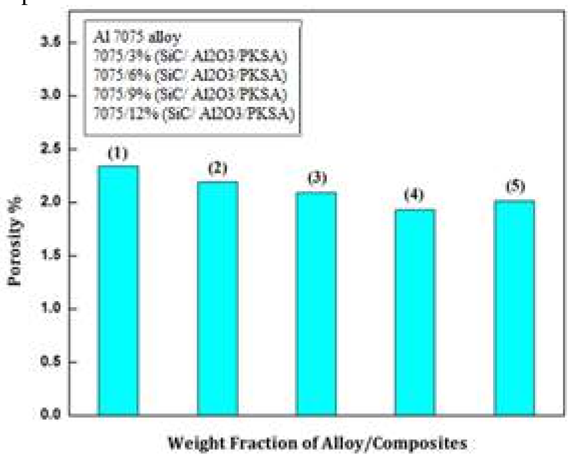

Fig. 8 Graphical representation of porosity for Al 7075 alloy/hybrid nano-composites

I. **Density**

In order to determine the density of a substance, it must first be correctly weighted in air and then its displacement in water or liquid must be compared. The equation (3) is what is used to determine the density of each and every sample [26] indicating that 7075 is an alloy with high strength and silicon as one of the primary alloying constituents. The determination of a product's bulk density serves the purpose of determining the mass proportion of the product in which the number of pores decreases as the bulk amount increases. The ASTM standards use the Archimedes principle to compute the bulk density of both aluminium alloys and hybrid nanocomposites. The physical characteristics of 7075 alloy and 7075/(SiC/ Al2O3/PKSA) hybrid nano-composites are compared and contrasted in Table 4. The density tends to grow as a result of the addition of 12% hybrid nano-composite, but the density progressively decreases as the focus of reinforcing particles increases to roughly 9% nano-composite (2.97%). The higher experimental density is responsible for the effect that particle wrapping has. The powder's permeability will be improved as a result of the small particles that are dispersed among the bigger ones, and the distance that separates the particles that are dominated by pores will be reduced. When 9% (SiC/ Al2O3/PKSA) was added to 7075 alloy, it resulted in low experimental density in comparison to the other concentrations. This contradictory trend was found in the bulk density data. As a result, the density measured in the lab is lower than the density predicted by theory in both the 7075 alloy and the 7075/(SiC/ Al2O3/PKSA) hybrid nano-composites shown in Table 4.

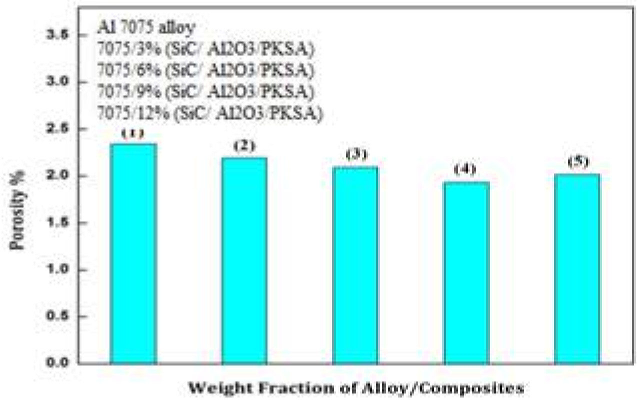

Fig. 9 TGA analysis of Al 7075 alloy and Al hybrid nano-composites

Table 4 Physical properties of aluminiumhybrid nano-composites

Alloy/Hybrid nano-composites	Theoretical density, (g/cm3)	Experimental density, (g/cm3)
Al 7075 alloy	2.81	2.73
7075/3% (SiC- Al2O3-PKSA)	2.93	2.84
7075/6% (SiC- Al2O3-PKSA)	2.97	2.88
7075/9% (SiC- Al2O3-PKSA)	3.02	2.97
7075/12% (SiC- Al2O3-PKSA)	2.96	2.91

J. **TGA analysis**

TGA methods evaluate material characteristics after mass loss at a specified temperature. The TGA is explored for aluminium 7075 alloy reinforced with SiC/ Al2O32/PKSA hybrid nano-composite at varied weight fractions (0–12 wt.%) under 49%CO2, 1% SF6, and 50% dry air shielding. The samples are cut to 12 x 12 x 10 mm, mechanically itched using SiC abrasive sheets of 600-1000 grit, then oxidised at 400oC for 5 hours. The furnace test is enabled when the surface appears to determine the commencement of rapid oxidation. All samples undergo the TGA test by measuring weight increase (mg/cm2) and oxidation time (min). Test results were analysed during boiler test. Due to its porosity and poor hardness, 7075 alloy gains weight quickly. Hard reinforcement particles decreased it, as illustrated in Fig. 9. The addition of 9% hybrid nano-composite increased Silica and titanium dioxide content, reducing weight gain by roughly 10 times (0.08 mg/cm2). The critical durations were 21 hours for 7075 alloy, 68 hrs for 3% (SiC/ Al2O3/PKSA), 87 hrs for 6%, 96 hrs for 9%, and 73 hrs for 12%. With reinforcing particles increased by 9%, the first oxide flaw at the macro scale is postponed substantially. Due of poor wettability, adding 12% hybrid nano-composite increases weight grain (0.15 mg/cm2). MgO growth is initially regulated by Al-cation transport and then by oxygen response in the gas interface. A temperature of 450oC accelerates Al evaporation and Al-cation diffusion [27] As Al vaporisation increases, film breaking and oxidation accelerate. Thus, 7075/9% (SiC/Al2O3/PKSA) hybrid nano-composite extends the protective incubation duration better than other nano-composites.

K. **Surface morphology**

Powerful and flexible scanning electron microscopes (SEMs) can determine material properties. The samples are first acetone-dried in air. Fig. 10(a-d) shows aluminium alloy and hybrid nano-composites base microstructures. Figure 10a showed worked structure with elongated grains and non-uniform, acicular grains and particles. It seems several globular apatite particles cause macro-cracks on Al 7075 alloy. It distributes phases uniformly throughout the matrix. The matrix-incorporating reinforcing particle microstructure was well preserved. While apatite nucleation causes alloy holes and fissures. SiC, Al2O3, and PKSA particles diminish it, as seen in Fig.10b. Several interfacial particles are also detected near SiC particles. The surface morphology demonstrates that the uniform distribution matrix with reinforcement particles embeds many silica fume particles, demonstrating the effectiveness of PKSA particles disseminated during mixing. The surface grain size of apatite particles may decrease with 6% hybrid nano-composite. The main goal is uniform particle dispersion and to-particle segregation during metallurgy. A stronger zone has equalised morphology, reducing surface cracks and holes[28]. The refined microstructure, exhibited in Fig.10c, has fine grain owing to 9% hybrid nanocomposite. However, the apatite pieces are much larger than the soft surface area, and Fig. 10d shows fissures caused by shortening increases in the strata (fracture surface). After adding 12% hybrid nano-composite (Fig. 10e), immersion rises and surface shape changes owing to non-homogeneity and porosity. This implies that reinforcing particles reduce aluminium alloy's main grain size. Thus, the automotive and industrial industries choose the hybrid nano-composite of 7075/79% (SiC/ Al2O3/PKSA).

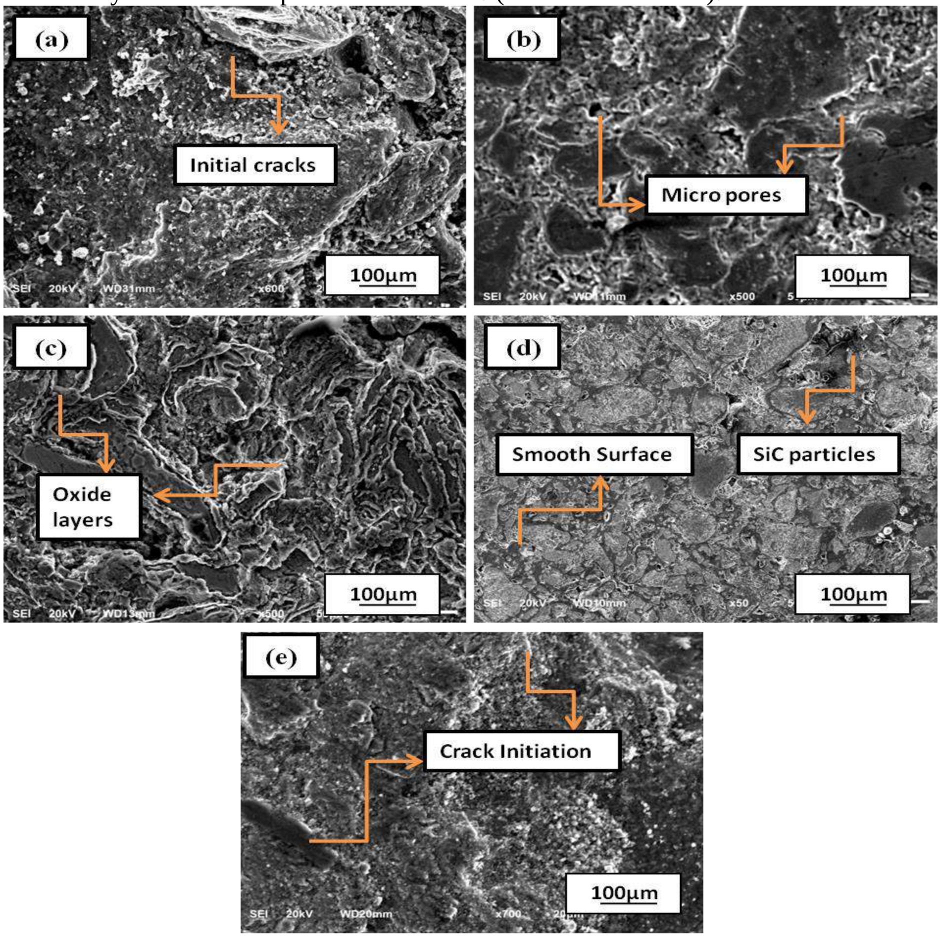

Fig. 10 Surface Morphology of (a) Al 7075 alloy, (b) 7075/3% (SiC/Al_2O_3/PKSA), (c) 7075/6% (SiC/Al_2O_3/PKSA), (d) 7075/9% (SiC/Al_2O_3/PKSA) and (e) 7075/12% (SiC/Al_2O_3/PKSA) hybrid nano-composites

L. **XRD analysis**

Crystalline materials are analysed using non-destructive X-Ray Diffraction. All samples undergo XRD examination to determine SiC, Al2O3, and PKSA production using various weight fractions, as illustrated in Fig. 11 (a-d). The 7075 matrix (Fig. 11a) has a significant Al phase for 2θ = 23°, 31°, 39° orientations. Thus, these orientation numbers match JCPDS card 89-4184 [29]. Although limited reflection strength relative to matrix gave a qualitative assessment of sample crystallinity. In addition to 3 to 6 wt.% hybrid nano-composite, sharp phase and powerful reflections imply Si phase rises [30] state that incineration (over 5% Al2O3) material becomes very crystalline as illustrated in Fig. (11b-c) by strong XRD reflections. The XRD pattern of the 9% hybrid nano-composite reveals strong reflections, with recent peaks at 2θ= 20°, 30°, and 68° (Fig. 11d) due to increased silica content and decreased density, enhancing material strength. Due to titanium dioxide and PKSA particles, C and O peaks dominate. Adding 12% hybrid nano-composite may enhance Al phases and decrease Si and C phases owing to excessive agglomeration (Fig. 11e). Very weak peaks create the rupture surface. The data imply that new brittle phases with increased intensity have a substantial effect in addition to hard reinforcement particles. Thus, the XRD trend demonstrates that these crystalline phases improve hybrid nano-composites' mechanical efficiency as the support weight percentage increases.

M. **EDS analysis**

SEM thermo-analysis uses Energy Dispersive X-ray spectrum (EDS). The EDS technique analyses x-rays from an electromagnetic field during illumination to identify a material's chemical characteristics. Fig.12 (a-d) shows Al alloy and aluminium hybrid nano-composites EDS spectra.

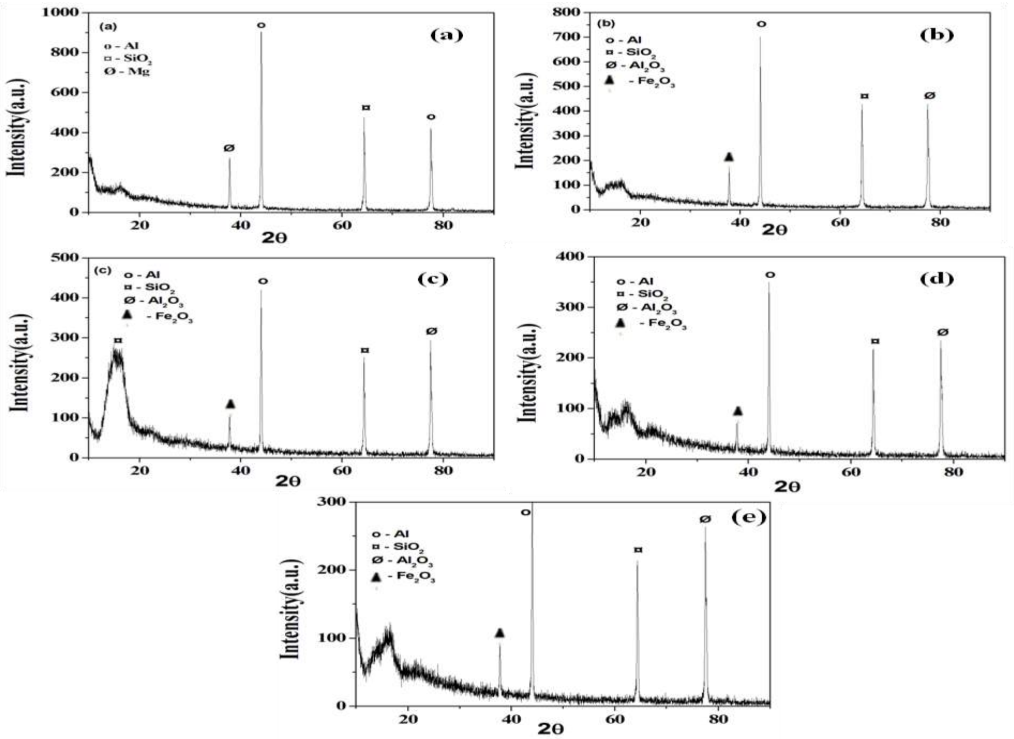

Fig. 11 XRD analysis of (a) Al 7075 alloy, (b) 7075/3% (SiC/Al_2O_3/PKSA), (c) 7075/6% (SiC/Al_2O_3/PKSA), (d) 7075/9% (SiC/Al_2O_3/PKSA) and (e) 7075/12% (SiC/Al_2O_3/PKSA) hybrid nano-composites

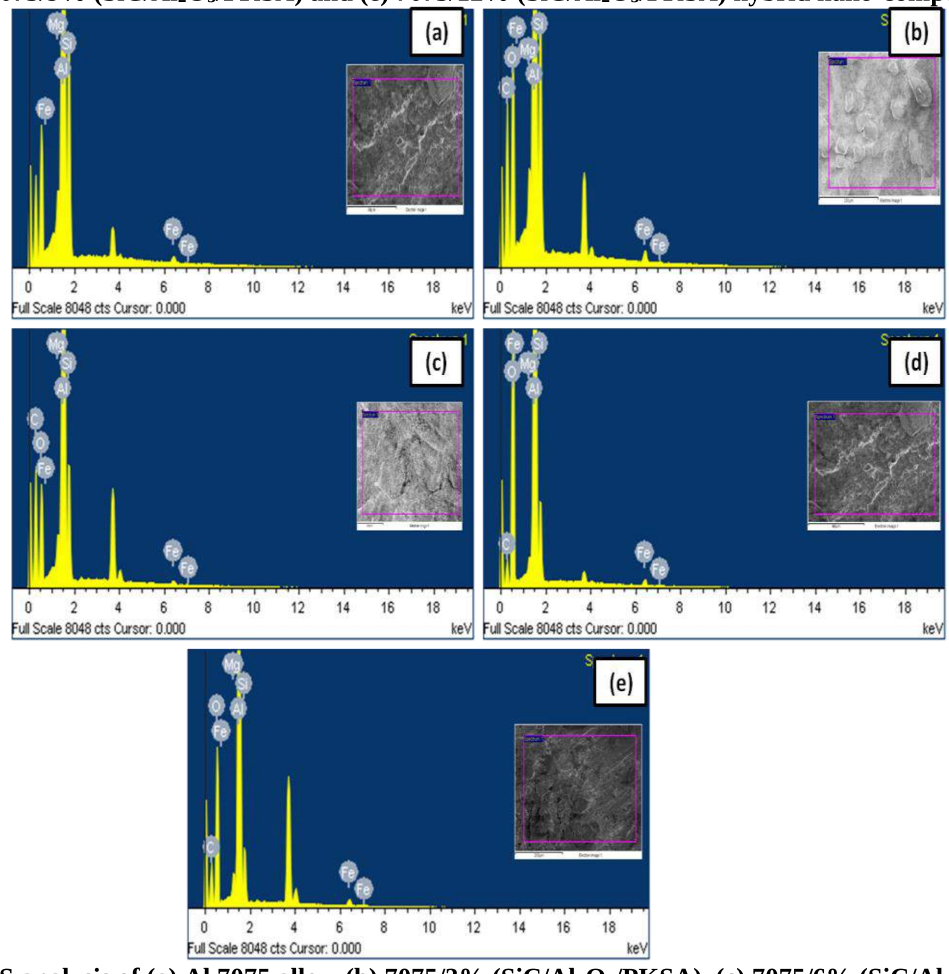

Fig. 12 EDS analysis of (a) Al 7075 alloy, (b) 7075/3% (SiC/Al_2O_3/PKSA), (c) 7075/6% (SiC/Al_2O_3/PKSA), (d) 7075/9% (SiC/Al_2O_3/PKSA) and (e) 7075/12% (SiC/Al_2O_3/PKSA) hybrid nano-composites

The Al, Fe, and C peaks in aluminium alloy are depicted in Fig.12a. Early on, aluminium peaks are powerful, but reinforcing particles weaken them. Figure 12 (b-c) shows the EDS spectrum of 7075/(SiC/ Al2O3/PKSA) hybrid nano-composites with Al, Fe, C, Si, and O peaks. The Si and O peaks rise with harder-reinforcing particles. As illustrated in Fig.12d, a greater (9%) silicon carbide and titanium dioxide concentration results in a shorter Al peak and bigger Si and O peaks. Aluminium dominates and silica content decreases in 12% hybrid nano-composite owing to poor wettability, which increases porosity and affects durability (Fig. 12e). However, oxide and carbon in the samples indicate titanium dioxide and PKSA[31]. Thus, 9% (SiC/Al2O3/PKSA) particles increase material strength.

IV. CONCLUSIONS

This current study's purpose is to determine if the conversion of waste products into raw materials is useful for the removal of hazards from their respective environments and whether this conversion results in cost savings for the materials themselves. Titanium dioxide and silicon carbide with 7075 alloy are explored in this study to investigate the impact of PKSA. This is done by taking different weight fractions in order to forecast how the material would behave. The automotive industry makes extensive use of this particular kind of material for the production of connecting rods, shafts, and piston rings.

1. The waste material palm kernel shell has been effectively converted into ash and chemically processed for the purposes of this study..
2. The fabrication was successfully carried out by using a modified gas injection ultrasonic probe double-stir casting technology, and the mechanical and physical parameters were accurately determined.
3. It was discovered that the porosity values of the 9% (SiC/ Al2O3/PKSA) reinforced with 7075 alloy were lower (1.92%) than those of the A356 alloy (2.34%). The inclusion of amorphous silica led to better microhardness (89%) and strength for the addition of 9% hybrid nano-composite when compared to a matrix and other nano-composites. This was due to the addition of amorphous silica content.
4. When compared to alloy, the tensile strength is greater (26%), and the impact strength is higher (22%), with the inclusion of 9% aluminium hybrid nano-composite. This is because of the existence of Al2O3/PKSA and a high quantity of silica carbide.
5. Comparing the flexural strength of the 9% (SiC/ Al2O3/PKSA) hybrid nano-composite to the flexural strength of the other nano-composites reveals that it has a higher value of 439 MPa.
6. Due to the presence of hard reinforcement particles, the EDS verifies the existence of Si and C peaks, and XRD examination identifies novel phases that were not present in the base alloy.
7. The microstructural study shows that the inclusion of 9% hybrid nano-composite results in improved material behaviour. This is supported by the observation of smooth grooves in the material. In addition, the incorporation of 12% hybrid composite material resulted in a fracture surface that might be attributable to the elevated porosity level.
8. Because of this, the hybrid nano-composite made of 7075/9% (SiC/Al2O3/PKSA) exhibits much more significant physical and mechanical characteristics than the matrix and other nano-composites.

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