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Influence of TAC/TI/Si_3N_4 on mechanical and corrosion performance of AA7075 alloy matrix composite processed by stir processing route

J Pradeep Kumar[a], D S Robinson Smart [a*], & Kuldeep Kr Saxena[b]

[a]Department of Mechanical Engineering, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu 641 114, India

[b]Department of Mechanical Engineering, GLA University, Mathura, Uttar Pradesh 281 406, India

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In modernistic years, Metal Matrix Composites (MMCs) are becoming enchanting in fields of aerospace, military, defence and automobile applications reason being they offer merit such as high strength to weight proportion, good tribological, good corrosion resistance, excellent fatigue and creep performance and good bending behaviour etc. In the current research, an attempt was made to synthesize AA7075 blended with distinct wt% of Titanium (Ti), Tantalum Carbide (TaC) and Silicon Nitride (Si_3N_4) multi hybrid MMCs were examined. Microstructural, flexural, corrosion and low cycle fatigue aspects of the developed multi hybrid MMCs were examined as per ASTM standard. The brittleness of Si_3N_4, TaC and Ti particulates structured with the interface betwixt matrix culminates in increment in the flexural strength of the composite. The bending analysis clearly shows that, TaC and Si_3N_4 are the major contributing materials for flexural aspect because the presence of hard ceramic particulates restricts the dislocation movement by providing additional strength. Microstructural analysis reveals the existence of reinforcements. Also, homogeneous dissemination and good interfacial bonding betwixt the matrix and reinforcement particulates were noticed. AA7075 reinforced with 1 wt% Ti, 6 wt% Si_3N_4 and 0.5 wt% TaC operated at higher load (1500 N) and higher number of cycles 14×10^3 cycles with a stable strain rate. The number of cycles to failure was observed to be enhanced for the matured composites on account of an inconsequential percentage of induced plastic strain.

Keywords: Corrosion, Fatigue, Flexural, Mechanical behaviour, Stirring, Tantalum Carbide

1 Introduction

In the present contemporary engineering environment, the demand for new age materials with ultra-light weight along with significant strength, toughness, hardness, stiffness and wear resistance brought out the evolution of composite materials. The main purpose of using composite material is the influence of attaining property consolidations that can result in several service assists[1]. MMCs are a unique origination of composites that provide the capability of assisting the growing insistence for progressed engineering utilizations such as transportation, structural, thermal, electrical, marine, aerospace, automobile, defence and military due to its enhanced strength to weight ratio, stiffness, good damping capability, good wear and creep resistance over monolithic alloy[2]. Compared to polymer and ceramic matrix composites, MMCs are widely accepted material and subjected to research and development over the past few decades. However, MMCs can operate at elevated temperatures when compared to conventional monolithic materials[3]. The aluminium based MMCs shown colossal probable in the multeity of aircraft, ship, motorcar and diverse transport wagons due to its less weight to potency correlation, good mechanical workability, desirable corrosion defiance and comparatively smaller price[4]. Generally composite material consists of base alloy known as matrix and ceramic reinforcements to escalate the overall attribution of the material. The consolidation of matrix and reinforcement composition exhibits lesser density, high hardness, lesser coefficient of expansion, reasonably larger elastic modulus and corrosion defiance which prefers to be a potential candidate for diverse applications like aero-frame structures, space shuttle components, knuckle housing, suspension arm, piston rings, landing gear, connecting rods etc[5]. The main merits of particulate based MMCs include excellent metallic properties. AA7075 is a light weight material. Because of high strength and high toughness and capability of withstanding elevated temperature AA7075 are mainly utilized in aerospace, defence, military and automobile applications. Addition of hard ceramic

*Corresponding author (E-mail: smart@karunya.edu)

reinforcements does not change the overall density of the material but improve the specific strength. Several fabrication techniques have been developed for production of MMCs. Among all of these, Mechanical Stir Casting (MSC) is more rottenly and exhaustively utilized[6]. In MSC, reinforcing particles might be fragmented during stirring. Mechanical stirrer material gets eroded incessantly during stirring and eroded particles are mixed with composite. This leads to unpretentious quality of AMCs. According to Hashin Shtrikman bound theory, the composites strength can be greatly upgraded by the adjustment of reinforcing particulates and depending upon the theory, disparate researchers attempted enormous numbers of additives in the matrix for several applications[7]. The intention of utilization of ceramic reinforcement material is to further enhance various mechanical, corrosion, thermo-mechanical, microstructural and tribological properties of chosen matrix material. In order to evaluate the quality of the newly developed metal matrix composite materials, mechanical and corrosion analysis of materials such as tensile, compression, hardness, creep and fatigue etc is mandatory. Fayomi *et al.*[8] explored the microstructural and tribological etiquette of 8011 aluminium alloy blended along ZrB_2 and Si_3N_4 nano particulates fluctuating up to 20 wt%. The MMCs were developed using two step stir casting technique was utilized with optimal process parameters. The tribological characterization was experimented at disparate loads of 20N to 40 N placing alternate parameters constant like the travel stretch of 5000 m, sliding pace of 3 mm/s and duration of 60 seconds. As the wt% increases, the wear rate found to be reduced. This reduction in wear rate was because of the firm interfacial adherence and complete wettability betwixt matrix and reinforcement. Also, the advanced MMCs could be associated to the mixed consequence of the grain conversion at the time of fabrication, particular strengthening characteristics and load-bearing capacity of hard ceramic materials. Ramadoss *et al.*[9] developed Al7075 hybrid composite blended with B_4C and BN manufactured by stir casting route mainly for marine application. The selected reinforcements were consistently dispersed over the base alloy along with the clustering of particulates inclusion in single spot over the grain boundaries. By increasing the wt% of reinforcements, tensile and compression strength found to be high because of good interfacial bonding betwixt the reinforcement & matrix, grain intensity, and strain gradient strengthening ramification of composites. It was also noticed that increase in mass fraction of B_4C behaves as a disincentive to abide the dislocation movement to bring on larger hardness compared to matrix. Abhijit Bhowmik *et al.*[10] investigated the wear aspects of AA7075 blended with SiC hybrid MMCs processed by mechanical casting technique. Microstructural and pin on disc wear analysis were carried. The results reveal that wear rate; specific wear rate enhances with decrease in COF was noticed with increment in sliding distance. Huge amount of flash temperature was formed in betwixt the disc and the pin surface. COF was noticed to be declined due to the interfacial contact temperature which was found to be increased between the two surfaces. Worn surface morphology showed the formation of mechanically mixed layer that enhances the material removal rate. Salihi *et al.*[11] investigated the mechanical and wear behaviour of AA7075 reinforced with 5 wt% Al_2O_3 particulates processed through stir casting technique. The tensile, wear and hardness of the developed composite significantly enhanced with the addition of reinforcement. The hard ceramic particulates impart their strength from matrix to the reinforcing nano particles. The improvement in strength was observed from matrix strengthening followed by reduction in grain size.

From the detailed literature outline, it was noticed that the effect on addition of reinforcement materials such as Si_3N_4, TaC and Ti in the aluminium matrix has not explored much. Also, high and low temperature behaviour of aluminium based composite materials is not reported widely. Tantalum carbide (TaC) is one of the primary and expensive ceramic reinforcement material that could serve the purpose of withstanding high temperature. Therefore, for low economy applications, this particular reinforcement cannot be used. In order to enhance the hardness above a particular limit, the material becomes more brittle. Therefore, the material may not be suitable for applications such as heavy cutting tools due to its extreme hardness. AA7075 reinforced hybrid MMCs can be utilized for all other engineering applications related to high and low temperature environmental condition.

In the present research work, the new age multi hybrid composite dealing with AA7075 as the base matrix and Si_3N_4/TaC and Ti as the reinforcements has been processed by utilizing the traditional stir casting method owing to its benefits like simplicity, low cost, and easy portability. The reinforcements were added in fluctuating proportions by weight and the developed multi hybrid composites exposed to several mechanical and corrosion analysis. The current exploration was focused to interpret the outcome of microstructural, corrosion, flexural and fatigue behaviour of AA7075/Si_3N_4/TaC/Ti multi hybrid MMCs and thereby develop a composite that could serve turbine, defence, military and automobile applications particularly mechanical components such as pistons, brake disks, cylinder head, inlet, and exhaust manifold, wind turbine blades and camera dome etc.

2 Materials and Methods

2.1 Matrix Material

Among various groups of aluminium alloys, 7000 series of aluminium alloy known for its immense strength, reduced defiance to stress corrosion cracking and afford advance combination of strength, fracture toughness and corrosion resistance. AA7075 is widely used for its high mechanical strength to weight ratio, but is still the subject of several studies to further improve its mechanical properties. AA7075 is also known as aluminum–zinc alloy due to the maximum zinc content ranging betwixt 5.1 and 6.1 percentage with minimal fraction of magnesium[12]. In the current research work, commercially available AA7075 in the form of ingots were utilised as the matrix alloy. The empirical configuration of AA7075 was illustrated in Table 1. Due to the presence of zinc as major alloying element in AA7075, it is demonstrated to be providing higher efficiency correlate to various materials like steel and has acceptable fatigue firmness with mediocre machinability[13].

2.2 Reinforcement Materials

In the present investigation, aluminium based MMCs containing TaC, Ti and Si_3N_4 ceramic reinforcement particulates with distinct wt% was preferred based on trial experiments and previous research works. Based on several preliminary approaches, the combination of reinforcements in terms of wt% is illustrated in Table 2. UHTC are a family of compounds that display a unique set of properties, including extremely high hardness, high melting temperature, and chemical stability and strength at elevated temperatures. The increasing interest in hypersonic vehicles and weapons points to the need for UHTC materials for wing leading edges and nose tips, as well as propulsion system components. Group IV and V elements such as borides, carbides and nitrides, as well as mixtures based on these compounds are some of the UHTC materials. UHTCs are the most widely studied materials due to their good oxidation resistance from room temperature to over 2000°C.

Table 1 — Empirical Configuration of aluminium 7075 alloy

Elements	Si+Fe+Ti+ Ni+Zr+Mn	Cu	Mg
Minimum (wt%)	1.33	1.2	2.1
Maximum (wt%)	F_{pedal}	2.0	2.9
Elements	Si+Fe+Ti+ Ni+Zr+Mn	Cu	Mg
Minimum (wt%)	1.33	1.2	2.1

Table 2 — Formulation of base alloy and reinforcements

Configuration	Quantity of matrix (wt%)	Quantity of reinforcements (wt%)		
	AA7075	Ti	Si_3N_4	TaC
B1	100	0	0	0
B2	91.25	0.5	8	0.25
B3	92.5	1	6	0.5
B4	93.75	1.5	4	0.75
B5	95	2	2	1

TaC is one of the Ultra-High Temperature Ceramics (UHTC) and an transition metal carbide that is suitable for high temperature applications such as camera dome used in military vehicles, aerospace and rocket propulsion systems[14]. Generally, TaC has maximal melting point (3985°C) amidst the UHTC group of materials. Likewise huge melting point, TaC is preferred for its high elastic modulus, good wear protection, chemical inertness and balanced thermal coefficient of expansion operating in various areas of rocket nozzles, cutting tools etc[15]. TaC with average particle size 200 – 250 nm was used. Embodiment of hard ceramic particulates like Si_3N_4 acts as a solid lubricant on the base alloy that enhances the abrasive and sliding wear resistance of composites. Si_3N_4 consists of hard ceramic particles with high mechanical strength, capability of withstanding high temperature and good tribological characteristics. Si_3N_4 was selected with average particle size of 40 nm based on previous studies[16]. Titanium is exceptionally an interesting hard ceramic material because of its high hardness, low density, high elastic modulus, modified thermal characteristics and high specific strength with good fatigue properties. However, standard particle size of 70 μm was utilized depending on preceding examinations[17].

2.3 Synthesis of Composite Materials

AA7075 with different weight fraction of $TaC/Si_3N_4/Ti$ HMMCs were developed using conventional stir casting technique [18]. Stir casting process make high kind aluminium based HMMCs. In this approach, the AA7075 blocks were originally held in a graphite crucible at 650°C. Simultaneously the procured ceramic particulates were foreheated at 550°C in a foreheater available with the furnace. Mechanical stirring using a motor was appropriate in order to accomplish homogeneous dissemination of reinforcement in the matrix material [19]. The melt was blended at constant rotational speed of 200 rpm utilizing a mechanical stirrer to acquire a passable vortex for approximately 5 minutes. The reinforcement powders were foreheated and supplied to the molten melt at a stable feed rate into the vortex of aluminium melt. Thereafter, the liquid alloy was discharged in the rectangular long-lasting metallic die of the size of 10 mm in thickness, 100 mm in width and 100 mm in length and the mould temperature was confessed to diminish at ambient atmosphere. Later, the developed HMMCs were shaped by SH300 medium speed wire cut EDM machine (Make: S&T Engineering Pvt. Ltd., Coimbatore, Tamilnadu, India) to develop various testing samples for evaluating the microstructural, flexural, corrosion and fatigue behaviour according to ASTM standards.

2.4 Metallographic Examinations

The microstructural analysis of the developed HMMCs was studied by opting computerized optical microscopy. As per ASTM standard, the samples of proportion 10 x 10 x 10 mm^3 were developed by wire cut EDM machine and then polished with distinct grades of emery sheets for determining an articulate periphery for microstructural investigation. To analyse the progressive microstructure of the composites, chemical etchant called Keller's reagent was utilized to polish the circumference of the test specimens and was dehydrated in atmospheric air using air gun for 30 seconds [20]. Scanning Electron Microscopic (Make: JEOL, Japan – JSM 6390) investigations were carried out to evaluate the micrographs of the opted alloy and reinforcements. Later, EDAX was exploited to perceive the configuration of the matrix and the X-ray Diffraction (XRD) was treated to affirm that, there's a satisfactory amalgamation of reinforcements with base alloy.

2.5 Static Immersion type Corrosion Analysis

As per ASTM G31-72 standard, stationary immersion type corrosion experiment was operated on the advanced aluminium HMMCs at ambient atmospheric condition. Generally, Hydrochloric acid (HCl) is more acidic when compared to Sodium Chloride (NaCl) and Sulfuric Acid (H_2SO_4) solution. Hence, HCl acidic solution was used as corrosive habitat for the analysis [21]. The corrosion testing samples is shown in Fig. 1. The prepared corrosion testing templates were glistened physically utilizing distinct levels of emery papers to attain smooth surface. Since there are five different composite specimens, five beakers were taken and cleaned thoroughly using distilled water. The experiment was started by filling the beakers with 90 ml of HCl and 10 ml of distilled water solution. Before immersing in HCl environment, the prepared samples were properly cleaned with distilled water and drowned in methanol. Individual sample was scaled before and after each experiment. The loss in weight (milligrams) of $AA7075/TaC/Si_3N_4/Ti$ HMMCs specimens with distinct wt% was obtained by computerized weighing machine. The retrieved weight was reconstructed in the form of rate due to corrosion. From the weight loss, the rate due to corrosion was inspected exploiting consecutive association as displayed in Eq. (1).

$$Corrosion\ Rate = \frac{(K \times W)}{(A \times D \times T)} \quad \text{... (1)}$$

Therefore, K is conversion factor (87.6), T is the submerged duration (hours), A is the sample region (cm^2), W is the fall in mass (milligrams) & D is the composite density (g/cm^3).

2.6 Flexural Strength Analysis

In most of the defence and aerospace applications, the failure of aircraft wings and other mechanical components occur due to heavy structural load. Therefore, flexural analysis needs to be conducted to evaluate the flexural properties of the developed composites. The flexural analysis provides values for the modulus of elasticity in bending, flexural stress and flexural strain. Three andfour point bending experiments was executed to reveal the flexural

Fig. 1 — Corrosion test samples.

strength of AA7075 grade with distinct wt% of Si_3N_4/TaC/Ti particulates. In three and four point flexural strength analysis, the maximum bending load was investigated. This load data was altered into flexural strength (MPa). The flexural test samples were displayed in Fig. 2. The flexural experiments were executed using the servo operated universal testing machine, to obtain the flexural strength of the multi hybrid MMCs and base alloy. Flexural strength, flexural strain and maximum flexural stress were determined based on the following E*q*s2 – 4 shown below. Before testing, the specimens were cut according to ASTM A370 using wire cut EDM machine and polished metallographically. Four composite specimens for each composition with a size of 140 × 20 × 11 mm^3 were tested with a loading rate of 0.5 mm/min and a span length of 80 mm (three point analysis) and 20 mm (four point analysis). The average flexural strength of the composites, and base alloy was found.

$$Flexural\ strain = \frac{6 \times D \times d}{L^2} \quad \dots (2)$$

$$Flexural\ strength\ \left(\frac{N}{mm^2}\right) = \frac{M \times y}{I} \quad \dots (3)$$

$$Maximum\ flexural\ stress\ \left(\frac{N}{mm^2}\right) = \frac{3 \times P \times L}{2 \times b \times t^2} \quad \dots (4)$$

Whereas, D – Maximum deflection at centre (mm), d – Thickness of the specimen (mm), L – Span length (mm), P – Load (N), b – Width of the sample (mm), t – Thickness of the sample (mm), M – Bending moment (N-mm), Y – Natural axis distance (mm), I – Moment of Inertia (mm^4).

2.7 Low cycle Fatigue Strength Analysis

Fatigue analysis is important to determine the maximal weight that a specimen can endure for a particular number of cycles. The main logic for fatigue failure are number of cycles, range of stress and local stresses [22]. To figure out the fatigue strength at ambient atmospheric condition, fatigue experiments were regulated on the developed HMMCs confirming to ASTM E606 regulation as shown in Fig. 3. Initially, the fatigue samples as shown in Fig. 4 were developed from the casted specimens utilizing medium speed wire-cut EDM machine.

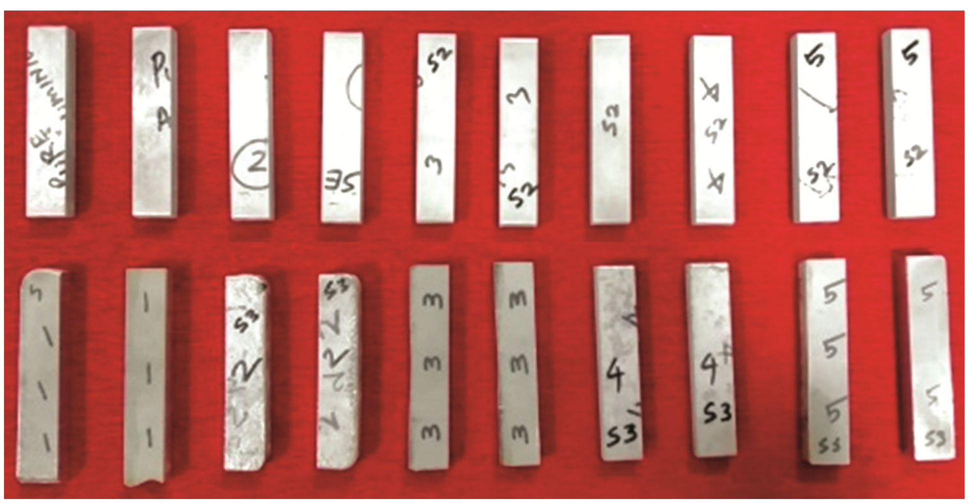

Fig. 2 — Flexural test samples as per ASTM standard.

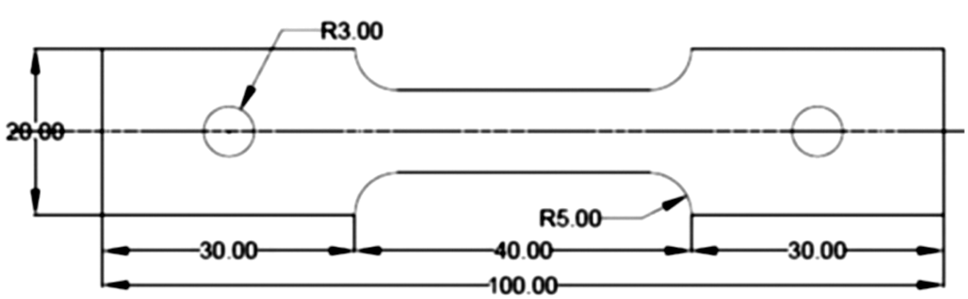

Fig. 3 — Geometry of Fatigue test specimen as per ASTM.

For different loading conditions, maximum three samples were prepared for each composition of the aluminium HMMCs. Strain controlled, tensile-compression fatigue experiments were conducted by mounting the fatigue specimens on the computerized hydraulic load-controlled fatigue testing machine (Make: AVJ Engineering Pvt. Ltd., Coimbatore, Tamilnadu, India) equipped with standard load cell. The fatigue testing machine has an average fluctuation ranging from 20 – 40 cycles/min and maximum weight capacity of 1000 kg, corresponding to 50 – 90 % of yield stress. During experimentation, if the material fails at stress data a minimal stress is incorporated for the next sample and if the sample doesn't break down the test is continued with a larger stress data. The total cycles to induce the overall calamity or partition of specimen are considered as fatigue life (N_f). A median of three outputs were analysed as fatigue life (N_f) of every specimen.

3 Results and Discussion

In this section, various significant outcomes such as microstructural, corrosion, flexural and low cycle fatigue characteristics of the developed AA7075 reinforced with TaC/Ti/Si3N4 multi hybrid MMCs were explored. Also, the effect of reinforcements on the AA7075 matrix material were also acknowledged and discussed in detail.

3.1 Microstructural Exploration of AA7075/Si_3N_4/TaC/ Ti Hybrid Composites

Figure 5 displays the typical optical micrograph of etched unreinforced AA7075 and reinforced AA7075 reinforced with distinct wt% of reinforcements. From the microstructural observations, it was confirmed that reinforcement particulates are homogeneously circulated over the cross sectional area and it was established that, the conglomeration of particulates of reinforcement incorporation in particular region and along the grain perimeters of alloy material. This confirms the performance of the liquid metallurgy route used in flourishing the HMMC. It was observed that the prepared hybrid specimens display the dissemination of the dark coloured particulates in bright base material [23]. Therefore, opaque reinforcement particulates do not reflect light and appear dark in reflective base alloy area. Therefore, the reinforcement particulates show definite geometrical grains. The morphology also reveals a

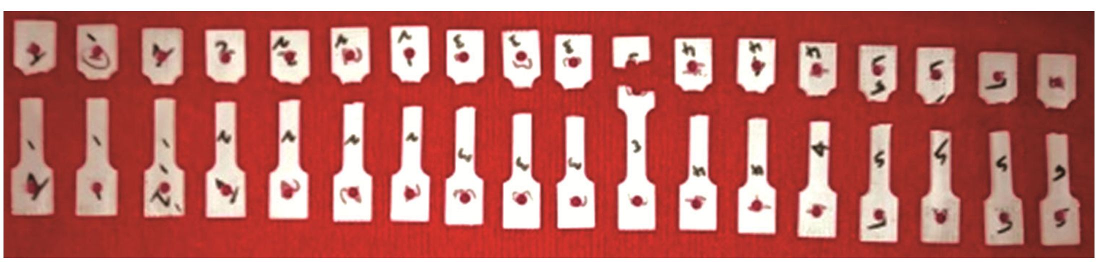

Fig. 4 — Fatigue specimens.

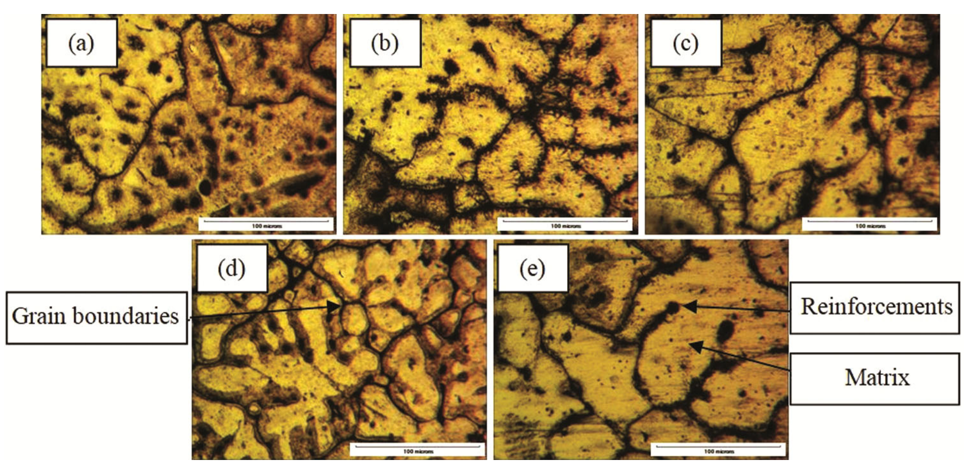

Fig. 5 — Optical micrograph of (a) Pure AA7075, (b) AA7075+0.25wt%TaC+8wt%Si_3N_4+0.5wt%Ti, (c) AA7075+0.5wt%TaC+6wt% Si_3N_4+1wt%Ti, (d) AA7075+0.75wt%TaC+4wt% Si_3N_4+1.5wt%Ti, and (e) AA7075+1wt%TaC+2wt% Si_3N_4+2wt%Ti.

durable interfacial bonding, excellent wettability betwixt the TaC/Si_3N_4/Ti and base alloy (AA7075). The durable intermetallic adherence, good wettability betwixt the perpetual matrix constituent and the disconnected ceramic constituent, and the homogeneous dissemination can be associated to the procedure specifications obtained from stir casting [24].

It has been noticed that the higher concentration of composite particles showed higher quantum of reinforced particles in the metal matrix. Some fine particles of composite are also observed and it forms the grain boundaries of primary aluminum. Fig. 6 displays the SEM micrographs of AA7075 reinforced with distinct weight fraction of TaC/Si_3N_4/Ti particulates so that primary plots (matrix) and the secondary plots (reinforcements) were clearly visible.

Minor casting deficiencies such as scratches, porosity and asperities were noticed in the unreinforced alloy. However, the deliberately combined reinforcement particulates were dispersed compatibly over the base material. These homogeneous disseminations of reinforcement particulates are required to improve the mechanical behaviour of HMMCs[25]. Nonetheless, the appropriate interface betwixt the hard particulates and matrix sector with the desirable adherence of reinforcements in the base alloy was attained in the on-going research activity.

3.2 Static Immersion type Corrosion Analysis of AA7075/Si_3N_4/TaC/Ti Hybrid Composites

Figure 7 shows the rate of corrosion of AA7075 reinforced with different wt% of TaC/Si_3N_4/Ti HMMCs as well as pure AA7075 decreased linearly with increase in exposure duration in HCl medium. Generally, it has been found that the aluminium reinforced composites displayed exceptional corrosion resistance when correlated with the pure aluminium alloy. Corrosion rate was found to be higher at initial period due to the absorption of chloride content on the surface of the composite and it was the first stage of localized corrosion attack on the samples. Enhancing the weight fraction of the TaC and Ti particulates increases the corrosion defiance of the HMMCs. The increase in mass loss with increase in time of exposure is an indication that the passive film framed on the MMCs was unable to give adequate fortification to the substrates. Increased duration of exposure in HCl solution tend to form a passive protective layer composed of hydrogen hydroxyl chloride film during the corrosion reaction. Moreover, deducing the wt% of Si_3N_4 particulates improved significantly the corrosion defiance of the composite material. From the results acquired, it was clear that, AA7075 blended with 0.75 wt% TaC, 4 wt% of Si_3N_4 and 1.5 wt% of Ti shows better corrosion resistance in the presence of HCl solution. Compilation of passive lamina on the circumference of the specimens and deduction of chlorides gist in the acrid medium[26]. The specific mechanism of corrosion inhibition TaC/Ti/Si_3N_4 to the surface of AA7075 can be clearly defined by chemisorption process. The chemisorption process is denoted by donor acceptor interaction between the lone pair of the electron from the orbitals of AA7075 alloy. The inhibition of corrosion begins by the displacement of molecules in HCl medium by inhibitors capacity towards toward specific adsorption of the inhibitor on the metal's

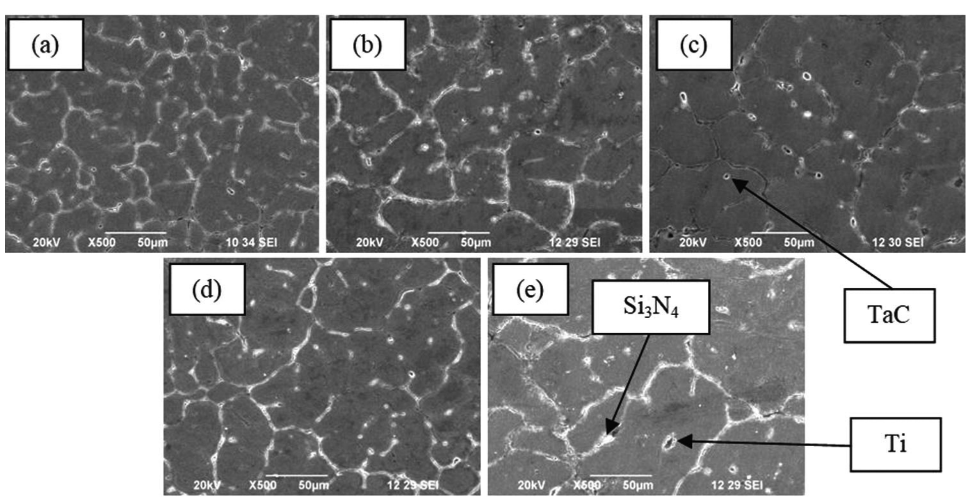

Fig. 6 — Optical micrograph of (a) Pure AA7075, (b) AA7075+0.25wt%TaC+8wt%Si_3N_4+0.5wt%Ti, (c) AA7075+0.5wt%TaC+6wt% Si_3N_4+1wt%Ti, (d) AA7075+0.75wt%TaC+4wt% Si_3N_4+1.5wt%Ti, and (e) AA7075+1wt%TaC+2wt% Si_3N_4+2wt%Ti.

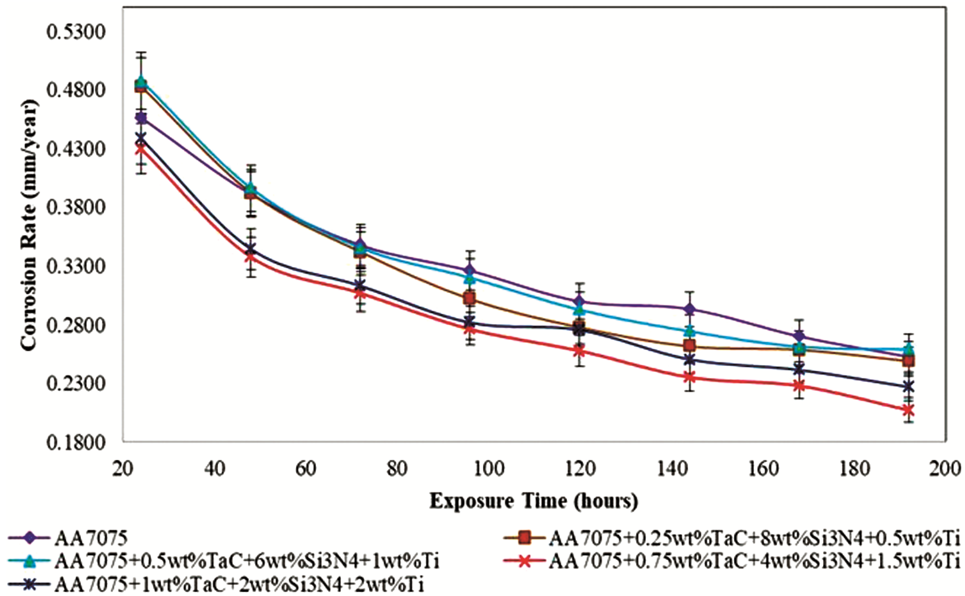

Fig. 7 — Variation in rate of corrosion with respect to exposure time.

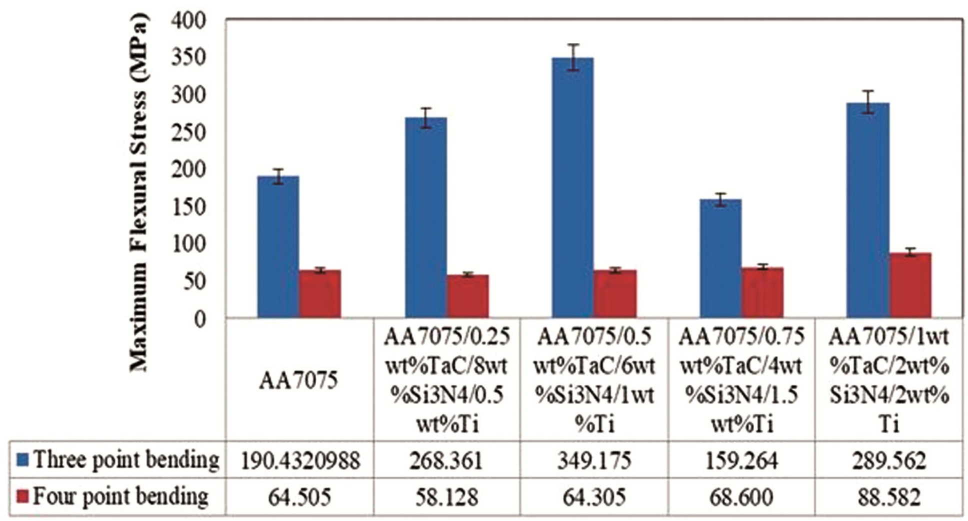

Fig. 8 — Variation of maximum flexural stress of the developed hybrid composites time.

surface. Minimum research has been reported on the improvement in corrosion resistance of AA7075/TaC/Si_3N_4/Ti HMMCs. This reduction in the rate of corrosion may be due to the significant decrease in pitting potential in the developed composite material. Addition of titanium is one of the dominant reason for reduction in corrosion rate of the developed composite material because it is hard and does not furnish any chemical revulsion with aluminium to generate any secondary phase[27].

3.3 Flexural Strength Analysis of AA7075/Si_3N_4/TaC/Ti Hybrid Composites

The flexural strength of pure AA7075 base material and the developed composite material obtained from three point and four point flexural analysis is displayed in Fig. 8 illustrates that the flexural strength enhanced with the inclusion of Si_3N_4, TaC and Ti. It was found that the breaking load and flexural strength was observed to be higher for composite material when compared to base material. The structure and properties of the ceramic reinforcements controls the overall mechanical properties of the composites that are reasoned to strong interfacial bonding that transfers and distributes the load from the matrix to the reinforcements exhibiting increased elastic modulus and strength of the composite material. The structure and characteristics of the reinforcements controls the mechanical behaviour of the MMCs that are reasoned to strong interface that transfers and distributes the load from the matrix to the reinforcements exhibiting increased elastic modulus and strength. The brittleness of the Si_3N_4, TaC and Ti particulates well-ordered with the interface betwixt matrix leads to the increment in the bending strength of the MMCs and it was observed to be larger than that of matrix material. The composite material with 0.5 wt% TaC, 6 wt% Si_3N_4 and 1 wt% Tishowed maximum flexural strength of 349.175 N/mm^2 compared with pure AA7075 that showed 190.432 N/mm^2 for threepoint bending analysis. Also, composite material with 1 wt% TaC, 2 wt% Si_3N_4 and 2 wt% Ti showed maximum flexural strength of 88.582 N/mm^2 compared with pure AA7075 that showed 64.505 N/mm^2 for four point bending analysis. This analysis clearly shows that, TaC and Si_3N_4 are the major contributing material for flexural behaviour of the material because hard ceramic materials restricts the dislocation movement by providing additional strength to the material. The flexural strength was enhanced by 45% than that of AA7075.

3.4 Low Cycle Fatigue Analysis of AA7075/Si_3N_4/TaC/Ti Hybrid Composites

Figure 9 shows the variation of typical stress versus number of cycles plot deformation for the developed hybrid MMCs. This clearly reveals that, the failure modes and the total number of cycles completed by each of the developed composite material at various loading conditions. Also, the table shows the various stress levels and elongation obtained by the developed HMMCs. During experimentation it was noticed that the established composite material unveiled ductile nature at 0.5 wt% TaC, 6 wt% Si_3N_4 and 1 wt% Ti by elongating up to 0.36 mm as shown in Fig. 10. Beyond this composition slight reduction in ductility was observed because of the increment in hardness of the HMMCs. It was clearly showed that, the proposed HMMCs showed higher fatigue life in comparison with unreinforced alloy. The renovation in the fatigue firmness of the matured HMMCs was symbolic at smaller stress levels compared to higher stress levels.

It was also observed that AA7075 reinforced with 0.5wt% TaC, 6wt% Si_3N_4 and 1 wt% Ti displays higher fatigue life by operating at higher tension-compression cycles at varying loading condition, when compared to other developed HMMCs. Smaller addition of tantalum carbide and titanium enhances the fatigue life of the developed MMCs to a greater extent. At this composition the composite material showed ductile ability of the material. The localized sectors of ductile deficiency provoked by the commonly combined structures of fluctuation slip and fracture tip blunting. The inception of the microscopic cracks initiated from aluminium caused by fatigue due to periodic weighing very likely associated to the cumulative aggregation of micro-plastic attrition at the restricted region[28]. This inferred that cyclic

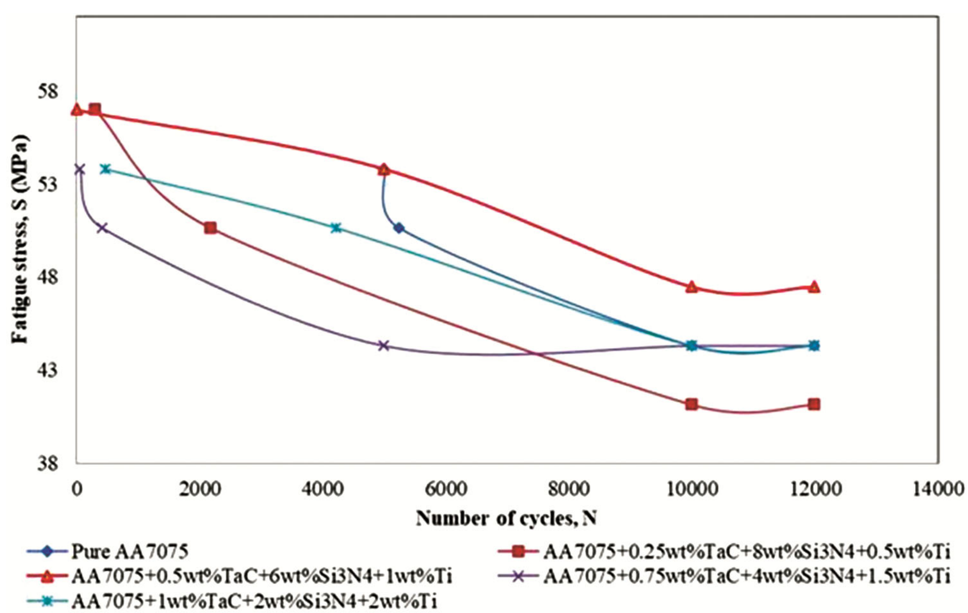

Fig. 9 — S/N plot for the developed hybrid MMCs.

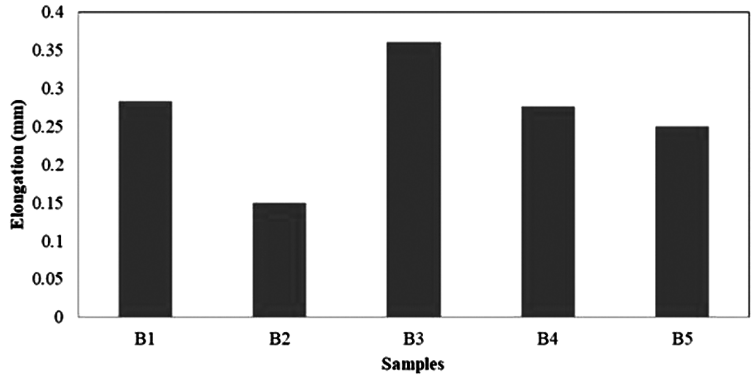

Fig. 10 — Elongation obtained from various samples.

hardening happened during the periodic nature of distortion. This spontaneously demonstrated that original periodic hardening happened with periodic behaviour of distortion and then initiated with balanced softening type[29]. From the analysis, the higher weight fraction of TaC, Si_3N_4 and Ti particles demonstrated remarkable enhancement in fatigue firmness of the HMMCs while correlated with the base matrix alloy. This phenomenon was associated with the occurrence of solid TaC, Ti and Si_3N_4 particulates. When the weight fraction of the reinforcement particulates enhances the fatigue nature of the HMMCs due to the momentous quantity of the weight being relocated to the arthritic particulates and overall strains at a given fatigue stress.

Also, enhancement in fatigue firmness very likely associated to the reduced plastic and elastic strains that outcome from the magnitude of work hardening and modulus, both of which enhances with enhancing weight proportion of the particulates [30]. Reduction in porosity of the composite material attributes in improved fatigue life. The larger yield firmness of advanced HMMCs is also culpable for admirable fatigue defiance. Adding to that, the excellent bonding betwixt matrix and reinforcement and finer grain size is also a dominant parameter which persuaded the enhanced fatigue resistance of developed HMMC. When correlated with base matrix and cast HMMCs, hot forged alloy and its MMCs displayed symbolic enhancement in behaviour due to fatigue.

4 Conclusion

In this research, attempts have been made to fabricate and investigate various mechanical and corrosion characteristics of AA7075 based multi hybrid MMCs using Si_3N_4, TaC and Ti as reinforcements. The significant outcomes of this experimental investigation are summarised below.

- AA7075 alloy reinforced with different wt% of TaC, Si_3N_4 and Ti were manufactured by conventional stir casting technique by using optimum casting process parameters.
- Microstructural analysis reveals the presence of reinforcements and almost homogeneous distribution with good interfacial bonding betwixt the matrix and reinforcements.
- AA7075 reinforced with 0.75 wt% TaC, 4 wt% of Si_3N_4 and 1.5 wt% Ti showed enhanced corrosion resistance. Reduction in the rate of corrosion may be due to the significant decrease in pitting potential of MMCs and the formation of the passive protective layer composed of hydrogen hydroxyl chloride film.
- The HMMCs with 0.5 wt% TaC, 6 wt% Si_3N_4 and 1 wt% Ti showed maximum flexural strength of 349.175 N/mm^2. The brittleness of Si_3N_4, TaC and Ti and the strong interfacial bonding between the matrix and the reinforcement. TaC and Ti restricts the dislocation motion by providing additional strength to the material.

Improvement in fatigue life was noticed from the developed hybrid MMCs. Due to the cushioning effect of the reinforcements, the developed HMMCs with 0.5 wt% TaC, 6 wt% Si_3N_4 and 1 wt% Ti operated at higher number of cycles. It was clearly evident, that a smaller wt% of TaC and Ti improved the fatigue life to a larger extent.

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