Reinforcements, production techniques and property analysis of AA7075 matrix composites – a critical review

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Abstract. Aluminium alloy based metal matrix composites are being extensively used in the aerospace, automobile, defense, marine and electronic industries owing to their excellent strength, high resistance to wear, corrosion and better thermal stability. Many investigators have explored different aluminium alloy series composites, like heat treatable AA2024, AA6061 and AA7075 since the properties of these matrix alloys can be easily tailor made to suite specific application due to easy processability and heat treatability. AA7075 alloy matrix is predominantly being used, as it exhibits high ultimate tensile strength, resistance to corrosion and fatigue in the group. In the current review work, attention is focused to present types of reinforcing materials used, benefits of reinforcement hybridization, methods employed for composite production and critical property analysis, with conclusions of experimentation and the suggested prospective applications of AA7075 composites. Due to good castability and moldability variety of processing techniques in solid, semisolid and liquid states are possible. As matrix alloy, low processing temperature, ability to accommodate reinforcements and adoptability to different reinforcing techniques, it is easy to obtain optimal properties as per the application. AA7075 with small addition of copper is paved the path in the field of electronic and military applications due to high thermal and electrical conductance. Even pure metal addition & magnesium with copper facilitate good weldability, plasticity and corrosion resistance. Due to the flexibility in accommodating carbide and oxide compound reinforcements in the matrix, this matrix composite widens versatility limit due to excellent hardness and wear resistance. CNT and graphite reinforcements to this aluminium series matrix are marked as ultra-high precision components in defense field.

Keywords: AA7075 alloy / reinforcements / processability / property and metal matrix composites

1 Introduction

It is the never ending dream of the materials engineer to discover materials with specific characteristics like, light weight, high formability, high strength and hardness at affordable cost. Accordingly, aluminium matrix composites have become versatile materials to satisfy the requirements of the applications in present industries as per the posing demands of present market. One of the recognizable factors in these composites is property tailorability by suitable heat treatment. Because of flexibility to alter existing properties, aluminium based composites are most preferred for its usage in aerospace, automotive, sporting goods, defense, electronic, thermal management and in general engineering industries [1–3]. In the past few decades many investigations were undertaken

on different series of aluminium alloy for developing the composite materials with an intention of exploring new possible application areas. In the present paper, an effort is made to review the research undertaken in recent past on AA7075 based composites. This work is believed to support many researchers for further exploring the potential areas of investigation on these composites.

2 AA7075 as a matrix material

AA7075 (7xxx grade aluminium) alloys are most favorable for applications due to high specific tensile strength, versatility and performability [4]. This series of aluminium alloys are the most attractive materials for aerospace, marine and automobile applications because of their high ultimate tensile strength to weight ratio, good corrosion resistance and excellent workability [5–9]. They are also employed in structures of missile, structural parts of

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Table 1. Usage limitations of AA7075.

Type of limitation	References
Difficulty in joining by conventional fusion-welding techniques	[37]
Involves complicated process for welding and it is highly reactive to caustic acids, water, and oxygen.	[31]
Poor tribological properties	[4,14,20,25,38–42]
Fatigue cracks due to cyclic loading is one of the most important issues in these alloys	[43–45]
Poor mechanical and the tribological properties at high temperatures	[18]
Reduced strength and hardness due to residual coarse and insoluble secondary phases	[19]
Lower compression strength and hardness	[46]
Formation of built-up-edge to lower machinability and reduce tool life	[23]

automotive and aircraft, railroad cars, sports industry and other high performance structural applications because of formability and specific strength [4,10–13]

Among all other series of aluminium alloys, AA7075 (a typical Al-Zn-Mg-Cu alloy) is much explored. This is the commonly preferred alloy of 7xxx series as it provides a good combination of properties like, very high strength, higher toughness, high thermal and electrical conductance, high abrasion and wear resistance, damage resilience at elevated and cryogenic temperatures, good fatigue strength, creep resistance, highest failure elongation. Hence, is preferred in submarines, ships, prosthetic devices, trucks, rail vehicles, machinery, pressure vessels, aerospace, aircraft (lower drag brace landing gears, ventral fins, and helicopter blades), electronic applications, military and automobile sectors (piston, brake calipers, wheels, and rocker arms) [14–36].

Despite many favorable properties of AA7075 alloy, it also suffers with some limitations that hinders its usage in some applications. The summary of these limitations which needs to be addressed to improve the application range of this alloy is listed in Table 1.

3 Reinforcements with AA7075

Aluminium alloys in general are less hard and have low wear resistance, which hinder their adaptability in high performance mechanical and tribological applications. In order to overcome these problems hard reinforcements are dispersed in the matrix for achieving superior strength to weight ratio, wear resistance, stiffness, resistance to fatigue and higher temperature performance. Hence nowadays the composites containing hard particles are gaining importance [1,47]. Also to improve quality, nature sustainability and bring down the cost of composites, investigations are centered to use reinforcements for higher matrix wettability and dispersivity [48].

Morphologically the reinforcements can be continuous or discontinuous. Continuous fibers in composite provide good strengthening in a specific direction and discontinuous fibers are attractive because of their comparatively low cost and isotropic properties [49]. With these advantages of

discontinuous reinforcements, many such reinforcements are tried in aluminium alloys. Accordingly, various types of particulate reinforcements found place in AA7075 matrix as shown in Figure 1. The summary on type, size and quantity of reinforcements employed by different researchers is presented in Table 2.

4 Techniques used for producing AA7075 MMCs

4.1 Solid state processing techniques

4.1.1 Powder metallurgy (PM)

PM consists of wet mixing of the powders of matrix and reinforcements followed by cold isostatic pressing, degassing, sintering, and hot isostatic pressing [52,55]. Few researchers [85] have developed blended powder semisolid forming (BPSF) which besides providing the benefits of conventional semisolid powder metallurgy, also changes the quantity and size of each element in a compound. This process is done in three main stages, in first stage, the homogeneous dispersion of elemental powders takes place, in second stage mechanical alloying is carried out, it elevates the elemental state powders temperature and allows for solid diffusion, and in third stage semisolid compaction is done which fills the free spaces in between the solid particles with liquid phase.

Due to the application of higher pressure during compaction there was a better liquid phase filling of the voids, which resulted in improvement of density and hardness of composites. Compressive strength was improved by 93% for 20 microns AA7075 matrix particles with incorporation of 20% vol. 45 microns B₄C because of homogeneous distribution of particles which is evident from Figure 2.

In order to obtain a clean metallurgical interface between the reinforcement particles and matrix as well as grain refinement, powders can be cryomilled followed by consolidation through plasma activated sintering (PAS) to prevent any undesirable phases. Cryomilling, involves milling in liquid nitrogen with stearic acid as a surfactant [86]. After milling the mixture of matrix and reinforcement

Fig. 1. Different reinforcements adapted to produce AA7075 MMCs.

powder, it is poured into a graphite mold without pre-pressing [9]. Powders are then consolidated by plasma activated sintering to produce cylindrical composite specimens. For the production of composites, mechanical ball milling of powders was carried out in an argon atmosphere, then mixed powders were subjected to hot press sintering followed by extrusion [5,77,96,104]. In another route, after milling process, the mixed powders were packed in a graphite mold and then cold pressed. Subsequently, the graphite mold was fixed in vacuum hot press sintering furnace to produce the composite compacts [18,103]. As alternate process, the authors [12] produced composite by first milling the matrix and reinforcements followed by encapsulating in pure Cu container with subsequent pressing by equal channel angular pressing (ECAP) route. Investigators even tried vacuum impregnation and explosive pressing for producing AA7075/h-BN and AA7075/B amorphous composites respectively [78]. During the vacuum impregnation the alloy was slightly over heated for enhancing the wettability with BN particles

(upto 40 %vol.). Also these researchers reported that method of explosive pressing consists of affecting a pressure impulse of shock wave to finally obtain the composites. Literature shows that very few researchers have tried these routes for producing MMCs.

4.1.2 Friction stir processing/welding (FSP/FSW)

FSP method is beneficial in enhancing the surface properties of material. This process uses a hard and rotating tool that penetrates into work piece and traversing in forward direction. By this approach, reinforcing particles penetrate the metal surface at a certain depth. The process set up is as shown in Figure 3(i) [65]. It is an alternative to FSW, FSP is developed to overcome the challenges related to uniform distribution of nano reinforcements in aluminium matrix. The experimental setup used by the researchers [23] is as shown in Figure 3(ii). Also, researchers [4,40,90,91] have adapted FSP in their studies for

Table 2. Details on type of reinforcement, quantity and production approach adapted by different researchers.

Type of reinforcement/ reinforcement combination	Particle size	Quantity dispersed	Production approach	References
SiC	20 μm	10, 15 & 20 %vol.	Stir casting	[50]
SiC	20 μm	10, 15 & 20 %vol.	Stir casting	[51]
SiC	50 nm	1 & 5 %vol.	Powder metallurgy	[52]
SiC	20–40 μm	10 %wt.	Stir casting	[53,54]
SiC	40–150 μm	5–25 %vol.	Powder metallurgy	[55]
SiC	150 μm	2–6 %wt.	Stir casting	[14]
SiC	20–40 μm	10 & 15 %wt.	Stir casting	[17]
SiC	45–65 nm	–	Friction stir welding	[56,57]
SiC	80 nm	1 %vol.	Rheofforming	[58]
SiC	15 μm	15 %vol.	Spray deposition	[59]
SiC	45–50 μm	10 %wt.	Stir casting	[60]
SiC	7–34 μm	6 & 9 %wt.	Centrifugal casting	[61]
SiC	–	15 %wt.	Stir casting	[62]
SiC	50 nm	1–4 %wt.	Stir casting	[63,64]
SiC	45–65 nm	–	Friction stir processing	[65]
SiC	50 nm	2–6 %wt.	Stir casting	[66]
SiC	–	5–15 %wt.	Stir casting	[34]
SiC	15–20 μm	8 %wt.	Stir casting	[67]
SiC & Al_2O_3	20–40 μm each	7.5 %wt. each	Stir-casting	[7]
SiC & Al_2O_3	16–100 grit & 100–200 mesh	5–15 %wt. each	Stir casting	[68]
(SiC+Ti)	7 & 35 μm	(40+5) %vol.	Squeeze casting	[69]
SiC & Flyash	SiC: 53 μm	2.5 & 5 %wt. each	Stir casting	[70]
SiC & Cr	7 $\pm$ 0.6 & 30 $\pm$ 1.4 μm	50 & 5 %vol.	Squeeze casting	[21]
SiC & B_4C	10 & 5 μm	1:1 vol. fraction	Liquid pressing process	[71]
SiC & ZrO_2	–	2–6 %wt. & 3%wt.	Stir casting	[72]
SiC & Gr	SiC:150–180 μm Gr:	5 %wt. each	Stir casting	[73]
SiC & h-BN	180–200 μm	5 %wt. each		
SiC & MoS_2	h-BN:90–120 μm MoS_2 :50–80 μm	5 %wt. each		
SiC & Graphene	36 μm & nano size	10, 15 & 1 %wt.	Stir casting	[36]
SiC & TiB_2	20 & 13–14 μm	5 %wt. each individually	Stir casting	[74]
Ag-C NP	10–20 nm	0.5–2.0 %wt.	Mechanical milling	[75]
CNT	20 nm(D) & 8 μm (L)	3 %vol.	Friction stir processing	[23]
CNT	40 nm(D) & 2 μm (L)	1 %wt.	Powder metallurgy	[76]
MWCNTs	30 nm	1–3 %wt.	Stir casting	[32]
Gr	38.33 μm	0.5–1.5 %wt.	Mechanical milling	[5]
Gr	–	Up to 1.5 %wt.	Mechanical alloying and hot extrusion	[77]
h-BN, amorphous B & (B_4C +n-W)	– 100 μm & (100 μm + 50 nm)	40, 30, & (20+2) %vol.	Vacuum impregnation technology, explosive pressing and mechanical alloying	[78]
Al_2O_3	36–72 μm	–	Stir casting	[79]
Al_2O_3	20 nm	Up to 7 %wt.	Mechanical milling	[18]
Al_2O_3	–	10 %vol.	High pressure torsion	[80]

Table 2. (continued).

Type of reinforcement/ reinforcement combination	Particle size	Quantity dispersed	Production approach	References
Al ₂ O ₃	Nano size	1.5 %wt.	Casting	[81]
Al ₂ O ₃	30–50 μ m	2.5 %wt.	Squeeze casting	[82]
Al ₂ O ₃	20–30 nm	1–4 %wt.	Stir casting	[29]
Al ₂ O ₃ & graphite	—	2-8 & 5 %wt.	Stir casting	[83]
Al ₂ O ₃ & h-BN	30–50 & 80–100 nm	1 & 0.5 %wt.	Stir casting	[21]
Al ₂ O ₃ & h-BN	5-10 μ m each	2.5 & 5 %wt. each	Two step stir casting	[84]
Al ₂ O ₃ & Flyash	—	5 & 10 %wt. each	Stir casting	[28]
Al ₂ O ₃ & SiC	20–30 & 50 nm	1–4 %wt. combined	Stir casting	[30]
Al ₂ O ₃ & SiC	3 & 2 μ m	1.8-7.5 & 1.5-6 %wt.	Friction stir processing	[40]
TiO ₂	30–40 nm	10–20 %wt.	Mechanical milling	[12]
B ₄ C	<10 μ m	Up to 12.5 %wt.	Mechanical milling	[9]
B ₄ C	15–18 μ m	—	Friction stir processing	[4]
B ₄ C	—	15 %wt.	Stir casting	[62]
B ₄ C	45 μ m	5–20 %vol.	Powder metallurgy	[85]
B ₄ C	2 μ m	20 %wt.	Powder metallurgy	[86]
B ₄ C	2.031 μ m	7.5 %wt.	Plasma activated sintering	[8]
B ₄ C & Coconut shell flyash	75 & 62 μ m	Up to 12 & 3 %wt.	Stir casting	[87]
B ₄ C & Rice husk ash	50 & 62 μ m	5 & 3.5 %wt.	Stir casting	[46]
B ₄ C & MoS ₂	10 & 2 μ m	4–12 & 3 %wt.	Stir casting	[25]
B ₄ C & Flyash	3–10 μ m each	2–8 & 2 %wt.	Stir casting	[26]
B ₄ C & Flyash	150 μ m each	1–4 & 6-9 %wt.	Stir casting	[88]
B ₄ C & BN	1 μ m each	3–9 & 3 %wt.	Stir casting	[89]
B ₄ C & BN	1 & 10 μ m	3–9 & 3%wt.	Stir casting	[42]
B ₄ C & Cow dung ash	50–70 & 40–60 μ m	2.5–7.5 %wt. each	Two step stir casting	[33]
ZrO ₂	110 nm	2 & 5 %wt.	Mechanical milling	[90]
ZrB ₂ & hBN	5 & 3 μ m	5 %wt. each	Stir-squeeze cast technique	[39]
TiC	20 nm	2 %wt.	Friction stir processing	[91]
TiC	3.5 μ m	2–6 %vol.	Friction stir processing	[92]
TiC	—	2.5–7.5 %wt.	Stir casting	[27]
TiC	6-8 μ m	—	laser shock peening (LSP) and friction stir welding (FSW)	[93]
TiC & B ₄ C	5–15 & 10–25 μ m	5–10 %vol. each	Two step stir casting	[94]
TiC & MoS ₂	Micro particles	2, 4 & 2%wt.	Stir casting	[95]
Ti & Gr	≤ 80 & ≤ 150 μ m	3, 5, 6 & 8 %wt. combined	In situ process	[96]
TiB ₂	—	15 %wt.	Stir casting	[62]
TiB ₂	20-500 nm	6 %wt.	In-situ process	[97]
TiB ₂	Nano size	1.5 %vol.	In-situ process	[98]
TiB ₂	—	6 %wt.	In-situ process	[99]
TiB ₂ & Gr	—	1.5–6 & 1%wt.	In-situ process	[24]
Si ₃ N ₄	—	2-8 %wt.	Stir casting	[100]
Si ₃ N ₄	10–40 μ m	4, 8 & 12%wt.	Stir casting	[101]
Si ₃ N ₄	—	4, 8 & 12%wt.	Stir casting	[102]

Table 2. (continued).

Type of reinforcement/ reinforcement combination	Particle size	Quantity dispersed	Production approach	References
TaC, Si ₃ N ₄ , Ti	200-250 nm, 20 μ m, 70 μ m	0.25–1, 2-8 %wt., 0.5-2 %wt.	Stir casting	[35]
MoSi ₂	2–8 μ m	2–5 %wt.	Stir casting	[38]
VN	10–50 μ m	15 %wt.	Hot press sintering	[103]

Fig. 2. SEM images of composites with 5% and 20% B₄C under different experimental conditions: (a) 50 MPa, 20 μ m Al7075/45 μ m B₄C; (b) 100 MPa, 20 μ m Al7075/45 μ m B₄C; (c) 50 MPa, 45 μ m Al7075/45 μ m B₄C; (d) 100 MPa, 45 μ m Al7075/45 μ m B₄C; (e) 50 MPa, 63 μ m Al7075/45 μ m B₄C; (f) 100 MPa, 63 μ m Al7075/45 μ m B₄C [85].

(i)

(ii)

Fig. 3. (i) Schematic of FSP [65] and (ii) Set up of FSP [23].

Fig. 4. (a) Cross section of S17 sample. (b) and (c) Amplified zones of the TiC particle distribution [91].

Fig. 5. Variation of dislocation density of AA7075 after different numbers of LSP impacts [93].

developing composites with homogeneous dispersion of reinforcement in the matrix. FSW is a solid-state joining method, which uses a non-consumable rotating tool with a specially designed pin and shoulder inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint. Figure 4 shows the microstructure showing the achieved homogeneous dispersion by FSP [91]. FSP causes intense plastic deformation and high strain rates in the processed material resulting in precise control of the microstructure through material mixing and densification.

Basically FSP is an outgrowth of FSW [56,57]. Laser shock peening (LSP) is a surface processing method which refines the grains and extends the life of metallic structural components and hence investigators [93] used LSP in conjunction with FSW to produce HMMCs with

high-density dislocation. They developed AA7075 alloy based hybrid composites by FSW, followed by LSP on AA7075. The specimens in their study were shocked by the laser with a 1.5 mm spot diameter, and 8 J pulse energy released by a convergent lens with a focal length of 120 mm, 60% overlap rate and different numbers. Also flowing clean water and black paint were chosen to reduce the reflection of shock waves and the laser thermal injury to the laser shock peened surface with a thickness of approximately 1 and 0.1 mm. Figure 5 shows the improvement in dislocation density due to LSP. From Figure 5, it can be inferred that LSP with 2 impacts is advantageous to increase the dislocation density in the composite. Higher the dislocation density, more nucleation sites for the secondary precipitation of strengthening phase during intentional deformation and heat treatment.

Fig. 6. (i): SEM images of the polished surface of composite reinforced with 10% SiC particle [34]. (ii): Fairly uniform dispersion of SiC and TiB₂ attributes throughout the aluminium matrix [74].

Fig. 7. Schematic diagram of stir casting setup [74].

4.2 Liquid state processing techniques

4.2.1 Stir casting

MMCs are generally produced by different techniques like, powder metallurgy, squeeze casting, and the stir casting. Stir casting is a least expensive technique as compared to others and also it is possible to achieve homogeneous distribution of reinforcements [Figure 6](#) [17,34,63,74,95].

This process provides a minimal damage to reinforcement with no limitation on stir cast components size and shape [36]. This process involves melting of the matrix material, and pouring the reinforcements into the melt and achieving an appropriate distribution and bonding through stirring. This technique is very basic and versatile, and also, being used for big quantity manufacturing [66]. The schematic representation of stir casting is shown in [Figure 7](#). But some of the challenges reported in respect of this technique is that improper distribution, poor wettability and porosity formation [26,67] and also higher stirring time leads to formation of voids and agglomeration

of reinforcements [7]. The various stir cast processing parameters used by the investigators in the past for AA7075 matrix composites have been listed in [Table 3](#).

4.2.2 Squeeze casting and stir-squeeze casting

The researchers [82] prepared AA7075 alloy based alumina reinforced MMCs by squeeze casting technique. Initially the alloy temperature was raised to 750 °C and alumina particles were charged into a preheater for pre heating at 300 °C. Once the alloy melts, it is agitated by a stirrer between the speed range 400–500 rpm. The alumina particles are then introduced in the vortex and melt is stirred continuously at 500 rpm for 5 min. Melt is then poured into a die which is preheated to 150 °C. A squeeze pressure of 125 MPa was applied for 15 s during the solidification of composite. Investigator [22] fabricated aluminium alloy/SiC_p composites by squeeze casting. The molten AA7075 at 800 °C was squeezed into a preheated ceramic preform at 580 °C with a pressure of 75 MPa. The casting is held under pressure for about 3 min and cooled down to the room temperature. The researchers in [39] used the squeeze casting set up as shown in the schematic diagram of [Figure 8](#).

AA7075 of required quantity is melted in an induction electric resistance furnace at a temperature of 800 °C with a shield of argon atmosphere. The reinforcement particles were initially preheated to 250 °C for 1 h in a pre-heater furnace. This aids for removing the moisture content and to enhance wettability. An alumina coated stainless steel stirrer is used for the stirring. The melt is stirred at 400 rpm for 5 min. The reinforcements are then added to melt at a constant flow rate. The depth of immersion of stirrer was at two-third of the height of the melt for even distribution of particles in the matrix. After the completion of stirring cycle, the mixed reinforced melt is poured into a preheated die, through a preheated run-way channel. The temperature of melt is kept constant at 750 °C, while pouring. On completion of the pouring, a squeeze pressure of 393 kN is applied to the molten melt in

Table 3. Processing parameters used by the investigators in stir casting for producing AA7075 MMCs.

Melt temperature	Preheating temperatures	Wetting agent	Protective environment	Impeller details	Degassing agent	Stirring speed/time	References
–	SiC _p : 250 °C	–	Argon gas	–	–	–	[50]
720 °C	SiC _p : 250 °C	–	Argon gas	–	–	300 rpm/20 min	[51]
710 °C	–	–	–	–	Hexa chloro ethane tablet	400 rpm/10 min	[14]
800 °C	SiC _p : 250 °C Mold: 400 °C	–	–	–	Hexa chloro ethane tablet	300 rpm/12–15 min	[62]
850 °C	Nano-SiC: 250 °C	–	–	3 blades; stainless steel material	–	750 rpm/10 min	[64]
750–800 °C, held for 1 h	Nano-SiC: 400–550 °C Die: 300 °C	1 %wt. Mg	–	–	–	500–650 rpm	[66]
Raised to: 700 ^o , down to: 630–640 °C Raised to: 700 ^o 715 °C	– Al ₂ O ₃ & SiC: 900 °C	–	Argon gas	BN coated, 2 blades	–	900 rpm/5 min	[34]
Raised to: 750 °C, down to: 620 °C	–	–	Inert gas & electromagnetic assisted	–	–	–	[7]
–	–	–	–	–	–	600 rpm	[68]
725 °C	SiC & ZrO ₂ : 300 °C Die: 250 °C	–	Argon gas	–	–	450 rpm	[70]
750 °C	SiC, graphite, hBN, and MoS ₂ : 450 °C	–	–	–	–	350 rpm	[72]
800 °C for 2 h	SiC & Graphene: 1000 °C, 2 h Die: 300 °C, 2 h	Mg ribbon	–	–	–	200–300 rpm/15 min	[73]
750 °C	SiC and TiB ₂ : 450 °C, 0.5 h	2% Mg	–	–	–	200 rpm/10 min	[36]
650 °C for 2–h, raised to 750 °C & 730–800 °C	MWCNT: 650 °C for 2 h. Mold: 250 °C for about 2 h	–	–	3 bladed, stainless steel stirrer coated with alumina	5 g of nucleant & degasser	300 rpm/10 min 200–400 rpm/10–20 min	[74] [32]
900 °C	n-alumina: 650 °C	1 %wt. Mg	–	stainless steel stirrer coated with alumina	–	–	[29]
850 °C	–	–	–	spiral-shaped stirrer	–	500 rpm for 5 min	[83]
–	Alumina & hBN: 500 °C	–	ultrasonic assisted cavitation	–	10grams hexafluoride (Na ₃ AlF ₆) for slag removal	–	[21]
720 °C	Al ₂ O ₃ and flyash: 300 °C for 3 h	3 % Mg	–	–	–	–	[28]

Table 3. (continued).

Melt temperature	Preheating temperatures	Wetting agent	Protective environment	Impeller details	Degassing agent	Stirring speed/time	References
650 °C	nano- Al_2O_3 and nano-SiC: 900 °C	1 %wt. Mg	–	3 bladed, stainless steel stirrer coated with alumina	–	10 min	[30]
800 °C	SiC: 250 °C Mold: 400 °C	–	–	–	Hexa chloro ethane tablet	300 rpm/12–15 min	[62]
780 °C	B_4C and Coconut shell flyash: 300 °C	–	–	–	Potassium titanium fluoride	800 rpm/10 min	[87]
–	B_4C & rice husk ash: 300 °C/40 min Mold: 450 °C	–	Argon gas/10 lt./min	–	Potassium titanium fluoride	415 rpm	[46]
680 °C, 15 min–raised to 900 °C–raised to 1100 °C	Steel die: 300 °C	–	Argon gas/3.5 L/min	–	–	450 rpm/10 min raised to 500 rpm/15 min	[25]
850 °C	B_4C : 300 °C Flyash: 400 °C	1 %wt. Mg	Argon gas	graphite stirrer impeller of blade angle 30° with stainless steel rod	Potassium titanium fluoride	550 rpm	[26]
1000 °C	B_4C & Flyash: 500 °C, 1 h B_4C & BN: 550 °C	1 %wt. Mg	–	–	–	–	[88]
–	750 °C, 20 min, raised to 850 °C, raised to 950 °C	–	–	–	–	600 rpm/15 min	[89]
750 °C, 20 min, raised to 850 °C, raised to 950 °C	Steel die: 350 °C	–	Argon and SF_6 gas mixture at 3.5 L/min	–	–	500 rpm/15 min, raised to 600 rpm/20 min	[42]
1000 °C	B_4C & cow dung ash: 400 °C	–	–	4 blades/45°	–	300–400 rpm/3 min	[33]
800 °C	TiC: 200 °C	–	–	–	–	300 rpm/10 min	[27]
740 °C, reduced to 590 °C	–	–	–	–	–	350 rpm/10 min	[94]
850 °C	Die: 250 °C	–	–	–	–	700 rpm/10 min	[95]
950 °C	Si_3N_4 : 450 °C	–	–	–	–	250 rpm/10 min	[100]
780–800 °C	Si_3N_4 : 350–375 °C	–	–	–	–	4–5 min	[101]
650 °C	TaC/ Si_3N_4 /Ti: 550 °C	–	–	–	–	200 rpm/5 min	[35]
750 °C	MoSi ₂ : 400 °C, 2 h	–	–	graphite impeller blade/30°	–	540 rpm, 500 rpm–10 min	[38]

Fig. 8. Schematic depiction of stir-squeeze casting setup [39].

Fig. 9. Schematic depiction of centrifugal casting machine showing orthographic views ((a) & (b)) and isometric view (c) [61].

a die chamber. Inside of the die chamber is coated with a graphite lubricant for protecting the die and for easy removal of castings.

4.2.3 Centrifugal casting

The schematic diagram of centrifugal casting adapted by [61] is as shown in Figure 9. It is one of the widely adapted, simplest and low cost process to achieve continuous gradient composites. The centrifugal force resulting during the mold rotation is a key parameter in order to create a continuous gradient in the composites. This force distributes the constituent (reinforcements) from the axis of rotation (core) to the periphery (surface) in the continuous manner without any mechanically weak interfaces based on their density. Besides forming the gradient structure, the centrifugal force also helps in providing complete mold filling with the required microstructure control in the product. In their study, researchers used aluminium alloy matrix material which was superheated to 780 °C at a heating rate of 25 °C/min in a resistance furnace (7.5 kW) under the normal air atmosphere.

The SiC particles were preheated to 400 °C for 30 min before they are poured into molten metal to obtain the composite slurry. The slurry is agitated with a stirrer to provide the wetting between particles and the molten metal. The pouring temperature of the slurry is maintained nearly at 700 °C. The preheating of graphite mold is done at 250 °C to prevent the mold chilling effect. The mold rotational speed is 700 rpm.

4.2.4 In-situ process

In this process, the matrix material is initially melted. Then the reinforcements are formed in situ in the molten alloy by displacement reactions between alloying elements, or between the alloying elements and the ceramic compounds. In situ process avoids the problems of particle clustering and the loss of particles when the traditional spray forming processes are used. Fine particles with the size of sub microns can be formed, which is hard to achieve by the conventional injection processes [96]. In their study it is observed that fine TiC particles decrease effectively the growth rate of the grains in the solidification process, hence 3 wt.% TiC/7075 composite showed the grain size smaller than that of the alone 7075 alloy Figure 10. This technique is also adapted by researchers [24,97–99] for their investigation.

4.3 Other techniques

4.3.1 Rheoforming

The investigators [58] in their study prepared n-SiC/7075 AMCs semisolid slurries, further they are transferred into a die cavity and rheoformed. The die is preheated to 300 °C. A lubricant consisting of a mixture of graphite and water is used to reduce the friction between die and semisolid slurries. The rheoforming experiments are carried out on a hydraulic press of 2000 kN. The semisolid slurries are rheoformed under a force of 2000 kN. Meanwhile, a rheoforming of the AA7075 matrix is also carried out under the same conditions to compare their mechanical properties to n-SiC/7075 AMCs. The schematic of rheoforming equipment used in their study is as shown in Figure 11.

Other techniques which are rarely adapted for producing AA7075 MMCs include liquid pressing process [71], spray deposition [59] and high pressure torsion [80].

The summary of various production processes adapted by researchers for producing AA7075 matrix based composites has been depicted in Figure 12 and the reinforcement specific production approaches have been tabulated in Table 2.

5 List of research and findings related to AA7075 MMCs during the year 2010-20

5.1 Research on the composites based on carbides

Harikrishna Rana and Vishvesh Badheka [4] fabricated AA7075 matrix composites by dispersing hard B₄C in to it. These reinforcing particles are in the range 15–18 μm. The fabrication technique adapted in this study is friction stir processing. The researchers carried out parametric inves-

Fig. 10. Microstructure of the matrix alloy and 3 wt.% TiC/7075 composite showing the grain size of the composite is smaller than that of the alone 7075 alloy.

Fig. 11. Schematic diagram of the rheoforming die [58].

tigation to obtain homogeneous distribution of reinforcements in the substrate matrix by adapting different combination of parameter sets like tool rotational speed and alteration in direction of tool travel. The conclusions of the study are that lowest tool rotational speed and changing tool travel direction resulted in homogeneous distribution of B_4C in the alloy and is confirmed by microstructure studies.

Chuangdong Wu et al. [8] have produced AA7075 composite by reinforcing 7.5 %wt. of B_4C and synthesized by plasma activated sintering (PAS) and investigated the effect of temperature, in the range of 450–540 °C, and holding time on the densification characteristics of AA7075- B_4C composites. Nearly full density combined

with good spreadability, relatively high Vicker's hardness, high bending strength, high compression yield strength and fracture strength are found to be attainable at 530 °C and a short PAS holding time of 3 min. Also raising the sintering temperature to 540 °C or extending the holding time is found to increase of solid-state diffusion on the surface and formation of the MgO , resulting in the reduction of bending strength.

Qiang Shen et al. [9] prepared AA7075/ B_4C (2.5, 5, 7.5, 10 and 12.5 %wt.) composites by milling powder mixtures using a shaker-mixer mill, sintering the milled mixtures using plasma activated sintering (PAS), and heat treating the sintered product. Increasing the B_4C quantity has improved the hardness, bending strength, and compressive yield strength of composite. But addition of higher weight percentage of B_4C led to agglomeration, reducing the hardness and bending strength of the composite. Excellent mechanical properties are due to good interfacial bonding between the matrix alloy and reinforcement.

Rajesh Kumar Bhushan et al. [17] have fabricated AA7075, AA7075-10 %wt. SiC (20–40 μm) and AA7075-15 %wt. SiC (20–40 μm) composites by stir casting method and have analyzed composites using SEM, XRD, DTA and electron probe microscopic analysis (EPMA). Authors have concluded that the uniform distribution of SiC_p is possible to achieve by stir casting and have found that there are no secondary chemical reactions, and is confirmed by XRD and EPMA analysis. By DTA analysis, it is concluded that the developed composites are suitable for applications where the temperature could be as high as 1250 °C.

Lu et al. [21] in their investigation have reinforced a mixture of 50 %vol. SiC_p and 5 %vol. Cr particles in aluminium alloy 7075 by squeeze casting to produce HMMCs. The aim of their investigation was to understand the mechanical and thermo-physical characteristics of produced composites.

Fig. 12. Different production methods adapted to produce AA7075 matrix based composites.

Ramkumar et al. [27] have developed TiC reinforced AA7075 MMCs to understand microstructure, mechanical and tribological behavior of the composites. The quantity of reinforcement is 2.5, 5, and 7.5 %wt. and the fabrication approach was stir casting with bottom pouring facility. The results indicated that the bending strength of composite with 7.5 %wt. TiC had noticeable improvement by 5.8 times when compared to base alloy, which resulted due to the grain refinement, uniform distribution, dispersion of reinforcement particles in the matrix. Also increasing of reinforcement in the matrix had showed an enhanced resistance to wear because of increase in strength of the matrix, dispersion strengthening and very good interfacial bonding.

Devaganesh et al. [31] conducted tests to understand the mechanical and tribological properties of SiC reinforced AA7075 MMCs. The composites are also reinforced with 5 %wt. of solid lubricants like Gr, MoS₂ and h-BN along with SiC to produce three kinds of hybrid composites. The results indicated that Al7075 with 5 %wt. SiC and 5 %wt. graphite composite performed well among all other hybrid

composites by evincing excellent mechanical and tribological properties which might be due to the synergic effect of graphite with the AA7075-SiC MMC.

Ficici [34] has studied the surface roughness in drilling particle-reinforced composites. In this study he reinforced silicon carbide (SiC_p) in AA7075 matrix by stir casting method. The results of the drilling test indicate that the feed and cutting speed have very strong effect on the surface roughness of matrix alloy and composite materials.

Hemalatha et al. [36] have fabricated SiC and Graphene reinforced AA7075 based hybrid metal matrix composites. Their objective was to understand the effect of reinforcements of the matrix alloy. The fabrication approach adapted in this study was stir casting. Here the chosen mass of SiC was 10 and 15 %wt. and Graphene maintained constant at 1% for both compositions. The conclusion of this research is that the addition of reinforcement from 10 to 15 %wt. the mechanical properties increased whereas the wear rate decreased.

Karthikeyan et.al [50] in 2010 have produced 7075 Al-SiC composites by stir casting method with changing amount of SiC particles (10, 15 and 20 %vol.) and

Fig. 13. Variation of CTE for different temperatures [51].

conducted the calorimetric study by differential scanning calorimetry (DSC) to analyze specific heat properties of alloy and composites. It is observed in the study of all types of composites with the same conditions had entirely different heat capacity (C_p) values and were lower than the AA7075.

Keeping in mind the demand for lightweight, dimensionally stable materials for critical aerospace applications Karthikeyan et al. [51] have investigated the thermo physical property of stir cast AA7075 reinforced with SiC composites (10, 15 and 20 %vol.) in thermo mechanical analyzer (TMA). Their experimental work indicated that composites had lower coefficient of expansion (CTE) values than that of alloy. Figure 13 shows that higher the volume fraction, the smaller is the CTE value of the metal matrix composites.

In the research work of Ahmed et al. [52], PM technique is used to produce the n-SiC_p/7075 AMMCs. The composites were reinforced with 1 and 5 %vol. fraction of n-SiC_p. The alloy and composites are mechanically tested for knowing the modulus of elasticity, yield strength, ultimate tensile strength and ductility. The conclusions of these authors is that by reinforcing n-SiC_p, a significant variation is observed in microstructure and tensile properties of the AA7075 and no grain refinement is noticed in the composites. The grain structure of composites is noticed to be coarser than that of the base alloy. The hardness and tensile strength of the composites are observed to be fairly low (25–35% and 35–44% decrease in the hardness and ultimate tensile strength of the composites, respectively) as compared to base alloy. Deterioration in properties is due to segregated magnesium at the oxidized n-SiC_p-Al interfaces and grain boundaries, resulting in reduced precipitation hardening of the aluminium matrix.

Rajesh Kumar Bhushan et al. [53] have analyzed the effect of cutting speed, depth of cut, and feed on surface roughness while machining of AA7075 and 10 %wt. SiC_p MMCs. The AA7075 and 10 %wt. SiC_p (particle size 20–40 μm) composites are produced by stir casting route. The observation made by the investigators through their experiments is that the surface roughness of aluminium alloy is less in comparison to AMCs during turning by carbide as well as polycrystalline diamond (PCD) inserts. Wear of carbide and PCD inserts is found to be less while turning of aluminium alloy as compared to composites and wear of PCD insert is less as compared to wear of carbide insert while turning of composites. For optimum surface roughness while turning composite specimen by carbide insert it is suggested to maintain cutting speed within the range of 180–220 m/min, feed within range of 0.1–0.3 mm/rev, and depth of cut within range of 0.5–1.5 mm. Also while using PCD inserts the cutting speed above 220 m/min but at a feed of less than 0.2 mm/rev and depth of cut less than 1.0 mm to be maintained.

In the year 2010, Saeed Zare Chavoshi [54] has investigated the effects of feed, depth of cut and cutting speed on flank wear of tungsten carbide and polycrystalline diamond (PCD) inserts in CNC turning of AA7075 and 10 %wt. of SiC composite. Also artificial neural network (ANN) and co-active neuro fuzzy inference system (CANFIS) are used to predict the flank wear of tungsten carbide and PCD inserts. Conclusions made by this researcher is that increase in feed, depth of cut and cutting speed increases the flank wear. The feed and depth of cut are found to be the most effective parameters on the flank wear but the cutting speed has least effect and there is no interaction between the feed, depth of cut and cutting speed. Also the predictive ANN model is observed to be much more accurate in predicting of tool flank wear as compared to CANFIS model.

The influence of pin geometry on the macrostructure, microstructure and mechanical properties of the friction stir welds, reinforced with n-SiC particles are studied by Bahrami et al. [56] during 2014. Study is undertaken with five FSW tools with different pin geometries i.e. threaded tapered, triangular, square, four-flute square, and four-flute cylindrical (TT, T, S, FFS, and FFC). Of all these, highest ultimate tensile strength is obtained with triangular pin tool. Lowest average microhardness value as well as the more homogeneous particle dispersion is found to be in threaded tapered specimen. Also four-flute cylindrical specimen resulted the highest average microhardness with respect to other specimens.

Bahrami et al. [57] fabricated AA7075 matrix based n-SiC reinforced composites by friction stir welding (FSW) and conducted analysis on the influence of SiC on fatigue life, impact energy and tensile strength of alloy and composites. These researchers adapted threaded tapered friction stir welding tool for FSW. In each friction stir welded joint, three distinct areas are discovered, namely stir zone (SZ), thermo-mechanically affected zone (TMAZ) and heat affected zone (HAZ). The presence of n-SiC particles, tensile strength, percent elongation, fatigue life,

and toughness of the joint improved significantly. The improvement of mechanical properties is due to finer grain size of SZ associated with n-SiC particles.

Jiang and Wang [58] prepared semisolid slurry of AA7075 MMCs by reinforcing n-SiC particulates which is further rheoformed to get cylindrical components. Yield strength and ultimate tensile strength of these components made of composite are superior in comparison to that of base alloy.

Wu et al. [59] investigated the flow stress behavior and processing map of extruded aluminium composites with SiC as reinforcements. They adapted spray deposition technique and the results showed that true stress-true strain curve exhibited almost a rapid flow softening behaviour without an obvious work hardening, and the stress decreased with increase in temperature and decreasing strain rate.

Shrivastava et al. [60] have fabricated SiC based AA7075 MMCs by stir casting route. The SiC were in the range 45–50 μm and their reinforced quantity was 10 %wt. The objective of these researchers is to assess sliding wear under dry, oil lubricated and inert gas environments. The test results showed that wear rate is minimal for both the alloy and the composite under lubricated condition in comparison to dry and inert condition. Rate of wear has increased with the normal load and sliding speed and it reached peak in inert condition of matrix alloy at 30 N. Also the coefficient of friction is observed to have reduced for MMCs as compared to alloy under all the conditions of lubrication.

Prabhu [61] fabricated AA7075-SiC composites and conducted experiments to arrive at the material characterization. The centrifugal casting is adapted to reinforce 6 and 9 %wt. of SiC in the alloy matrix. His research output shows that as the quantity of SiC is increased accordingly the properties like hardness, strength and wear resistance have found to improve. The composite with 9 %wt. reinforcement is found to be having superior properties as compared to alloy and the other composite under consideration.

Bandhu et al. [62] fabricated four types of AA7075 based composites. These composites are reinforced with SiC, Al_2O_3 , B_4C and TiB_2 respectively each with 15 %wt. The researchers have used stir casting for the production of composite. The composites produced are tested for tensile strength, hardness, and impact strength and these are noticed to be higher in comparison to the alloy.

Lee et al. [105] developed AA7075 MMCs by reinforcing SiC particles of size 10, 30 μm , and bimodal (10+30) μm in quantity of 49.5, 54.1 and 56.5 %vol. respectively. The investigators worked on to understand effects of SiC particulate size on dynamic compressive properties of the composites. It is observed that after the quasi-static compressive tests, cracks are formed in a shear mode as a number of SiC particles readily initiated cracks, which resulted in relatively low compressive strains which is far below that of the AA7075 matrix.

Suresh et al. [63,64] have used n-SiC (50 nm) to reinforce them in AA7075 matrix. They synthesized composites by stir casting method and also their wear and friction characteristics are evaluated. SiC is reinforced in varying proportion of 1, 2, 3 and 4 %wt. in AA7075 matrix for obtaining MMCs. It is concluded that by increasing applied load and sliding

distance the wear performance of the test samples linearly decreases. There is a relative reduction in weight loss and friction coefficient with increase of quantity of nano reinforcements. The most efficient result is observed to have achieved at 4 %wt. of n-SiC.

Ramezani et al. [65] used friction stir processing and have developed the composites consisting of nano-SiC particles reinforced in AA7075 alloy. The mean size of SiC are in the range 45–65 nm. These researchers have studied the influence of input parameters along with speed of rotation, speed of traverse and number of pass on the tool wear, microhardness and the topography through the response surface methodology. Analysis of variance showed that quadratic polynomial models are fitting to predict tool wear and microhardness. Also the results showed that tool wear also varied between 12 and 116 mm under different parameters and the speed of rotation, number of passes of 52.9 and 13.1%, respectively, making higher influence on tool wear.

Suresh and Sudhakara [66] carried out the electric discharge machining and mechanical characteristics of AA7075/n-SiC composites that are fabricated by stir casting techniques. These have incorporated n-SiC with 2, 4 and 6 %wt. quantity along with Mg 1.5%wt. The results of this study showed that AA7075-6 %wt. SiC nanocomposite material having highest hardness in comparison to base alloy and other category of nano composites. The gap voltage (V) is the prime influential parameter for material removal rate followed by wire feed and pulse-off time. Also it is noticed that quantity of reinforcements is the prime influencing parameter for surface roughness.

Singh et al. [67] reinforced SiC (60–70 μm , 8 %wt.) in AA7075 matrix by using stir casting techniques. These researchers conducted dry sliding wear of composites in pin-on-disc machine. Their experimentation indicated that the coefficient of friction and wear rate are decreased to an amount equal to 30–40% in comparison to the base alloy.

Chul Jo et al. [71] have reinforced SiC and B_4C particles in AA7075 matrix by liquid pressing process. The volume fraction ratio maintained was 1:1. The HMMCs developed in this study indicated high dynamic compressive strength and a good strain rate.

Javdani and Daei-sorkhabi [85] have cold compacted AA7075- B_4C blends and pressed at semisolid state to prepare MMCs. The researchers aimed at understanding the effect size of the matrix (20, 45 and 63 μm), reinforcement quantity (5, 10 and 20 %vol.) and semisolid compaction pressure (50 and 100 MPa) on the morphology, microstructure, density, hardness, compression and bending strength. The results revealed that composites with 20 μm AA7075 and 20 %vol., 45 μm B_4C powder pressed under 100 MPa possessed the highest values of hardness (HV 190) and compressive strength (336 MPa).

Wu et al. [86] produced AA7075/ B_4C composites by cryomilling and consolidation under a uniaxial pressure of 20 MPa. The focus of investigation is to understand the influence of content of B_4C on microstructure and mechanical behavior of composites. The result of this study has revealed that the heat treatment does not have any influence in the annealing of the dislocations in the composites. A high dislocations density is noticed inside the

grains of alloy lying at the vicinity of the B_4C particles. Also the heat treated specimen, having high yield strength, displayed a plasticity of 11.7%.

AA7075-TiC (3.5 μm) composites produced by FSP have been studied for corrosion behavior [91] in the year 2018. Polarization tests have been conducted by Electrochemical Work Station. The molarity of the electrolyte is changed to 1, 2, and 3 M NaCl. Corrosion rates are calculated in terms of the corrosion current by using Tafel curves. These investigators concluded the rate of corrosion of all the samples had raised with the increase the concentration of the NaCl irrespective of the quantity of TiC.

Wang et al. [93] have studied the influence of laser shock peening on the coefficient of thermal expansion (CTE) of AA7075 matrix composites. Size of TiC taken is approximately 6–8 μm . The composites are fabricated by friction stir processing. The results of this study showed that the CTE value of the laser shock peened samples having TiC has reduced by 30% in comparison with that of the as-friction stir weld sample.

Liu et al. [106] developed MMCs based on AA7075 with B_4C reinforced in it. The adapted cryomilling and one-step consolidation process. These researchers studied the microstructure and mechanical behavior of produced composites. In this research analysis of the strengthening mechanism showed that increasing of sintering temperature leads to the reduction of grain-boundary strengthening and dislocation strengthening in the composites.

5.1.1 Summary of the properties of AA7075 composites based on carbides

The properties noticed by experimentation on composites based on carbides has been listed in Table 4.

5.2 Research on the composites based on oxides

Bera et al. [12] in the work during 2013 fabricated the AA7075 based composite by dispersing nano- TiO_2 (10 and 20 %wt.) by mechanical milling and consolidation by equal channel angular pressing (ECAP). The compacts obtained by ECAP exhibited higher density (90% of theoretical density), superior hardness (3.72 GPa/344 VHN) and higher stiffness (modulus of elasticity 92 GPa) and high compressive strength (nearly 1.7 GPa).

Bai et al. [18] have used mechanical milling with subsequent hot pressing to produce aluminium alloy 7075/nano Al_2O_3 MMCs. Objective of these researchers is to assess the mechanical and high temperature tribological characteristics of composites. The composites with 5 %wt. reinforcement is found to exhibit highest hardness, had excellent compressive property and showed a noticeable improvement in high-temperature wear resistance as compared to alloy and the lower quantity reinforced composite.

Sabbaghianrad and Langdon [80] used high pressure torsion to process AA7075/10 %vol. Al_2O_3 to induce superplasticity in composite while tensile testing. The

experimental results indicate that the grain refinement took place and Vicker's hardness has also increased with maximum elongation while tested in tension.

Zhang et al. [81] carried out the research study to know the effect of T6 heat treatment on microstructure and hardness of nano composites. They dispersed 1.5 %wt. of nano- Al_2O_3 in AA7075 matrix by casting process. They observed that solution treatment at 480 °C for 5 h and aging treatment at 120 °C for 24 h is the optimum T6 heat treatment as the hardness of composite is superior as compared to alloy because of the microstructural refinements.

The investigators Muraliraja et al. [82] have used squeeze casting technique for producing AA7075 matrix based MMCs by dispersing 2.5 %wt. of alumina (30–50 μm). The observations in this research is that hardness of the composite improved by 24.5% and compressive strength by 39% as compared to the AA7075.

Hernández-Martínez et al. [90] have produced AA7075- ZrO_2 MMCs by planetary, horizontal attritor and shaker ball mills to assess the effectiveness in dispersing n- ZrO_2 particles (2 and 5 wt.%) in matrix. The investigation showed that in the case of the planetary ball mill, a full dispersion of the ZrO_2 through the matrix can be attained because an excess of the process control agent, enhances the fracture of particles instead of welding, leading to the breakdown of ZrO_2 agglomerates and resulting a complete dispersion of the reinforcement.

5.2.1 Summary of the properties of AA7075 composites based on oxides

The properties of composites based on oxides has been listed in Table 5.

5.3 Research based on hybrid composites

Lal et al. [7] produced AA7075-SiC/ Al_2O_3 HMMCs by inert gas-assisted electromagnetic stir-casting method. Composite having 15 %wt. Al_2O_3 and SiC particulates (7.5 %wt.) in AA7075 are reported to be produced successfully and have studied the influence of wire cut electrical discharge machining process parameters like duration of discharge, pulse interval time, discharge current and the wire drum speed on the kerf width while machining. Taguchi method is applied for optimizing parameters and the level of importance is determined using analysis of variance (ANOVA). The experimentation showed that duration of discharge, discharge current and wire drum speed are the significant parameters.

Kannan and Ramanujam [21] have evaluated the effectiveness of two methods of processing and treatments on the mechanical characteristics of AA7075 based HMMCs. In this investigation, 1 %wt. Al_2O_3 particles (avg. size: 30–50 nm) and 0.5 %wt. of h-BN particles (avg. size: 80–100 nm) were reinforced in AA7075 matrix by ultrasonic assisted cavitation and a combinational approach of molten salt processing with ultrasonic assistance and optimized mechanical stirring. The researchers have

Table 4. Properties of composites based on carbides.

Reinforcement	Production approach	Properties achieved	References
B ₄ C	Plasma activated sintering	Al-7075/B ₄ C composite sintered at 530°C for 3 min had Hardness 181.6 HV, bending strength 1100.3 MPa, compression yield strength 878.0 MPa and fracture strength 469.3 MPa	[8]
B ₄ C	Plasma activated sintering	At 7.5 wt.% B ₄ C, the Vickers hardness, bending strength, and compressive strength of the consolidated samples were 184.3 HV, 813 MPa, and 895 MPa, respectively	[9]
SiC, Cr	Squeeze casting	The addition of Cr particles remarkably improved the mechanical properties and thermo-physical properties of the 50%SiC+5%Cr composite in comparison to the 50%SiC and 55% SiC composites. For 50%SiC+5%Cr thermal conductivity is 145 W m ⁻¹ k ⁻¹ , thermal expansion is 10.8 × 10 ⁻⁶ °C ⁻¹ , bending strength is 821 MPa	[21]
TiC	Stir casting	With the addition of ceramic content, the bending strength of AA 7075-7.5 wt.% TiC composites had significantly increased by 5.8 times when compared to monolithic AA 7075 alloy	[27]
SiC, MOS ₂ , Gr, hBN	Stir casting	Composite having 5%SiC, 5%Gr had VHN 176, UTS 247.21 MPa, compression strength 61.74 MPa with very good wear resistance	[31]
SiC	Stir casting	Under 0.10 mm/rev and 20 m/min drilling conditions and using high speed steel drill, surface roughness values for matrix, 5% SiC, 10% SiC, and 15% SiC-reinforced composites were obtained as 2.57, 2.59, 2.61, and 2.64 mm respectively. An increase in the quantity of SiC _p results in a very crucial deterioration quality of the drilled hole	[34]
SiC, Graphene	Stir casting	Al7075 HMMC with (15%SiC + 1%Graphene) had VHN 94.8, UTS 266.62, impact strength 1.4 J, wear rate 77.5 microns	[36]
SiC	Stir casting	Each category of MMCs with varying quantity of SiC had significantly different heat capacity (C _p) values. MMCs had lower specific heat values than the alloy	[50]
SiC	Stir casting	Co-efficient of thermal expansion of AA7075/SiC _p composites characterized under identical conditions varies significantly and composites exhibit lower co-efficient of thermal expansion values than the alloy. Reinforcing SiC produces MMC with low co-efficient of thermal expansion	[51]
n-SiC	PM	25 to 35% and 35 to 44% drop in the hardness and ultimate tensile strength of the composites is observed as compared to alloy	[52]
n-SiC	Friction stir welding	The joints produced with rotational speed of 1250 rpm and traveling speeds of 40 and 50 mm/min, had the highest mechanical properties. Owing to the presence of n-SiC _p , at 1250 rpm and 40 mm/min, ultimate tensile strength (UTS) and percentage of elongation were improved by 31% and 76.1% respectively	[57]

Table 4. (continued).

Reinforcement	Production approach	Properties achieved	References
n-SiC	Ultra sonic assisted semisolid stirring	Yield, ultimate tensile strength and elongation of the rheoformed cylinder components of the n-SiC/7075 Al composite without T6 are 264 MPa, 357 MPa and elongation of 7.5% respectively. n-SiC/AA7075 composite exhibited yield strength of 381 MPa, ultimate tensile strength of 478 MPa and elongation of 8.5%	[58]
SiC	Spray deposition	Superplastic deformation characteristics of spray deposited 7075Al/15%SiC _p composites are found at temperature of 450°C and strain rate range of 0.001- 0.1 s ⁻¹ with strain rate sensitivity of 0.72. The optimum parameters of hot working for the composites are obtained to be temperature of 430–450°C and strain rate of 0.001-0.05 s ⁻¹	[59]
SiC	Centrifugal casting	At low sliding speed (2m/s) and load (15N) conditions, the abrasive wear and matrix cracking are found to be dominant in comparison to the multi-mode wear mechanisms such as tribo oxidation, abrasive wear, third body wear and delamination wear are operative at higher load and speed conditions.	[61]
SiC,B ₄ C,Al ₂ O ₃ ,TiB ₂	Stir casting	Al7075-15% B ₄ C composite materials exhibit greater hardness property of 164 BHN as compared to the other reinforced composites. The tensile test shows that the Al7075-15% B ₄ C has excellent ultimate tensile strength of 261 MPa when compared to other ceramic reinforced MMCs. Highest impact strength of 11 N-m has been seen in the composite reinforced with B ₄ C. Age hardening of composite specimens has improved the tensile strength of the aluminium metal matrix composites from 261 MPa to 271 MPa	[62]
SiC	FSP	The rotation speed and pass number of 52.9% and 13.1%, respectively, have the greatest impact on tool wear. Traverse speed with more than 55% had the most effect on micro hardness comparatively. The micro hardness reached the highest level of 127.24 Vickers	[65]
n-SiC	Stir casting	it is noticed that by increasing wt.% of SiC leads to increased R _a and decreased MRR	[66]
SiC	Stir casting	reduction of 30% – 40% are observed in values of coefficient of friction and wear rates for composite in comparison to alloy. With increase in sliding speeds, the values of coefficient of friction and wear rates for both Al alloy and composites also increase	[67]
SiC, B ₄ C	Liquid pressing	The hybrid composite exhibited dynamic compressive strength over 1.5 GPa, along with a good total strain of 11.7%	[71]

Table 4. (continued).

Reinforcement	Production approach	Properties achieved	References
B ₄ C	Blended powder semisolid forming	Composites with 20 μm AA7075 and 20% (volume fraction) 45 μm B ₄ C powder pressed under 100 MPa exhibited HV 190 and compressive strength 336 MPa	[85]
B ₄ C	Cryomilling	The heat treated sample, with a high yield strength, exhibits acceptable plasticity of 11.7%	[86]
n-TiC	FSP	Hardness is found to be reducing in the sintered zone in all FSP samples	[91]
TiC	Laser shock peening (LSP) and friction stir welding (FSW)	The CTE of composite decreased to $17.1 \times 10^6 \text{ K}^{-1}$ by increasing the LSP impact times over a wide temperature range from RT to 300°C. This value was reduced by 10% compared with that of the as-FSW 7075 Al alloy	[93]
B ₄ C	One step consolidation	The Vickers hardness, compressive yield strength and fracture strength of the AA7075/B ₄ C consolidated at 450°C were 233 HV, 724.9 MPa and 834.5 MPa respectively	[106]

concluded that composite processed through molten salt processing and undergone T6 treatment exhibited superior mechanical characteristics as compared to all other samples.

Sivasankaran et al. [24] have fabricated TiB₂/Gr-Al7075 HMMCs by in-situ liquid metallurgy route. Their objective is to study sliding wear characteristics by response surface methodology. Reinforcing quantity of TiB₂ is 0, 1.5, 3, 4.5 and 6 %wt. while Gr was 1 %wt. in the alloy. The test results showed that increase in both RF and SV percentages have reduced the wear loss curve, whereas the load at all sliding velocities and the sliding distances have increased the wear loss. Surface morphology of worn out specimen showed that the adhesive mechanisms were dominating during the wear test. Further, severe and mild wear occurred for higher and lower load respectively.

Liu et al. [25] developed HMMCs by dispersing B₄C (4, 8 and 12 %wt., 10 μm) and MoS₂ (3 %wt., 2 μm) in AA7075 matrix alloy by stir casting technique. They investigated compressive strength, tensile strength, hardness, microstructural analysis and tribological characteristics. By their study it has been observed that there is a noticeable improvement in resistance to wear and friction coefficient of AMMCs in comparison with base matrix.

Kumar Sahu and Kumar Sahu [26] synthesized AA7075-B₄C and flyash composites by stir casting. The flyash (FA) quantity of 2 %wt. is kept constant but B₄C quantity is varied in the range 2–8 %wt. in the matrix. The size of the reinforcements used were in the range 3–10 μm . The composite with 2 %wt. flyash and 8 %wt. of B₄C exhibited excellent value of microhardness and was 37.2% greater than matrix alloy. Also these authors observed that the addition of B₄C and flyash in the Al matrix resulted in an increase of microhardness of composite and it increases with the increase of B₄C quantity in the matrix.

Prabhu et al. [28] have tried to understand the effect of flyash and Al₂O₃ particulates on wear and tensile properties of AA7075 composites. The combined quantity of reinforcements considered is 5, 10, 15 and 20 %wt. The wear tests are performed at 10, 20, 40, 80 N loads, sliding speed of 1.45 m/s and sliding distance of 500 m. It is found that wear resistance of the composite increases with the addition of Al₂O₃ and flyash. Enhanced resistance to wear is noticed for composite with 10 %wt. Al₂O₃ and 10 %wt. flyash composite.

Suresh et al. [29] used stir casting to produce AA7075-Al₂O₃/Mg composites to study their mechanical properties. Alumina particles were in the size range 20–30 nm. The quantity of alumina dispersed was 1, 2, 3 and 4 %wt. Also 1 %wt. Mg was added for improving the wettability between alumina and matrix. The results indicated that heat treatment process increased the mechanical properties of nano aluminium oxide composites when compared to as-cast. By increasing the wt.% of nano-reinforcement the density decreased when compared to base alloy. The tensile strength, hardness, and toughness gradually improved by increasing weight % of Al₂O₃.

Suresh et al. [30] have developed AA7075-Al₂O₃/SiC/Mg by stir casting. The quantity of reinforcement taken in composites was 1, 2, 3, and 4 %wt. of (Al₂O₃ + SiC) and 1 %wt. Mg. The Al₂O₃ had size range 20–30 nm and SiC 50 nm. The mechanical characteristics of MMCs such as tensile strength, compression strength, and hardness test are performed on the produced composites. The microhardness, compression strength, and tensile strength of AA7075 observed to have increased by incorporating Al₂O₃ and SiC reinforcements. Also it is noted that there is a decrease in coefficient of friction and wear rates with the increment in wt.% of reinforcement.

Smart et al. [35] have fabricated composites by reinforcing TaC, Si₃N₄ and Ti in AA7075 alloy. The fabrication approach adapted by these researchers was stir

Table 5. Properties of composites based on oxides.

Reinforcement	Production approach	Properties achieved	References
n-TiO ₂	Equal channel angular pressing (ECAP)	Compact density 90% of theoretical density, hardness 3.72 GPa/344 VHN and Young's modulus 92 GPa. Compacts consolidated by 4 ECAP passes at 473 K had highest density and high compressive strength of nearly 1.7 GPa	[12]
Al ₂ O ₃	Mechanical alloying and hot press sintering	Hardness and compressive strength of Al ₂ O ₃ /7075 composites first increased and then decreased with Al ₂ O ₃ quantity increasing, and 5 wt.% Al ₂ O ₃ addition made the material displayed superior comprehensive mechanical properties. The tribological properties also indicated that 5 wt.% Al ₂ O ₃ nanoparticle significantly improved the high-temperature wear resistance of 7075 alloys	[18]
Al ₂ O ₃	High-pressure torsion (HPT)	The initial hardness Hv167 after HPT increased to nearly Hv260. Tensile testing at 623 K demonstrated the potential for achieving true super plasticity in the HPT-processed MMC with a maximum elongation of nearly 670% when testing at a strain rate of $1.0 \times 10^{-2} \text{ s}^{-1}$	[80]
n-Al ₂ O ₃	Ultrasonic vibration	Compared to the hardness of AA7075 (VHN94.7), the hardness of Al ₂ O ₃ /7075 composites (VHN113.8) increased by nearly 20%. Compared to the hardness of Al ₂ O ₃ /7075 composites (VHN 113.8), the hardness of Al ₂ O ₃ /7075 composites under solution treatment (VHN150.4) at 480 °C for 5 h increased by nearly 32%. Hardness of Al ₂ O ₃ /7075 composites under optimum T6 heat treatment (VHN173.5) increased by nearly 52%	[81]
Al ₂ O ₃	Squeeze casting	The hardness of the composite is 59 HRB. The compressive strength is 587 MPa	[82]
ZrO ₂	PM	By the planetary ball mill, a full dispersion of the ZrO ₂ through the matrix is achieved. In the case of the Simoloyer mill, the results showed that there was not a fine dispersion of the ZrO ₂ particles. The shaker mill produced the best results, because full dispersion of the ZrO ₂ particles took place in a homogeneous way in half the time taken by the other mills tested	[90]

Fig. 14. (i & ii): Variation of ultimate compressive strength and flexural strength of composites with the quantity of Al_2O_3 respectively [83].

casting. They studied microstructural, mechanical and wear characteristics of the developed composites. The results of their study revealed that highest compression strength was 634 MPa at 1 %wt. of TaC and 8 %wt. of SiN_4N_4 and 2 %wt. of Ti in hybrid composite. The results portrayed that the wear rate and coefficient of friction of HMMCs are lesser than that of the pure AA7075 alloy and later diminishes with rising TaC/ Si_3N_4 /Ti content.

Suganeswaran et al. [40] have studied the influence of secondary phase particles $\text{Al}_2\text{O}_3/\text{SiC}$ on the microstructure and tribological characteristics of AA7075 based surface hybrid composites fabricated through friction stir processing. The study results showed that addition of 3.7 %wt. $\text{Al}_2\text{O}_3 + 3.0$ %wt. SiC in AA7075 enhanced the microhardness about 33.96% higher than base matrix. Hence, wear resistance of the specimen is improved.

Ramadoss et al. [42] have done the synthesis of B_4C and BN reinforced AA7075 hybrid composites using stir casting method. B_4C was varied as 3, 6 and 9 %wt. and BN was kept constant as 3 %wt. The results of their study indicated that the hardness increased with the addition of reinforcements as compared to alloy. Also the composites have shown a maximum of 22% more strength as compared to bare alloy, and the corrosion rate decreased by 18.5% between 3 and 6 %wt. boron carbide addition whereas it decreased by 22.4% between 6 and 9 %wt. boron carbide addition.

Verma and Vettivel [46] have dispersed B_4C and rice husk ash (RHA) in AA7075 matrix with 5 %wt. B_4C and 3, 5 %wt. of ash by using stir casting method. They tested composite and alloy for hardness, tensile and compression behaviours. The results of these tests indicated that composites displayed superior mechanical behavior in comparison to bare alloy.

Rajesh et al. [68] have worked towards material characterization of SiC and Al_2O_3 particulates dispersed AA7075 MMCs. Composites are produced by stir casting with SiC and alumina as reinforcement (5, 10, and 15 %wt. each). Wear test is conducted in a pin-on-disc device at room temperature for both post aging and pre aging states. This study showed that the improvement in resistance to

wear is because of higher quantity of reinforcements in the matrix. By increasing the sliding speeds and sliding distance, a reduction in the rate of wear is observed. Higher quantity reinforcement composites showed lesser wear rate.

Liu et al. [69] produced $(\text{SiC}_p + \text{Ti})/7075$ hybrid MMCs and $\text{SiC}_p/7075$ MMCs. Their main focus of study is to investigate the effect of Ti on aging behavior and mechanical properties of composites. Composites in this research is produced by squeeze casting process. Quantity of SiC particles is 40 %vol. with 7 μm and Ti was 5 %vol. with 35 μm . After aging heat treatment under the optimum conditions, the tensile strength of both composites is improved due to precipitation hardening of the matrix alloy. Ductility of composite containing Ti particles is improved because of the strengthened interfaces between the Ti particles and the matrix alloy.

Rama Kanth et al. [70] employed stir casting technique and developed flyash and SiC particles (53 μm both) reinforced Al-Zn alloy-based MMCs. The flyash and SiC reinforcement quantity varied in the range 0–15 %wt. The results of experiments showed that the dispersion of flyash and SiC particles improved the hardness and tensile properties.

Boobesh Nathan et al. [72] reinforced SiC (2, 4 and 6 %wt.) and ZrO_2 (3 %wt.) by stir casting technique. These investigators have studied the mechanical and metallurgical properties of the produced composites. The researchers observed that the properties like hardness, impact energy, tensile strength and compressive strength increases with increase in quantity of reinforcements.

Bhowmik et al. [74] have fabricated AA7075-SiC and AA7075-TiB₂ MMCs for making comparative study of microstructure, physical and mechanical properties of these materials. Stir casting is used by these researchers to produce the materials. The results showed that TiB₂ reinforced composite acquired 3.29% higher strength and 4.93% higher hardness compared to SiC reinforced composite.

Gorshenkov et al. [78] in 2012 have investigated the dry sliding friction characteristics of AA7075/h-BN (40%vol.), Al 7075/B amorphous (30%vol.) and AA7075/ $\text{B}_4\text{C} + \text{W}$ (20 %vol. + 2 %vol.) composites. These composites are fabri-

Fig. 15. (i & ii): Dependency of tensile strength and impact energy of composites on the quantity of reinforcements respectively [87].

cated by vacuum impregnation technology, explosive pressing, and mechanical alloying followed by hot extrusion. By experimentation it is observed that superior antifriction properties and resistance to wear for composite containing B₄C and tungsten nanoparticles as compared to matrix alloy and composites with h-BN and amorphous boron.

Baradeswaran and Elaya Perumal [83] developed AA7075-Al₂O₃/graphite HMMCs by stir casting technique with 5 %wt. graphite particles addition and 2, 4, 6 and 8 % wt. of Al₂O₃. The composite is given a T6 heat treatment and the specimens are tested for hardness, tensile strength, compressive strength, flexural strength and wear test. The hardness of composites is observed to increase due to increasing Al₂O₃ quantity and it is noticed to be higher than that of base alloy in all categories of specimens. Addition of Al₂O₃ particle increased the tensile strength, compression strength (Fig. 14(i)) and flexural strength (Fig. 14(ii)) of the hybrid composite and it is again higher than that of base alloy. It is concluded that the presence of graphite in the composites has reduced wear, because of formation of thin layer of graphite on the tribo surface. Also graphite has reduced the friction coefficient of the hybrid composite.

Rakshath et al. [84] have used alumina and hexagonal boron nitride as fillers with AA7075 alloy. They have used two step stir casting method and formulation of the composites are 2.5 and 5 %wt. particulates. The objective of their study is to understand dry sliding and abrasive wear behavior of alloy and composites. Mechanical and dry sliding wear test results indicated that both alumina and h-BN fillers show improved mechanical properties and wear resistance. Wear resistance of composites is increased by increasing the weight percentage of reinforcements and the reinforced composite gave better resistance against abrasion than the control sample (AA7075). Also 5 %wt. micro h-BN reinforced AA7075 composite prompted a predominant abrasion resistance.

Subramaniam et al. [87] fabricated and evaluated mechanical properties of composites consisting of B₄C (0, 3, 6, 9 and 12 %wt.; 75 µm) and coconut shell flyash (3 %wt.) as reinforcements and AA7075 as matrix material. These have adapted stir casting process for producing the composites. The experimentation in their work showed

that hardness, tensile strength (Fig. 15(i)) and impact strength (Fig. 15(ii)) of composites are superior as that of alloy.

Pratheep Reddy et al. [88] developed 7075/B₄C/flyash composites to study the dry sliding wear behavior in Pin-on-disc machine. The quantity of reinforcement is varied in the range 1–4 %wt. in steps of 1 and flyash in the range 6–9 %wt. in steps of 1. Their results indicated that AA7075/B₄C/flyash composites with wt.% (90:3:7) exhibited superior wear performance.

Vignesh Kumar et al. [89] in their study have fabricated AA7075-B₄C/BN by stir casting method. The prime focus of the study is to evaluate thrust force and perform microstructure characterization of composites. The reinforcing particles are of 1 µm size and the weight percentage of BN is kept constant of 3 and B₄C is varied from 3–9 insteps of 3. Their results showed that feed and point angle are the highly influential parameters for thrust force and surface roughness of the prepared HMMCs.

Sasikumar et al. [94] studied the kerf characteristics while abrasive jet machining of the composites made by reinforcing TiC and B₄C in 7075 aluminium alloy matrix. The kerf characteristics such as kerf top width, kerf angle and surface roughness are investigated against the abrasive water jet machining process parameters, namely, water jet pressure, jet traverse speed and standoff distance.

Dhulipalla et al. [95] in their investigation have reinforced TiC ceramic and MoS₂ soft particulates in AA7075 matrix by stir casting technique. They studied the machinability characteristics of the composite. The results of their study indicated that the aluminium composites exhibited excellent machinability in comparison to the base AA7075. The chip morphology has transformed from continuous sheared in AA7075 to discontinuous in composites. The transformation is brought out by the decreased ductility in composite because TiC and MoS₂ micro reinforcements. The surface roughness has increased for the AMCs when compared to that of base alloy due to hard TiC particles.

Rama Kanth et al. [107] have studied mechanical behaviour of flyash/SiC particles reinforced in AA7075 alloy matrix composites. The reinforcements were of 53 µm and the combined quantity is 5 and 10 %wt. in 1:1 proportion. Their results showed that with increase in

Table 6. Properties of HMMCs investigated.

Reinforcement	Production approach	Properties achieved	References
SiC/Al ₂ O ₃	Inert gas assisted electromagnetic stir casting process	The pulse on time in EDM was the most significant parameter that contributed maximum of 46.04% to the MRR followed by pulse current of 34.72%, pulse off time of 10.23% and interaction, pulse on time 3 pulse off time of 5.46%. The wire drum speed had insignificant effect on the material removal rate	[7]
Al ₂ O ₃ , h-BN particles	Ultrasonic assisted cavitation and molten salt processing methods	Deep cycle cryogenic treatment (DCT) T ₆ treatment is observed to elevate mechanical properties to a greater extent. Under T ₆ condition, the VHN is improved to the maximum of 44.1% in unreinforced aluminium alloy and 39.6% in case of the hybrid nanocomposite, while the corresponding improvement of 5.1% and 4.5% is observed under DCT	[21]
TiB ₂ /Gr	In-situ liquid metallurgy route	By investigation it is found that TiB ₂ particles were pinned the matrix grain growth while casting itself which acted as the grain refiner. ANOVA results were showed that the sliding distance was had more influence on the wear rate followed by the load	[24]
B ₄ C and MoS ₂	Stir casting	Wear loss of AA7075 + 12% B ₄ C +3% MoS ₂ is found to be 0.0387 g at 30 N load, tensile strength 298.52 N/mm ² , yield strength 172.6 N/mm ² and elongation 3.7%, hardness 94.32 VHN	[25]
B ₄ C/Fly ash	Stir casting	The composite with 2 wt.% fly ash and 8 wt.% B ₄ C had 123.29 HV, which is 37.2% higher than base matrix alloy	[26]
Fly ash + Al ₂ O ₃	Stir casting	Presence of fly ash had no significant effect on the tensile strength and hardness, the better results are obtained when both Al ₂ O ₃ and fly ash are mixed with Al 7075 matrix. Improved wear resistance is obtained for composite with 10% Al ₂ O ₃ + 10% fly ash	[28]
Al ₂ O ₃ /Mg	Stir casting	By increasing the wt.% of nano-reinforcement the density decreased when compared to base alloy. Tensile strength, hardness, and toughness gradually improved by increasing wt.% of Al ₂ O ₃	[29]
Al ₂ O ₃ /SiC/Mg	Stir casting	The compressive strength, ultimate tensile strength, and hardness values increase by increasing the weight percentage of nano-Al ₂ O ₃ and n-SiC reinforcement. HMMCs exhibited a significant decrease in friction coefficient and wear rates with an increase in the wt.% of reinforcement particles	[30]
TaC/Si ₃ N ₄ /Ti	Stir casting	Combined TaC/Si ₃ N ₄ /Ti reinforcements with in AA7075 elevated the mechanical properties. Theoretical and experimental densities were noted to be 3.11 g/cc and 3.09 g/cc as compared to the density of base alloy. However, the highest compression strength was 634 MPa at 1 wt.% of TaC and 8 wt.% of Si ₃ N ₄ and 2 wt.% of Ti in hybrid composite	[35]

Table 6. (continued).

Reinforcement	Production approach	Properties achieved	References
Al ₂ O ₃ /SiC	FSP	Addition of 3.7 wt.% Al ₂ O ₃ +3.0 wt.% SiC in AA7075 enhanced the micro hardness about 33.96% which is higher than base matrix. Specimen with 3.7% Al ₂ O ₃ + 3.0 % SiC has better lubrication and load-bearing capacity that exhibited superior tribological characteristics at 40 and 60 N	[40]
B ₄ C and BN	Stir casting	Dispersion of B ₄ C and BN to alloy has raised the strength by 22%. The corrosion rate decreased by 18.5% between 3% and 6% B ₄ C addition whereas it decreased by 22.4% between 6% and 9% B ₄ C addition	[42]
B ₄ C and Rice husk ash (RHA)	Stir casting	The hardness for AA 7075-5%B ₄ C-5%RHA is 121 HV, tensile strength is 260 MPa at 5 wt.% of B ₄ C. The compression strength is 563 MPa at 5 wt.% of B ₄ C and 5 wt.% of RHA in hybrid composite	[46]
SiC and Al ₂ O ₃	Stir casting	By raising the sliding speeds, there is a reduction in the wear rate and it decreases with increase in the sliding distance. With increasing weight fraction, there is decrement in the rate of wear of composites.	[68]
SiC _p , Ti	Squeeze-casting	Tensile properties: 7 vol% SiC/Al composite (unreacted interface)- $\sigma_y \sim 97$ MPa, $\sigma_{max} \sim 113$ MPa, elongation $\sim 16\%$. 7 vol% SiC/Al composite (reacted interface)- $\sigma_y \sim 103$ MPa, $\sigma_{max} \sim 139$ MPa, elongation $\sim 14\%$. As cast with Ti particle (diffusion layer)- $\sigma_y \sim 523$ MPa, $\sigma_{max} \sim 622$ MPa, elongation $\sim 1.2\%$. As cast with Ti particle (diffusion & reaction layer)- $\sigma_y \sim 539$ MPa, $\sigma_{max} \sim 673$ MPa, elongation $\sim 1.6\%$.	[69]
Fly ash/SiC	Stir casting	10% fly ash/SiC-142 VHN, UTS>210 MPa, YS>150 MPa. 5% fly ash/SiC-120 VHN, UTS ~ 200 MPa, YS ~ 150 MPa Alloy-102 VHN, UTS ~ 180 MPa, YS ~ 140 MPa	[70]
SiC/TiB ₂	Stir casting	UTS and micro hardness of Al composite is 182 MPa and 81 HV respectively	[74]
h-BN, B ₄ C and amorphous B	Vacuum impregnation technology, explosive pressing, and mechanical alloying with subsequent hot extrusion	AA7075-HRB<5, density 2.85 g/cc, wear 55.3 microns. AA7075/B-amorphous-HRB ~ 86 , density 2.39 g/cc, wear 7.2 microns. AA7075/h-BN-HRB ~ 85 , density 2.30 g/cc, wear 3.3 microns. AA7075/B ₄ C+W-HRB ~ 75 , density 2.87 g/cc, wear 6.4 microns	[78]
Al ₂ O ₃ /graphite	Stir casting	Hardness, tensile strength, flexural strength of the hybrid composites increased with increasing Al ₂ O ₃ particulates. Graphite decrease the hardness, tensile strength, compression strength and flexural strength and it was overcome by the addition of Al ₂ O ₃ particulates in the hybrid composites.	[83]

Table 6. (continued).

Reinforcement	Production approach	Properties achieved	References
B ₄ C-Coconut shell fly ash(CSFA)	Stir casting	The presence of graphite in the hybrid composite as also been able to decrease the wear and coefficient of friction of the composite Hardness of the composites increased 33% by reinforcements of 12wt.% B ₄ C and 3wt.% CSFA in aluminium 7075 alloy. The tensile strength of the composites increased 66% by the addition of 9wt.% B ₄ C and 3wt.% CSFA in aluminium 7075 alloy. The impact energy of the composites increased up to 2.3 J with 9 wt.% B ₄ C and 3wt.% CSFA addition in aluminium alloy	[87]
B ₄ C/fly ash	Stir casting	Mechanical and tribological properties are improved for Al 7075 wt.% 90, B ₄ C wt.% 3, and fly ash wt.% 7 as 111 BHN, UTS is 290 MPa, % elongation 0.75 mm, impact strength 0.76 J, and wear rate 1.4 mm ³ /min	[88]
B ₄ C/BN	Casting technique	Density of the prepared composites was notably increased with the addition of B ₄ C and BN particles. For MMC UTS, yield strength and hardness, were 57, 44 and 72% higher than alloy matrix	[89]
TiC ceramic and MoS ₂	Stir casting	The measured Rockwell Hardness (HRB) values are 52.5 ± 1.5 (AA7075), 67.2 ± 2.2 (Al + TiC (2%)), 75.4 ± 4.3 (Al + TiC (4%)), 54.1 ± 2.4 (Al + TiC (2%) + MoS ₂ (2%)), and 61.9 ± 6.6 (Al + TiC (4%) + MoS ₂ (2%)). The surface roughness increased from 0.15 ~ 0.35 microns for AA7075; 0.38 ~ 0.46 microns for AA7075 + TiC (2%) + MoS ₂ (2%); and 0.54 ~ 0.62 AA7075 + TiC (4%) + MoS ₂ (2%)	[95]
TiB ₂ , Al ₂ O ₃ , Mg, and Zn	FSP	The results indicate that poor bonding between the reinforcement-matrix significantly reduces strength and wear behaviors. The effective dispersion of reinforcement results in net enhancement in strength and wear performance both when the processing done within a specific range of processing time-temperature	[108]

quantity of the reinforcements there is improvement in hardness, tensile strength and flexural strength of composites as compared to the base alloy.

Gangil et al. [108] have adapted friction stir processing to produce the surface composites with a mixture of reinforcements that included TiB₂, Al₂O₃, Mg, and Zn in proportions of 66.5, 22.5, 6.5 and 3.5 (in wt. %) respectively. The base alloy used was AA7075. The objective of the study was to do microstructural characterization and understand tribological behavior of the composites. The results showed that the wear performance of all samples which are processed at large shoulder diameters has improved.

5.3.1 Summary of the properties of AA7075 based hybrid composites

The properties of HMMCs are listed in Table 6.

5.4 Research based on other compounds composites

Deaquino-Lara et al. [5] have produced AA7075 and graphite (0.5, 1 and 1.5 %wt.) composites by milling process with subsequent hot extrusion. The mechanical properties of the alloy and composites are found out by tension tests and hardness measurements. It is discovered that as the content of graphite particles and milling time

Fig. 16. ((i), (ii) & (iii)): Variation of hardness, tensile strength and flexural strength with quantity of reinforcements of composites respectively [101].

are increased correspondingly, the yield strength, the maximum strength and the Vicker's microhardness are increased, but the elongation is decreased noticeably in few specimens. Overall the mechanical properties of composites are higher as compared to alloy without graphite addition.

Tekiyeh et al. [23] developed carbon nanotube (CNT) reinforced AA7075 MMCs by FSP. The objective was to improve machinability characteristics of the produced composites. The thrust force and surface roughness were the two main criteria considered to study the machinability. The experimentation indicates that dispersion of CNT results in decrement of thrust force and surface roughness due to lubrication effect of CNT.

Suresh et al. [32] in their study have fabricated MWCNT reinforced AA7075 MMCs. The quantity reinforced was in the range 1–3 %wt. in steps of 1. They investigated mechanical, wear, and machining characteristics of composites. The results of this study indicated that the microhardness and tensile strength increase by 6 and 25% respectively. The wear rate and friction coefficient of composites have decreased by 39 and 48% respectively at a sliding speed of 3 m/s. Also, the metal removal rate has reduced by 40% and the surface roughness is improved by 38% respectively.

Manoj and Gadpale [38] produced AA7075-MoSi₂ composites by stir casting. The purpose of their research is to study the dry sliding wear behavior of these composites. The reinforcements used are in the range 2–8 μ m and reinforcing quantity is 2, 3, 4 and 5 %wt. They observed that with increase in applied load, mode of material removal changes as ploughing, delamination, crater formation and plastically deformed layers. Amount of reinforcement and frictional heating affect the wear response of composites. With increase in applied load, wear resistance of composite has been found to be improved as compared to base alloy.

Loganathan et al. [39] have studied the influence of ZrB₂/hBN particles on the wear response of AA7075 composites produced by stir and squeeze casting technique. ZrB₂ and hBN at levels of 5 %wt. were chosen as reinforcements for their investigation. The results of this study showed that ZrB₂ particles reinforced composite displayed an improvement in hardness in comparison as-cast and composite containing hBN.

Flores-Campos et al. [75], in 2010 have developed AA7075 matrix composites by reinforcing silver nanoparticles coated with carbon (Ag-C nano particles in the range 10–20 nm) through the mechanical milling process. The reinforcement quantity in matrix is varied up to 2 %wt. in steps of 0.5 %wt. Microhardness of composites is observed to have increased with increase in milling time and the quantity of reinforcement. Concentrations of Ag-C nano particles higher than 2 %wt. is found to have no significant effect on microhardness.

Researchers from Mexico, Deaquino-Lara et al. [77] have fabricated AA7075 composites by reinforcing graphite particles (0–1.5 %wt.) by employing mechanical alloying with subsequent hot extrusion. The influence of time for milling and the quantity of reinforcement on friction, hardness and wear are studied. Experimental results showed a significant improvement in composite hardness and wear resistance for 1.5 %wt. of graphite and milling time of 10 h. Composites also had a uniform distribution of the reinforcement particles in the matrix and the wear resistance of aluminum alloy followed a linear relation with (grain size)^{-1/2} which is similar to the Hall–Petch effect.

Wang et al. [97] studied elevated temperature ductility and fracture mechanisms of an in-situ particle reinforced 7075Al-TiB₂ composite. Their experimentation disclosed that the effect of temperature on ductility of the composite is more noticeable, while the effect on strain rate is very least. Also temperature has greater influence for increasing the ductility of the composite when it below 400 °C while there is a decrease in ductility above 400 °C. Also it is found that nucleation of voids and void growth is the primary mechanism of fracture the composite at elevated temperature.

Pan et al. [98] have tried to understand the tribological performance of composites with matrix as AA7075 alloy and reinforcements as TiB₂. The composites in this work are fabricated by in-situ method. The produced composites are subjected to heat treatment and further they are tested for wear performance in Pin-on-disc apparatus. A new measurement method is applied in the tribological study to distinguish the contributions from pure friction and wear for AA7075 nanocomposites in this study. The investigators concluded that study is of significance for a rational design of AA7075 nanocomposites for optimized tribological performance.

Table 7. Properties of HMMCs based on other compounds.

Reinforcement	Production approach	Properties achieved	References
Graphite	Milling processes and hot extrusion	yield strength, the maximum strength and the Vickers micro hardness were enhanced as a function of graphite particles content and milling time, but the elongation was reduced significantly in some cases	[5]
MWCNT	Stir casting	Micro hardness and tensile strength increase by 6% and 25%. The wear rate and coefficient of friction of composites are decreased by 39% and 48% at a sliding speed of 3 m/s. In addition, the metal removal rate decreases by 40% and the surface roughness enhanced by 38% respectively	[32]
MoSi ₂	Stir Casting	With increase in applied load, mode of material removal changes as ploughing, delamination, crater formation and plastically deformed layers. Particle content and frictional heating affect the wear characteristics. With increase in applied load, performance (wear resistance) of composite has been found to be improved when compared with that of the monolith	[38]
ZrB ₂ /hBN	Stir-squeeze cast technique.	The ZrB ₂ particles reinforced composite showed an improvement in hardness compared to as-cast and hBN containing composite. A minor reduction in the hardness of ZrB ₂ -hBN hybrid composite was observed	[39]
Ag nanoparticles	Mechanical milling	Micro hardness increases as Ag-C NP content increases. Micro hardness increases in the nanocomposite as the milling time increases. By combining nanoparticles dispersion and MM process it is possible to obtain better properties than those reached by T73 and T6 tempers in AA7075 alloy	[75]
Graphite	Mechanical alloying and hot extrusion	Considerable improvement in MMC hardness and wear resistance by adding 1.5% graphite (wt.) and 10h of milling, showed homogenous distribution of the reinforcement particles in the Al-based MMC	[77]
TiB ₂	In-situ	The ductility of MMC rises with temperature in the range 350-400°C, and reduces in the range 400-450°C	[97]
TiB ₂	In-situ	AA7075 - E ~ 75 GPa, Mohs hardness ~ 2.3GPa, Vickers hardness ~ 180 VHN. AA7075 + 1.5 vol% TiB ₂ -E ~ 80 GPa, Mohs hardness ~ 3 GPa, Vickers hardness ~ 200 VHN	[98]

Table 7. (continued).

Reinforcement	Production approach	Properties achieved	References
Si ₃ N ₄	Stir casting	Increase in silicon nitride reinforcement the micro hardness improved. The micro hardness showed a decreasing trend with the increase in indentation load and a decreasing trend with the increase in dwell time	[100]
Si ₃ N ₄	Stir casting	Tensile strength and flexural strength of HT AMCs were increased up to 8% wt. Si ₃ N ₄ addition, but decreased at 12% wt. Si ₃ N ₄ addition in AA7075. Wear loss of 12% wt. Si ₃ N ₄ reinforced HT AMCs was decreased up to 37.17% as compared to HT AA 7075 matrix. Whereas, COF of 12% wt. Si ₃ N ₄ reinforced HT AMCs was decreased up to 11.03% as compared to pure HT AA 7075	[101]
Si ₃ N ₄	Stir casting	The presence of Porosity, consequently, decreases most of the mechanical properties of cast MMCs. By means of heat treatment also we can reduce porosity by heating the metal	[102]
VN	Ball milling and hot-press sintering	The hardness (119.5 Hv) of 15 wt.% VN/7075 composite was 46.1% higher than the AA7075 alloy (81.8 Hv). The friction coefficient of 15 wt.% VN/7075 composite decreased by 37.6% compared with the AA7075 alloy	[103]
CNTs	PM	After aging treatment, the CNTs/7075 Al composites had the peak hardness of 151.4 HV. CNTs/7075 Al composites exhibited a tensile strength of 558.3 MPa and an elongation of 7.7%	[104]

Zhao et al. [99] studied the particle dispersion and grain refinement of in-situ TiB₂ particle reinforced AA7075 composite processed by elliptical cross-section torsion extrusion. A modified torsion extrusion (TE) method, entitled elliptical cross-section TE (E-TE), was proposed as a severe plastic deformation (SPD) process to refine the microstructures and improve the mechanical properties of a bulk in-situ TiB₂ particle reinforced AA7075 composite. The results of the test indicates that proposed E-TE process thus can be used as an efficient process for optimizing mechanical properties of metal matrix composites.

Ul Haq and Anand [100] produced AA7075/Si₃N₄ composites by stir casting to study the microhardness. Silicon nitride is varied from 0–8%wt. in steps of 2. The microstructure revealed a grain refinement with increase in the Si₃N₄ quantity and improvement in microhardness. But microhardness decreased with the increase in indentation load and increase in dwell time.

Mistry and Gohil [101] in their work have reinforced Si₃N₄ by varying it from 4 to 12 %wt. in steps of 4 in AA7075 alloy. They have adapted electromagnetic stir casting for producing the composites of interest. The composites are heat treated and have been studied for wear and friction behavior. The results of this work revealed that, hardness of heat treated composites has improved with dispersion of Si₃N₄ in AA7075. Tensile strength and flexural strength of heat treated composites have increased with the addition of 8 %wt. Si₃N₄, but eventually decreased for 12 %wt. Si₃N₄ addition. An increased quantity of Si₃N₄ in the matrix also has led to decrease in loss of wear and friction coefficient. Wear loss of composite having 12 %wt. Si₃N₄ with heat treatment has reduced up to 37.17% in comparison to heat treated AA7075 matrix. Friction coefficient of composite with 12 %wt. Si₃N₄ under heat treated condition has reduced up to 11.03% which is in comparison to pure heat treated AA7075.

Table 8. Details of investigated parameters of AA7075 MMCs and the targeted parameter for improvement/application as taken up by the researchers.

Type of reinforcement/ reinforcement combination	Investigated parameters of AA7075 MMCs	Targeted improvement/ application	References
SiC	Calorimetric study-heat capacity (C_p)	Thermal control system of spacecraft	[50]
SiC	Thermo-physical properties	Critical aerospace application material	[51]
SiC	Characterization of MMC	Improving performance of MMCs	[52]
SiC	Machining parameters-cutting speed, depth of cut, and feed rate	Surface roughness and tool wear in turning	[53,54]
SiC	Abrasive wear rate	Improve tribological conditions of MMCs	[55]
SiC	Mechanical and dry sliding wear behavior	Improve tribological conditions of MMCs	[14]
SiC	Characterization of MMC	Improving performance of MMCs	[17]
SiC	Pin geometry in FSW	Macro-micro structure, improve mechanical properties of MMCs	[56]
SiC	Fatigue life, impact energy, tensile strength	Improve mechanical properties by nano reinforcements	[57]
SiC	Approach: Ultrasonic-assisted semisolid stirring	Overcome the challenges in dispersion of Nano sized reinforcements	[58]
SiC	Processing maps approach for studying hot compression deformation mechanism and effect of processing parameters	Improve properties of MMCs by optimizing deformation process parameters	[59]
SiC	Tribological properties	Understand tribological conditions of MMCs	[60]
SiC	Mechanical and dry sliding wear behavior	Understand tribological conditions of MMCs	[61]
SiC	Mechanical characterization	Study the influence of age hardening	[62]
SiC	Rate of wear and friction coefficient	Understand wear characteristics and develop potential application for aircraft components	[63,64]
SiC	Tool wear and mechanical properties	Reduce tool wear in FSP	[65]
SiC	EDM and mechanical properties	Optimal wire EDM parameters for machining of metal matrix nano composites for aerospace and automobile applications	[66]
SiC	Surface roughness in drilling	For best operational parameters, materials parameters and cutting tool selection	[34]
SiC	Dry sliding wear behavior	Improve the resistance to wear of AA7075	[67]
SiC & Al_2O_3	EDM	Optimal wire EDM parameters for machining of metal matrix composites for aerospace applications	[7]

Table 8. (continued).

Type of reinforcement/ reinforcement combination	Investigated parameters of AA7075 MMCs	Targeted improvement/ application	References
SiC & Al ₂ O ₃	Dry sliding wear behavior	Improve the resistance to wear of AA7075	[68]
(SiC+Ti)	Effect of Ti reinforcement on aging behavior and mechanical properties	Improve the strength of AMC	[69]
SiC & Flyash	Microstructural analysis and examine grain structures	Improve mechanical behavior	[70]
SiC & Cr	Thermo-physical and mechanical properties	Improve the strength of AMC	[21]
SiC & B ₄ C	Approach: Liquid pressing process	Improve dynamic and ballistic properties	[71]
SiC & ZrO ₂	Characterization of MMC	Improving performance of MMCs	[72]
SiC & Gr SiC & h-BN SiC & MoS ₂ SiC & Graphene	Effect of ceramics and solid lubricants –Mechanical and sliding wear characteristics	Develop material for piston	[73]
	Effect of ceramics and solid lubricants –Mechanical and sliding wear characteristics	Aerospace vehicles and racing automobiles	[36]
SiC & TiB ₂	Characterization of MMC	Improving performance of MMCs	[74]
Ag-C NP	Microstructural and mechanical characterization	Improving the properties of AA7075 by dispersing nano-Ag	[75]
CNT	Machinability study	Overcome problems related to chip adhesion on rake face of cutting tool and subsequent formation of built-up-edge	[23]
CNT	Precipitation hardening behavior	Effects of CNTs on precipitation hardening behavior of Al alloys	[76]
MWCNTs	Mechanical, wear and machining characteristics	Understanding of the effects of MWCNTs	[32]
Gr	Microstructural and mechanical characterization	Structural applications	[5]
Gr	Dry sliding wear behavior	Improve the resistance to wear of AA7075	[77]
h-BN, amorphous B & (B ₄ C+n-W)	Dry sliding friction and wear properties	Improve the resistance to wear of AA7075	[78]
Al ₂ O ₃	Impact strength	Eliminate primary discontinuities associated with MMCs	[79]
Al ₂ O ₃	Mechanical and high-temperature tribological behavior	Material for cylinder piston ring system	[18]
Al ₂ O ₃	Grain refinement by high pressure torsion	Improving mechanical properties	[80]
Al ₂ O ₃	Effect of heat treatment on microstructure and hardness	Microstructure and overall properties of MMCs	[81]
Al ₂ O ₃	Approach: Squeeze casting for producing MMCs	Eliminate casting defects and to improve compressive strength for automotive brake discs and connecting rods	[82]

Table 8. (continued).

Type of reinforcement/ reinforcement combination	Investigated parameters of AA7075 MMCs	Targeted improvement/ application	References
Al ₂ O ₃	Mechanical characterization	Improve the properties of MMCs	[29]
Al ₂ O ₃ & graphite	Mechanical properties and dry sliding wear characteristics	Improve mechanical properties and resistance to wear	[83]
Al ₂ O ₃ & h-BN	To evaluate the effectiveness of ultrasonic assisted cavitation, molten salt processing methods and T ₆ treatment and deep cryogenic treatment	Decide the effective processing method and heat treatment method which improves the mechanical properties	[21]
Al ₂ O ₃ & h-BN	Dry sliding and abrasive wear behavior	Improve resistance to wear of MMCs	[84]
Al ₂ O ₃ & Flyash	Wear and tensile properties	Improve the wear resistance and tensile strength in comparison to alloy	[28]
Al ₂ O ₃ & SiC	Mechanical and wear behavior	Mechanical properties and wear behavior of the MMCs for structural applications	[30]
Al ₂ O ₃ & SiC	Microstructure and tribological characteristics	Cylinder liners of automotive and aircraft engines	[40]
TiO ₂	Mechanical properties and texture analysis	Improve mechanical properties of MMCs	[12]
B ₄ C	Microstructure and mechanical properties	Effect of B ₄ C quantity on microstructure and mechanical properties	[9]
B ₄ C	Parametric investigation (tool rotational speed and alteration in tool travel direction) adapting FSP	Improve the uniformity in reinforcement distribution	[4]
B ₄ C	Mechanical characterization and effect of age hardening	Mechanical properties of MMCs	[62]
B ₄ C	Microstructure and mechanical properties	Define properties under different conditions	[85]
B ₄ C	Elucidate the relationship between the microstructure and mechanical behavior of submicron-grained, precipitation strengthened Al- based metal matrix composites	Distribution of reinforcement particles, which had a high number density	[86]
B ₄ C	Plasma activated sintering parameters on microstructure and mechanical properties	Understand densification behavior and mechanical properties	[8]
B ₄ C & Coconut shell flyash	Mechanical properties	High strength MMCs for automotive and aerospace industries	[87]
B ₄ C & Rice husk ash	Mechanical characterization	Badminton shaft and defense sectors for making rifles and armors	[46]
B ₄ C & MoS ₂	Microstructure and dry sliding wear	Resistance to wear and friction coefficient for automotive applications	[25]

Table 8. (continued).

Type of reinforcement/ reinforcement combination	Investigated parameters of AA7075 MMCs	Targeted improvement/ application	References
B ₄ C & Flyash	Microstructure and hardness	Automobile and aerospace application	[26]
B ₄ C & Flyash	Mechanical and tribological properties	Sand cast brake rotor, aeronautical and automobile applications	[88]
B ₄ C & BN	Mechanical properties and influence of drilling parameters	Improving mechanical properties and minimizing thrust force in drilling	[89]
B ₄ C & BN	Microstructure and mechanical properties characterization	Marine applications	[42]
B ₄ C & Cow dung ash	Micro structural characteristics, mechanical and tribological behaviors	Improving properties of MMCs	[33]
ZrO ₂	Approach: effect on distribution of reinforcement due to the use of different ball mills	Improve the homogeneity of dispersion of Nano particles	[90]
ZrB ₂ & hBN	Dry sliding wear behavior	Minimizing porosity and improving wear performance	[39]
TiC	Processing conditions in FSP	Distribution of reinforcements	[91]
TiC	Polarization studies using an Electrochemical work Station	Corrosion characteristics	[92]
TiC	Microstructure, mechanical, and tribological behavior	Aerospace applications	[27]
TiC	Coefficient of thermal expansion	Retard the thermal expansion of AMMCs useful for aerospace and automotive industries	[93]
TiC & B ₄ C	Kerf characteristics in AJM	Improve machinability of MMCs	[94]
TiC & MoS ₂	Machining characteristics	Improved machinability	[95]
TiB ₂	Mechanical characterization and effect of age hardening	Improve mechanical properties of MMCs	[62]
TiB ₂	High-temperature ductility and fracture mechanisms	Formability and fracture mechanisms for elevated temperature applications	[97]
TiB ₂	Tribological performance	Tribological performance	[98]
TiB ₂	Particle dispersion and grain refinement	Microstructure and mechanical properties	[99]
TiB ₂ & Gr	Dry sliding wear behavior	Optimizing the wear process parameters	[24]
Si ₃ N ₄	Microhardness	Study the improvement in microhardness with quantity of reinforcement	[100]
Si ₃ N ₄	Wear & friction behavior	Brake disc and cam	[101]
Si ₃ N ₄	Porosity studies and Spectro analysis	Reduce porosity and improve properties of MMC	[102]
TaC, Si ₃ N ₄ , Ti	Microstructural, mechanical and wear characteristics	Understand the influence of reinforcements	[35]
MoSi ₂	Mechanical characterization and dry sliding wear behavior	Improving properties of MMCs	[38]
VN	Microstructure, hardness, and wear behavior	Engine piston	[103]

Variation of hardness, tensile strength and flexural strength as a function of quantity of reinforcements are shown in [Figure 16](#).

Arun Kumar et al. [102] have investigated the effect of porosity on AA7075 alloy reinforced with Si_3N_4 metal matrix composites through stir casting process. The results of their study reveals that the presence of porosity, consequently, decreases most of the mechanical properties of cast composites. Failures initiated from the pores within the matrix material, particle fracture and reinforcement-matrix interface are due to voids coalescence, reduction of ductility, and reduced composite cross-section. [Table 4](#) gives an overview of the parameters of interest in the investigation carried out so far by individual researchers with a specific objective.

Bai et al. [103] have produced AA7075-15 %wt. VN composite by ball milling and hot press sintering. The experiments of this study indicated that there was a homogeneous distribution of VN in composite with 15 %wt. VN in AA7075 matrix, with no noticeable agglomeration. The hardness of 15 %wt. VN/7075 composite was 46.1% higher than the base alloy. Friction and wear test results indicated that the friction coefficient of 15 %wt. VN/7075 composite decreased by 37.6% in comparison to AA7075 alloy.

Zhang et al. [104] have studied the influence of aging treatment on the microstructure and mechanical properties of CNTs/AA7075 composites. These researchers have fabricated composites by milling and hot press sintering. After aging treatment, the CNTs/7075 Al composites had the peak hardness of 151.4 HV, and the peak-aging time decreased from 14 to 10 h compared to AA7075. Also the CNTs/AA7075 composites exhibited a tensile strength of 558.3 MPa and an elongation of 7.7%.

5.4.1 Summary of the properties of AA7075 composites based on other compounds

The properties of MMCs based on other compounds are listed in [Table 7](#).

[Table 8](#) gives an overview of the parameters of interest in the investigation carried out so far by individual researchers with a specific objective.

6 Conclusion

The in depth review on the vast area of AA7075 grade aluminium alloy matrix composites presented here critically discusses famous solid state production methods like, powder metallurgy and friction stir processing/welding. Among these production methods modified powder metallurgy was extensively used for quality components. Paper also suggests various liquid state processing techniques like stir casting, squeeze casting, centrifugal casting and in-situ process for better dispersivity of reinforcements in the aluminium alloy matrix composites. The review indicates that the focus of investigation on AA7075 matrix composites is mainly revolving around the recent year innovation publication results with the

addition of metal or ceramic compound reinforcements and possible heat treatments to elevate thermal and physical properties, machining characteristics and abrasive wear performance. Due to the possibility of improving the corrosion resistance, weldability in fusion welding and electrical properties by the addition of copper and magnesium the use is expanded to submarines, ships, prosthetic devices, aerospace, electronics applications, including military domain. It is observed that reinforcement hybridisation with one or more nano in addition to micro improves AA7075 composites properties drastically. The possible drawbacks of poor tribological properties, lower compression strength and low performance at elevated temperature is overcome by judiciously introducing borides, nitrides and carbides in the matrix. The numerous work reported in recent years on hybridization with the addition of light and heavy organic/inorganic reinforcements diversified the application in wider sectors of tribology. In spite of these possibilities to record its worthiness as possible competitor in materials field there is a need to focused research to overcome the existing limitations of poor ductility and toughness for exploring new application domains of this alloy matrix composites.

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