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# DEVELOPMENT AND CHARACTERIZATION OF ALUMINUM METAL MATRIX COMPOSITE BRAKE DISC-A REVIEW

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## ABSTRACT

The brake system is the most critical part as regard to safety in automobiles, with high demands imposed with respect to reliability, durability and consistency in its behavior. The braking system comprises of brake disc, brake pad connected with the hub via caliper .The brake discs are usually made of grey cast iron. In automotive industries, to achieve reduced fuel consumption and greenhouse gas emission, which is an issue of utmost importance, introduction of composite materials that combine two or more constituents on microscopic scales to synthesize a useful material is adopted. This review highlights mechanical, electrical, corrosion and thermal properties that enhance the use of aluminum composite. Under each properties aluminum composite was discussed to reveal the improvement on properties. It was found out that using different reinforcement increases the properties, varying volume fraction and also the particle size. However, the reinforcement of hard ceramic particles like silicon carbide, alumina, silica and zirconium copper, titanium in aluminum alloys using casting or powder metallurgical process has been found to improve the wear resistance and high temperature strength properties. The results gives materials with lower density and higher thermal conductivity compared to gray cast irons reducing weight to about of 50 – 60 % in brake systems.

**Keywords:** Automobile, Brake Disc, Braking, Coefficient Of Expansion, Composite, Corrosion, Friction, Grey Cast Iron.

## 1. INTRODUCTION

An automotive brake disc is a mechanism for slowing or stopping the motion of a wheel running at a certain speed. Braking systems are undoubtedly the most important component for road safety, as it determines the total or partial stop of a vehicle and, therefore, guarantees the safety of passengers. These systems benefit from friction to stop a moving vehicle, under the umbrella of hydraulic pressure that pushes the brake pads against the cast disc. The widely used brake disc material is cast iron, which consumes much fuel due to its high specific gravity.In recent years, Aluminium Metal Matrix Composite (AMMC) has been playing a significant role in engineering applications particularly in light weight materials. Aluminium-based metal matrix composite can be an efficient and effective braking material compared to cast iron. In this review, concepts of development and characterization of brake discs are provided, which highlight various properties such as strength, hardness, toughness, impact, wear thermal, electrical conductivity, and corrosion. Frictional heat developed elevates linearly as the pressure applied increases. During the accelerated conditions, the sudden rise in pressure applied grows the thermal distortions unstably, finally resulting in hot spots and leaving thermal cracks on the material. This condition is refer to as Thermo - Elastic instability. Thermo –Elastic instability occurs as the speed of rotation increases. The frictional heat developed at this condition deteriorates the braking performance which is referred to as "brake fade"(Ramesha et al.,2012), which resulted to an unusual vibration. Brake disc must have sufficient strength to resist these thermo-elastic instability conditions by having good thermal conductivity, thermal capacity, sufficient mechanical strength and hardness with suitable metallurgical structure (Yoshio and Takahiro, 2014).One lightweight material that is used extensively in engineering applications is metal matrix composite, or MMC. Metal matrix composite based on aluminum may be a more effective and efficient braking material than cast iron (Das, 2004). High specific strength, stiffness, excellent formability, superior electrical and thermal conductivity, high ductility, weld ability, and strong corrosion resistance are only a few of the desirable qualities of aluminum alloys(Polmear, 2006). However, aluminum alloys are the material of choice for brake discs due to their great thermal elongation and wear resistance. Without significantly altering the properties of the base material, the reinforcement with silicon carbide (SiC) particles will improve wear behavior and decrease thermal elongation; it will also marginally improve certain properties (Adebisi et al., 2011).

### 1.1 Metal Matrix Composites (MMCs)

The term "composite" broadly refers to a material system composed of a discrete constituent distributed in continuous phase, and which derives its distinguishing characteristics from the properties of constituents, from the geometry and architecture of constituents and from properties of the boundaries between constituents (Saravanan et al.,2017). Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase e.g., polymer matrix, metal matrix and ceramic composites (Blau et al.,2007). There are reports of emergence of

Intermetallic-Matrix and Carbon-Matrix Composites (Sadagopan et al.,2017; Parth et al.,2016). The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. The reinforcements being used are fibers, whiskers and particulates (Miyajima & Iwai, 2003). The advantages of particulate-reinforced composites over others are their formability with cost advantage (Mortensen &Wong, 2011), inherent heat and wear resistant properties (Gultekin et al., 2010; Lori and James, 2017). Metal Matrix Composite (MMCs) reinforcements like SiC and $Al_2O_3$ are widely used. The reinforcement of hard ceramic particles like silicon carbide and alumina in aluminum alloys has been found to drastically improve properties such as wear resistance and high temperature strength (Miracle and Hunt, 2004; Gomes et al.,2005). Abrasion resistance was improved by reinforcing the materials with ceramic particulate (Kassim et al.,1999). Their major area of applications are cylinder blocks, pistons, piston insert rings, brake discs and calipers (Ceschini et al.,2001). The strength of these composites is proportional to the percentage volume and fineness of the reinforced particles (Bermudez et al.,2001). These ceramic particulate reinforced Al-alloy composites led to a new generation tailor-able engineering materials with improved specific properties (Aigbodion and Hassan, 2007), structure and the properties of these composites are controlled by the type and size of the reinforcement and also the nature of bonding (Bodunrin et al., 2005; Sanjay and Brij, 2001). Aluminium Metal Matrix Composites (AMMCs) generally referred to the materials consisting of a metallic matrix and ceramic reinforcement, such as oxides, borides and carbides The metallic matrix provides ductility, toughness, formability, thermal and electrical conductivity while the ceramic reinforcement offers high hardness, strength, modulus, high-temperature durability, and low thermal expansion (Kaczmar et al.,2000). Some of the techniques for the development of these composites are stir casting, powder metallurgy, spray atomization and electro co-deposition, plasma spraying and squeeze-casting (Daoud et al.,2004)

### 1.2 Aluminum Binary Composites

To improve the mechanical, thermal, tribological and physical properties of the Al matrix, a choice can be made of one type of reinforcement, ceramics for instance, to produce a binary composite system. Ceramics are always the choice material as they possess high hardness, high thermal stability and high wear resistance deficient in monolithic Aluminum. Hence, reinforcing aluminum with ceramics produces a composite with good ductility, high strength, high formability, high thermal and wear resistance, and high toughness . Advanced ceramics such as alumina ($Al_2O_3$), Aluminium Nitride (AlN), Zirconia (ZrO2), Silicon Carbide (SiC), Silicon Nitride ($Si_3N4$), Boron Nitride (BN), Boron Carbide (B4C), Carbon Nanotubes (CNTs), Tungsten Carbide (WC), and Titanium Carbide (TiC) are used to engineer aluminum into specific configurations suitable for specific applications (Ujah et al.,2022).

### 1.3 Reinforcement types and properties they impact on the aluminum matrix

#### 1.3.1 Hardness

Rahimian et al. (2009) investigated how adding alumina affected the characteristics of an Aluminum alloy matrix. The hardness of the composite increased from 33 to 62 BHN and to 75 BHN when the weight fraction of alumina was increased from 0 to 10% and 20%. It was found that only the hardness increased as the other parameters decreased. Therefore, 10 weight percent was thought to be the ideal weight fraction for the reinforcement. According to experimental research by Saravanan et al. (2017), the hardness of an aluminum alloy at 100 weight Percent is 96.83 BHN; at 5 and 10 weight percent MgO, the hardness rises to 92.07BHN and 100 HBN, respectively. The mechanical characteristics of Al/SiC were investigated by Zhang et al. (2016). Hardness rose from 20 HV for unreinforced Al to 55.43 HV for Al-20 vol.% SiC. The impact of SiC reinforcement (average particle size 30-45 μm) on the microstructure and mechanical characteristics of aluminum metal matrix composite was investigated by Pavitraet al. (2018). The results showed that the hardness increased gradually from 23 HV to 47 HVwhen SiC reinforcement was added to the aluminum matrix. The mechanical characteristics and surface fracture of an Al/ZrO2 composite were investigated by Baghchesara et al. (2007) using either the direct inclusion method or a vortex. Hardness rose from 45 BHN to 64 BHNwhen 15 vol.% ZrO2 was produced at 750 ◦C. In their 2007 study, Haq et al found that theAl-3Si3N4 nano composite's hardness, yield, and compressive strengths improved by 102.6%over monolithic aluminum, from 38 ± 3 HV to 77 ± 2 HV, respectively. An examination into the microstructural and tribological properties of stir-cast AA6351/Si3N4 composites wascarried out by Mattli et al. (2019). With a 0 weight percent and 3 weight percent fraction ofSi3N4 (40.3%), the micro hardness rose from 67 HV to 94 HV. High bonding in the matrix reinforcement interface and Si3N4 grain refining were credited with all of the improvements.Gostariani et al. (2018) use hot extrusion and planetary ball milling to improve boron nitrate,Al/BN, utilizing 1, 2, and 4 weight percent BN. When compared to pure Al, the hardness rose to 102 HV (55% improvement), 112 HV (70% improvement), and 124 HV (90%improvement) with the addition of 1, 2, and 4 weight percent BN. Reinforced Al7075-5 weigh percent TiC+5 weight percent SiC by Ravi (2017). The hardness of AMMC is 39% higher than that of the Al7075 base alloy. a 32 percent improvement over the as-cast. Cerit et al.(2008) also noted that when the volume of reinforcement increased,

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the composite's harnesses. According to research by Devaneyan et al. (2017), the mechanical properties were improved when 90 weight percent of Al7075, 4 weight percent of TiC, and 6 weight percentof SiC composition were used to formulate the design matrix using a statistical tool called response surface methodology (RSM). The results of the ring compression test seem to indicate a higher coefficient of friction. Micro hardness of up to 52.12 HV is achieved with90 weight percent Al7075, 4 weight percent SiC, and 8 weight percent TiC, according to the investigations and tests carried out. The effect of aspects ratio was studied and it was found that CNTs with large aspect ratio entangle easily, causing irregular dispersion of reinforcement and pronounced micro pores in the composite (Lu et al., 2021). A comparative study to determine the best carbon reinforcements for the Al matrix was carried out by Sahooet al. (2019). The variety of carbon materials used included MWCNT, graphene nanoparticles, graphite flakes, and ball-milled graphite. The results showed that the particle with a smaller size and higher aspect ratio enhanced the grain structure more, and had more internal transfer of shear stress. Among the whole reinforcements tested, CNTs generated the highest Young’s modulus and hardness, with values of 90 and 3.5 GPa, respectively.

**1.3.2 Tensile Strength**

Rahimian et al. (2009) investigated the impact of alumina addition on the characteristics of,an Al alloy matrix. The hardness of the composite was found to increase from 33 to 62 and to 75 BHN, respectively, when the weight fraction of alumina was raised from 0 to 10%and 20%. The yield strength increased from 118 MPa (pure Al) to 190 MPa (Al-10Al2O3)and then decreased to 160 MPa (Al-20Al2O3), while the wear rate decreased from 0.0447mm3/m to 0.0262 mm3/m at a sintering temperature of 550 ◦C. The compressive strength increased from 133 MPa (pure Al) to 273 MPa (Al(Al2O3)) and then dropped to 190 MPa(Al-20Al2O3). Consequently, using alumina to reinforce Al enhanced not only its mechanical qualities, Therefore, reinforcing Al with alumina not only improved the mechanical properties, but also the tribological properties.( Rahimian et al.,2009) Kumar etal. (2013) studied the properties of an Al359 reinforced with Al2O3 using an electromagnetic stir casting technique. It was concluded that there is an increase in thehardness and tensile strength properties of the composite this was attributed to the electromagnetic stirring method inducing the improvement by producing a composite witha refined grain size and high interface bonding between the matrix and reinforcement.Therefore, the Al/Al2O3 composite has proven to be a choice material for industrial,household and high strength applications. By using liquid metallurgy, Nagaral et al. (2013)studied and created 6061Al composites with varying weight percentages ofAl2O3 particles up to 0–9%. The 6061 aluminum alloy was found to have lower ductilityand a lower tensile strength than the 6061Al-Al2O3 composites. The 6061Al alloy'sincreased Al2O3 composition helped to improve the composites' hardness. The impact ofstir casting temperature on the mechanical and microstructural characteristics of Al-3SiCcomposite was investigated by Soltani et al. (2017). The UTS and yield strength were found to be at their highest of 130 MPa and 90 MPa, respectively, at 680 ◦C stirring temperature. However, when the temperature was increased to 850 ◦C, they dropped to 110 MPa and 75MPa, respectively. The decline in characteristics were ascribed to the enhanced production of Al4C3 at the Al–SiC contact and the development of shrinkage porosity. In contrast, the sample that was agitated at 850 °C had a higher micro hardness and elastic modulus than the sample that was stirred at 680 °C. An AA6061 matrix with SiC reinforcement of 0, 5, 10, and 15 weight percent consolidated via stir casting was used to further investigate a mechanical feature of the Al/SiC composite. At 15 weight percent SiC, the tensile strength increased by 65.2% (Moses et al., 2014). The mechanical characteristics and surface fracture of an Al/ZrO2 composite were investigated by Baghchesara et al. (2007) using either the direct inclusion method or a vortex. The composite with 15 vol.% ZrO2 produced at 750 ◦C showed an increase in UTS from 145 MPa to 232 MPa. Nevertheless, a brittle fracture without necking was visible in the composite. Using stir casting, some researchers investigated the impact of zirconia reinforcement on an Al matrix. It was shown that adding 5 weight percent ZrO2 to Al6061 raised the yield strength to 196.92 MPa, the percentage elongation to 14.28, and the maximum ultimate tensile strength (UTS) to 227.332 MPa. Nevertheless, adding the same amount of alumina (5 weight percent Al2O3) to Al6061 alloy raised the yield stress139.65MPa and ultimate tensile strength to 181.36 MPa. Consequently, it is shown that zirconia enhances Al's mechanical qualities than alumina does. Even though zirconia reinforcement enhances mechanical properties, optimizing the volume fraction is of great importance. James et al. (2018) observed a constant increase in the UTS of an Al/ZrO2 composite when the volume fraction of zirconia went from 5 vol.% to 10 vol.%, but discovered a drop when the volume fraction got to 15 vol.% due to the increased porosity in the microstructures. In research, it was revealed that 6 vol.% of ZrO2 reinforcement was the ideal value (Abdizadeh &Baghchesara,2013) while Yadav et al. (2022) indicated 6 wt.% as the optimal concentration of zirconia in Aluminium (Al). Nonetheless, Al/ZrO2 is a potential material option for lowering highly wear-resistant materials like cutting implements. 10, 15, 20, and 25 weight percent B4C were added to Al matrices in order to enhance the mechanical properties of the Al alloy. It was shown that despite the percentage elongation reduced, the UTS and YS increased as the reinforcement increased. UTS of 206 MPa and 416 MPa and YS of 101 MPa and 369 MPa were obtained by Al6061/10B4C and Al6061/20B4C, respectively. Furthermore, according to Liu (2000), Al2124/15B4C and Al2124/25B4C produced UTS of 421 MPa and 511 MPa and YS of 315 MPa and 381 MPa, respectively. A comparative test between Al-SiC and Al-B4C was carried out by Shorowordi et al. (2006). It was shown that Al–B4C had a lower wear rate and friction coefficient than Al–SiC. The ultimate tensile strength and ultimate load for 100 weight percent aluminum alloy are 5.220 kN. has a 50.887 N/mm2 strength. The ultimate load is 13.500 kN and the ultimate tensile strength is 137.042 N/mm2 at 95 weight percent Al and 5 weight percent MgO. The ultimate load is 19.800 kN and the ultimate tensile strength is197.211 N/mm2 at 90 weight percent Al and 10 weight percent MgO (Saravanan et al., 2017Using volume fractions ranging from 5 to 30%, Park et al. (2008) investigated the impact of adding Al2O3 to an Al matrix. It was found that the AMMC's fracture toughness decreased as the volume fraction of Al2O3 increased. What is responsible for this is the reduction in inter-particle spacing between nucleated micro voids.

**1.3.3 Wear resistance**

The tribological behavior of stir cast Al-SiC composite sliding against brake lining material on pin on disc equipment was reported by Uyyurua et al. (2015). When the load increases,the coefficient of friction, which was approximately 0.3, decreases. As sliding speed increases, the coefficient of friction falls. For all composites, the wear rate reduces as the sliding speed increases. It was determined that the tribo-layer depressions were caused by the layer splitting in the debris, which could result in abrasive wear (Uyyurua et al., 2015). Using a planetary ball mill and different percentage weight fractions of 0, 2.5, 5, and 10, Abdoli et al. (2010) examined the impact of AlN reinforcement on the Al matrix. The powders underwent die-pressing, degassing, and 25 hours of milling. When the load increases, the coefficient of friction, which was approximately 0.3, decreases. As sliding speed increases, the coefficient of friction falls. For all composites, the wear rate reduces asthe sliding speed increases. It was determined that the tribo-layer depressions were caused by the layer splitting in the debris, which could result in abrasive wear (Uyyurua et al., 2015).(2010) Abdoli et al. used different percentage weight fractions of 0, 2.5, 5, and 10 to grind in a planetary ball mill to examine the impact of AlN reinforcement on the Al matrix. Following a 25-hour milling process, the powders were degassed, die-pressed uniaxially in a steel die, and sintered at 650 °C. It was found that the wear resistance was enhanced by 5 and 10% aluminum nitrate.By strengthening the composite against oxidative and abrasive wear under all applied loads, aluminum nitrate increased the wear resistance of the material even more (Abdoli et al., 2010). However, the reinforcement decreased the pitting potential (Epit) in the diluted solution but had no discernible influence on the corrosion current density of the composite in either the 0.05 or 0.5 mol/L NaCl media. When a 40–60 volume fraction of AlN was added to the Al matrix, the thermal conductivity of Al-AlN increased up to 180 W/mK while the Coefficient of Thermal Expansion was significantly reduced (Mizuuchi et al., 2012). Another great ceramic for strengthening the Al matrix and improving its mechanical, tribological, and thermal characteristics is ZrO2. Regarding tribological improvement. According to Pal et al. (2020), applying 6 weight percent ZrO2 to the Al matrix increased wear resistance by 63.91%. When zirconia addition increased from 0 to 6 weight percent, corrosion resistance increased from 30 to 70% (133.33 percent), and the hardness improved from 84.7 to 92.7 HRB (9.45% improvement) (Pal et al., 2020).Haq and Anand(2018) investigated an AA7075-Si3N4 composite's wear behavior and dry sliding friction. When the weight fraction of Si3N4 reached 8 weight percent, it was found that the compressive strength and hardness increased. A 20% increase in hardness and a 50% increase in compressive strength were noted at that reinforcing percentage. At 10 N loading, the reinforcement increased wear resistance by 37%, and at 50 N loading, it increased by 61%.When the weight fraction of the reinforcement was raised to 4 weight percent, the COF first increased; after that, it began to decline. Surendran et al. (2017) added nano alumina to aluminum alloy to improve its wear properties. Reinforcement of nano-sized particles with aluminium matrix yields superior mechanical and physical properties and modifies shape of nano-composites. It was confirmed that the wear decrease experienced was due to strong binding formation between Al and Al- Al2O3 nano composites. In comparison to the results of pure LM 25 and other Al-Al2O3, the results demonstrate that the addition of nano powder in different proportions effects the increased wear performance of the aluminum alloy, with the addition of 2.5% nano Al2O3 yielding the maximum wear reduction.With other Al-Al2O3 composites, brake linings made of bronze werecreated, and their friction-wear characteristics were examined. Al2O3 reinforced bronze-based brake linings were created by Mustafa and Adem (2007) by adding 0.5%, 1%, 2%, and 4% alumina (Al2O3) powders to the bronze-based powders. Because friction raises the temperature, the samples withAl2O3 had the highest friction coefficient, which was in the range of 4%. When 2% Al2O3 was added to the samples, the friction coefficient remained constant (Mustafa and Adem, 2007).According to Nirala et al. (2020), the wear, mechanical, and corrosion properties of Al/SiC composite were enhanced by the addition of SiC up to 15 weight percent. These characteristics, however , decreased when this range was exceeded. Particles of silicon carbide improve Al/SiC's resistance to corrosion .These characteristics, however, decreased when this range was exceeded. Particles of silicon carbide improve the Al/SiC composite's resistance to corrosion. At room temperature, it was discovered that the corrosion resistance of Al/SiC was superior to that of the monolithic Al alloy by either increasing its volume fraction or decreasing its particle size. However, the corrosion resistance decreases at higher temperatures (50 ◦C and 75 ◦C) (Zakaria, 2 014).These characteristics, however, decreased when this range was exceeded. Particles of silicon carbide improve the Al/SiC composite’s resistance to corrosion. At room temperature, it was discovered that the corrosion resistance of Al/SiC was superior to that of the monolithic Al alloy by either increasing its volume fraction or decreasing its particle size. However, the corrosion resistance decreases at higher temperatures (50 ◦C and 75 ◦C) (Zakaria, 2 014).

**1.3.4 Corrosion**

When the volume fraction of zirconia climbed from 5 to 10 vol.%, the UTS of an Al/ZrO2 composite increased steadily, according to Abdizadeh & Baghchesara's (2013) study However, when the volume fraction reached 15 vol.%, the UTS decreased because of the increased porosity in the microstructures. Another study by Mosleh Shirazi et al. (2016) found that adding SiC nanoparticles enhanced the Al matrix's resistance to corrosion by raising the Al-SiC nanocomposite's overall electron work function (EWF), which in turn raised the corrosion potential. Therefore, it is not only appropriate but also opportune to apply an Al/SiC composite in a corrosive industrial setting. Al 6061-SiC composite was aged by Rajasekaran et al. (2012), who then observed the results.Using an Al 6061-SiC composite, Rajasekaran et al. (2012) reported peak aging at 180 °C, over aging above 200 °C, and under aging between 1400 and 160 °C. According to Sambathkumar et al. (2017), the two-step stir casting method is recommended when reinforced with silicon carbide and titanium carbide. This technique demonstrated superior hardness, tensile strength, and density compared to the basic alloy. It has also been demonstrated that increasing the volume of reinforcement from 0 to 15 weight percent increases micro hardness. In addition, increasing the reinforcement's particle size has improved its corrosion resistance in a 3.5 weight percent NaCl solution, outperforming other aluminum alloys in terms of corrosion resistance (Sambathkumar et al., 2017).In their experimental study, the photomicrographs show that the two-step stir casting procedure produces a homogeneous distribution of reinforcement. According to Yadav et al. (2022), the ideal zirconia concentration in Al is 6 weight percent. Al/ZrO2 is generally a promising material for reducing high wear-resistant materials, such as cutting tools.

**1.3.5 Thermal**

Reddy et al. (2018) investigate how boron nitrate ceramic can improve aluminum. The tensile strength of boron nitrate reinforcement dispersed in an Al matrix increased by 36% at 1.5 vol.%, which was caused by the boron nitrate nanoparticles' dispersion hardening. Due to the intrinsically low coefficient of thermal expansion of BN nanoparticles, the coefficient of thermal expansion reduced as the amount of BN increased. The inclusion of 1.5.The damping properties of the Al matrix were enhanced by the addition of 1.5% BN nanoparticles. The Al-1.5 vol.% BN composite was determined to be a suitable material for industrial applications that are sensitive to weight.Al-Aluminum Nitride composite was created in an in situ experiment by mixing molten aluminum with a CaO and NH4Cl mixture, keeping it at a temperature between 7500 and 9300C, and then casting it into a metal mold. The findings demonstrated that the Al-AlN (30–30) composite reached a maximum hardness of 572.12 MPa. The wear resistance of the composite also increased as the amount of NH4Cl + CaO increased (Pradhan et al., 2011).

**Table 1:** Effect of reinforcements on mechanical properties of aluminum composite

| S /N | Name of author(s) and year | Reinforcement(s) /filler | Base material | Mechanical properties | Effect(s) of reinforcement |
|---|---|---|---|---|---|
| 1 | Rahimian et al. (2009) | Alumina | Aluminium alloys | Hardness and tensile strenght | Increase in weight volume fraction improvement from 33 - 62to75BHN |
| 2 | Zhang et al. (2016) | $S_iC$ | Aluminium alloys | Hardness | Increase in hardness value from 20HV TO 55HV WITH 20% $S_IC$ |
| 3 | Pavitra etal 2018 | $ZrO_2$ | Aluminium alloys | Hardness | Increase in hardness value from 23 HV to 47 HV. |

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| 4 | Baghchesara et al. (2007) | $Si_3N_4$ | Aluminium alloys | Hardness | Hardness increased from 45 BHN to 64 BHN. |
| 5 | Mattli et al. (2019) | $Si_3N4$ | Aluminium alloys | Hardness | micro hardness increased from 67 HV to 94 HV |
| 7 | Gostariani et al. (2018) | BN | Aluminium alloys | Hardness | . The hardness increased to 102 HV - 112 and 124 HVwith1, 2 and 4 wt.% BN |
| 8 | Ravi (2017) | TiC, SiC | Aluminium alloys | Hardness | hardness is increased by 39% w |
| 9 | . Devaneyan et al. (2017) | TiC and SiC | Aluminium alloys | Hardness | micro hardness of up-to 52.12 HV |
| 10 | by Sahoo et al. (2019). | CNT | Aluminium alloys | | of 90 |
| 11 | . Soltani et al. (2017) | | Aluminium alloys | | |
| 12 | Moses et al., 2014). | SiC | Aluminium alloys | Tensile strength | tensile strength was improved by 65.2% at 15 wt.% SiC |
| 13 | Rahimian et al. (2009) | Alumina | Aluminium alloys | Tensile strength | the compressive strength increased from 133 MPa to 273 MPa ($Al(Al_2O_3)$), and decreased to 190 MPa ($Al\text{-}20Al_2O_3$); the yield strength increased from 118 MPa (pure Al) to 190 MPa ($Al\text{-}10Al_2O_3$), and decreased to 160 MPa ($Al\text{-}20Al_2O_3$ |
| 14 | | | | | |
| 15 | Uyyurua et al. (2015) | Al- SiC | Aluminium alloys | wear resistance | increase in sliding speed wear rate decreases for all composites |
| 16 | Abdoli et al. (2010). i | AlN reinforcement | Aluminium alloys | wear resistance | 5 and 10 wt.% Aluminium Nitrate improved the wear resistance of the co |
| 18 | Pal et al. (2020) | of $ZrO_2$ | Aluminium alloys | Corrosion resistance | Corrosion resistance increased from 30 to 70% (133.33%) when zirconia addition rose from 0 to 6 wt.%, |
| 19 | Surendran et al. (2017) | nano alumina. | Aluminium alloys | | |
| 20 | Reddy et al. | Boron nitrate | Aluminium | | The Coefficient of thermal Expansion |

| | | | | | |
|---|---|---|---|---|---|
| | (2018) | ceramic | alloys | | decreased with the increase in volume of BN |

## 2. CONCLUSION

This review provides the experimental and theoretical findings, which clearly state how improvement on composite improve the mechanical properties. It was discovered that increase in volume fraction increases the coefficient of thermal expansion (CTE). Also increase in weight fraction increases the hardness and strength of composite. It is evident that there is a drop in density of composites when ceramics are reinforced into the matrix material. The review shows that alumina ($Al_2O_3$), Aluminium Nitride (AlN), Zirconia (ZrO2), Silicon Carbide (SiC), Silicon Nitride ($Si_3$N4), Boron Nitride (BN), Boron Carbide (B4C), Tungsten Carbide (WC), and Titanium Carbide (TiC) gives a significant increase in tensile, wear, thermal and hardness of the metal matrix composite. The AMMC is found to have higher elastic modulus and tensile strength when compared to base alloys, which are being used currently in the industries. It is clear that wear rate of composites is increased when applied load and speed are increased. It is also observed that lowering particle size helps us to achieve uniform mixing in the hybrid composites.

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