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Aluminium-6061 Composites Produced Through Powder Metallurgy Method – A Critical Review

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Abstract
Modern era demands sophisticated materials which has enhanced properties. So, process of developing lightweight materials come into existence. Such alternative lightweight and high strength composite material can be used for aerospace launch vehicle, external fuel tank, and structural components. These materials show better material performance and can be used in various purposes. Aluminium 6061 is widely used due to its superb properties. The current study gives a review of Aluminium 6061 composites reinforced with different reinforcements such as Graphene SiC, B4C, etc. produced through powder metallurgy method. It focusses on process parameters, various reinforcements used, and the mechanical properties composites. In most of studies it has been found that there is increase in mechanical and tribological properties of the composites such as the tensile test, compression test, hardness, microhardness etc. with increase in reinforcement content, compaction pressure, compaction time, sintering time and sintering temperature. Moreover, hybrid composites showed better material properties than single reinforcement composites. Future studies could focus on the fabrication of Aluminium 6061 composites through powder metallurgy method and their material characterisation, since they have great potential as advanced materials the literature provides evidence that in recent years the powder metallurgy method has attracted the interest of many researches.
Keywords: *Aluminium-6061; Graphene; Composites; Compaction pressure; Tensile Strength; Hardness.*

1. Introduction
Aluminium and its alloys are commonly used for industrial purposes due its high young's modulus, specific strength, tensile strength and enhanced wear properties. It finds applications in various sectors like automobile, defence, marine, aerospace, medical, other manufacturing industries etc. [1]. 2XXX, 3XXX, 6XXX are most commonly used aluminium grades but 6XXX series is most preferred due to its high strength to weight ratio, good machinability and corrosion resistance [2-3]. Composite materials draw great attention in multiple areas due to their distinct features and superior quality with respect to their base materials [4]. A number of techniques are commonly used to produce Aluminium 6061 composites. Some typical examples are squeeze casting, powder metallurgy, stir casting and chemical vapor deposition. Due to ability to adjust density, microstructure and to attain low production cost powder metallurgy is a highly-preferred method.

1.1. Aluminiun - 6061
It is most commonly used for industrial purposes due its superior mechanical properties. Heat treatable nature makes it unique than aluminium other grades. It finds various applications due its strength, weldability and corrosion resistance, shown in Table 1. [5-6].

Table 1 Chemical Composition of Aluminium 6061 Alloy [4]

Elements	Al	Fe	Cr	Mg	Ti	Cu	Mn	Zn	Si
Wt.%	97.05	0.7	0.8	0.14	0.15	0.24	0.24	0.25	0.43

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1.1.1. Properties of Aluminiun- 6061

This table 2 shows properties after heat treatment. It shows some mechanical and physical properties.

Table 2 Mechanical Properties of Aluminium 6061 Alloy [7]

Properties	Units
Ultimate Tensile strength	310 Mpa
Tensile Yield Strength	276 Mpa
Hardness	60 HRB
Melting Temperature	(585–692) ^{0}C
Modulus of Elasticity	68.9 GPa
Density	g/cm^3

1.2. Powder Metallurgy

This process involves cold pressing and sintering to manufacture primarily particle or whisker reinforced MMCs. Homogeneous distribution is obtained by mixing parent metallic powder and reinforcement powders, then cold pressed in order to produce a green sample and then sintered. The sintered part is hot pressed, either uniaxially or isostatically, so that highly dense composite is formed which is followed by extrusion process.

2. Methods

2.1. The Systematic Way to Manufacture Parts by Powder Metallurgy is

2.1.1. Mixing

It involves the mixing of metal powder or powders with a suitable lubricant, which is done in ball milling machine in order to get homogeneous mixture by adding lubricant. Lubricants such as stearic acid, metallic stearates, stearin, most commonly zinc stearate and other organic compounds of waxy nature are used. The main function of the lubricant is to reduce the friction between the powder mass and the surfaces of die walls along which the powder must slide during compaction, thus helps in achieving the desired uniformity of density from top to bottom of the compact and also makes it easier to eject the compact and so minimises the tendency to form cracks.

2.1.2. Pressing or Compacting

Load the mixture into a die or mould and apply pressure, which leads to formation of a compact which have sufficient cohesion to be handled safely. Such compacts are known as green compacts. Rigid steel or carbide dies are used to press the mixed powder under pressures of 150-700 MPa. At this stage, the compacts maintain their shape due to cold welding of the powder grains among themselves, so that sufficient strength green sample can withstand ejection, shown in Figure 1.

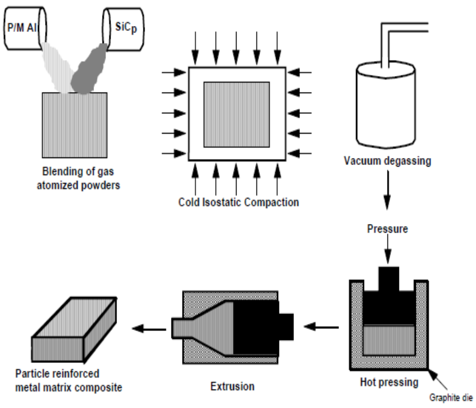

Figure 1 Process of Powder Metallurgy

2.1.3. Sintering

Sintering involves heating the green specimen in a protective atmosphere, at a temperature below the melting point of the matrix so that the powder particles weld together and attain sufficient strength. Liquid phase sintering can be seen in specific cases where minor constituent becomes molten. In industries sintering is done in a continuous belt furnace for continuous production in inert atmosphere.

2.1.4. Re-Pressing

Even with the best control that is feasible, there may be inevitably variation in the dimensions of parts produced in a die. It is possible to attain a tolerance of 0.0508 mm per mm, in the direction at right angles to the pressing direction and 0.1016 mm per mm parallel to the pressing direction. Dimensional accuracy can be greatly improved by re-pressing the part after sintering. This operation is called sizing. It leads to formation of denser. **Hot Isostatic Pressing** It is used as a post-sintering operation to eliminate flaws and microporosity in cemented carbides.

Heat Treatment: Aluminium-6061 under goes T6 tempering process. It involves tempering followed by quenching and then artificial age hardening. The

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whole process can be termed as solution-based tempering.

2.2.Powder Metallurgy Parameters

1) Compaction Pressure
2) Compaction Time
3) Sintering Temperature
4) Sintering Time

Taskin, A et al., (2024) tries to study the mechanical properties and microstructures of Al-2024, Al-6061, and Al-7075 composites mixed with graphene. The graphene content used was 0.15-0.45wt. %. The highest compressive strength was found as 506 MPa, hardness as 164 HV and density 2.65 g/cm^3 for Al-7075-0.15%GNPs composites. Al6061-0.15%GNPs composites shows lowest porosity rate i.e. 4.4%. Best mechanical properties were obtained Al-7075 composite. It has been determined that hot pressing processing improves the microstructure and mechanical strength of composite materials. Microstructure analysis exhibited a denser structure for samples produced through sintering and hot-pressing method [7]. Jayasekera, T et al., (2023) fabricated Al-6061 composites by mixing 0.5 and 1 vol. % graphene Nano platelets and 1 and 2 vol. % activated nanocarbon by using PM technique. Density Functional Theory (DFT) calculations are used to understand the effects of hybridized networks of carbon atoms on Al-6061 composites. Micro hardness and compressive tests were used to determine the mechanical properties of the samples. Composites shows increased hardness, yield strength and ultimate strength. However, Ductility was reduced. Hardness was increased by 26% [8]. Melik, W et al., (2022) investigated the effect of sintering temperature i.e. 585, 600, 615 and 630 ^{0}C on Al-6061 composite reinforced with 7.5% of SiC by weight, prepared by powder metallurgy technique. The segregation of SiC particles increases with the increase in sintering temperature. Density, hardness increased but porosity decreased by increasing sintering temperature up to 600 ^{0}C and vice versa up to 630 ^{0}C [9]. Surya, M. S et al., (2021) reported composites sintering temperature greatly influence the mechanical properties of composite. It shows higher relative densities, hardness and toughness are achieved at higher sintering temperatures and with a longer duration and by adding SiC. Composite was sintered at 530 C for different sintering durations (1 h, 2 h, and 3 h). Sintering temperature had an essential influence on samples' densification because sintering is a thermally activated process controlled mainly by diffusion. Therefore, a higher sintering temperature causes a higher diffusion rate and fewer pores in the bulk composite [10]. Wu, L et al., (2021) Sintering temperatures were set to 525 ^{0}C and 575 ^{0}C. A suitable temperature condition played a role to obtain a good mechanical performance. The Al-2024 powder was sintered under a pressure of 0.1 MPa at 575 ^{0}C and got density of 2.732 g/cm^3 and ultimate tensile strength of 228.16 MPa along with ductility of 12 % [11]. Hugo, M. L et al., (2021) conducted study with Al_2O_3 particles concentration which was set up to 5 wt.% and the milling time was 5 h. Thus, the compaction pressure was for 2 min under a pressure of 1862.65 MPa and then sintered for 3 h at 550 ^{0}C under vacuum with a 50 K/min heating rate. It shows increased mechanical properties [12]. Whenish. R et al., (2020) sintered samples at a temperature of 500 ^{0}C for one hour. SiC was added with Al 6061 in different weight percentages such as 3%, 6% and 9% and particle size was considered as 50 μm. The 50 tons load was for pressing the powder. It has been found that Al/SiC of 9 wt. % and 50 μm size showed the highest hardness and good surface finish than those other compositions [13]. Swamy, R. K et al., (2019) fabricated specimens by adding WC and heated at 540 ^{0}C for 2hrs in a muffle furnace. It was found that ultimate tensile strength is increased by 77%, hardness by 29% and compressive strength increases by 53% in MMCs when compared with base alloy. It was found that increasing the WC content, resulted in significant improvement in mechanical properties like hardness, tensile strength, and compressive strength. 12% by weight of WC gives highest values of mechanical properties like hardness, tensile strength and compressive strength [14]. Ashwath, P et al., (2018) Green compacts produced are reinforced with 0.25, 0.5 and 0.75 wt% of graphene particles and microwave sintered at 450 ^{0}C, 500 ^{0}C, 550 ^{0}C and 600 ^{0}C for 60 min. It is understood that 500 ^{0}C and 550 ^{0}C above recrystallization temperature of the parent material is observed to be the effective sintering temperature range to achieve good strength and flexural characteristics. Extrude sample after powder metallurgy processing of AA 2900 exhibited good flexural properties. 0.5 wt% Graphene exhibited good mechanical behaviour of composites after the extrusion process [15]. Arockiasamy, A et al., (2009) conducted study at three sintering temperatures (610, 630 and 650 ^{0}C) for three peak temperature hold times (10, 20 and 30 min) and three heating rates (1, 5 and 10 ^{0}C), by applying three compact pressures (110, 330 and 550 MPa). The optimum sintering conditions for density and hardness corresponded to the highest compaction pressure, the lowest sintering temperature, the slowest heating rate and the shortest hold time, and this is similar for TRS and hardness. However, UTS and elongation increases with the highest sintering temperature, the longest holding time, the slowest heating rate and the highest die compaction pressure [16]. Showaiter, N et al., (2008) conducted mechanical testing by preparing 4.5 g of Ag powder at 250, 340 and 510 MPa. The highest green densities (2.6 g/cm^3) were obtained at a compaction pressure of 510 MPa. UTS values of 233 and 248 MPa for compaction pressures of 340 and 510 MPa respectively [17].

Conclusion

1. Mechanical properties increase with addition of reinforcement.
2. Mechanical properties increase with increases in sintering temperature along with sintering duration.
3. Mechanical and tribological properties increases with compaction pressure.
4. Density of sample increases with increase in compaction pressure, compaction time and sintering temperature and time.

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References

[1]. Chib, S. S., & Sharma, S. K. (2020). Development of Port Vehicle with Semi-active Suspension—A Literature Review. International Journal of Mechanical Dynamics & Analysis (IJMDA), Volume-6, Issue 1, 1-8.
[2]. Halil, K., İsmail, O., Sibel D., & Ramazan, C. (2019). Wear and mechanical properties of Al6061/SiC/B4C hybrid composites produced with powder metallurgy. J Mater Res Technol 8(6), 5348–5361.
[3]. Khare M., Gupta R. K., & Bhardwaj B. (2019). Dry sliding wear behaviour of Al 7075/Al2O3/B4C composites using mathematical modelling and statistical analysis. Mater Res Express 6(12), 126512.
[4]. Kareem, A., Qudeiri, J. A., Abdudeen, A., Ahammed, T., & Ziout, A. (2021). A Review on AA 6061 Metal Matrix Composites Produced by Stir Casting. Materials 14(175). doi.org/10.3390/ma14010175.
[5]. Rahimian M, Ehsani N, Parvin N, reza Baharvandi, H. (2009). The effect of particle size, sintering temperature and sintering time on the properties of Al–Al2O3 composites, made by powder metallurgy. J Mater Process Technol 209(14), 5387–5393.
[6]. Surya, M. S., Prasanthi G (2018). Tribological behaviour of aluminum silicon carbide functionally graded material. Tribol Ind 40(2), 247–253.
[7]. Isik, E., Senel, M. C., & Taskin, A. (2024). Investigation of Microstructures and Mechanical Properties of Al2024/6061/7075-Graphene Composites. Journal of Science, 37(4). DOI: 10.35378/gujs.1390096.
[8]. Parada, W. R., Sirikumara, H. I., Karunanithy, R., Sivakumar, P., Jayasekera, T., & Nilufar, S. (2023). Effect of Nanocarbon on the Structural and Mechanical Properties of 6061 Aluminium Composites by Powder Metallurgy. Nanomaterials, 13, 2917, 1:14. doi.org/10.3390/nano13222917.
[9]. Melik, W., Boumerzoug, Z., & Delaunois, F. (2022). Characterization of the Al6061 Alloy Reinforced with SiC Nanoparticles

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and Prepared via Powder Metallurgy. Malaysian Journal on Composites Science and Manufacturing, 9, Issue 1 (2022), 22-34. doi.org/10.37934/mjcsm.9.1.2234.
[10]. Surya, M. S. (2021) Effect of SiC Weight Percentage and Sintering Duration on Microstructural and Mechanical Behaviour of Al6061/SiC Composites Produced by Powder Metallurgy Technique. Silicon, doi.org/10.1007/s12633-021-01053-z.
[11]. Wu, L., Yu, Z., Liu, C., Ma, Y., Huang, Y., Yang, L., Yan, H., Liu, W., & Wang, T. (2021). Microstructure and tensile properties of aluminium powder metallurgy alloy prepared by a novel low-pressure sintering. Journal of materials research and technology.14 (1419), 429.
[12]. Hugo, M. L., Garduno, I. E., & Melgar, A. G. (2021). Wear Dry Behaviour of the Al-6061-Al2O3 Composite Synthesized by Mechanical Alloying. Metals, 11, 1652. https://doi.org/10.3390/met11101652.
[13]. Whenish. R., Sureshbabu B., Johnrajan. A., kumar, S. N., Kavitharan, A., Pandikrishna, A., & Ragupathi, S. (2020). Effect of SiC reinforcement on mechanical properties of Al 6061 by Powder Metallurgy. Materials Science and Engineering, 988, 012063. doi:10.1088/1757-899X/988/1/012063.
[14]. Swamy, R. K., Bhaskar, & Raju, S. A. (2019). Mechanical Characterization of Al6061-Tungesten Carbide Composites Using Powder Metallurgy Technique. International Journal of Engineering Applied Sciences and Technology (IJEAST), 4(7), 2455-2143, 325-331.
[15]. Ashwath, P., Jeyapandiarajan, P., Joel, J., Kumar, H. G., Xavior, A., Sumanth, N., & Reddy, D. C. S. Flexural Studies of Graphene Reinforced Aluminium Metal Matrix Composite. International Conference on Materials Manufacturing and Modelling (ICMMM). (5), 2214-7853.
[16]. Arockiasamy, A., German, R. M., Wang, P., Horstemeyer, M. F., Morgan, W., & Park S. J. (2009). Sintering behaviour of Al-6061 powder produced by rapid solidification process. Powder Metallurgy. DOI 10.1179/003258909X12573447241626.
[17]. Showaiter, N., & Youseffi, N. (2008). Compaction, sintering and mechanical properties of elemental 6061 Al powder with and without sintering aids Materials and Design 29, 752–762.