An Analysis of Structural and Mechanical properties of Composites &its types

Ravinder , M.Tech Student, Ganga Institute of Technology & Management, Jhajjar.
Dr.Vivek Khokkr, Supervisor, Ganga Institute of Technology & Management, Jhajjar.

Abstract

Composite are the substances which might be composed of two or greater different phases (at least one of them is solid) such that the aggregate of those phases offers us with the properties that are advanced to any of the individual phases. The properties of the so obtained composite are the end result of the cooperation of the individual phases at the interface. The formation of the composite is due to mutual cooperation of the two phases at the interface, and this is called Synergy effect. Metal-matrix composites have several advantages over monolithic metals like high service temperature, hardness, resistance to wear and surface damages, etc. Al_2O_3 nano particles were synthesized via sol-gel method using aluminium chloride ($AlCl_3$) as a precursor. The wear resistance was found to increase with the increasing wt. % of Al_2O_3 in the composite.

Kewords:

Composite, nano materials, surface, alumina etc.

Introduction:

Composite are the substances which might be unruffled of two or greater diverse phases (at least one of them is solid) such that the cumulative of those phases offers us with the properties that are highly developed to any of the personage phases. The properties of the so obtained composite are the end result of the collaboration of the entity phases at the boundary. The configuration of the composite is due to common collaboration of the two phases at the boundary, and this is called Synergy effect. Another critical portion to abide in mind is the matrix-strengthening interaction i.e., wettability of the surface of the strengthening particles with the matrix phase. There has to be no chemical reaction between the strengthening and the matrix at the boundary, as this could lead to the configuration of a few fragile inter-segments, Metal composite materials have discovered application in numerous regions of everyday life for a long while in structural building. Aluminum is a concoctioncomponent in the boron assemble with image Al and nuclear number is 13. It is shiny white, and it is insoluble in water under typical conditions. Aluminum compounds are composites in which Aluminum (Al) is the most grounded metal. The commonplace alloying components are silicon and zinc. There are two divisions, to be specific throwing combinations and created compounds. Fly fiery debris is one of the buildups created in the burning of coal. It is a mechanical by-item recuperated from the vent gas of coal consuming electric power plants. In view of the source and cosmetics of the coal being singed, the fly fiery remains segments created changes significantly. When all is said in done, fly fiery debris contains Fe_2O_3, Al_2O_3, SiO_2, as significant extent and oxides of Ca, Na, Mg and so on as minor extent. Fly powder particles are for the most part round fit as a fiddle and range from under 1 μm to to100 μm with an upper zone, in the vicinity of 250 and 600 m^2/ kg. The particular gravity changes between 0.6-2.8 g/cc. Physical properties of fly fiery debris basically rely on upon the kind of coal consumed and the states of consuming. Class F sort fly fiery debris is created from consuming high rank (containing high carbon content) coals, for example, anthracite and bituminous coals, while, Class C fly slag is delivered from low rank coals.Cement is the world's most used construction binder material. Cement production emits large amounts of CO_2 and consumes significant amount of energy. Production of one ton of Portland cement releases one ton of CO_2 into the atmosphere. The global cement industry contributes around 6% of all CO_2 emissions. It is a typical perspective that finding an option material to the Portland concrete is inescapable. A few analysts have expressed that CO_2 outflow could increment by half contrasted and the present degree. Therefore, the impact of cement production on the environment issues a significant challenge to concrete industries in the future. As a result, it is imperative to search a new concrete material that can replace traditional Portland cement concrete, which is environmentally stressful, yet provides an effective building material. Promoting low-emission concretes is essential in order to face the crucial challenge to reduce the environmental impact of the construction sector and the concrete industry and to limit the impact of climate change. One method for diminishing these CO2 discharges is the utilization of mixed concretes in which a piece of the Portland bond clinker is supplanted with supplementary cementitious materials (SCMs). The most well-known SCMs utilized as a part of high-volume applications are fly fiery debris (FA) and ground granulated impact heater slag (GGBFS). Fly-fiery remains based and GGBFS based mixed bonds are broadly utilized yet cutoff points are forced on the OPC substitution. By and large, mixed bonds still contain more OPC clinker than SCM.

Components of a Composite

Generally, a composite is unruffled of two components i.e. primary phase which is continuous- **the matrix** and a secondary phase which is mostly discontinuous- **the corroboration.**

The matrix

The matrix is the mass part of the composite which holds the strengthening phase and protects the strengthening particles from the special effects of outer influences. The matrix phase is ought to spread the forces to the strengthening. Different types of matrices are used for the formation of different types of composites with defined and preferred properties such as metals, polymers, ceramics, etc.

The reinforcement

The strengthening phase is the irregular phase to which the outside load is transfer by the matrix. The properties of the composites depend upon the size, distribution, orientation, shape, etc. of the strengthening phase

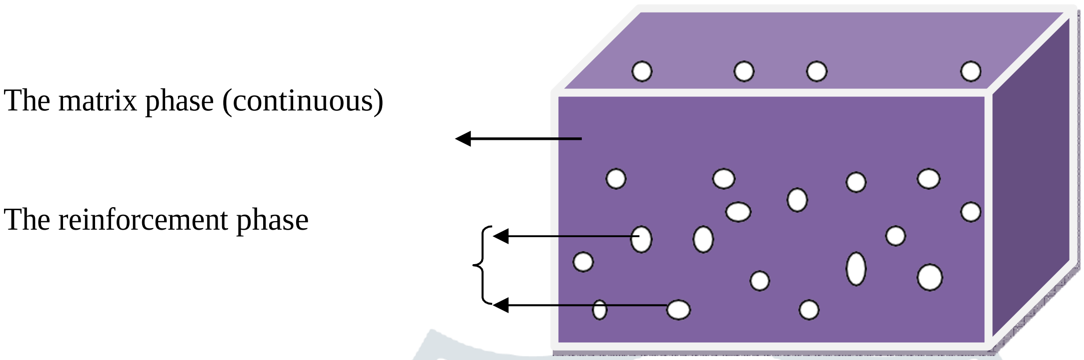


Fig.1.3: Components of a Composite [1]

Advantages of Composites

Composite substances in contrast to the conservative monolithic materials have highly developed property that may host the needs of the current era.

1) It is possible to get the preferred amalgamation of property of the parent materials which are otherwise unachievable.

2) Composites can have a very high strength-to-weight ratio, high stiffness, hardness, etc. with being very light in weight.

3) It can be engineered according to the needs -such as substitute composites to steel can be fashioned that do not crumble.

4) Better fatigue properties.

5) obtain high strength at extensive temperatures.

Disadvantages of Composites

1) Many important composites have anisotropic properties.

2) Attacks by chemical compounds or solvents could be very common to polymer-based composites.

3) Composites are normally high priced.

4) Manufacture strategies for composites are often steeply-priced, complex and slow.

5) Salvage and disposal are not smooth.

6) Weak transverse properties.

Applications of Composites

Composites are of great significance in different fields due to their bigger properties and superior performance such as-

1) Automobile parts
2) Aircrafts
3) Bulletproof vests
4) Construction materials
5) Sports
6) Sanitary – sinks, bathtubs, drains, etc.
7) Energy – fuel cells, solar panels, etc.
8) Household appliances – dishwasher, cooking, refrigerators, etc.

In a nutshell, composites are replace the previously accessible materials in diverse fields because of the compensation composites have over these materials. Therefore, research on composites is expanding through leaps and bounds.

Classification of Composites

Classification on the basis of reinforcement

On the basis of the type of reinforcement used, composites are classified as follows:

1) Particle –reinforced composites
2) Fiber –reinforced composites
3) Structural composites- laminates and sandwich panels

Particle reinforced composites

In particle unbreakable composites the strengthening is in the form of particles disseminated in the matrix phase. Depending upon whether the particles are small or large, the communication between the strengthening particles and the matrix is diverse and so is the intensification mechanism. Thus there are two sub-classifications of particle unbreakable composites i.e. large particle and dispersal strengthen particle unbreakable composites. In the large particle strengthening, the particle and matrix communication is not at the atomic level and the strengthening particles contain the association of the matrix. The intensification and the properties of the composite depend upon the particle-matrix communication. In dispersal strengthen composites the size of the particle is very small and thus the communication of particles and the matrix cause the intensification at the atomic level. The intensification in dispersion strengthen particle unbreakable composites is much more similar to the rain hardening. In large particle reinforcement, the matrix transfer the load to the particles and bears a fraction of load while in dispersal strengthen strengthening, the matrix bears the major portion of the load.

Fiber reinforced composites

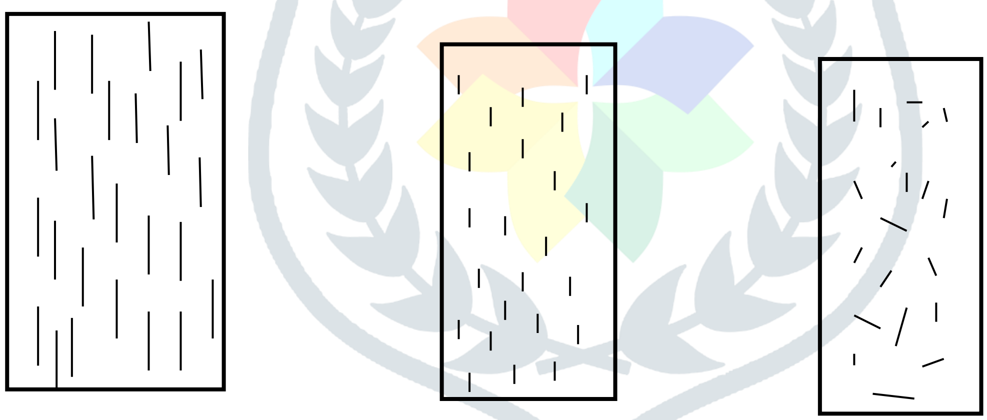
These are the most extensively used composites in which the strengthening is in the fiber phase dispersed in the matrix. The properties of the composite depend upon factors like fiber size, distribution, orientation, concentration, etc. On the basis of the size and character, fibers are classified as:

1) Whiskers – these are single crystals that have very high length-to-diameter ratio and thus are enormously thin. Whiskers are enormously strong owing to their crystal perfection and are flawless. Whiskers include- graphite, silicon carbide, aluminium oxide, silicon nitride, etc.

2) Fibers – these are either polycrystalline or formless materials with very small diameters which are either polymers or ceramics (e.g. Glass fibers, aramids, carbon fibers, etc.)

3) Wires – these usually have larger diameters and comprise materials like steel, molybdenum, tungsten, etc.

For the effective intensification of the composite, some serious fiber length (l_c) is required which depends upon the diameter of the fiber, its ultimate (tensile) strength, and the fiber-matrix bond strength. If the fiber length is better than this critical fiber length ($l>>l_c$), then it is called as continuous fibers.



b) c)

Fig.1.5: Schematic representation of fiber reinforced composites (a). Continuous fibers unidirectional aligned b). Discontinuous fibers unidirectionally aligned c). Discontinuous fibers arbitrarily oriented [1]

If the fiber length is less than this critical fiber length, then it is called as irregular or short fibers. The incessant fibers are mostly aligned while discontinuous fibers can be either aligned or randomly leaning.

Structural composites

Structural composites are composition of diverse materials whose property depend upon the intend and properties of the component materials. Two broad types of structural composites are- Laminates and

Sandwich panels.

Laminar composites are made by stack sheets of materials having the direction of the grain in each layer is diverse (generally at right angles) from the following layer. These composites have high directional strength; plywood is an example of laminar composites.

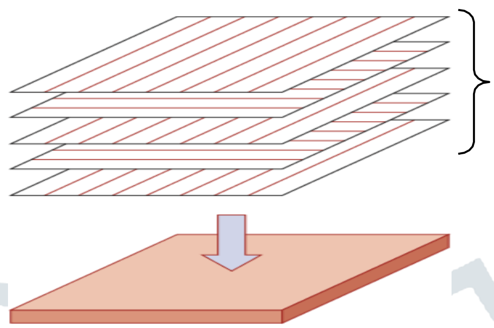


Fig.1.6: Basic structure of laminar composites [1]

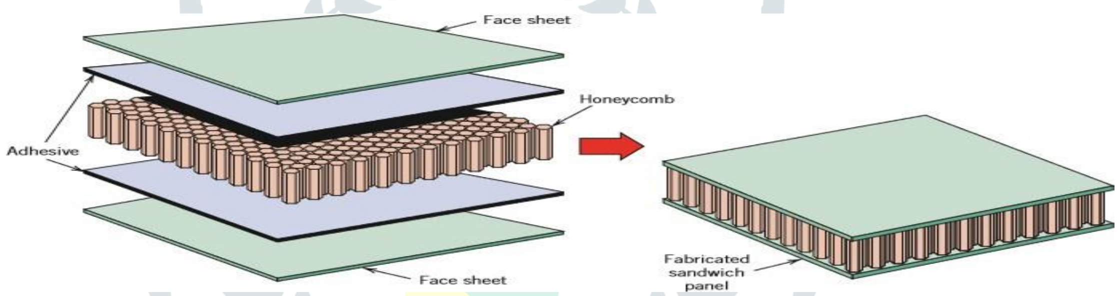


Fig.1.7: Sandwich panel with honeycomb core [1]

Sandwich panels are collected of two outer sheets sandwiching a core material in which the outer sheets provide stiffness and strength while the core is light in weight. The core also provide sustain to the outer sheets and has high shear strength. Classification on the basis of the matrix

On the basis of the type of matrix used, composites are classified as follows:

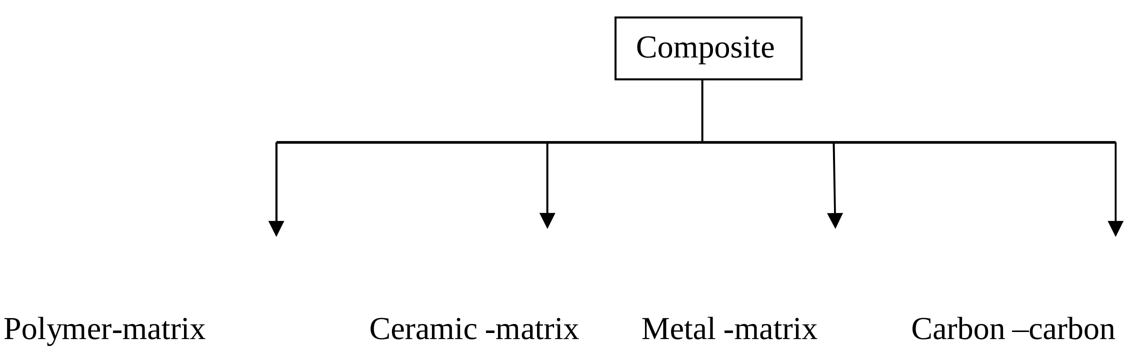


Fig.1.8: Classification of composites on the basis of matrix [1, 5]

Polymer-matrix composites

The matrix in the polymer matrix composite is polymer resin in which the strengthening is detached. These composites are used in a wide assortment of application because of their ease of production, cost, and room-temperature properties, etc. The most commonly used reinforcement in polymer matrix composites are glass fibers, carbon fibers, aramids (e.g. Kevlar, Nomex, etc.). Other reinforcement include silicon carbide, boron, aluminium oxide, etc. The most general polymers used as a matrix are-

- Polyesters and vinyl esters- most widely used and cheaper.
- Epoxies – better mechanical properties and resistance to moisture, extensively used for aerospace industry applications.
- Polyimide-for high-temperature applications
- Thermoplastic resins like poly (phenylene sulfide) (PPS), polyetherimide (PEI), etc.
- **Glass-fiber-reinforced polymer composites (GRFP)** – These are the major twisted polymer matrix composites with glass fibers as the strengthening in the polymer matrix. GRFP composites have the following characteristics-
- Strength to weight ratio is high
- Modulus of elasticity is high
- High corrosion resistance
- Efficient insulating properties

The limits to these polymers comprise low stiffness and severity making them inappropriate for many applications. The overhaul temperature for these composites is not very high as at high temperatures most of the polymers begin worsening. Most common applications of GRFP composites comprise marine bodies, plastic pipes, containers and in the carrying industry to decrease vehicle weight.

- **Carbon fiber –reinforced polymer composites (CFRP)**

These composites consist of high-performance carbon fibers unbreakable in the polymer matrix. Characteristics of carbon fibers which make it a better choice as strengthening are-

- Highest specific modulus and specific strength
- At elevated temperatures, they keep their high tensile modulus and strength.
- Not exaggerated by moisture or any solvents, acids, bases, etc. at room temperature. CFRPs are being used in leisure and sports (like in golf clubs, fishing rods, etc.), pressure vessels, lengthily used in military and commercial aircrafts structural components, etc.

Ceramic – Matrix Composites

Ceramic matrix composites are the composites with reinforcement in the form of particulates or fibers that are detached in a ceramic matrix. Ceramics are materials (mostly oxides, carbides, nitrides, etc.) that have tempting properties like high hardness, high-temperature stability, corrosion resistance, chemical inertness, etc. making it appropriate for the applications in fields like aerospace, automobile industries. But the major disadvantage of the ceramics is the fragile fracture. Therefore, ceramics are being unbreakable with other materials to diminish or diminish the confines of the ceramic materials manufacture them appropriate for use in these fields for different purposes. Different materials either in particulate form, whiskers or fiber form are unbreakable in the ceramic matrix to form ceramic-ceramic, ceramic – metal, etc. composites. Ceramic matrix composites are being used in cutting tools due to their properties like high hardness, wear resistance, etc.

Carbon-Carbon Composites

Carbon fiber unbreakable in carbon matrix usually termed as carbon-carbon composites is very tempting engineering materials with high-temperature tensile strength, creep resistance, high fracture toughness values. Carbon-Carbon composites are very less vulnerable to thermal shocks due to their low coefficient of thermal extension and high thermal conductivity. These composites have multifaceted dispensation technique and are quite exclusive making it difficult to use it in large scales. The significant restraint of carbon-carbon composites is the readiness to oxidation at high temperature. These are very highly developed composites materials used in rocket materials, high-performance machine components, components of the turbine, etc.

Metal-matrix Composites

Metal–matrix composites, as the name suggest, are composites with a ductile metal as a matrix. Most generally used metals as matrix are alloys of aluminium, nickel, titanium, copper, etc. Metals are being non-breakable with materials like ceramics to decrease the limits of metals for use at higher temperatures, recover property like specific strength, toughness, hardness, etc. Metals have a high coefficient of thermal development making it unsuitable for many applications; adding reinforcement advance the directional solidity of these materials. Metal matrix composites are being used as structural components, aircraft materials, in the automobile industry, etc. for their advanced properties than the metals.

Advantages of Metal-matrix composites

- High service temperature
- High hardness and toughness
- Non-flammability

- High resistance to wear/surface damages
- High specific strength and creep resistance
- Greater dimensional stability and more.

Aluminium is a silvery white element of the boron group of chemical elements. It has the symbol Al, and its atomic number is 13. It is not soluble in water under normal conditions. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite.

Aluminium is remarkable for the metal's low density and for its ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most supportive compounds of aluminium, at least on a weight basis, are the oxides and sulphates. In keeping with its pervasiveness, aluminium is well tolerated by plants and animals. Owing to their prevalence, potential beneficial (or otherwise) biological roles of aluminium compounds are of continuing importance.

Characteristics:

Physical:

Aluminium is a comparatively soft, durable, lightweight, ductile and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A brand new film of aluminium film serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared radiation. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa. Aluminium has about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Aluminium atoms are in order.

Chemical:

Corrosion resistance can be brilliant due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper. This corrosion resistance is also often greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

Owing to its resistance to corrosion, aluminium is one of the few metals that retain silvery reflectance in finely powdered form, making it an important component of silver-colored paints. Aluminium mirror finish has the highest reflectance of any metal in the 200–400 nm (UV) and the 3,000–10,000 nm (far IR) regions; in the 400–700 nm visible range it is slightly outperformed by tin and silver and in the 700–3000 (near IR) by silver, gold, and copper.

Aluminium is oxidized by water to construct hydrogen and heat:

$$2\ Al + 3\ H_2O \rightarrow Al_2O_3 + 3\ H_2$$

Natural occurrence:

In the Earth's crust, aluminium is the largely abundant (8.3% by weight) metallic element and the third most abundant of all essentials (after oxygen and silicon). Because of its strong affinity to oxygen, it is almost never found in the elemental state; instead it is found in oxides or silicates. Feldspars, the most common group of minerals in the Earth's crust, are alumina silicates. Native aluminium metal can only be found as a minor phase in low oxygen fugacity environments, such as the interiors of certain volcanoes. Native aluminium has been reported in cold seeps in the north eastern continental slope of the South China Sea. It also resides in the minerals beryl, cryolite, garnet, spinel and turquoise.

Applications:

Aluminium is the most extensively used non-ferrous metal. Global production of aluminium in 2005 was 31.9 million tonnes. It exceeded that of any other metal except iron (837.5 million tonnes). Forecast for 2012 is 42–45 million tonnes, driven by rising Chinese output. Aluminium is almost always alloyed, which markedly improves its mechanical properties, especially when tempered. For example, the common aluminium foils and beverage cans are alloys of 92% to 99% aluminium. The main alloying agents are copper, zinc, magnesium, manganese, and silicon (e.g., duralumin) and the levels of these other metals are in the range of a few percent by heaviness.

Some of the a lot of uses for aluminium metal are in:

- Transportation (automobiles, aircraft, trucks, railway cars, marine vessels, bicycles, etc.) as sheet, tube, castings, etc.
- Packaging (cans, foil, etc.)
- Construction (windows, doors, siding, building wire, etc.).
- A broad range of household items, from cooking utensils to baseball bats, watches.
- Street lighting pillars, sailing ship masts, walking poles, etc.

- A range of countries, including France, Italy, Poland, Finland, Romania, Israel, and the former Yugoslavia, have issued coins struck in aluminium or aluminium-copper alloys.

Silicon Carbide:-

Silicon carbide is composed of tetrahedra of carbon and silicon atoms with well-built bonds in the crystal lattice. This produces a very solid and strong material. Silicon carbide is not attacked by any acids or alkalis or molten salts up to 800°C. In air, SiC forms a protective silicon oxide coating at 1200°C and is able to be used up to 1600°C. The high thermal conductivity coupled with low thermal expansion and high strength gives this material exceptional thermal shock resistant qualities. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. Chemical purity, resistance to chemical attack at temperature, and strength retention at high temperatures has made this material very popular as wafer tray supports and paddles in semiconductor furnaces. The electrical conduction of the material has lead to its use in resistance heating elements for electric furnaces, and as a key component in thermistors (temperature variable resistors) and in varistors (voltage variable resistors).

Properties:

Silicon Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developing.

Stir casting:-

Stir-casting techniques are currently the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. Micro structural in homogeneities can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. In homogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. This process has main advantage that the production costs of MMCs are very low worsening the quality of the composite.

REFERENCES

1. Esawi, A.M.K.; Morsi, K.; Sayed, A.; Abdel Gawad, A.; Borah, P. Fabrication and properties of dispersed carbon nanotube-aluminum composites. *Mater. Sci. Eng. A* 2009, Vol. 508, 167–173.
2. Koli, D.K., Agnihotri, G. and Purohit, R., 2013. Properties and characterization of Al-Al_2O_3 composites processed by casting and powder metallurgy routes. *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, Vol. *2*(4), pp.486-496.
3. Park, Y.K., Tadd, E.H., Zubris, M. and Tannenbaum, R., 2005. Size-controlled synthesis of alumina nanoparticles from aluminum alkoxides. *Materials Research Bulletin*, Vol. *40*(9), pp.1506-1512.
4. Prasad, D.S., Shoba, C. and Ramanaiah, N., 2014. Investigations on mechanical properties of aluminum hybrid composites. *Journal of Materials Research and Technology*, Vol. *3*(1), pp.79-85.
5. Renuka, N.K., Shijina, A.V. and Praveen, A.K., 2012. Mesoporous γ-alumina nanoparticles: synthesis, characterization and dye removal efficiency. *Materials letters*, Vol. *82*, pp.42-44.
6. Shojaie-Bahaabad, M. and Taheri-Nassaj, E., 2008. Economical synthesis of nano alumina powder using an aqueous sol–gel method. *Materials Letters*, Vol. *62*(19), pp.3364-3366.
7. Karim, M.R., Rahman, M.A., Miah, M.A.J., Ahmad, H., Yanagisawa, M. and Ito, M., 2011. Synthesis of γ-alumina particles and surface characterization. *The Open Colloid Science Journal*, Vol. *4*(5), pp.32-36.
8. Koli, D.K., Agnihotri, G. and Purohit, R., 2015. Advanced aluminium matrix composites: The critical need of automotive and aerospace engineering fields. *Materials Today: Proceedings*, Vol. *2*(4-5), pp.3032-3041.
9. Behera, P.S., Sarkar, R. and Bhattacharyya, S., 2016. Nano alumina: a review of the powder synthesis method. *Interceram-International Ceramic Review*, Vol. *65*(1-2), pp.10-16.
10. Kallip, K., Babu, N.K., Alogab, K.A., Kollo, L., Maeder, X., Arroyo, Y. and Leparoux, M., 2017. Microstructure and mechanical properties of near net shaped aluminium/alumina nanocomposites fabricated by powder metallurgy. *Journal of Alloys and Compounds*, Vol. *714*, pp.133-143.
11. Mahboob, H.; Sajjadi, S.A.; Zebarjad, S.M. Syntesis of Al- Al_2O_3 Nanocomposite by Mechanical Alloying and Evaluation of the Effect of Ball Milling Time on the Microstructure and Mechanical Properties. In Proceedings of International Conference on MEMS and Nanotechnology (ICMN '08). Kuala Lumpur, Malaysia, 13–15th May, 2008, Vol. 3(8) pp. 240–245.
12. Jayalakshmi, S., Singh, R.A. and Gupta, M., 2016. Synthesis of light metal nanocomposites: challenges and opportunities. *Indian Journal of Advances in Chemical Science S1*, Vol. *283*,

p.288.

13. home.iitk.ac.in/~anandh/MME441/SEM.pdf
14. Nardone, V.C. and Prewo, K.M., 1986. On the strength of discontinuous silicon carbide reinforced aluminum composites. *Scripta Metallurgica*, Vol. *20*(1), pp.43- 48.
15. http://biomechanicalregulation-lab.org/afm
16. Wilson, R.A. and Bullen, H.A., 2011. Basic Theory-Atomic Force Microscopy (AFM). *Department of Chemistry, Northern Kentucky University, Highland Heights, KY, 41099*.
17. https://www.researchgate.net/figure/Pin-on-disc-wear-test apparatus_ fig3_ 285797951
18. Mirjalili, F., Mohamad, H. and Chuah, L., 2011. Preparation of Nano-Scale Al- Al_2O_3 Powder by The Sol-Gel Method. *Ceramics-Silikáty*, Vol. *55*(4), pp.378-383.
19. Yu, K.N., Xiong, Y., Liu, Y. and Xiong, C., 1997. Microstructural change of nano- SnO_2 grain assemblages with the annealing temperature. *Physical Review B*, Vol. *55*(4), p.2666.