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MECHANICAL BEHAVIOUR OF COMPOSITE MATERIALS IN METAL

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ABSTRACT

Composite materials have gained traction in the world today and are becoming of common use in industrial and specialized applications in general due to their flexible nature that involves mixing through layers or matrixes the components of various substances and therefore, a percentage of each substance's physical properties. In recent years there has been an increasing concern for industries to use cost effective reinforcement for metal materials like aluminum which is abundant cheap, with various desirable properties like its lightness, but lacks the strength for various applications – ceramic materials such as SiC and aluminum oxide are used generally for reinforcing the aluminum MMC. There is a good probability, backed up by tests for certain materials, that reinforcing metals with composites can increase failure displacement, fatigue life, ultimate failure load and energy absorption capacity, amongst many others by substantial amounts.

Keywords: Composite, Metals, Mechanical behaviors, Properties, Reinforcement, Materials.

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1. INTRODUCTION

Composite are generally becoming more involved in every aspect of production due to the ability of individuals to make materials with desired properties available from the mixture of various other materials and an aggregate of their properties. The possibilities of traditional materials such as metals and their alloys have been absolutely overused to a point where we know that their already familiar properties will be inadequate for most modern techniques, and therefore high performance through high material characteristics [18][31].

Most metal compounds have limitations that make them unsuitable for use in the modern technological era we are in right now [29][32]. Therefore, composites - which are materials created from the “fusion” of multiple components or constituent materials with varying beneficial properties either chemical or mechanical, or both, which are combined to develop a material with varying characteristics from the base components – are the materials of choice because of the extensive number of combinations that can be done to provide suitable material [24].

Composites have varying physical properties and therefore, different mechanical behaviors in a system, but due to the general tendency for research to be done on increasing strength and reducing the weight of the material, we are given a rough estimate on how composites in metals behave mechanically when they are acted on [9]. To understand composite behavior, we have to understand composites: They are composed mainly of a matrix i.e. a continuous phase (e.g. metals), which is armored with a reinforcement i.e. secondary phase (e.g. ceramics), which is usually the discontinuous phase [18]. Matrices make use of different phases of the metal and reinforcement to strengthen it [28]. This phasing can come in various shapes, layers, patterning, concentration and orientation, that influence the movement of the material particles and hence, its physical properties.

The composite of focus for this paper would be those of Metal Matrix Composites (MMCs), as this is a review of the behaviors of the reinforcement (composite) in the metal matrix. MMCs were separated into four main parts, which are: particulate reinforced MMCs, continuous fiber (sheet) – reinforced MMCs, laminated MMCs and short fiber – reinforced MMCs [11]. Each MMC type will have its own mechanical properties due to the physical arrangement of phases that will influence greatly the bonding and shape of materials between one another [12].

2. FINDINGS

2.1. Common Applications of Composite Materials

As we have seen, composites are able to exhibit a variation of properties due to their differing structures in combinations of reinforcements and metal matrices. These composite materials have multiple uses in various industries that have helped to move the industry forward and have become the stable material when it comes to that aspect every single time. Examples of various materials and their impacts in their respective industries are:

2.1.1. Applications of MMCs in Space

Space is an extreme environment that needs metals with extreme properties to handle the harsh realities. Extremely close to the earth’s atmosphere, various natural phenomena occur that can annihilate normal organic materials and cause deterioration of non-reinforced based metals we have discovered here on earth. Effects like ionizing radiation, thermal radiation, plasma, x-rays, high temperature entry and debris [22]. An example is the ISS which is predicted to undergo almost 200 thousand thermal cycles from positive and negative 125 degrees Celsius.

The initial successful deployment of a continuous-fiber reinforce metal matrix composite has been the application of B/Al tubular struts which have been applied in the landing gear drag link in the space shuttle orbiter and as members around the section for mid-fuselage, this design allowed weight saving of up to 45% over the original aluminum design, with added benefits of structural strength [22][11].

Antennas are of very important use when communicating over large distances, especially a distance like that of space to earth where unmanned vehicles need to be controlled with precision to have any effort of having successful missions. Gr/Al composite has been used as a high-gain antenna boom for the one of the largest space telescopes: The Hubble space telescope which was launched in 1990 and still remains in operation. This composite was made through diffusion bonded sheets of P100 graphite fibers in aluminum 6061. The boom is 3.6 meters long and is able to offer a desired stiffness that allows for space maneuvers and functional wave-guiding, with low CTE while maintaining the position of the antenna [12][22].

2.1.2. Applications of MMCs in Automobiles

Alloys like aluminum possess good properties like its lightweight and other mechanical properties that make them attractive candidates for use in the automobile industry but are held back due to their short comings - poor resistance to seizure and galling (Prasad & Asthana, 2004). Reinforcement of this metal and its alloys with secondary phases like ceramic particles, whiskers and fibers result in MMCs. Tribological considerations involved, aluminum alloys were always weak to the effects of friction and touching mechanical parts.

Singh & Singh, 2018, describes the use of a metal matrix of aluminum and 25% boron carbide to form a composite by stir casting as a replacement for the material used as that moment which was EN45 steel for leaf springs. This replacement gives less weight and density, but more strength to the system enabling faster, fuel efficient and energy saving vehicles. Also, Composite Castings LLC has developed a new four-cylinder engine using lightweight carbon fiber. Matti Holtzberg who is president and founder of the company led the design of the V4 engine. The reinforcement was Tenax-brand carbon fiber with base epoxy resin, this new mix is to create an engine 45-50% lighter than a conventional aluminum block.

2.2. Composite

A composite material can be descried as a material which outcomes are more preferable than those with individual properties. Every material has its individual different chemical, physical and mechanical properties [19]. The advantage of these composite materials are high quality and solidness, low density when compared with mass materials, it creates weight reduction in completed part. A composite is a multiphase material that consists of matrix and reinforcement. There are various matrix types, they can be metal matrices with a base material of metal, ceramic matrices with a base material of ceramic materials like clay, and polymer matrices that consist of plastics and the likes Composite give a new pathway to define and create new materials that are influential to the growth of our industries and therefore humanity [30].

A composite material is composed of mainly a matrix, for this case, a metal such as aluminum, the metal is armored with reinforcement such as fly-ash or aloe-vera. Then we explain the components:

2.3. Matrix (metal matrix)

The function of the matrix is to transmit the load onto the reinforcement so bearing the load does not rely only on the matrix. In this case, matrixes are the main metals involved, and used as the base material for work. For the composite to work, the matrix has to be in good bonding with the reinforcement or the load does not get transmitted properly, these properties usually include," perfect wettability" and light weight [18] The matrix is usually monolithic and thereby continuous: meaning there is a way through the matrix to any point in the material. Common metals used as matrixes include aluminum, magnesium and titanium due to their lightness which provides proper support for the reinforcement; Cobalt and cobalt-nickel or titanium boride are used for high temperature applications. Other materials used as a metal matrix include beryllium, Iron, Nickel and silver. Matrix is the major constituent in composites which help to hold the reinforcement and to control the inter-laminar structure at elevated temperature [6].

2.4. Reinforcement

The reinforcement, i.e. the reinforcement phase transmits most of the eternal loads, with its tensile behavior originating from a bulk of things (mostly geometric properties) it is expected to have high strength and a modulus of elasticity," E", which should be one order higher than that of the matrix [18]. Reinforcements are a sort of additive that drastically change the physical properties of the materials they reinforce because of their particle behavior.

2.5. Mechanical Behaviors (physical properties)

Mechanical properties or physical properties of a material are the properties of a material - in this case a metal - that determines the reaction of that material to mechanical/physical stresses. These mechanical properties are of upmost importance when determining the material to be used to accomplish a task in a design. The common properties which are ductility, hardness, malleability, tensile strength (yield strength, ultimate tensile strength), elastic modulus and any other important measurement of its physical properties that can lead to various mechanical behaviors are determined in order to make material selection easier and gain useful knowledge on materials [10].

3. REVIEW EXTRACT FROM PREVIOUS RESEARCHES

There has been a focus in the area of research in creating lighter but stronger materials that can be made as cheaper replacements to existing materials in the industry, for this to be done, suitable methods of creation have to be utilized to bring forth new material, and various experiments have to be done comparing the vital physical properties in use during mechanical operations. Material researchers work on composites materials more than monolithic materials due to the fast growth of the demand for better materials because of the limitations of conventional metals. In the metal matrix composite of aluminum, the metal or its alloy with a reinforcement, has been dispersed in the matrix. Reinforcement types like whiskers, ceramics and particulates constitute to its increased density, increased hardness and increased ability to withstand heat. A lot of the research that has been carried out on this subject matter have been done on reinforcement and matrix load sharing. One of these researches conclude that effectiveness on load sharing mechanism can be increased by having control over the particulate geometry [17]. It also states that the reinforcing particulates in a hard matrix composite, gives it higher composite strength relative to the strength of the matrix and load sharing.

Properties like density of composites has been shown to be directly proportional to the fraction volume of particulates i.e. an increase in density follows an increase in volume, because of the high-density value of ceramic particulate. In this report is another conclusion which states that density increases with increase in filler content. It also mentioned that a reason for increased composite can be caused by the higher density of reinforcement particles [6].

Kulkarni et al., [15], conducted an experiment and concluded that a core-shell structure was formed as a result of sintering powder particles in an inert atmosphere. The shell in this experiment had a Cr3Cr2 phase with NbC, Mo2C and Cr3C2 in its core. Using an atmosphere of Argon, for a one-hour burn-off step produced a core structure without the presence of Cr3C2 shell.

Di et al., [7], assessed the grindability of MMCs with the use of information gotten from tests carried out using an even surface processor Examinations manage the pounding powers and the debasement of the granulating wheel surface, obtained amid the machining procedure and surface harshness of the workpiece material. The impacts of crushing wheel abrasives, both ordinary and super abrasives and in addition the material attributes, for example, shape, introduction and substance of the fortification and kind of lattice, on the granulating wheel debasement and ground surface quality is broke down by methods for grindability records.

It was concluded that grindability files, which consider single machinability qualities, for example, powers, wheel debasement and workpiece surface harshness, have been utilized to characterize a Total Grindability Index that has permitted to think about the grindability of various Metal Matrix Composites when grounded utilizing distinctive grating pounding wheels. MMCs for the most part show free cutting conduct as for non-fortified light combinations. The silicon carbide wheel speaks to the best arrangement to the extent it concerns level zone, harshness and in addition the crushing powers. By thinking about the kind of support, stubbles fortified composites show a superior generally conduct (higher aggregate grindability file) than the powder strengthened ones. In any case, the grindability turn into the equivalent at the most elevated hardness estimations of the material.

There properties are noted down and then compared to pre-existing materials in that industry or their base metals that are being used without reinforcements. Numerous researches have been done, which has paved way for composite material as a standard in today's industries, giving it a market share of 2 in every 8 engineering materials used in the world today [2]. Various literature regarding the topic has been reviewed in relation to their results and methods involved:

Gopi Krishna et al., [9], studied MMCs and derived an intuitive method for multiple strengthening. Al-20Cu-10Mg alloy system and A356 alloy were used as reinforcement and matrix respectively, and investigations were carried out on them. This experiment resulted in the following conclusion: increasing reinforcement content , decreases particle size enhancing the bonding between matrix and reinforcement; density increases with weight fractions of reinforcement added, and thereby increasing total weight; The resistivity of the composite gotten is determined by the percentage quantity of reinforcement added; Hardness was seen to increase with the percentage quantity of reinforcements added due to the refined grain structure of the matrix and finally, the alloy composite compared to the base alloy, shows increased strength values proportional to the increasing reinforcement quantity.

Hima Gireesh et al., [11] studied the mechanical characterization of aluminum MMC reinforced with aloe-vera powder", The experiment conducted compared the mechanical properties of aluminum metal matrix when composited with two naturally occurring reinforcements. These reinforcements resulted in the composites: "fly-ash reinforced aluminum MMC" and "aloe-vera reinforce aluminum MMC". The two samples were created using stir-casting and tested for mechanical properties with results showing a lower density, higher tensile strength, higher yield strength, higher hardness, higher impact strength and less wear for the aloe-vera counterpart compared to the fly ash. Compared to the base metal and the composite with fly ash, the aloe-vera composite is less dense but has better strength properties, and hence, a better weight to strength ratio.

Singh & Brar, [26], Characterized and Investigated the mechanical properties of composite materials used for leaf spring", MMC of aluminum and 25% manufactured by stir casting was researched for application in a leaf spring commonly used in automobiles. The results compared the aluminum composite to the EN45 steel commonly used for leaf springs showing the composite leaf spring with lower density, lower weight and high strength, with desirable properties compared to that of the steel spring. It was also discovered that an increase in the strength and hardness of the sample was gotten by increasing the size and weight percentage of the particles.

Badoi & Constantinescu, [1], compared the wear behavior of metal matrix composite to sintered metal carbides. This gave a detailed information on the behavior of MMCs compared to sintered metal carbides with respect to wear, functionally graded composite materials which had 3 layers with one of each being MMCs, and another being the sintered metal carbides. The results of this work being that the observed low alloy steel powder which can be represented in various possible combinations of composites are predicted to be a replacement for conventional carbon steel tools, high alloyed steel tools and conventional high-speed steels. It also describes the possibility of powder metallurgy technology in creating composites which can have controlled properties based on particle amount and arrangement.

Balasubramanian et al., [2], investigated the mechanical characterization and machining of squeeze cast AZ91D/SiC magnesium-based metal matrix composite" magnesium alloy AZ91D which was reinforced with silicon carbide using squeeze casting method and tested for machine removal rate and surface roughness. It was discovered that an increase in the reinforcement of SiC decreased the surface roughness, produces good performance parameters for use during machining, and that the distribution of reinforcement (SiC) to a magnesium matrix can be done with ease by squeeze casting.

Huang et al., [12], discussed about Al alloy MMCs reinforced with WS_2 inorganic materials. They impinged AA6061 MMCs with 0.1, 0.2 and 0.5 wt% WS_2 INT and AA6061 MMCs with 0.1 and 0.2 wt% WS_2 IF. They found that with little addition of WS_2 INT and WS_2 IF, the mechanical properties of the alloys were greatly improved. They also found that AA6061/0.5 wt% WS_2 INT showed the best results for hardness test.

Shirvanimoghaddam et al., [24], discussed the fabrication process for Carbon-Fiber MMCs. He found that Carbon-Fiber MMCs hold potential as replacement for various unreinforced metals and alloys in the various engineering fields. But they found that poor dispersion of carbon fillers in the metal matrix led to a breakdown in the composite properties of the MMC.

Rezaei, 2018 talked about Tensile mechanical characteristics and deformation mechanism of metal- graphene nanolayered composites. He found that in MGLNCs, their mechanical behaviors can be improved by using the advantages of monolayers of graphene particularly its intrinsically high elastic modulus and strength, and its 2d geometry. He found that the inclusion of graphene increased greatly the tensile strength, stiffness, and failure strain of the nanolayered composites, the strength and modulus of the composite sample increased by 86% and 104.6% in comparison to control volume. He also revealed new insights into the tensile behavior of newly developed composite material MGNLCs, and these insights can be considered in their design and synthesis.

Krishna et al., [9], discussed an innovative way for multiple strengthening using metal-metal composites. They fabricated MMCs by reinforcing High Strength Alloy Particulates (HSA(P)) in A356 matrix using the stir casting method after which it was processed using direct hot extrusion. It was found that with an increase in reinforcement content came a resultant decrease in the particle size due to increased casting times used. It was also found that the reinforcements decreased the resistivity and increased the hardness of the composite.

Niraj et al., [19], discussed Tribological behavior of Magnesium MMCs reinforced with fly ash cenosphere. They reviewed the frictional behavior and wear of magnesium MMCs when they were reinforced with various kinds of reinforcements. They found that significant refining of the surrounding metal alloy by the fly ash cenospheres in AZ91D-fly ash composites produced by die casting. They found that with increase in percentages of fly ash came a decrease in the density of the composites and an increase in the hardness of the composites.

Chu et al., [3], investigated the thermal properties of graphene/metal composites with aligned graphene. They found that graphene has excellent thermal properties leading to great potentials for applications in thermal management systems. Graphic Nanosheet/Copper composite was prepared by vacuum filtration techniques and they found that the GNSs were highly aligned with well-packed laminated structure, good structural integrity and well-bonded interface.

Liu et al., [16], discussed the influence of particles size and its distribution on the degree of stress concentration in particulate reinforced MMCs. They worked on Particulate Reinforced Metal Matrix Composites (PRMMCs) and investigated the degree of stress concentration by FEA methods and they found that the PRMMCs reinforced with irregular particles bears more load than those reinforced with spherical ones and the stress concentration in the matrix is reduced with decrease of the particle size.

Jarz, [14], discussed the impact of weak interfacial bonding strength on mechanical properties of metal matrix – Ceramic reinforced composites. They prepared Ni-SiC composites with 10% of SiC and they found that the pure nanocrystalline nickel is stronger than the Ni-SiC composite prepared.

Isaza et al., [13], evaluated the reinforcement of MMCs with carbon nanotubes using an alternative technique. The Sandwich technique, a new manufacturing process for producing MMCs reinforced with carbon nanotubes has been developed and the MMCs produced comprised a metal matrix and banded structured-layers of multiwall carbon nanotubes (MWCNTS). They worked on using the sandwich technique to reinforce magnesium sheets with MWCNTs and tested the composites to validate the method as a tool for producing the MWCNTs without evidence of damage. They observed an increase in the tensile mechanical properties of the composites as a result of addition of the MWCNTs.

Shiva, [25], discussed the mechanical and wear behavior of ZA-27/SiC/Gr hybrid MMCs. He worked on producing the ZA-27 alloy and hybrid composite reinforced with 1.5 wt% of silicon carbide (Sic) and 0.5 wt% of graphite (Gr) using the ultrasonic assisted stir casting method and carried out tests to check the mechanical properties of the MMCs formed. He found that the mechanical properties of the hybrid composites increased while the wear volume decreased compared to the ZA-27 alloy.

Dileep et al., [8], discussed the corrosive and mechanical behavior of Al-Ni-Sic MMCs which have been manufactured through P.M. (Powder Metallurgy). He tried to develop the corrosive and mechanical resistivity of aluminum by reinforcing it with Silicon Carbide (SiC) and nickel (Ni) using P.M. technique to create the Al-Ni-SiC MMC and tested the mechanical and corrosion behaviors of the composite. He found that the composite's properties varied with the various percentages of the SiC and Ni present in the MMC. The quantity of SiC in the composite is directly proportional to the degree of hardness and wear resistance of the composite sample and also inversely proportional to its resistance to corrosion.

Ozerov et al., [20], talked about the evolution of microstructure and mechanical properties of Ti/TiB metal-matrix composite during isothermal multiaxial forging.

Su et al., (2014) discussed composite structure modeling and mechanical behavior of particle reinforced MMCs. They investigated the relationship between the composite structure and mechanical behavior of silicon carbide (SiC) particle reinforced aluminum matrix composites. Upon various tests using the 3d software, it was discovered that the volume fraction of SiC particles showed significant improvement to the mechanical behavior of the MMC as regards the tensile properties.

Cong & Lee, [4], studied the mechanical behavior of BNNT-reinforced aluminum composites using molecular dynamics simulations. Several molecular dynamics simulations were implemented to investigate the tensile mechanical behaviors of BNNT-Al composite and they found that increasing the volume fractions lead to an increase in mechanical strength.

Dattoma et al., (2018) discussed mechanical behavior of composite material in presence of wrinkles. Composites having an artificial wrinkle are tested using open hole compression and open hole tension configuration. They determined the failure mechanism and knockdown of ultimate strength of the CFRP MMC.

From these reviews, it is seen that there is a general agreement for the positive nature of composite materials in respect to their properties, especially those of strength to weight where most materials experience an improvement in their strength and hardness with a reduction in density. These properties can be assumed to be derived from the physically positioning, orientation, shape and overall geometrical makeup of the particles embedded in the base material. These particles which have been named appropriately as, “reinforcement”, reinforce the base materials through various means, depending on the materials involved and the strength of bonding. This paper’s aim is to go through the possible behaviors of the particles that makes this phenomenon possible.

4. MECHANICAL BEHAVIOUR OF COMPOSITES

To understand the mechanical behavior of composites in materials, we must understand deeply, what a composite is composed of, and what makes its composition work together to give such properties.

4.1. Reinforcement Behavior

The behavior of reinforcement materials varies from material to material as each material possess a particular particle arrangement that reinforces its physical behavior. The mix and match nature of composites allows metal in this case, to associate itself with certain properties by “reinforcement” from the second phases’ physical behavior due to geometry. The main geometric properties that cause the behavior of this materials include:

4.1.1. The Concentration

The material density is of great importance as a higher density means that per volume of material dictates more weight per molecule or number of molecules. The molecules more molecules or particles in the system, the tighter the fit: more particles tend to close vacancies and make the material super tight.

4.1.2. The Orientation

The isotropy of the system is affected by this phase. If the particles of the reinforcement phase have the same shape and dimensions in all directions, that means there would be a homogenous or uniform distribution throughout the material. If the phase is not similar throughout, then the new material formed (the composite) will have an irregular pattern. The placement of various particles in the pattern determine the strength of bonds and such in that material.

4.1.3. The Shape

There are approximate descriptions for particles based on shapes: for the powder form of reinforcement, their shapes are seen as spheres; and for the fiber forms of reinforcements, their shapes are seen cylinders. The texture of the composite is determined by the distribution and sizes of these properties.

(All properties from Miroslava Klárová. [18], Composite materials, 43.)

The reinforcement phases are most of the time separated based on their geometry as well based on the similarities of the three base properties above, into these:

4.1.4. Particulate Reinforcement

The particles in composites are used not only to reinforce the mechanical properties of the material, but also various properties such as: electrical conductivity, resistivity, heat resistance etc. in most cases ceramic reinforcements are used. The particles in the matrix are meant to be distributed uniformly.

4.1.5. Dispersion Reinforced Composites

Dispersion reinforced composites are similar to precipitation -reinforced metal alloys except they have better properties than the former at low temperatures but coagulate at high temperatures. The dispersion reinforced composites are made independent with respect to the effects of temperature. When evenly distributed in the matrix, this group effectively removes the action of movement of dislocations and in turn limits the plastic deformation of the composite.

4.1.6. Particle Reinforced Composites

The optimal particles are in a few micrometers. The amount in a matric should be around 25% and not more than 50% so that the reinforcement is noticeable, where large particles can no longer prevent dislocations, so therefore, act as load bearings from the matrix.

4.1.7. Composites with Hollow Particles

Where the density of the particles adds up extensively to the density of the composite, which is not wanted, hollow spheres are used instead of full spheres. These are often made of glass.

4.1.8. Fiber Reinforcement

Fiber materials are usually very strong due to their cross section. With decreasing cross section, the strength of the fiber increases. They are of various kinds varying from natural fibers like aloe vera.

(All types from Miroslava Klárová. [18], Composite materials, 43.)

4.2. RESULTING BEHAVIOR OF COMPOSITES DUE TO VARYING PROPERTIES

MMCs get their properties from a mixture of various properties, when their properties are gotten from the physical properties of the geometry of their particles are relates to vacancies, dislocations, grains and so on. A strong material has a particular arrangement of its particles that make the particles hard to move and a minimal number of dislocations, when reinforced with a secondary phase, displays new behavior due to the physical interaction between the physical particles involved with changes in no of dislocations and orientation of particles. Common properties involved in observing the mechanical behaviors of materials include:

4.2.1. Hardness

Hardness of the composite depends on reinforcement of particulate reinforcements with low aspect ratio. It was investigated that the value of hardness of the Aluminum composites reinforced with fixed amount (10%) of SiC particles and different fraction of mica particles. And after the experiment result shows maximum hardness is gotten from 3% mica particles and after that the value of hardness goes on decreasing. Hardness and strength of a composite is very good for machining characteristics. The hardness value of hybrid aluminum-based composite with reinforced SiC and particles of graphite increased up to 2.5wt% content for both reinforcing materials and then decreased. If hardness increases this may be due to the presence of hard ceramic particles and a decrease in hardness maybe due to soft graphite reinforcement particles [6].

4.2.2. Fracture Toughness

In composite material fracture toughness is a property which describes the ability of a material with crack to resist failure, and it is particularly one of the most vital material properties for many designs. Particle cracking, particle de-bonding or interfacial cracking are some factors that lead to failure. Ceramics particles are hard and brittle. Metallic composites possess poor fracture toughness when reinforced with hard ceramics [8][6]

4.2.3. Tensile Strength

They are two types of strengthening mechanism i.e. direct strengthening and indirect strengthening. Direct strengthening is gotten from addition of hard and stiff reinforcement in the soft matrix. This hard reinforcement in the matrix caused the load applied to be transferred from the matrix itself to the reinforcement, this caused increased the resistance of composite to deform plastically during loading externally [19][6].

The main purpose for indirect strengthening was due to high thermal mis-match between higher coefficient of thermal expansion and particles that have lower coefficient of thermal expansion and the reinforcing particles having lower CTE during the cooling and solidification. As the temperature changes, it generates the thermal stresses in the composite that lead to the formation of dislocations at the matrix/reinforcement interface. This increase in the dislocation density delivers a development in the strength of the composite [6].

5. CONCLUSION

The mixture of various metal matrices and the multitude of reinforcements has created a large table of useable materials for various purposes based on their given properties to create a desired effect. The effects of these materials are due to the permutation and combination of all materials. The mechanical behavior of the MMCs has been found to be greatly improved compared to their base alloys. In the case of hardness, it was found that the inclusion of composites in the metal matrix increased its hardness up to a certain weight % of composite, after which a reduction of hardness occurred. In the case of fracture toughness, the inclusion of composites results in a material that has relatively lower fracture toughness than the base alloy due to the increase in its hardness. In terms of tensile strength addition of composite leads to an increase in ultimate tensile strength and yield strength of the material.

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