Evaluation of Mechanical Behaviour and Micro Structure Analysis on AL6063 and Mg+SiC

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Abstract – The use of a latent heat storage system using phase change materials (PCMs) is an effective way of storing thermal energy and has the advantages of high-energy storage density and the isothermal nature of the storage process. PCMs have been widely used in latent heat thermal storage systems for heat pumps, solar engineering, and spacecraft thermal control applications. Phase change material (PCM) is a substance with a high heat of fusion which, on melting and solidifying at a certain temperature is capable of storing and releasing large amount of energy. Phase change materials (PCMs) are one of the latent heat materials having low temperature range and high energy density of melting – solidification compared to the sensible heat storage. There are large numbers of phase change materials (PCMs) that melt and solidify at a wide range of temperature making them.

Index Terms – PCM, Thermal Energy, Isothermal.

1. INTRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced in situ from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with a high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs).Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks.

These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands, or is the solution of the problem. However, the technology of MMCs is in competition with other modern material technologies, for example powder metallurgy. The advantages of the composite materials are only realized when there is a reasonable cost – performance relationship in the component production. The use of a composite material is obligatory if a special property profile can only be achieved by application of these materials.

The possibility of combining various material systems (metal – ceramic – non-metal) gives the opportunity for unlimited variation. The properties of these new materials are basically determined by the properties of their single components. The allocation of the composite materials into groups of various types of materials.

The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition here is the improvement of the component properties. The development objectives for light metal composite materials are:

- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness,
- Increase in creep resistance at higher temperatures compared to that of conventional alloys,

- Increase in fatigue strength, especially at higher temperatures,
- Improvement of thermal shock resistance,
- Improvement of corrosion resistance,
- Increase in Young's modulus,
- Reduction of thermal elongation.

For other applications different development objectives are given, which differ from those mentioned before. For example, in medical technology, mechanical properties, like extreme corrosion resistance and low degradation as well as biocompatibility are expected.

Although increasing development activities have led to system solutions using metal composite materials, the use of especially innovative systems, particularly area of light metals, has not been realized. The reason for this is insufficient process stability and reliability, combined with production and processing problems and inadequate economic efficiency. Application areas, like traffic engineering, are very cost orientated and conservative and the industry is not willing to pay additional costs for the use of such materials. For all these reasons metal matrix composites are only at the beginning of the evolution curve of modern materials.

Metal matrix composites can be classified in various ways. One classification is the consideration of type and contribution of reinforcement components in particle-, layer-, fiber- and penetration composite materials. Fiber composite materials can be further classified into continuous fiber composite materials (multi- and monofilament) and short fibers or, rather, whisker composite materials.

2. FABRICATION MATERIALS

2.1 Selection of Materials

- The base metal is chosen as Magnesium and AL6063.
- The reinforcement is chosen as Silicon Carbide composite.

2.2 Matrix Material

- Magnesium, the eight most abundant metallic element on the earth.
- The metal matrix selected for present investigation is pure Mg.

2.3 Magnesium

Magnesium is a chemical element with the symbol Mg and atomic number 12. Its common oxidation number is +2. It is an alkaline earth metal and the eighth most abundant element in the Earth's crust and ninth in the known universe as a Whole–Magnesium is the fourth most common element in the Earth as a whole (behind iron, oxygen and silicon), making up 13% of the planet's mass and a large fraction of the planet's mantle. The free element (metal) is not found naturally on Earth, as it is highly reactive (though once produced, it is coated in a thin layer of oxide (passivation), which partly masks this reactivity). The free metal burns with a characteristic brilliant white light, making it a useful ingredient in flares.

2.4. Aluminum 6063

- Aluminum alloy 6063 is one of the most extensively used of the AL 6063series aluminum alloys.
- It is a versatile heat treatable extruded alloy with medium to high strength capabilities.
- AL 6063 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements.

2.5. Ceramics

Ceramics are generally compounds between metallic and nonmetallic elements and include such compounds as oxides, nitrides, and carbides. Typically they are insulating and resistant to high temperatures and harsh environments. Ceramics exhibit good strength under compression and virtually no ductility under tension. The word ceramic, derives its name from the Greek *keramos*, meaning "pottery", which in turn is derived from an older Sanskrit root, meaning "to burn". The other material classes include metals and polymers. The combination of two or more of these materials together to produce a new material whose properties would not be attainable by conventional means is called a composite. Examples of composites include steel reinforced concrete, steel belted tyres, glass or carbon fibre - reinforced plastics(so called fibre-glass resins) used for boats, tennis rackets, skis, and racing bikes.

Mechanical properties of ceramics

Material	**D(g/cm^3)**	**T (psi)**	**F (psi)**	**C (psi)**	**Y (psi)**	**Ft (psi√in)**
Al_2O_3	3.98	30,000	80,000	400,000	56×10^6	5,000
SiC (sintered)	3.1	25,000	80,000	560,000	60×10^6	4,000

Si_3N_4 (rxn bonded)	2.5	20,000	35,000	150,000	30×10^6	3,000
Si_3N_4 (hot pressed)	3.2	80,000	130,000	500,000	45×10^6	5,000
Sialon	3.24	60,000	140,000	500,000	45×10^6	9,000
ZrO_2 (partially stabilized)	5.8	65,000	100,000	270,000	30×10^6	10,000
ZrO_2 (transformation toughened)	5.8	50,000	115,000	250,000	29×10^6	11,000

(Tensile strength = T; Flexural strength = F; Young's modulus = Y;

Compressive strength = C; Fracture toughness = Ft; Density = D.)

2.6 Silicon Carbide – SiC

Silicon Carbide is a synthetic material with an outstanding hardness, only superseded by Diamond, CBN and B_4C. The chemical inertness to most of the alkaline and acids in combination with its excellent heat and abrasion resistance make Silicon Carbide every suitable under extreme operating conditions. 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 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 good mechanical properties. It is used in abrasives, refractories, ceramics and numerous high performance applications.

3. STUDIES OF MECHANICAL PROPERTIES

3.1 Hardness

Hardness is the characteristic of a solid material expressing it's resistance to permanent deformation. Hardness refers to various properties of matter in the solid phase that gives it high resistance to various shape change when force is applied. In materials science there are three operational definitions of hardness:

- Scratch hardness: Resistance to fracture or plastic (permanent) deformation due to friction from a sharp object
- Indentation hardness: Resistance to plastic (permanent) deformation due to impact from a sharp object
- Rebound hardness: Height of the bounce of an object dropped on the material, related to elasticity.

Hardness can be measured on the Mohs scale or various other scales. Some of the other scales used for indentation hardness in engineering - Rockwell, Vickers, and Brinell can be compared using practical conversion tables.

3.1.1. Scratch hardness:

In mineralogy, hardness commonly refers to a material's ability to penetrate softer materials. An object made of a hard material will scratch an object made of a softer material. Scratch hardness is usually measured on the Mohs scale of mineral hardness. One tool to make this measurement is the sclerometer.

Pure diamond is the hardest known natural mineral substance and will scratch any other natural material. Diamond is therefore used to cut other diamonds; in particular, higher-grade diamonds are used to cut lower-grade diamonds. The hardest substance known today is aggregated diamond nano rods, with hardness over 2 of and stiffness 1.11 of diamond. Estimates from proposed molecular structure indicate the hardness of beta carbon nitride should also be greater than diamond (but less than ultra hard fullerite). This material has not yet been successfully synthesized. Other materials which can scratch diamond include boron sub oxide and rhenium diboride.

3.1.2. Indentation hardness:

Primarily used in engineering and metallurgy, indentation hardness seeks to characterise a material's hardness; i.e. its resistance to permanent, and in particular plastic, deformation. It is usually measured by loading an indenter of specified geometry onto the material and measuring the dimensions of the resulting indentation. There is, in general, no simple relationship between the results of different hardness tests. Though there are practical conversion tables for hard steels, for example, some materials show qualitatively different behaviours under the various measurement methods. The Vickers and Brinell hardness scales correlate well over a wide range, however, with Brinell only producing overestimated values at high loads. It is important to note that hardness of a material to deformation is dependent to its micro durability or small-scale shear modulus in any direction, not to any rigidity or stiffness properties such as its bulk modulus or Young's modulus.

3.1.3. Rebound hardness:

Also known as dynamic hardness, rebound hardness measures the height of the "bounce" of a diamond-tipped hammer dropped from a fixed height onto a material. The device used to take this measurement is known as a scleroscope. One scale that measures rebound hardness is the Bennett Hardness Scale.

3.2 Taguchi technique

The Taguchi approach to experimentation provides an orderly way to collect, analyze, and interpret data to satisfy the objectives of the study. By using these methods, in the design of experiment, one can obtain the maximum amount of information for the amount of experimentation used. This is accomplished by the efficient use of experimental runs to the combinations of variables studied. This technique is a powerful tool for acquiring the data in a controlled way and to analyze the influence of process variable over some specific variable which is unknown function of these process variables. The overall aim of this technique is to make the products that are robust with respect to influencing parameters. The most important stage in the plan of experiments is selection of factors. Taguchi creates a standard orthogonal array to accommodate the effect of several factors on the target value and defines the plan of experiment. The experimental results are analyzed using analysis of means and variance to study the influence of factors.

3.3 Chemical Properties

A chemical property is any of a material's properties that becomes evident during a chemical reaction; that is, any quality that can be established only by changing a substance's chemical identity. Simply speaking, chemical properties cannot be determined just by viewing or touching the substance; the substance's internal structure must be affected for its chemical properties to be investigated.

Chemical properties can be contrasted with physical properties, which can be discerned without changing the substance's structure. However, for many properties within the scope of physical chemistry, and other disciplines at the border of chemistry and physics, the distinction may be a matter of researcher's perspective.

Material properties, both physical and chemical, can be viewed as super venient; i.e., secondary to the underlying reality. Several layers of super veniency are possible.Chemical properties can be used for building chemical classifications. They can also be useful to identify an unknown substance or to separate or purify it from other substances. Materials science will normally consider the chemical properties of a substance to guide its applications.

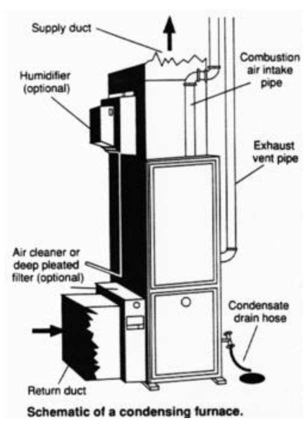
4. PROJECT IDENTIFICATION

4.1. Furnace

A furnace is a device used for heating. The name derives from Latin fornax, oven. The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking, and is part of the standard English names for many metallurgical furnaces worldwide. In American English and Canadian English usage, the term furnace on its own refers to the household heating systems based on a central furnace and sometimes as a synonym for kiln, a device used in the production of ceramics. In British English, a furnace is an industrial furnace used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns.

4.2. Household furnaces

A household furnace is a major appliance that is permanently installed to provide heat to an interior space through intermediary fluid movement, which may be air, steam, or hot water. The most common fuel source for modern furnaces in the United States is natural gas; other common fuel sources include LPG (liquefied petroleum gas), fuel oil, coal or wood. In some cases electrical resistance heating is used as the source of heat, especially where the cost of electricity is low. Combustion furnaces always need to be vented to the outside. Traditionally, this was through a chimney, which tends to expel heat along with the exhaust. Modern high-efficiency furnaces can be 98% efficient and operate without a chimney. The small amount of waste gas and heat are mechanically ventilated through a small tube through the side or roof of the house.



Household furnaces

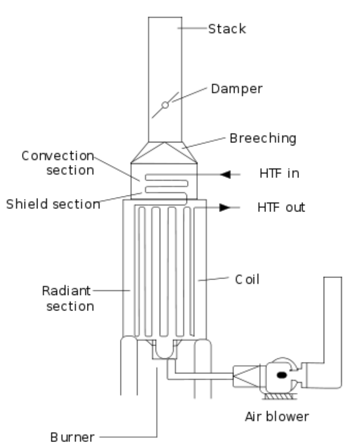
4.3. Heat distribution

The furnace transfers heat to the living space of the building through an intermediary distribution system. If the distribution is through hot water (or other fluid) or through steam, then the furnace is more commonly called a boiler. One advantage of a boiler is that the furnace can provide hot water for bathing and washing dishes, rather than requiring a separate water heater. One disadvantage to this type of application is when the boiler breaks down, neither heating nor domestic hot water are available.

By comparison, most modern "warm air" furnaces typically use a fan to circulate air to the rooms of house and pull cooler air back to the furnace for reheating; this is called forced-air heat. Because the fan easily overcomes the resistance of the ductwork, the arrangement of ducts can be far more flexible than the octopus of old. In American practice, separate ducts collect cool air to be returned to the furnace. At the furnace, cool air passes into the furnace, usually through an air filter, through the blower, then through the heat exchanger of the furnace, whence it is blown throughout the building. One major advantage of this type of system is that it also enables easy installation of central air conditioning, simply by adding a cooling coil at the outlet of the furnace.

4.4. Industrial process furnaces

An industrial furnace or direct fired heater, is an equipment used to provide heat for a process or can serve as reactor which provides heats of reaction. Furnace designs vary as to its function, heating duty, type of fuel and method of introducing combustion air. However, most process furnaces have some common features.



Schematic diagram of an industrial process furnace

Fuel flows into the burner and is burnt with air provided from an air blower. There can be more than one burner in a particular furnace which can be arranged in cells which heat a particular set of tubes. Burners can also be floor mounted, wall mounted or roof mounted depending on design. The flames heat up the tubes, which in turn heat the fluid inside in the first part of the furnace known as the radiant section or firebox. In this chamber where combustion takes place, the heat is transferred mainly by radiation to tubes around the fire in the chamber. The heating fluid passes through the tubes and is thus heated to the desired temperature. The gases from the combustion are known as flue gas. After the flue gas leaves the firebox, most furnace designs include a convection section where more heat is recovered before venting to the atmosphere through the flue gas stack. (HTF=Heat Transfer Fluid. Industries commonly use their furnaces to heat a secondary fluid with special additives like anti-rust and high heat transfer efficiency.

4.5. Electrical stir casting furnace

The simplest and the most cost effective method of liquid state fabrication is Stir Casting. This is a primary process of composite production whereby the reinforcement ingredient is incorporated into the molten metal by stirring. A variant very applied of the Stir Casting is called "Compocasting" (or "Rheocasting), in which the metal is semi-solid. In particular the reinforcing ingredient are incorporated into vigorously agitated partially solid metal slurries. The discontinuous ceramic phase is mechanically entrapped between the pro-eutectic phase present in the alloy, which is held between its liquid us and solidus temperatures. This semi solid process allows near net shape fabrication since deformation resistance is considerably reduced due to the semi- fused state of the composite slurry. The technologies just displayed are the most common and widespread, but there are many variations, mostly applied depending on the specific case and based on the particular application which will face the piece in producing. Techniques is adopted such as processes involving infiltration by centrifuge, ultrasound and magnetic electromagnetic even having all the essential purpose of obtaining a composite reinforced by the distribution of more homogeneous as possible.

An electrical stir casting furnace

4.6. Muffle furnace

A muffle furnace (sometimes, retort furnace) in historical usage is a furnace in which the subject material is isolated from the fuel and all of the products of combustion including gases and flying ash. After the development of high-temperature electric heating elements and widespread electrification in developed countries, new muffle furnaces quickly moved to electric designs.

Muffle furnace

Today, a muffle furnace is (usually) a front-loading box-type oven or kiln for high-temperature applications such as fusing glass, creating enamel coatings, ceramics and soldering and brazing articles. They are also used in many research facilities, for example by chemists in order to determine what proportion of a sample is non-combustible and non-volatile (i.e., ash). Some digital controllers allow RS232 interface and permit the operator to program up to 126 segments, such as ramping, soaking, sintering, and more. Also, advances in materials for heating elements, such as molybdenum di silicide offered in certain models by Vecstar, can now produce working temperatures up to 1800 degrees Celsius, which facilitate more sophisticated metallurgical applications.

4.7. Crucible

A crucible is a container that can withstand very high temperatures and is used for metal, glass, and pigment production as well as a number of modern laboratory processes. While crucibles historically were usually made from clay, they can be made from any material that withstands temperatures high enough to melt or otherwise alter its contents.

Crucibles and their covers are made of high temperature-resistant materials, usually porcelain, alumina or an inert metal. One of the earliest uses of platinum_was to make crucibles. Ceramics such as alumina, zirconia, and especially magnesia will tolerate the highest temperatures. More recently, metals such as nickel and zirconium have been used. The lids are typically loose-fitting to allow gases to escape during heating of a sample inside. Crucibles and their lids can come in *high form* and *low form* shapes and in various sizes, but rather small 10–15 ml size porcelain crucibles are commonly used for gravimetric chemical analysis. These small size crucibles and their covers made of porcelain are quite cheap when sold in quantity to laboratories, and the crucibles are sometimes disposed of after use in precise quantitative chemical analysis. There is usually a large mark-up when they are sold individually in hobby shops.

5. CONCLUSION

Thus the metal matrix composite was carried out successfully by carrying out in various percentage of iterations. For proper mixing of the composite added to the crucible in the furnace, the stir casting setup was made to fabricate. This was fabricated mainly to make the proper mixing of the composition added to the furnace in such a way it should not stick at any side walls of the crucible. In our project work we carried stir for two minutes which is very much enough for magnesium composites.

- The main aim of our project is to increase the hardness in the magnesium composite and we got a better result in terms of hardness test for the percentage of composition (Mg/6% AL606312/7.5%).

- The density of the material was made to measure, which was better than actual magnesium value. This will increase the weight ratio.
- The analysis of variance was calculated for the various iterations involved in the project in which we found that factor (SiC) was responsible for increasing the hardness of the material.
- Microstructure was made to analyze by viewing it in the metallographic testing machine and which confirmed the reinforcement of Magnesium, Aluminium 6063, Silicon carbide.
- Wear testing was conducted for the material and it has identified that there is 2.53% of wear subjected.
- The reinforcement was made to analyze by means of seeing the chemical composition in the material. And which was made to result by means of percentage involved in it.

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