Fabrication of Mg alloy-CNT Nanocomposite for Automobile Wheel Rim Applications

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***Abstract*—Today's interest in magnesium alloys for automotive applications is based on the combination of high strength properties and low density. For this reason magnesium alloys are very attractive as structural materials in all applications where weight savings are of great concern. In automotive applications weight reduction will improve the performance of a vehicle by reducing the rolling resistance and energy of acceleration, thus reducing the fuel consumption and moreover a reduction of the greenhouse gas CO2 can be achieved. In automobile wheels rotates continuously during propulsion therefore total load on a vehicle induces alternating fatigue stress in a wheel rim. In order to sustain all loads and practical conditions wheel materials must be of good quality.Magnesium is the lightest of all metals used as the basis for constructional alloys.The requirement to reduce the weight of car components as a result in part of the introduction oflegislation limiting emission has triggered renewed interest in magnesium. The growth rate over the next 10 years has been forecast to be 7% per annum.Magnesium has a long history in automotive applications.In this project,we are going to make the hot extruded sheet by using the vacuum stir casting furnace and hot extrusion process and material used for this process is Mg alloy-Carbon Nano Tube and by comparing the properties with the exsisting wheel rim material.**

***Key words*—Wheel rim materials, Magnesium alloy, Carbon Nano-Tubes,**

I. INTRODUCTION

There is increasing interest in light weight construction since the automobile industry's commitment to achieve a 25% reduction in average fuel consumption for all new cars by the year 2005 (compared to levels in 1990). Magnesium with its good strength to weight ratio is one of the candidate materials to realise light weight construction, but it has to compete with various other materials. So the different light metals have to compete not only with each other, but also with polymers and steels. Materials selection is thereby determined by economical issues as much as by materials and components characteristics or properties.

However magnesium shows high potential to substitute conventional materials. Magnesium alloys should be used in applications where low mass and high specific properties are required. According to the combination of specific Young's modulus and high specific strength magnesium alloys show similar or even better values than aluminium and many commercial steels. With the increasing use of magnesium the cost per tonne is coming down, which makes it more competitive from the economic point of view too. The consumption of primary magnesium shows a broad increase in the last 20 years whereas North America is the main consumer followed by the western part of Europe and Japan[1]. Most of the available magnesium (40 %) is still used for alloying aluminium and only about 34% is directly used for magnesium parts,which can be divided into casting applications (33.5%) and wrought materials (0.5%). It was estimated that the market for magnesium die castings will grow from 105 tons in 2000 to twice this amount in 2006. Approximately 80 % of this market is expected to go towards die casting automotive parts[2].

The need for lightweight, high strength materials has been recognised since the invention of the airplane. As the strength and stiffness of a material increases, the dimensions, and consequently, the mass, of the material required for a certain load bearing application is reduced. This leads to several advantages in the case of aircraft and automobiles such as increase in payload and improvement of the fuel efficiency. With global oil resources on a decline, increase in the fuel efficiency of engines has become highly desirable. The inadequacy of metals and alloys in providing both strength and stiffness to a structure has led to the development of metal matrix composites (MMCs), whereupon the strength and ductility is provided by the metal matrix and the strength and/or stiffness is provided by the reinforcement that is either a ceramic or high stiffness metal based particulate or fibre. Metal matrix composites can be designed to possess qualities such as low coefficient of thermal expansion and high thermal conductivity which make them suitable for use in electronic packaging applications. Metal matrix composites today are extensively used in automobile and aerospace applications[3].

A. Recent Trends in Magnesium Technology

Alloy development

Magnesium alloys have two major disadvantages for the use in automotive applications; they exhibit low high temperature strength and a relatively poor corrosion resistance.The major step for improving the corrosion resistance of magnesium alloys was the introduction of high purity alloys. Alloying can further improve the general corrosion behavior, but it does not change galvanic corrosion problems if magnesium is in contact with another metal and an electrolyte. The galvanic corrosion problem can only be solved by proper coating systems. Beside the galvanic corrosion problems related with magnesium the low temperature strength is another serious problem, limiting the use of magnesium especially for power train applications.The use for transmission cases and engine blocks requires temperature stability up to 175°C and in some cases even 200°C for engine blocks. The new high temperature resistant alloys are under further development and testing. Few alloys are already available in the market (e.g. MRI, modified AE and AJ alloy systems).These alloys contain mostly aluminium for good castability and strontium,calcium and/or rare earth elements for better high temperature stability.For automotive applications it is important that the development of new casting alloys addresses creep resistance and cost effectiveness. Under this aspect Mg-Al-Si, Mg-Al-RE, Mg-Al-Ca, Mg-Al-Sr and quaternary combinations of them are very promising new systems for high pressure die casting and Ca, Sr and RE additions are also studied for gravity or low pressure castings. These new alloys have already high temperature properties comparable to common aluminium alloys. A comparison of the performance of an oil pan made from the new magnesium MRI153M alloy and from aluminium A380 alloy revealed that the magnesium alloy performed similar and had the better damping properties. Automotive applications require also good ductility for many components, especially energy absorbed in the case of an accident is a very crucial issue. One direction in the alloy and process development for wrought alloys is to optimise the energy absorption of the material.Thus alloy development follows various requirements and certain alloy groups can be identified to provide certain properties[4].

B. Processing

Casting

Magnesium alloys, especially those with aluminium as a major alloying element show a very good castability. This lead to the use of magnesium alloys in pressure assisted casting processes like warm and cold chamber high pressure die casting. By using the alloy AZ91 thin walled castings with wall thickness less than 1 mm can be obtained easily. Other alloy systems like the WE series show a lowered castability but they are well suitable for permanent mold casting or for sand casting. Even these casting operations can be supported by pressure to achieve thin walled structures. Thus magnesium has excellent die-filling properties and large, thin walled and complex components can be produced by casting rather than by joining smaller parts together. Low heat capacity, lower latent heat of solidification and less affinity to iron are further advantages of magnesium castings resulting in shorter casting cycles and longer die life times. Magnesium alloys further more show thixotropic properties and there are several processes (Thixomolding,Thixocasting, New Rheocasting) under development and optimisation to use semi-solid processing. Better properties and a greater choice of castable alloys (e.g. rare earth containing alloys) are expected. Today protective gases are used in magnesium casting operations rather than covering salts. This greatly improves the quality of the castings. Research is performed to substitute SF6 by more environmental friendly protective gas mixtures[5].

Forming

Wrought alloys generally have higher strength and ductility in comparison with cast alloys. Thus exploitation of the whole potential of light weight construction requires the increased use of rolled, extruded or forged magnesium components.Unfortunately the hexagonal structure of magnesium requires elevated forming temperatures to activate more slip systems and to allow better formability, causing higher energy consumption during processing and causes also a poorer surface appearance. Surface quality and corrosion requirements of the present magnesium sheet alloys are not sufficient for outer panel applications. Therefore alloy and process development especially for sheet material is from major interest to solve these problems. So far mainly AZ31 sheet products are available on the world market in a thickness of 0.8 – 30 mm and widths of up to 1850 mm.Twin roll casting for the production of continuous Mg strips has reached a prototype stage and promises reduced costs due to a reduced number of passes to achieve the fine sheet thickness. The deep drawing potential of AZ31 sheet was successfully demonstrated as magnesium has similar hot deep-drawing characteristics as steel and aluminium sheet. At 225°C the limiting draw ratio of AZ31 is 2.6, and is thus higher than that of deep drawing Al and deep drawing steels in common use which have a ratio of 2.5 and 2.2 respectively. Further research is performed for processes like bending and hydroforming. A typical automotive applications are extruded and bent profiles for car bumpers. Realisation of mass reduction for extruded magnesium components with comparable strength and stiffness to steel and aluminium requires use of hollow sections with reduced wall thickness and increased cross-section area. Minimal wall thicknesses of approx.1.5 mm are possible, depending on the section's geometry. To use the forming temperature of the taken if very fine chips occur during machining operations. Especially grinding creates fine dusts or powders that may react easily with water or oxygen. Therefore dry machining or the use of water free coolants is advised[6].

Surface protection

To improve the corrosion and wear resistance of magnesium and to fulfil decorative requirements coating systems are generally used in automotive applications, especially for view parts which are in contact with the environment. Combinations of conversion coatings as a primer and sealing top coats (paint, laquer, e-coat etc.) are state-of-the-art for corrosion protection of magnesium. Chemical conversion coatings are just a few micrometer thick and thus they are only offering a limited protection. However they are an excellent primer for a subsequent organic coating. Best results were obtained by chromating, but because of the health risk involved with chromating the use is strictly limited since 2003 in Europe. Alternatives for chromating are conversion coatings based on phosphate-permangenate or fluoro-zirconate. Depending on the application and the aggressiveness of the environment multilayer systems are used. A typical coating on Mg wheels consists of the conversion coating, a primer, a filler (wet paint or EPS), base coat and clear coat (Norsk Hydro). Sufficient corrosion resistance is also required for the tailgate of the 3-l VW-Lupo, which is a Mg-Al hybrid construction [7]. The inner lining is made of AM50 (HPDC), which is joint to an outer aluminium sheet by adhesive bonding and seaming. A similar multilayer system (pickling treatment, chromating, wet paint (KTL 20 µm) + EPS (> 80 µm) is also suitable to prevent contact corrosion on the magnesium part. A two layer system can be sufficient, if a part is less exposed to the surrounding. An example is the inlet pipe of the Audi W 12 cylinder engine which is made of AZ91 and coated with MAGPASS-COATÒ and a 200 µm polyester powder coating. Better wear resistance and also good primer properties are obtained with anodized coatings instead of conversion coatings. However the use for automotive applications is limited due to much higher costs, especially for the new high voltage electrolytic plasma anodizing treatments (AHC, Keronite, etc.). Keronite is addressing the problem by reducing the coating time and has reached a deposition rate of 5µm/min by optimising the process (introduction of acoustic vibrations and air micro-bubbles). A two minute treatment offers now sufficient corrosion resistance to replace multi layer systems by a single layer of Keronite and moreover the coating is able to withstand a conventional steel body automotive paint line. Electroplating of magnesium is also used in the automotive industry for decorative applications, especially for parts inside the car. For higher corrosion resistance electroplating is deposited as a top layer on a conversion coating/special e-coat layersystem. Such a system provides with a chromium top layer a corrosion resistance of 500 h salt spray. In many cases it is sufficient to simply coat the counterpart and leave the magnesium uncoated (if it is no view part), as a defect in a coating on magnesium would result in an enhanced localized corrosion attack of the magnesium component. No contact corrosion of magnesium is caused by anodized AlMg3 alloy. Conventionally galvanised steel bolts can be attached to magnesium by using a silicate sealing. The silicate sealing of galvanised steel bolts was successfully applied by Audi and VW at the B80 magnesium gear housing 35. A good protection can also be obtained by multi-layer coatings on the critical counterpart, e.g. a zinc coating in combination with a cathodic dip-coating (KTL, 15 µm) . Another possibility is the use of Sn/Zn-coatings instead of conventional zinc galvanising. Additionally new electrolytic deposited Al-Mg coatings for steel bolts are under development and testing. Already used are also insulating polymer coatings (nylon) or plastic caps for screw heads. In addition often washers made of aluminium or polymers are used with steel bolts to minimise the contact corrosion on magnesium. Fibre reinforced PEEK based polymer screws with carbon- or polyamide fibres are also available, with the advantage that polymers are inert against contact corrosion[8].

C. Material used for Hot extruded Sheet

CNTs reinforced magnesium composites

Developing lightweight and high strength carbon nano-tubes reinforced magnesium matrix composites through rein-forcing magnesium and magnesium alloys by CNTs have be-come a hot research field. The conventional method for devel-oping CNTs reinforced magnesium matrix composites is stir-ring casting. Since the chemical activity of Mg is high, it can react with many elements easily. When use stirring casting method, the harm from magnesium melt to CNTs is slight. Magnesium alloys have been increasingly used in the automotive industry in recent years due to their lightweight. The density of magnesium is approximately two thirds of that of aluminum, one quarter of zinc, and one fifth of steel. As a result, magnesium alloys offer a very high specific strength among conventional engineering alloys. In addition, magnesium alloys possess good damping capacity, excellent castability, and superior machinability. Accordingly, magnesium casting production has experienced an annual growth of between 10 and 20% over the past decades and is expected to continue at this rate. However, compared to other structural metals, magnesium alloys have a relatively low absolute strength, especially at elevated temperatures. Currently, the most widely used magnesium alloys are based on the Mg-Al system. Their applications are usually limited to temperatures of up to 120◦C. Further improvement in the high-temperature mechanical properties of magnesium alloys will greatly expand their industrial applications. During the past decades, efforts to develop high temperature magnesium materials have led to the development of several new alloy systems such as Mg-Al-Ca, Mg-Re-Zn-Zr, Mg-Sc-Mn and Mg-Y-Re-Zr alloys[9].

However, this progress has not engendered extensive applications of these magnesium alloys in the automotive industry, either because of insufficient high temperature strength or high cost.

The need for high-performance and lightweight materials for some demanding applications has led to extensive R&D efforts in the development of magnesium matrix composites and cost-effective fabrication technologies[10].

For instance, the magnesium matrix composite unidirectionally reinforced with continuous carbon fiber can readily show a bending strength of 1000 MPa with a density as low as 1.8 g/cm3. The superior mechanical property can be retained at elevated temperatures of up to 350–400◦C.Moreover, composite materials are flexible in constituent selection so that the properties of the materials can be tailored. The major disadvantage of metal matrix composites usually lies in the relatively high cost of fabrication and of the reinforcement materials. The cost-effective processing of composite materials is, therefore, an essential element for expanding their applications. The availability of a wide variety of reinforcing materials and the development of new processing techniques are attracting interest in composite materials. This is especially true for the high performance magnesium materials, not only due to the characteristics of composites, but also because the formation of a composite may be the only effective approach to strengthening some magnesium alloys. Mg-Li binary alloys at around the eutectic composition, for example, are composed of HCP (α) and BCC (β) solid solution phases. The dissolution of Li into Mg causes a minor solution strengthening effect without the formation of any Mg-Li precipitates during the cooling process. Thus, heat treatment based on phase transformation cannot be applied to improve their properties. Efforts to strengthen this binary system by producing LiX (X =Al, Zn, Cd etc.) type precipitates have not been successful because these precipitates tend to overage easily, even at room temperature. In contrast, the incorporation of thermally stable reinforcements into composite materials makes them preferable for high temperature applications.The potential applications of magnesium matrix composites in the automotive industry include their use in: disk rotors, piston ring grooves, gears, gearbox bearings, connecting rods, and shift forks. The increasing demand for lightweight and high performance materials is likely to increase the need for magnesium matrix composites[11].

D. Introduction to Carbon Nanotubes

Carbon nanotubes (CNTs; also known as buckytubes) are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of up to 132,000,000:1, which is significantly larger than that of any other material. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science, as well as potential luses in architectural fields. They exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors. Nanotubes are members of the fullerene structural family, which also includes the spherical buckyballs. The ends of a nanotube might be capped with a hemisphere of the buckyball structure. Their name is derived from their size, since the diameter of a nanotube is in the order of a few nanometers (approximately 1/50,000th of the width of a human hair), while they can be up to 18 centimeters in length (as of 2010). Nanotubes are categorized as single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs).Carbon nanotubes (CNTs) are made by rolling up of sheet of graphene into a cylinder. These nanostructures are constructed with length-to-diameter ratio of up to (1.32 × 108):1 (Wang 2009) that is significantly larger than any other material. As their name suggests, the diameter of nanotube is in the order of few nanometers, while they can be up to 18 centimeters in length (Javey and Kong, 2009). CNTs are most promising candidates in the field of nanoelectronics, especially for interconnect applications. Metallic CNTs have aroused a lot of research interest for their applicability as VLSI interconnects due to high thermal stability, high thermal conductivity, and large current carrying capability. A CNT can carry current density in excess of 103 MA/cm2, which can enhance the electrical performance as well as eliminate electro migration reliability concerns that plagues current nanoscale Cu interconnects (Wei et al., 2001). Recent modeling works have revealed that CNT bundle interconnects can potentially offer added advantages over Cu. Moreover, recent experiments have demonstrated that the resistance values as small as 200 Ω can be achieved in CNT bundles[12].

E. Structure and Types of Carbon Nanotubes

To understand the crystal structure of CNTs, it is necessary to understand their atomic structure. Both CNTs and GNRs (graphene nano ribbons) can be understood as structures derived from a graphene sheet, shown in Fig.1. A graphene sheet is a single layer of carbon atoms packed into 2D honeycomb lattice structure. CNT, considered as rolled-up graphene sheet, have the edges of the sheet joint together to form a seamless cylinder.The vector is defined as _C = $n1$ ˆ$a1$ + $n2$ ˆ$a2$ where $a1$ and $a2$ are the lattice vectors of graphene and $n1$ and $n2$ are the chiral indices. The chiral indices ($n1$, $n2$) uniquely defines the chirality, or the rolled-up direction of grapheme sheet. Depending on the chiral indices ($n1$, $n2$), CNTs can be classified to zigzag and armchair structures as shown in Fig.1.1 a, b, respectively. For armchair CNTs, the chiral indices $n1$ and $n2$ are equal while for zigzag CNTs, $n1$ or $n2$ = 0 (Li et al., 2009b). For other values of indices, CNTs are known as chiral. Depending upon their different structures, CNTs can exhibit metallic, whereas zigzag CNTs are either metallic or semiconducting in nature (Javey and Kong 2009; Li et al. 2009b). Statistically, a natural mix of CNTs will have 1/3rd metallic

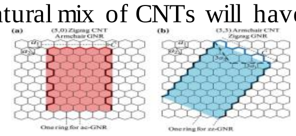

Fig.1 Schematic view of CNT made from graphene sheet **a** zigzag and **b** armchair CNT

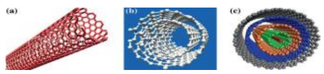

Fig.2 Basic structures of **a** single-walled, **b** double-walled,and **c** multi-walled CNTs

and 2/3rd semiconducting chiralities. Depending on the number of concentrically rolled-up graphene sheets, CNTs are also classified to single-walled (SWNT), double-walled (DWNT), and multiwalled CNTs (MWNT) as presented in Fig. 2. The structure of SWNT can be conceptualized by wrapping a one-atom-thick layer of graphene into a seamless cylinder (Majumder et al. 2011c). MWNT consists of two or more numbers of rolled-up concentric layers of graphene. DWNT is considered as a special type of MWNT wherein only two concentrically rolled up graphene sheets are present[13].

F. Properties of CNTs

The atomic arrangements of carbon atoms are responsible for the unique electrical, thermal, and mechanical properties of CNTs. These properties are discussed below:

Strength and Elasticity

Each carbon atom in a single sheet of graphite is connected via strong chemical bond to three neighboring atoms. Thus, CNTs can exhibit the strongest basal plane elastic modulus and hence are expected to be an ultimate high strength fiber. The elastic modulus of SWNTs is much higher than steel that makes them highly resistant.

Although pressing on the tip of nanotube will cause it to bend, the nanotube returns to its original state as soon as the force is removed. This property makes CNTs extremely useful as probe tips for high resolution scanning probe microscopy Although, the current Young’s modulus of SWNT is about 1 TPa, but a much higher value of 1.8 TPa has also been reported (Hsieh et al. 2006). For different experimental measurement techniques, the values of Young’s modulus vary in the range of 1.22 TPa–1.26 TPa depending on the size and chirality of the SWNTs (Dresselhaus et al. 2001). It has been observed that the elastic modulus of MWNTs is not strongly dependent on the diameter. Primarily, the moduli of MWNTs are correlated to the amount of disorder in the nanotube walls[14,15].

Thermal Conductivity and Expansion

CNTs can exhibit superconductivity below 20 K (approximately −253 ºC) due to the strong in-plane C–C bonds of graphene.The strong C-C bond provides the exceptional strength and stiffness against axial strains. Moreover, the larger interplane and zero in-plane thermal expansion of SWNTs results in high flexibility against non-axial strains. Due to their high thermal conductivity and large in-plane expansion, CNTs exhibit exciting prospects in nanoscale molecular electronics, sensing and actuating devices, reinforcing additive fibers in functional composite materials, etc[16].

Recent experimental measurements suggest that the CNT embedded matrices are stronger in comparison to bare polymer matrices (Wei et al. 2002). Therefore, it is expected that the nanotube may also significantly improve the thermo-mechanical and the thermal properties of the composite materials[17].

Aspect Ratio

One of the exciting properties of CNTs is the high aspect ratio, inferring that a lower CNT load is required compared to other conductive additives to achieve similar electrical conductivity. The high aspect ratio of CNTs possesses unique electrical conductivity in comparison to the conventional additive materials such as chopped carbon fiber, carbon black, or stainless steel fiber[18].

Absorbent

Carbon nanotubes and CNT composites have been emerging as perspective absorbing materials due to their light weight, larger flexibility, high mechanical strength and superior electrical properties. Therefore, CNTs emerge out as ideal candidate for use in gas, air and water filtration. The absorption frequency range of SWNT-polyurethane composites broaden from 6.4–8.2 (1.8 GHz) to 7.5–10.1 (2.6 GHz) and to 12.0–15.1 GHz (3.1 GHz) (Wang et al. 2013). A lot of research has already been carried out for replacing the activated charcoal with CNTs for certain ultrahigh purity applications[19]

G. Processing Techniques For Fabricate The Metal Matrix Composite (MMC) With CNT

The reinforcing phases such as powders, fibers and whiskers are generally incorporated into the metal matrices mostly by two typical techniques of liquid state fabrication and solid state fabrication. The key techniques in the processing of MMC are how to realize the homogeneous distribution of reinforcement phases and to achieve a defect-free microstructure.

Liquid state fabrication of MMC

Liquid state fabrication of MMC involves incorporation of dispersed reinforcing phase in to a molten matrix metal, followed by its solidification.There are many liquid state fabrication methods such as stir casting, rheocasting, infiltration, gas pressure infiltration, squeeze casting infiltration, pressure die infiltration, etc., however, a few methods are applied for fabricating MMC with CNTs. Their features are written below.In order to provide high level of mechanical properties of the MMC, good interfacial bonding (procuring the wetting reaction) between CNTs and matrix should be obtained. Wetting improvement may be usually achieved by coating the reinforcing phases. Unfortunately, proper coating for CNTs has not yet established[20].

Stir casting

Stir Casting is the simplest and the most cost effective method of liquid state fabrication. Adispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal bymeans of mechanical stirring. Liquid state composite material is then cast by conventionalcasting methods and may also be processed by conventional metal forming technologies.When CNTs are selected as a reinforcing phase, uniform distribution of CNTs in the matrix structure should be obtained since the CNT exhibits inherent deficiency of wetting for molten magnesium and magnesium alloy matrices[21].

Rheocasting

Rheocasting is a modified method using stirring metal composite materials in semi-solid state.Distribution of dispersed phase may be improved because the high viscosity of the semi-solid matrix material enables better mixing of the dispersed phase[22].

Solid state fabrication of MMC

Typical solid state fabrication method in which MMC is formed as a result of bonding matrix metal and dispersed phase due to mutual diffusion occurring between them. Raw powders of the matrix metal are mixed with the dispersed phase in form of particles or short fibers for subsequent compacting and sintering. Sintering involves consolidation of powder grains by heating the “green” compact part to the elevated temperature below melting point[23].

H. Characteristics of the CNTs introduced into matrix

Kroto *et al*. discovered fullerene (C60) in 1985 and won Nobel Prize in Chemistry in1996. After their discovery, Iijima found that carbon nanotube (CNT) generated on the electrode of the generation device of C60 in 1991and opened the beginning to the CNT generation.As it should be noted that CNTs are sorted into two main groups by their structure and size. Fig.1 shows the illustration sorting the carbon fiber and CNTs. The first group of CNTs is single-layered carbon nanotube (SWCNT) having wondrous strength such as 1 TPa in Young’s modulus and 140 GPa in Yield strength. However, SWCNT is too expensive for normal industrial application.The second CNT group is multilayered carbon nanotube (MWCNT). Table 1 presents the characteristics of an example of MWCNT called as a vapor grown carbon fiber (VGCF) made by SHOWA DENKO K.K. in Japan.In late years mass production of MWCNT has been achieved and enabled to use it with relatively low cost[24].

Density	(kg/m^3)	2000
Bulk density	(kg/m^3)	40
Fiber diameter	(nm)	150
Fiber length	(μm)	10~20
Aspect ratio		10~500
Elastic modulus [28]	(GPa)	100~700
Tensile strength [28]	(GPa)	0.5~2.2
Thermal conductivity	(W/mK)	1260

Table 1. Characteristics of the MWCNT

II. LITERATURE SURVEY

M. Sabari et.al (2015) has studied the comparative study of car wheel rim materials for its deformation with the help of FEA methods. In his study he considered two materials namely carbon steel and aluminium alloy. CAD model of both material has drafted using Solid works software and then analysis performed by using CATIA software. In this research researcher changed the two parameters such as load applied and speed of wheel rim. By changing load and cruising speed rims has analyzed also graph of maximum displacement against speed plotted and it is found that as speed increases displacement of both material increases. Displacement in alloy wheel rim is more than the steel[25].

T. Siva Prasad et.al (2014) has studied the properties of various types of wheel rims with advantageous and disadvantages of various materials such as Al, Mg, carbon fiber, steel, etc. he studied comparatively aluminium and forged steel for static displacement, von Mises stress and dynamical displacement. Researcher found that stress induced as well as displacement of aluminium wheel rim is more than the forged steel. Researcher suggested forged steel is best material for a wheel rim[26].

Sourav Das (2014) has studied the design and weight optimization of sport utility car wheel rim by taking AlSi7Mg0.3 aluminium alloy wheel. According to researcher and wheel rim material manuals aluminium alloys, magnesium alloys are light in weight, very good heat conductor as well as excellent aesthetic appearance. Ductility of magnesium alloys is very low as compared to aluminium alloys. Also magnesium rims are not repairable after it’s bending[27].

S. Ganesh et.al (2014) has studied the Al 356.2 aluminium alloy wheel for spiral wheel rim used for four wheel vehicles and given the properties of various rim materials with some drawbacks. Paper said that magnesium rims are strong enough but not suitable for off road vehicles yet they are used in a Mercedes-G car models. Only one big disadvantage of magnesium is bent rim cannot be repaired therefore such rims are directly fall in scrap[28].

N. Satyanarayana et.al (2012) has studied the over casted Aluminium alloy (Al.356.2) wheel rim for finding fatigue behaviour under constant loading. Researcher not considered the comparison of Al.356.2 with other types of materials[29].

The Aluminium Automotive Manual (2011) has studied the various types of wheel rim materials with its advantageous, disadvantages, rim manufacturing processes, mechanical properties of materials, aluminium sheet metal wheel rims as well as basic requirements of rim. But research is limited to only aluminium material and not explained the other types of materials. According to this manual basic requirements are strength, structural stiffness,fatigue behaviour and crash worthiness etc[30].

Qiuyu Huang studied the corrosion of CNTs/Mg in sodium chloride solution. When CNTs was added, compact net structure will be formed on the corrosion interface, it can prevent the invasion of Cl- and protect the alloy. The degree of corrosion is most slight and corrosion rate is lowest when the content of CNTs is 1.5%, the corrosion resistance increased by 9.79 times. The main compositions of corrosion product are Mg (OH) 2, MgO and CNTs, and this can be tested by the analysis of the surface and structure of mineral. CNTs can thinning grain size and increasing the corrosion resistance[31].

Weixue Li analyzed the stress of each components of CNTs reinforced magnesium matrix composites when being loaded. The main strengthening mechanism is stress transfer-ring. The more the layer number is, the more sparse the dis-persing is, and this go against the raise of yield strength. Only within the specially appointed scope of CNTs length, can the yield strength rise[32].

Zhao Ping prepares the CNTs particu-late reinforced magnesium matrix amorphous composite ma-terial. Observing through transmission electron microscope found that carbon nanotubes particles combined with matrix perfectly, and XRD characterization also proved that the amorphous structure was not big changed. Compression test prove that the maximum compression strength and the frac-ture displacement were improved. The large area agglomera-tion of CNTs was not found. CNTs formed a lot of toughening nest structure in the matrix. But the change of macro plastic toughness material is not obvious[33].

Zhou guohua pre-pared CNTs reinforced AZ31 magnesium matrix composites, and the effect of carbon nanotubes on corrosion resistant properties of magnesium alloys was tested. Doing the static salt water immersion test in 3.5% NaCl solution (mass fraction, the same below). Tests showed that the corrosion resistance improved obviously after adding CNTs. When the addition amount is 1.5% (mass fraction), the average corrosion rate dropped to 1.1069 mg/(m2·s)[34].

III. Problem Statement

The objective of the present work is to make the cylindrical rod with the help of vacuum stir casting furnace and make it into the hot extruded sheet through hot extrusion process.Material used for this process is the combination of Magnesium alloy and Carbon NanoTube Nanocomposite. After forming the sheet, make the study of it's mechanical properties like Ultimate tensile strength,Hardness,compressive strength and Weight of the sheet with the exsisting wheel rim material property.The aim of the project is to reduce the weight of the sheet which is used for the automobile wheel rim application.

IV.Methodology

Fig.3 Vacuum Stir Casting Furnace

A. Specification For Vacuum Stir Casting Furnace:

Furnace structure:

1.General sketch : Crucible furnace with autoflushing of the melt
2.Outer shell size : 700*600*1000mm
3.Useful volume:Crucible inner dimension 120mm dia.*300mm height with conical bottom of 50 mm dia.
4.Shell construction:Thick gauge mild steel sheet and M.S.Angle's structure with proper stiffeners and neat powder painting
5.Melt discharge system :Automatic Open/close mechanism provided at the bottomof the crucible with pneumatic will be arranged alongwith the suitable pipe line.

Insulation & Heating elements:

1.Furnace insulation:Mechanically pressed zirconia blend ceramic fiber.
2.Heating elements:Advanced powder metallurgical grade kanthal
3.Operation: Single phase / AC /230V
4.Power: 4kw
5.Maximum temperature : 1100°C
6.Working temperature : 850°C

Control Panel

1.Panel box:Separate control panel box with other accessories.
2.Temperature control :Nippon (16 segment) PID controllercum digital temperature controllercum indicator
3.Temperature sensor :K type thermocouple
4.Control switches :Mains on,Furnace on,melt dischargeon,melt discharge off

Stirrer

1.Stirrer :High speed stirrer with various speed 300 to 500 RPM

2.Stirrer material :Made with mild steel with zirconia coated (300 micron thickness)

3.Fittings for controlled atm :Stainless steel ports are provided.

Fig. 4 Magnesium block (Before process)   Fig. 5 Magnesium rod (After Process)

B. Hot Extrusion:

A compression forming process in which the work metal is forced to flow through a die opening to produce a desired cross-sectional shape.

Keeping the processing temperature to above the recrystalline temperature. Reducing the ram force, increasing the ram speed, and reduction of grain flow characteristics. Controlling the cooling is a problem.Glass may be used as a lubricant[35].

It is the process by which a block/billet of metal is reduced in c/s by forcing it to flow through a die orifice under high pressure.In general, extrusion is used to product cylindrical bars or hollow tubes or for the starting stock for drawn rod,cold extrusion or forged products.

Fig. 6 Hot Extrusion Setup

Most metals are hot extruded due to large amount of forces required in extrusion.Complex shapes can be extruded from the more readily extrudable metals such as aluminium.

The products obtained are also called as extrusion.

Similar to forging,lower ram force & a five grained recrystalised structure are possible in hot extrusion.

Hot extrusion is done at fairly high temp. appro. 50 to 75% of the melting point of the metal.The pressures can range from 35-700 Mpa.

The c/s shape of the extrusion is defined by the shape of the die.Due to the high temperatures and pressures & its detrimental effect on the die life as well as other components, good lubrication is necessary[36,37].

C. Hot extrusion die design:

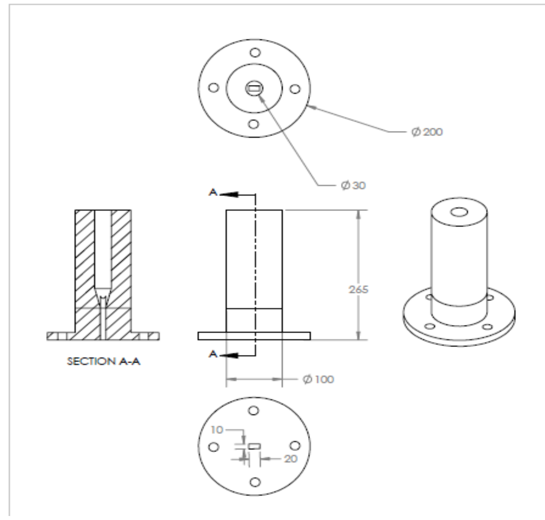

Fig.7 Drawing of extrusion die

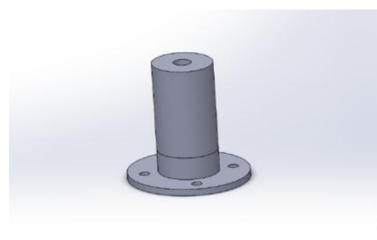

Fig. 8 Solid model

D. Results of Hot Extrusion Process:

Fig. 9 Magnesium rod after Machine   *Fig. 10 Hot extruded Sheet*

V. CONCLUSION

From this project, we conclude that we can study the various mechanical properties of the Mg alloy-CNT Nanocomposite and make the comparison of this material with the existing wheel rim material properties.Due to the light weight applications of Magnesium,weight will reduce and hence fuel efficiency is increased.Cost is high due to the Carbon Nano Tubes are used for increasing the strength of the magnesium.

ACKNOWLEDGEMENT

I would like to express my honor, deep gratitude and genuine regard to project guide **Prof.J.Jayakumar** giving me all guidance required for project reportapart from being a constant source of inspiration and motivation. It was indeed my privilege to have work under them.

I am also extremely thankful to our Principal Dr.H.N.KUDAL sir, HOD Dr. K.B.Kale & ME Coordinator Prof.R.R.Navthar for their various valuable suggestions and all staff members of Mechanical department for their constant encouragement and kind help during my project for providing all facility & help for smooth progress of project report work.

The backbone of my success & confidence lies solely on blessing of my parent and constant encouragement from our project guide and my best friends.

Thanking You.

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