Novateur Publication's
International Journal of Innovation in Engineering, Research and Technology [IJIERT]
ICITDCEME'15 Conference Proceedings
ISSN No - 2394-3696

STUDY ON MECHANICAL PROPERTIES OF HOT EXTRUDED AZ91-MWCNT COMPOSITES FABRICATED BY STIR CASTING

Suhas B. Savant
PG Student,Department Of Mechanical Engineering,University of Pune,
Pune, Maharashtra-413801,India.

Jayaraman Jayakumar
Associate Professor, Dept. of Mechanical Engineering, PDVVP College of Engg.,
Ahmednagar, Maharashtra, India.

ABSTRACT

Magnesium alloys have been increasingly used in the automotive industry in recent years due to their lightweight. The density of magnesium is approximately two third of that of aluminium, one quarter of zinc, and one fifth of steel.Carbon nanotubes (CNTs) are promising reinforcements for light weight and high strength composites due to their exceptional properties. Experimental results have indicated their extraordinary strength up to 150 GPa and Young's modulus up to 1 TPa. The main problem for Mg-CNT composites is to obtain homogenous dispersion in the matrix material. However the problem of homogeneous dispersion has been overcome through ball milling process by milling the CNTs with Mg-metal and alloy materials in powder form. Hot extrusion almost eliminated this particle aggregation and improved the particle distribution of the composites. The results show that hot extrusion significantly improves the mechanical properties of the composites. In the as-extruded composite, with the increase of MWCNT contents, the strength and elastic modulus increase. In this study we have used low cost stir casting processing technique for synthesis of the composites with an objective to achieve homogeneous distribution and alignment of carbon nanotubes in the Mg matrix using hot extrusion.

INTRODUCTION

Magnesium alloys have been increasingly used in the automotive industry in recent years due to their lightweight. The density of magnesium is approximately two third 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 mach inability. 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 [Jayakumaret.al.(2012)].

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 120^0C. Further improvement in the high-temperature mechanical properties of magnesium alloys will greatly expand their industrial applications. Steady progress has been made in exploring the mechanical properties and potential applications of two types of CNTs: single-walled carbon nanotubes (SWCNT) and multi-walled carbon nanotubes (MWCNT). The measured specific tensile strength of a single layer of a MWCNT can be as high as 100 times that of steel, and the graphene sheet (in-plane) is as stiff as diamond at low strain. These mechanical properties motivate further study of possible applications for lightweight and high strength materials. Composite materials reinforced by either SWCNT or MWCNT have been fabricated and significant enhancement in mechanical properties.

Nanocomposites are composites, which are produced when the reinforcing phase of the composite consists of nano-sized particles. Hence magnesium nanocomposites are composites in which the matrix is of Mg and the reinforcing material is nano-sized particles. Carbon nanotubes are the nano-sized reinforcement material generally used, which tend to improve the strength, electrical and thermal conductivity of the composites. Magnesium-CNT nanocomposites have greater strength (both yield strength and ultimate tensile strength) and stiffness as compared to other Mg-MMC [R. Purohit,et.al.(2007)]. 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. The main problems for CNTs reinforced metal composites are to disperse each of CNTs separately in the matrix and develop a tight interface between CNTs and the matrix.

THE PROCESSING OF MAGNESIUM MATRIX COMPOSITES

Due to the similar melting temperatures of magnesium and aluminium alloys, the processing of a magnesium matrix composite is very similar to that of an aluminium matrix composite. For example, the reinforcing phases (powders/fibers/whiskers) in magnesium matrix composites are incorporated into a magnesium alloy mostly by conventional methods such as stir casting, squeeze casting, and powder metallurgy.

2.1 SQUEEZE CASTING

During squeeze casting, the reinforcement (either powders or fibers/whiskers) is usually made into a preform and placed into a casting mold. The molten magnesium alloy is then poured into the mold and solidified under high pressure. Compared with stir casting, squeeze casting has the advantages of allowing for the incorporation of higher volume fractions (up to 40–50%) of reinforcement into the magnesium alloys[Jayakumar et.al.(2012)], and the selective reinforcement of a portion of a mechanical component.

In the magnesium matrix composites, however, the pressure for squeeze casting has to be properly controlled because an excessively high pressure may produce a turbulent flow of molten magnesium, causing gas entrapment and magnesium oxidation. The excessively high pressure can also damage the reinforcement in a composite material and reduce the mechanical properties of the composites.

2.2 POWDER METALLURGY

In the powder metallurgical process, magnesium and reinforcement powders are mixed, pressed, degased and sintered at a certain temperature under a controlled atmosphere or in a vacuum. The advantages of this processing method include the capability of incorporating a relatively high volume fraction of reinforcement and fabrication of composites with matrix alloy and reinforcement systems that are otherwise immiscible by liquid casting. However, this method requires alloy powders that are generally more expensive than bulk material, and involves complicated processes during the material fabrication. Thus, powder metallurgy may not be an ideal processing technique for mass production.

2.3 STIR CASTING

Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practised commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production, and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth.

Table.1 Comparison of various fabrication processes of composites [J. Hashim,et.al.(1999)]

Method	Range of shape and size	Damage to reinforcement	Cost
Liquid metallurgy (Stir casting)	Wide range of shapes; larger size; up to 500 kg	No damage	Least expensive
Squeeze casting	Limited by preform shape; up to 2 cm height	Severe damage	Moderately expensive
Powder metallurgy	Wide range; restricted size	Reinforcement fracture	Expensive

EXPERIMENTAL SETUP FOR STIR CASTING

Fig.3 shows the stir casting setup. The setup has a crucible made of Inconel alloy in which the materials are loaded for melting. The materials are melted in the crucible using a resistance heating furnace.

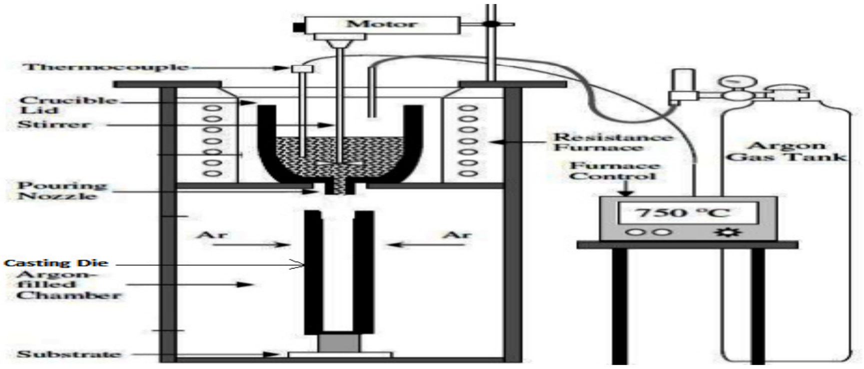


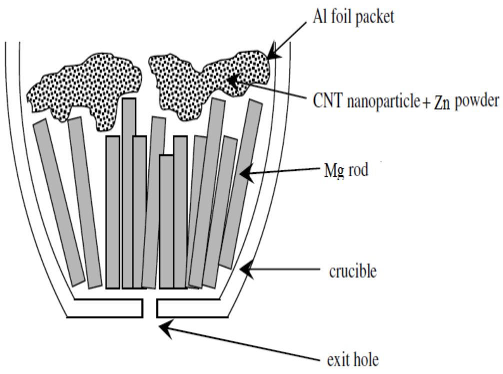
Fig.3 Schematic diagram showing the Stir casting method.

The crucible is equipped with an arrangement for bottom pouring. Upon reaching the target temperature, the molten slurry will be stirred using a twin blade (pitch 45°) mild steel impeller to facilitate the uniform distribution of reinforcement [Muralidharan S/O Paramsothy, (2009)]. The twin blade mild steel impeller is coated with zirconia-ceria alloy powder to avoid iron contamination of the molten metal. The melt was then released through a 10mm diameter orifice at the base of the crucible. An ingot of 40mm diameter can be obtained in the casting die.

3.1 EXPERIMENTAL PROCEDURE FOR STIR CASTING

The fabrication of composite was done in two stages. In first stage, as shown in fig.4, we loaded Mg-Ingot and the alloying element powders and CNTs wrapped in Al foil directly into crucible for melting. Material was heated to 800^0 C in 2hr duration and then given 30min soaking time, so that the material completely become to liquid state. During soaking period the material was stirred for 5min at an interval of 10min.

The melted molten material was poured in to the mould which was kept at the bottom of crucible. Argon gas was supplied continuously during the pouring to inert atmosphere. After solidification of the material it was found that CNTs were agglomerated on the top and side surfaces of the cast specimen as shown in fig 6. To overcome this problem of agglomeration, in second stage, we used planetary ball milling for mixing alloying powder with CNT. The ball milling was done for 1hr at a speed of 250rpm.After the ball milling the powder was compacted into small billets and these billets were added into the crucible along with Mg-ingot as shown in fig.5. The melting was done in the same temperature and processes as discussed in the first phase of the study.



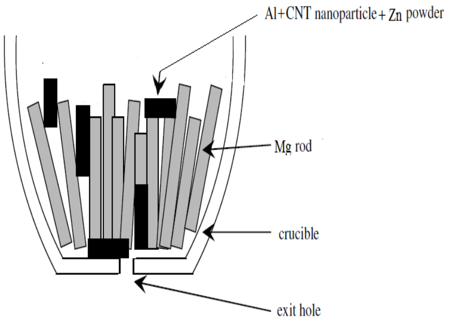


Fig.4. Mg-strips with alloying element powder **Fig.5. Mg-strips with alloying element billets.**

RESULTS AND DISCUSSION

The fig. 6 and fig.7 shows the specimen fabricated by the first phase and second phase of work respectively. It is found that in first phase the CNTs were found agglomerated on the surface and top side of specimen. This is due to improper wetting of CNTs in the Mg-Matrix. This problem of wettability has been improved in second phase of work by reinforcing CNTs into Al particles through ball milling and further reinforcing Al particles into Mg-matrix during melting, which has improved wettability and proper homogenous mixing of CNTs into Mg-matrix.

Fig.6 Agglomeration of CNT on Surface of Cast Specimen.

Fig.7 Proper mixing of CNTs without agglomeration on surface.

It is found that CNTs bring out good strengthening effects on magnesium alloy. As compared with AZ91 magnesium alloy matrix, the tensile strength, yield strength and elongation of the AZ91 nanocomposite are improved in permanent mould casting. [LIU Shi-ying, et.al.(2009)]. Ball milling leads to excellent dispersion but might result in the damage to CNTs. While the quality of dispersion is important, the processes used should also be amenable to bulk production of powders [Jayakumar et.al.(2012)] . The mechanical properties of AZ91-MWCNT are given in Table. 2

Table 2. Effect of CNT addition in MMC on various properties

Material	**Ultimate tensile strength (MPa)**	**Yield Strength(MPa)**
AZ91	187.05	163.32
AZ91+0.33 wt% CNT	219.40	169.5
AZ91+0.66 wt% CNT	267.45	182.5
AZ91+0.99 wt% CNT	210.09	162.3

Similarly the mechanical properties AZ91 alloy after extrusion processes are shown in table.3.The grain of AZ91 alloy as-cast is refined by extruding and dynamic recrystallization, the mechanical properties increase obviously. Hot extrusion of the as-cast and as-extruded AZ91 composites improves the particle distribution, as shown in table.3 refines the grains of matrix, and significantly improves the mechanical properties.

Table.3 Effect of extrusion on mechanical properties of AZ91

Material	**Hardness(RHE)**	
	As-Cast	**As-Extruded**
AZ91	51.5	54.5
AZ91+0.33 wt% CNT	52.75	59.5
AZ91+0.66 wt% CNT	53.5	66
AZ91+0.99 wt% CNT	55.5	76.5

It is found that from our study the mechanical properties are improve due to homogenous mixing of CNT into Mg-matrix and simultaneously extrusion process also will help in aligning the CNTs unidirectional.

CONCLUSION

Processing variables such as holding temperature, stirring speed, size of the impeller, and form of mixing reinforcement to the melt are among the important factors to be considered in the production of cast metal matrix composites as these have an impact on mechanical properties. It is found in our study that the ball milling further helps in reinforcing CNT properly into AZ91 matrix.

I. Tensile properties of AZ91 increases by 42.9% as result of reinforcement of MWCNT and proper alignment of MWCNTs due to hot Extrusion.
II. Hardness of AZ91 increase only by 7.76% due to addition of MWCNTs in casting but after hot extrusion it increases by 40%.

Therefore, by controlling the processing conditions as well as the relative amount of the reinforcement material, it is possible to obtain a composite with a broad range of mechanical properties. The inert atmosphere used during stir casting was effective in preventing oxidation of the Mg melt. Mg-nanocomposites have good future prospects in the automotive and aerospace industries, which will result in enhanced performance.

REFERENCES

[1] R. Purohit, A. Bharathi, A. Chandrashekar, M. Saxena, O. Gahlawat and P. Sharma (2007): Future Trends in Magnesium Matrix Composites, Proceedings of International and INCCOM-6 Conference on Future Trends in Composite Materials and Processing, 12-14 December 2007.
[2] S. R. Bakshi, D. Lahiri and A. Agarwal (2010): Carbon nanotube reinforced metal matrix composites – a review, 2010 Institute of Materials, Minerals and Mining and ASM International Published by Maney for the Institute and ASM International DOI 10.1179/095066009X12572530170543.
[3] HaiZhi Ye, Xing Yang Liu (2004) : Review of recent studies in magnesium matrix composites, Journal Of Materials Science 39(2004) 6153 – 6171.
[4] JayaramanJayakumar ,B.K.Raghunath, T.H.Rao (2012): Recent Development and Challenges in Synthesis of Magnesium Matrix Nano Composites- A Review, International Journal of Latest Research in Science and Technology, Vol.1,Issue 2 :Page No.164-171 ,July-August (2012).
[5] WANG Xiao-jun, HU Xiao-shi, NIE Kai-bo, WU Kun, ZHENG Ming-yi (2012): Hot extrusion of SiCp/AZ91 Mg matrix composites, Trans. Nonferrous Met. Soc. China 22(2012) 1912–1917.
[6] Ming Tan, Zhaoming Liu, GaofengQuan (2012): Effects of Hot Extrusion and Heat Treatment on Mechanical Properties and Microstructures of AZ91 Magnesium Alloy, 2012 International Conference on Future Energy, Environment, and Materials, Energy Procedia 16 (2012) 457 – 460.
[7] LIU Shi-ying, GAO Fei-peng, ZHANG Qiong-yuan, ZHU Xue, LI Wen-zhen (2010):Fabrication of carbon nanotubes reinforced AZ91D composites by ultrasonic processing,Trans.NonferrousMet.Soc.China 20(2010) 1222-1227.
[8] J. Wei, C. S. Goh, S. M. L. Nai, and G. J. Bi (2011): Simultaneous enhancement in strength and ductility by reinforcing magnesium with carbon nanotubes, SIMTech technical reports, Volume 12 Number 3 Jul – Sep 2011.
[9] Zhang Qiang (2010): Development of Hybrid Mg-based Composites, University of Windsor, qiangz@uwindsor.ca 1-1-2010.
[10] Muralidharan S/O Paramsothy (2009):A Thesis Of Degree OF Doctor (2009) BASc.Hons, MEng, NTU, Singapore.
[11] J. Hashim, L. Looney*, M.S.J. Hashmi (1999): Metal matrix composites: production by the stir casting method, Journal of Materials Processing Technology 92±93 (1999) 1-7.