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Optimization and Investigation of Mg-Alloy with MWCNT Nano-Composites for Connecting Rod Application

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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.The automobile engine connecting rod is a high volume production, critical component. It connects reciprocating piston to rotating crankshaft, transmitting the thrust of the piston to the crankshaft. Every vehicle that uses an internal combustion engine requires at least one connecting rod depending upon the number of cylinders in the engine. As the purpose of the connecting rod is to transfer the reciprocating motion of the piston into rotary motion of the crankshaft. Connecting rods for automotive applications are typically manufactured by forging from either wrought steel or powdered metal.The objective of this paper is to optimization and fabrication of connecting rod using Mg-alloy material. Forged steel used to manufacturing the connecting rod presently. Connecting rod is modeled in Solide Works V13.and Model will be imported in ANSYS 13 for analysis. After analysis results will be comparing with experimentally in terms of stress, strain and deformation.The material will be prepared with stir casting process and hot extrusion process***

Index Terms—FEA of connecting rod, Mg-alloy, CNT , stir casting process , hot extrusion process etc.

I. INTRODUCTION

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 [2]. The density of Magnesium is only 65% of the density of commonly used aluminum alloys in the aerospace industry and therefore can be a breakthrough technology if used for low weight airframe structures. However to use this low weight material several mechanical properties have to be increased and the technological behavior improved. The energy crisis and global inclination to reduce green house gas emissions have been catalytic in directing the attention of research scientists to look for light weight materials [3]. Magnesium Matrix Composites (MMCs) have been attracting much attention as light weight materials due to their high specific strength, good castability, good machinability, high damping capacity, and its availability as a natural mineral. Magnesium materials are also 35% and 75% lighter compared aluminum and iron based materials, respectively [4].

A. Recent Trends in Magnesium Technology

Alloy development

Magnesium alloys have two major disadvantages forth 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 aluminum 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

B. Processing

Mechanical Properties of Mg-Alloy

Table No.1 Properties of Mg Alloy

Material selected	Mg-alloy
Compressive yield strength	220 Mpa
Tensile yield strength	220 Mpa
density	1.8 gm cm-3

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THEORETICAL CALCULATION OF CONNECTING ROD :

A]. Pressure calculation:

Consider a 150cc engine

Engine type air cooled 4-stroke
Bore × Stroke (mm) = 57×58.6
Displacement = 149.5CC
Maximum Power = 13.8bhp at 8500rpm
Maximum Torque = 13.4Nm at 6000rpm
Compression Ratio = 9.35/1

- Density of petrol at 288.855 K - 737.22*10-9 kg/mm3
- Molecular weight M - 114.228 g/mole
- Ideal gas constant R – 8.3143 J/mol.k

From gas equation,
PV=m.Rspecific.T
Where, P = Pressure
V = Volume
m = Mass
Rspecific = Specific gas constant
T = Temperature
But,
mass = density * volume
m =737.22E-9*150E3
m = 0.11 kg
Rspecific = R/M
Rspecific = 8.3143/0.114228
Rspecific = 72.76
P = m.Rspecific.T/V
P = 0.11*72.786*288.85/150E3
P = 15.4177 MPa.

Finite Element Method

Finite element method is used to analyze structures by computer simulations and therefore it helps to reduce the time required for prototyping and to avoid numerous test series.The modeling and analysis will be done using Finite element Analysis software.
Steps for finite element analysis:

FEA is mainly divided into three following stages:

- Preprocessing
- Creating the model.
- Defining the element type
- Defining material properties
- Meshing
- Applying loads
- Applying boundary conditions
- Solution: Assembly of equations and
- obtaining solution
- Post processing: Review of results.

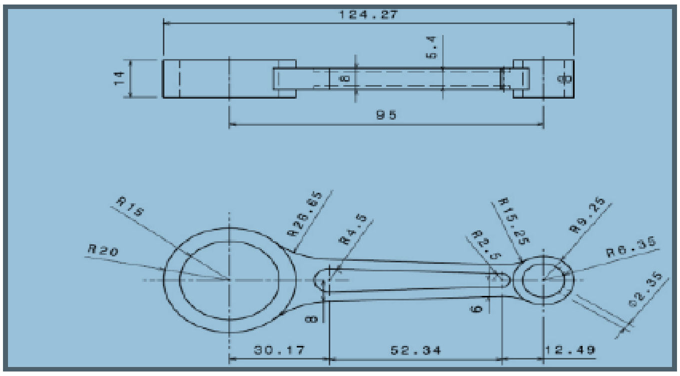

Fig.1 Drawing of Connecting Rod

Modelling of Connecting Rod

The modeling of connecting rod is done with solidworks V13 and after modeling it will be saved in IGS format for analysis.[8]

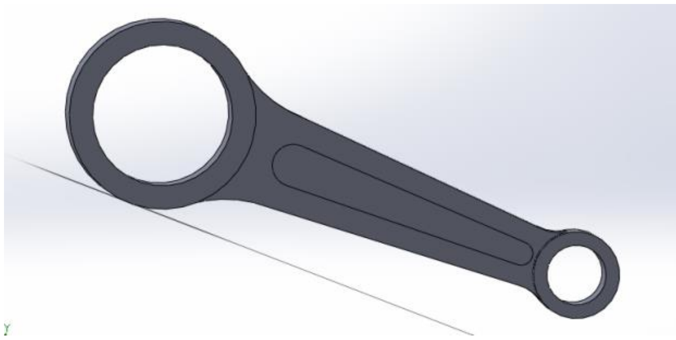

Fig.2 Modelling of Connecting Rod

Meshing

For meshing of the model, element size was taken 1 mm. No. of elements were 22171 and no. of nodes are 37068.

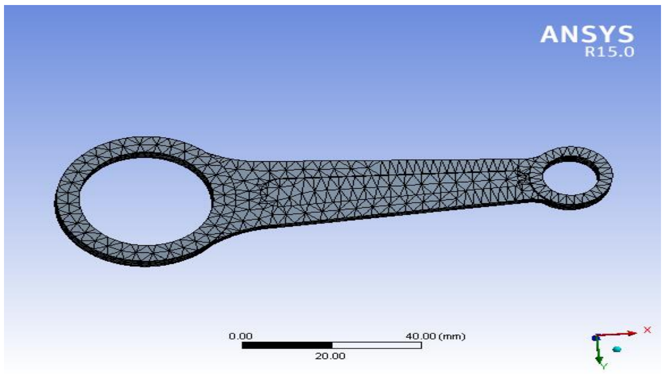

Fig.3 Meshed model

Apply the boundary condition

1) Fixed support

In the ansys we applied the boundary condition Big hole of the connecting rod fixed as shown in below fig.4

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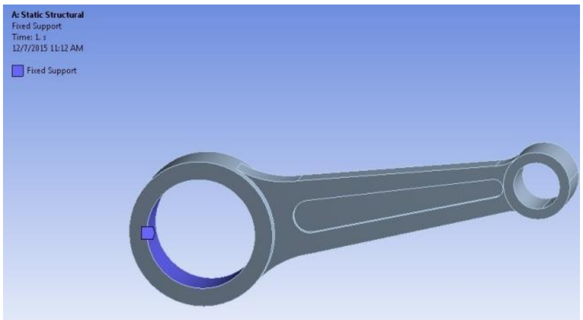

Fig.4 Fixed Support

2) Pressure

For the finite element analysis 15 Mpa of pressure is used. The analysis is carried out using ANSYS software. The pressure is applied at the small end of connecting rod keeping big end fixed. The maximum and minimum vonmisses stress, strain and displacement are noted from the ANSYS.

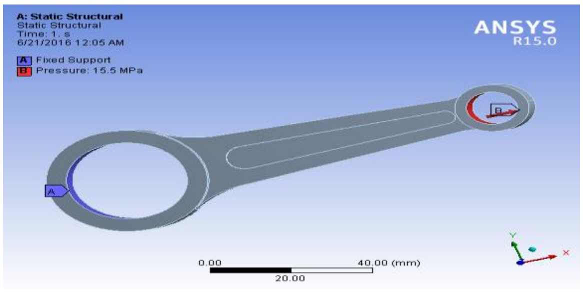

Fig.5 pressure applied on small end

Results of FEA Using Magnesium

1)Von-misses stress

After applying the boundary conditions we get the results in terms of stress as shown in below figure 6. The stress occurs in Mg-alloy connecting rod is 77.579 Mpa.

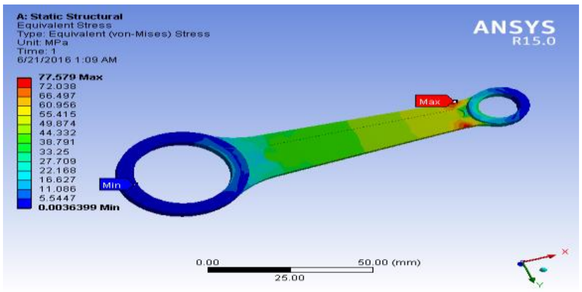

Fig.6 Von-misses stress of Magnesium connecting rod

2)Deformation

The Deformation occurs in the connecting rod is 0.070516 mm as shown in below figure.7

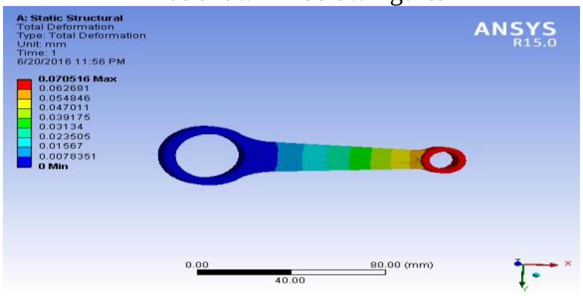

Fig.7 Deformation of Magnesium connecting rod

Results of FEA Using Aluminium Alloy

1)Von-misses stress

After applying the boundary conditions we get the results in terms of stress as shown in below figure 8. The stress occurs in Mg-alloy connecting rod is 99.682 Mpa

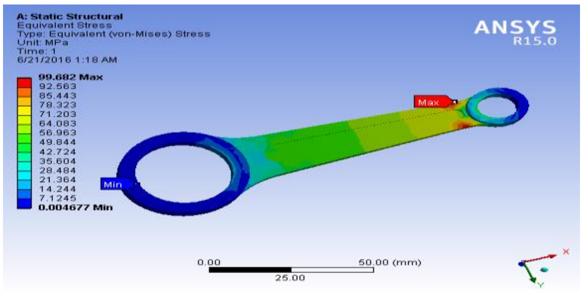

Fig.8 Von-misses stress of structural steel connecting rod

2)Deformation

The Deformation occurs in the connecting rod is 0.080143 mm as shown in below figure.9

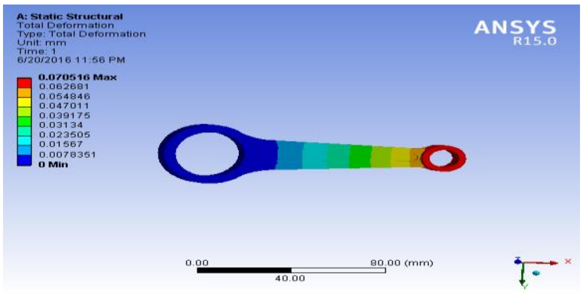

Fig.9 Deformation of structural steel connecting rod

Comparison of FEA Results

Sr no	Type	Magnesium (Mpa)	structural steel (Mpa)
1	Von-misses stress	77.589	99.628
2	Deformation	0.070516	0.080143

Table No.2 FEA Results of Mg-Alloy

Finite Element analysis of the connecting rod has been done using FEA tool ANSYS Workbench and are tabulated in table 2.

1. Static analysis of two materials is carried out by ANSYS and the maximum von misses stress for magnesium alloy 77.589 Mpa and the maximum stress for structural steel is 99.628Mpa
2. Comparing the different results obtained from the analysis, it is concluded that the stress induced in the magnesium is less than the structural steel for the present investigation. Here magnesium can be used for production of connecting rod for long durability.

C. Material used for Connecting rod

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 developing 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.

II. PROBLEM STATEMENT

From the literature review found that the weight of the existing connecting rod is more. and also nobody has done the work with Mg-Alloy with MWCNT composites material for manufacturing. So In this thesis we are optimizing the weight of the connecting rod using Mg-alloy with MWCNT material. And also fabricating the material Mg-Alloy with MWCNT for connecting rod using stir casting process. And trying to optimize the weight. After manufacturing, investigating the mechanical properties of material and comparing with the existing material i.e. structural steel.

IV.METHODOLOGY

A.Stir Casting

Fig.No.10 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 : 1000°C
7.Element position:Elements wound in spiral form and placed in refractory have outside inner chamber.

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.

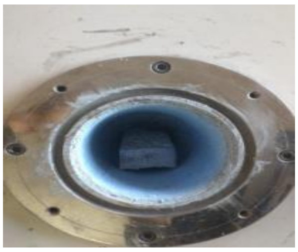

Fig.11 Magnesium block (Before process) **Fig.12** Magnesium rod (After Process)

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.

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 tubes or for the starting stock for drawn rod,cold extrusion or forged products.

Fig. 13 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.

Results of hot extrusion process

Fig.14 Before process

Fig.15 After process

V.RESULTS AND DISCUSSION

1}Tensile Test:

The Tensile test are carried out as per ASTM E8 standard with a specimen size of 5mm diameter and 25mm gauge length on UTM same as compression test carried out on UTM.

Fig.15 Tensile Testing Specimen

1} Ultimate Tensile Strength:

`Sample	UTS Sample1 (Mpa)	UTS Sample 2(Mpa)	Avg.UTS
Pure Mg	155.36	168.4	161.88
Mg+AZ91+0.5%CNT	241.23	230.65	236.01
Mg+AZ91+1%CNT	250.22	264.76	257.49

Table No.3 Ultimate Tensile Strength of Specimen

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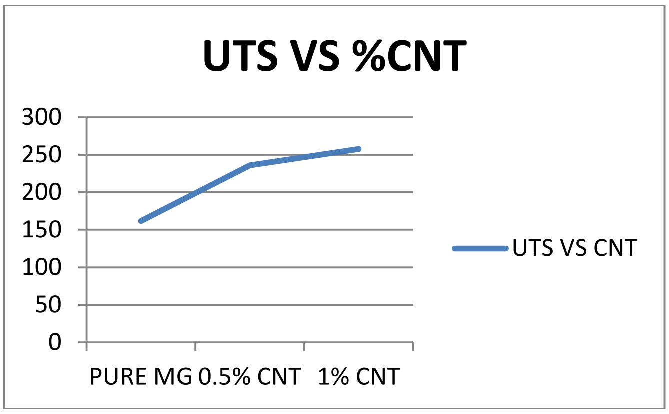


Graph No.1 Ultimate tensile strength Vs % of CNT

2} Yield strength:

`Sample	UTS Sample1 (Mpa)	UTS Sample 2(Mpa)	Avg.UTS
Pure Mg	155.36	168.4	161.88
Mg alloy AZ91+0.5%MWCNT	241.23	230.65	236.01
Mg alloy AZ91+1%MWCNT	250.22	264.76	257.49

Table No.4 Yield strength

2}Hardness Test:

Hardness can measured using Rockwell hardness tester with a load setting of 100 Kg and dual time of 15 sec. Hardness will measured at 4 places in each sample and the average value was taken.

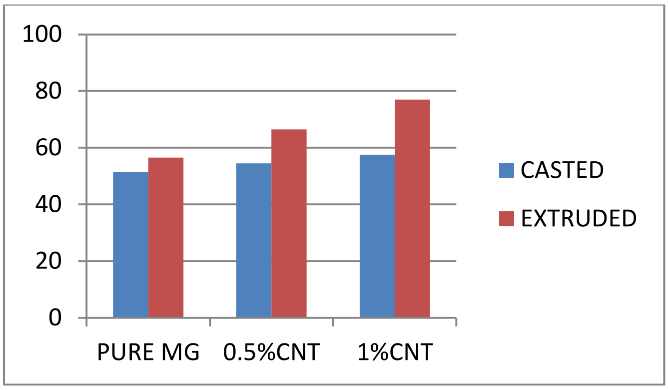
1}Hardness of specimen before extrusion:

`Sample	HRB Sample1	HRB Sample 2	Avg.HRB
Pure Mg	60	61	60.5
Mg alloy AZ91+0.5%MWCNT	62	62	62
Mg alloy AZ91+1%MWCNT	64	64	64

Table No.5 Hardness of specimen before extrusion

2} Hardness of specimen after extrusion:

`Sample	HRB Sample1	HRB Sample 2	Avg.HRB
Pure Mg	63	64	63.5
Mg alloy AZ91+0.5%CNT	67	69	68
Mg alloy AZ91+1%MWCNT	74	76	75



Graph No.2 Hardness Vs CNT

3} Density:

Density measured using Archimedean principle at room temperature using toluene as auxiliary liquid.

Fig.16 Density Measurement

Sample	Density(gm/cm^3)
Mg-Alloy	1.4708
Mg alloy AZ91+0.5%CNT	1.5933
Mg alloy AZ91+1%CNT	1.7902

Table No.6 Density of diff. sample

VI. CONCLUSION

I. Tensile properties of Mg-Alloy+AZ91 increases by 37.13% as result of reinforcement of MWCNT and proper alignment of MWCNTs due to hot Extrusion.

II. Hardness of Mg-Alloy+AZ91 increase only by 10.43% due to addition of MWCNTs in casting specimen but after hot extrusion it increases by 26.62%.

III. The increasing yield strength with higher weight fraction of CNTs is applicable only until wt.1 % of CNT, above which, the yield strength starts to degenerate due to higher amount of porosity in the Mg matrix.

IV. The results of the mechanical behavior reveal that an increasing weight fraction MWCNTs in the AZ91 matrix leads to an improvement in compressive strength.

So after investigation of mechanical properties we found that the all mechanical properties are achieved with comparing the exiting material i.e structural steel for connecting rod. hence this material we can use for connecting rod.

V. In the present study, the prime concern is to find the best suitable material for connecting rod. By checking and comparing the above results it has been noticed that Mg-alloy-MWCNT is the best suitable material for connecting rod of two wheeler vehicle.

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