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Design and Analysis of Connecting Rod with Modified Materials and FEA Analysis

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Abstract **- The main objective is to reduce the weight of connecting rod by replacing steel with aluminium fly ash composite material without losing any of its strength and hardness. Experimental results are obtained from the compressive and tensile tests of connecting rods. Spectrometer test is also performed and the results are found out. It is found that by using aluminium fly ash composite material weight is greatly reduced up to 50% without losing any of its strength and hardness. Finally aluminium and steel connecting rods are analyzed with the help of Ansys and the FEA results are compared with the experimental results both the results are give equal value.**

Key words; Aluminium, fly ash, FEA, Ansys,

1. INTRODUCTION

Connecting rods that function in internal combustion engines are subjected to high cyclic loads comprised of dynamic tensile and compressive loads. They must be capable of transmitting axial tension and compression loads, as well as sustain bending stresses caused by the thrust and pull on the piston and by the centrifugal force of the rotating crankshaft. The invention of the crank-connecting rod system has enabled the invention of numerous machines the most notable of which is the internal combustion engine. It gives a detailed analysis of the comparison of fatigue behavior of wrought forged and powder metallurgy. Finally, this paper will cover some of the more recent developments in the connecting rod industry including: titanium, aluminium, magnesium, and polymeric connecting rods.Starting with the 1962 Buick V-6 engine, General Motor's Central Foundry produced 50 million cast pearlitic malleable iron connecting rods for use in 11 different engines, ranging up to 428 cubic inches in displacement. The design was modified slightly from the existing forging designs due to different requirements of the cross-section. Specifically, the I-beam cross section was increased and more generous radii was given to the end of the connecting rod that fits around the crankshaft. In a 1993 study comparing cast malleable iron connecting rods and ductile iron connecting rods, ductile iron connecting rods outperformed the malleable iron connecting rods in push-pull fatigue tests. These fatigue tests were performed to directly mimic the stresses a connecting rod undergoes in an engine. The average life of a malleable iron connecting rod was 764,962 cycles at a 50% survival rate or 347,734 cycles at a 90% survival rate. While the majority of connecting rods used for automotive production are steel connecting rods, other materials and technologies exist for high performance applications. These materials and processes and discussed below.

2. LITERATURE REVIEW

K. V. Mahendra and K. Radhakrishna [2007] [1] Al–4.5% Cu alloy with Fly Ash as particulates were successfully fabricated using the stir casting method. The Fly Ash content have increases the fluidity length decreases, compressive strength, tensile strength, impact Strength, wear resistance the material matrix composite in good wear resistance The results show an increase in hardness, tensile strength, compression strength, and impact strength with increasing the fly ash content. J. BabuRao, et al [2010] [2] The fly ash has been mixed with 5% aluminium material composite was tested for fluidity, hardness, density, mechanical properties, impact strength and corrosion. The fly ash content increasing that was increase in hardness, tensile strength, compression strength, and impact strength. The density decreases with increasing fly ash content. There has been an increasing interest in composites containing low density and low cost reinforcements. Fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste by-product. The hardness of the composites increased whereas the density of the composites decreased with increasing the amount Fly Ash than the pure aluminium. The aluminium and Fly Ash composite were produced by stir casting route successfully.

Chirsty V Vazhappilly and P. Sathiamurthi [2013] [3] In this study, the objective is taken as to reduce the weight and cost in the design and production of a connecting rod. This paper deals with the study of weight reduction performed under two cyclic loads as dynamic, tensile and static compressive. The existing connecting rod material can be replaced with a now composite material.H. C. Anilkumar, et al [2011] [4] The reinforced aluminum alloy (Al 6061) composites samples, processed by stir casting route are reported in this paper. The Tensile Strength, Compression Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The composites with more than 15% weight fraction of fly ash particles, the tensile strength was seen to be decreasing.

Guangchun Wang and Guogun ZHAO [2002] [5] In this paper, a new technique of Powder forging is introduced A new method of powder forging has been proposed and studied experimentally. In this paper, the punch is divided in to three parts to achieve the desired uniform density. Set of forging dies with flash and another set of forging dies without flash were design and evaluated through hot forging experiments. Based on the properties achieved Fe- C-Cu – Mo was selected as the Powder. By the experimental results, the connecting rod produced by Powder metallurgy hot forging was found to be superior to those manufactured by the traditional method. Mohammad Ranjbarkohan, et al [2011] [6] Nissan Z24 is one of the numerous vehicles in Iran. Mega Motor's reports show high rate damaging in the crankshaft and connecting rod of this engine vehicle. So it is necessary doing a complete research about slider-crank mechanism because of high expensive repair and replacement of these parts and their effect on the other parts like cylinder block and piston. Result of initial researches show that the important reason of these parts damaging is using of downshifting in driving. In this research, we concerned on analysis of kinematics and kinetic of slider-crank mechanism in engine maximum power, maximum torque and downshifting situation and also stress analyze of connecting rod. For this purpose the engine was simulated in software and forces acting on different parts of crank mechanism were extracted after that connecting rod was simulated in Solid Works software, meshed in ANSYS software and critic all loads were stress analysis was done.
Vivek. C, et al [2012] [7] The automobile engine connecting rod is a high volume production critical component. Connecting rods must have the highest possible rigidity at the lowest weight. The connecting rod was analyzed in separately and replacement the connecting rod has been 14% reduced weight for designed. The stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end. Therefore changes with design from connecting rod are stress will be acting on fillet section and connecting rod was broken.

3. MATERIALS AND METHODOLOGY

Table 1. Dimensional parameter for steel connecting rod

Sl. No.	Design Parameters	Dimensions
1.	Centre to Centre length	144.75 mm
2.	Diameter of small end	34 mm
3.	Diameter of big end	58 mm
4.	Inner diameter of small end	23 mm
5.	Inner diameter of big end	32 mm
6.	Breadth of the small end	67.308 mm
7.	Breadth of the big end	36 mm
8.	Thickness of connecting rod	3M

Table 2.Properties Steel Connecting Rod

Sl.No	Parameters	Steel Connecting Rod
1.	Tensile Strength	850.08 N/mm^2
2.	Yield stress	532.56 N/mm^2
3.	Young's Modulus	$2x10^5$ N/mm^2
4.	Poisson's Ratio	0.3
5	Weight	0.795kg

Reducing the Weight, increasing the hardness are the objectives of our project. The existing connecting rod material is steel C55Mn75 which is used in the vehicle like Trump 40 Travelers etc., The dimensions of the connecting rod are measured which is shown in table 1. The mechanical properties of the C55Mn75 material connecting rod are shown in table 2. For reducing the weight and maintaining the strength of the connecting rod, Aluminium is mixed with fly ash. The detailed fabrication methods for aluminium with fly ash content are discussed below.

3.1. Introduction to aluminium Lm6 (Al-Sil2)

LM6 Aluminium is an alloy of silicon and aluminium often used in marine applications due to its corrosion resistance. LM6 can be used as a pressure die casting alloy but is also suitable for both gravity and low pressure casting techniques. LM6 is an Aluminium casting alloy (Al-Sil2). It possesses exceptional casting characteristics, which enable them to be used to produce intricate castings of thick and thin sections. Fluidity and freedom from hot tearing increase with silicon content and are excellent throughout the range. Their resistance to corrosion is very good, but special care is required in machining. In general, the binary alloys are not heat treated; at elevated temperatures their strength falls rapidly. Although of medium strength their hardness and elastic limit are low but they possess excellent ductility. The chemical composition of aluminium LM6 is shown table 3.

Table 3. Chemical composition of LM6

Chemical Composition	%
Copper(Cu)	0.1max
Magnesium(Mo)	0.10max.
Silicon(Si)	10.0-13.0
Iron(Fe)	0.6max.
Manganese(Mg)	0.5max.
Nickel(Ni)	0.1max.
Zinc(Zn)	0.1max.
Lead(Pb)	0.1max.
Tin(Sn)	0.05max.
Titanium(Ti)	0.2max.
Aluminium(Al)	Remainder

3.2. Fly ash

Fly ash is the finely divided residue that results from the combustion of pulverized coal that is carried from the combustion chamber of a furnace by exhaust gases. Fly ash produced during the burning of powdered coal in thermal power plants is a hazardous waste. However, its physical and chemical properties make it an ideal raw material for producing high quality and cost-effective bricks, interlocking pavers, herb stones and mosaic tiles. The chemical composition and engineering properties of fly ash is shown in table 4 and table 5.

Table 4. Chemical Composition of Al-Fly ash

Chemical Composition	%
Aluminium(Al)	93.38
Silicon(Si)	5.37
Iron(Fe)	0.635
Copper(Cu)	0.208
Manganese(Mn)	0.0552
Magnesium(Mg)	0.00
Chromium(Cr)	0.0085
Nickel(Ni)	0.018
Zinc(Zn)	0.148
Tin(Sn)	0.037
Titanium(Ti)	0.0084
Lead(Pb)	0.124
Calcium(Ca)	0.0094

Table 5. Engineering properties of fly ash

Parameter	Specifications
Specific gravity	1.90-2.55
Plasticity	Non Plastic
Proctor compaction - Maximum dry density (gm/cc)	0.90-1.60
Optimum moisture content (%)	38.0-18.0
Angle of internal friction (O)	30^0-40^0
Cohesion (kg/cm^2)	Negligible
Compression index	0.05-0.4
Permeability (CM/SEC)	10^5-10^3
Clay size fraction (%)	1-10
Silt size fraction (%)	8-85
Sand size fraction (%)	7-90
Gravel size fraction (%)	0-10
Coefficient of uniformity	3.1-10.7

3.3. Fabrication of connecting rod

The aluminium and Fly Ash is chosen for fabricating the connecting rod. Aluminium LM6 is the chosen grade which is shown in the Figure 1, due to its low cost. The fabrication of connecting rod is started by fabricating the composite material. At initial step, the fly Ash is shown in the Figure 2, which is pre heated from 150°C to 400°C. The aluminium LM6 is then heated up to 800°C then the fly Ash is mixed with aluminium. The aluminium and Fly Ash is mixed in the ratio of 5:1. Then heated composite is made into rectangular blocks is shown in the Figure 4. Sand casting method is used in making these blocks.

Figure 1. Aluminium LM6 materials

The dimension collected from the steel connecting rod is used for machining new cast aluminium blocks. The machining of blocks are made in the vertical milling machine. The machined connecting rod is shown in the Figure 5.

Figure 2. Fly ash

Figure 3. Crucible furnace

Figure 4. Sand cast rectangular block

Figure 5. Fabrication of connecting rod

4. RESULTS AND DISCUSSIONS

In this work, the aluminium (LM6) with fly ash material is used to fabricate the connecting rod. The fabricated connecting rod is compared with the steel connecting rod. The tensile strength and compressive strength of the two different materials connecting rods are compared. And it is noted that both the connecting rods are of equal strength. The hardness number of both connecting rods is also compared and it is noted that they are of nearly equal hardness. Both the connecting rod weight is also compared and it is found that the aluminium with fly ash composite material connecting rod is less weight when compared to the steel connecting rod. The final result is shown in table 5.

Table 5. Comparison Results

Sl.No.	Parameters	Steel Connecting Rod	Aluminium Connecting Rod
1.	Tensile Strength	850.08 N/mm^2	764.76 N/mm^2
2.	Yield stress	532.56 N/mm^2	552.6 N/mm^2
3.	Young's Modulus	$2x10^5$ N/mm^2	1491.2 N/mm^2
4.	Poisson's Ratio	0.3	0.33
5.	Weight	0.795kg	0.295kg

4.1. Finite Element Analysis

Using Ansys analysis software, the steel type connecting rod and aluminium fly ash material connecting rods were subjected to compressive load and tensile load. Then the rods under different loads were analyzed and the results were found and it is tabulated then which is compared with experimental results. The experimental results and FEA results are shown in table 6. In FEA analysis for analyzing the both connecting rods 8 node quad (plane 82) chooses as a element type. Poisson's ratio taken as 0.3. Mesh range selected as 0.5. table 6. Shows the FEA results for both steel and aluminium connecting rods.

Table 6. FEA Comparison Results

Sl.No.	Parameters	FEA analysis Steel Connecting Rod	FEA analysis Aluminium Connecting Rod
1.	Tensile Strength	858.1 N/mm^2	760.76 N/mm^2
2.	Compressive strength	529.47 N/mm^2	549.6 N/mm^2

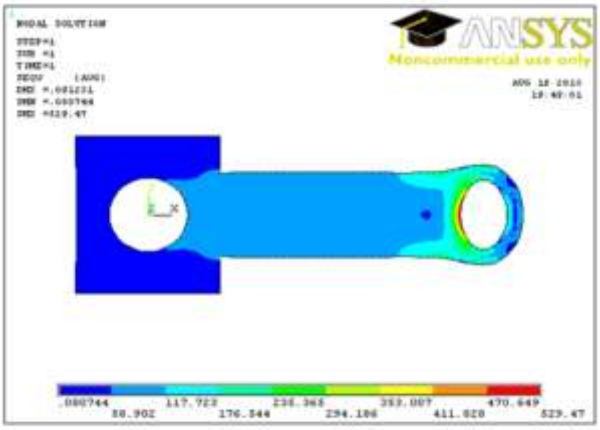

Figure 6. Compressive stress result for steel connecting rod.

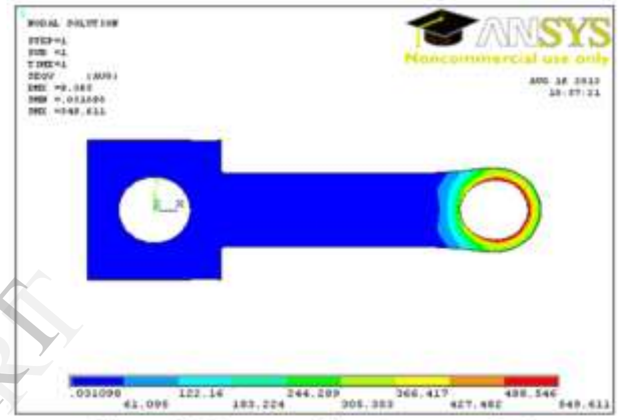

Figure 7. Compressive stress result for aluminium connecting rod.

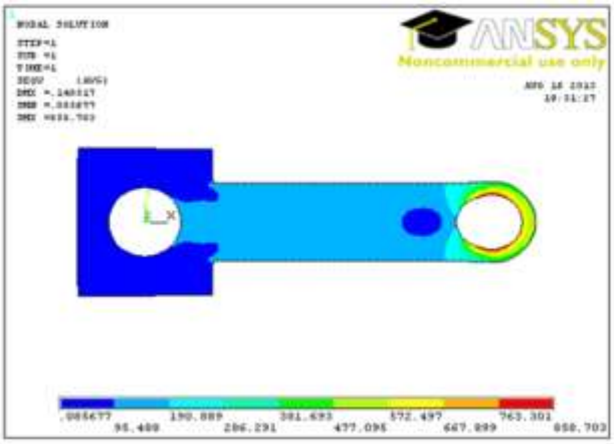

Figure 8. Tensile stress result for steel connecting rod

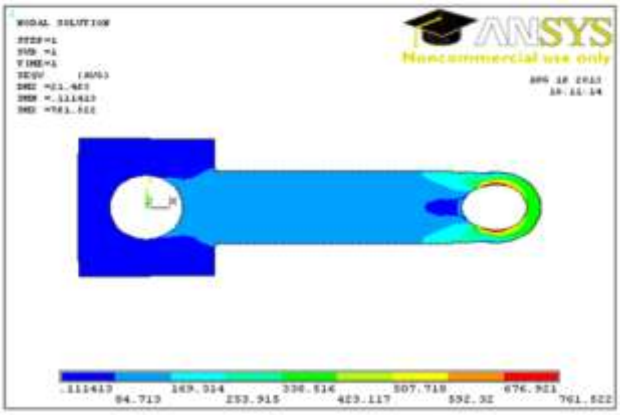

Figure 9. Tensile stress result for aluminium connecting rod.

The figure 6, 7, 8 and 9 shows the results of tensile and compressive stress for aluminium and steel connecting rods.

5. Conclusion

Experimental results from testing the tensile and compressive stresses are listed in the results and discussions. It is concluded that the aluminium Fly Ash composite material connecting rod weight is only one third when compared to the steel connecting rod. The steel connecting rod is replaced by the Fly Ash composite material connecting rod. The main objective of this work is to reduce the weight of the connecting rod without losing their strength by replacing the steel connecting rod with aluminium Fly Ash composite will reduce the weight up to 50%. Thus the main objective of reducing the weight in the connecting rod was obtained. The final results were compared with FEA results.

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