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Design, Fabrication and Analysis of a Connecting Rod with Aluminum Alloys and Carbon Fiber

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ABSTRACT: In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. The present work has been undertaken to replace the existing connecting rod made of forged steel which is broken for LML Freedom with the aluminum connecting rod. The spare parts of the motorcycle are not available as the production has stopped. In this thesis, the connecting rod is modeled in Pro/Engineer, forces are calculated, analysis is done on the connecting rod using materials aluminum 6061, aluminum 7075, aluminum 2014carbon fiber 280 gsm bidirectional, and Analysis is also done for the assembly of piston, connecting rod and crankshaft. The prototype of the connecting rod is made using direct machining for aluminum alloy and hand layup method for carbon fiber connecting rod.

I. INTRODUCTION

In a reciprocating piston engine, the connecting rod connects the piston to the crank or crankshaft. In modern automotive internal combustion engines, the connecting rods are most usually made of steel for production engines, but can be made of aluminum (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for a combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron for applications such as motor scooters. They are not rigidly fixed at either end, so that the angle between the connecting rod and the piston can change as the rod moves up and down and rotates around the crankshaft. Connecting rods, especially in racing engines, may be called "billet" rods, if they are machined out of a solid billet of metal, rather than being cast. The con rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bolts from a defect, improper tightening, or re-use of already used (stressed) bolts where not recommended. This is because production auto parts have a much larger factor of safety, and often more systematic quality control.

II. MATERIALS USED FOR CONNECTING ROD

The connecting rod is the intermediate member between the piston and the Connecting Rod. Its primary function the push and pull from the piston pin to the crank pin and thus converts the reciprocating motion of the piston into rotary

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motion of the crank. The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases to the third power with increasing engine speed. Steel is normally used for construction of automobile connecting rods because of its strength, durability, and lower cost. However, steel with its high mass density exerts excessive stresses on the crankshaft of a high speed engine. This in turn requires a heavier crankshaft for carrying the loads and, therefore, the maximum RPM of the engine is limited. Additionally, higher inertia loads, such as those caused by steel connecting rods and heavier crankshafts reduces the acceleration or declaration rates of engine speed. 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. With steel forging, the material is inexpensive and the rough part manufacturing process is cost effective. Bringing the part to final dimensions under tight tolerance results in high expenditure for machining, as the blank usually contains more excess material. The first aspect was to investigate and compare fatigue strength of steel forged connecting rods with that of the powder forged connecting rods. Due to its large volume production, it is only logical that optimization of the connecting rod for its weight or volume will result in large-scale savings. It can also achieve the objective of reducing the weight of the engine component, thus reducing inertia loads, reducing engine weight and improving engine performance and fuel economy.A composite is a material that is formed by combining two or more materials to achieve some superior properties. Almost all the materials which we see around us are composites. Some of them like woods, bones, stones, etc. are natural composites, as they are either grown in nature or developed by natural processes.. The hybrid glass/carbon fibre composite drive shafts, introduced around 1982 in Mazda's, provided more weight savings, lower maintenance cost, reduced level of noise and vibration and higher efficiency compared to their metal counterparts. The more recent pickup truck GMT-400 (1988 model) carries a composite driveshaft that is pultruded around a 0.2cm thick and 10cm diameter aluminum tube. The composite driver shaft is 60% lighter than the original steel shaft and possesses superior dampening and torsional properties. Chevrolet Corvette models carry filament wound composite leaf springs (mono-leaf) in both rear suspension (1081) and front suspension (1984). These springs were later introduced during 1985 on the GM Chevrolet Astor van and Safari van. Fiber glass reinforced polypropylene bumper beams were introduced on Chevrolet Corvette Ford and GM passenger cars (1987 models).

III.LITERATURE SURVEY

1.In the paper done by AbhinavGautam, K PriyaAjit , static stress analysis of connecting rod made up of SS 304 used in Cummins NTA 885 BC engine is conducted, It is observed that the area close to root of the smaller end is very prone to failure, may be due to higher crushing load due to gudgeon pin assembly. As the stress value is maximum in this area and stresses are repetitive in nature so chances of fatigue failure are always higher close to this region. **2.** In the paper by Ram Bansal, it is noted that the The connecting rod deformation was mainly bending due to buckling under the critical loading. And the maximum deformation was located due to crush & shear failure of the big & small end bearings. So these areas prone to appear the fatigue crack. Base on the results, we can forecast the possibility of mutual interference between the connecting rod and other parts. The results provide a theoretical basis to optimize the design and fatigue life calculation. **3.**In the paper by Kuldeep B, Arun L.R, Mohammed Faheem, it is concluded that Weight can be reduced by changing the material of the current al360 connecting rod to hybrid ALFASiC composites. The new optimised connecting rod is comparatively much stiffer than the former. **4.**In the thesis by Pravardhan S. Shenoy and Ali Fatemi, Optimization was performed to reduce weight and manufacturing cost of a forged steel connecting rod subjected to cyclic load comprising the peak compressive gas load and the peak dynamic tensile load at 5700 rev/min, corresponding to 360^o crank angle. **5.**In the thesis by GVSS Sharma and P SrinivasaRao, Statistical process control is an excellent quality assurance tool to improve the quality of manufacture and ultimately scores on end-customer satisfaction. SPC uses process monitoring charts to record the key quality characteristics (KQCs) of the component in manufacture. This paper elaborates on one such KQC of the manufacturing of a connecting rod of an internal combustion engine. **6.**In the thesis by K. Sudershn Kumar, Dr. K. Tirupathi Reddy, Syed Altaf Hussain, for considering the parameters, the working factor of safety is nearer to theoretical factor of safety in aluminum boron carbide. Percentage of reduction in weight is same in Aluminum 360 and aluminum boron carbide. Percentage of increase in stiffness in aluminum boron carbide is more. Percentage of reducing in stress ALUMINIUM BORON CARBIDE and ALUMNUM is same than CARBON STEEL. **7.**In the paper by Suraj Pal, Sunil kumar, Finite Element analysis of the

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connecting rod of a Hero Honda Splendor has been done using FEA tool ANSYS Workbench. It is concluded that the weight of the connecting rod is also reduced by 0.477g. Thereby, reduces the inertia force. Fatigue strength is the most important driving factor for the design of connecting rod and it is found that the fatigue results are in good agreement with the existing result. **8.**In the journal paper by Prof. Vivek C. Pathade , Dr. Dilip S. Ingole, From the theoretical , Finite Element Analysis and Photoelastic Analysis it is found that i) The stresses induced in the small end of the connecting rod are greater than the stresses induced at the big end. ii) Form the photoelastic analysis(from the fringe developed in the photoelastic model of connecting rod) it is found that the stress concentration effect exist at both small end and big end and it is negligible in the middle portion of the connecting rod. iii) Therefore, the chances of failure of the connecting rod may be at fillet section of both end. **9.** In the paper by Priyank D. Toliya, Ravi C. Trivedi, Prof. Nikhil J. Chotai, the objective of this research is to investigate the failure analysis of the connecting rod of the automotive engine. Apart from conventional material of connecting rod I choose the connecting rod of FM-70 Diesel engine which is made of Aluminium 6351. static analysis is done to determine the von Misses stress, elastic strain, total deformation in the present design connecting rod for the given loading conditions using the FEM Software Ansys 12.1 .In the starting of the work, the static loads acting on the connecting rod, After that the work is carried out for safe design and life in fatigue. Fatigue Analysis is compared with the Experimental results. **10.**In the paper by S. Shaari, M.M. Rahman, it is concluded that the modeling of connecting rod and FE Analysis has been presented. Topology optimization were analyzed to the connecting rod and according to the results, it can be concluded that the weight of optimized design is 11.7% lighter and maximum stress also predicted lower than the initial design of connecting rod. The results clearly indicate that the new design much lighter and has more strength than initial design of connecting rod. **11.**In the paper by Bhuptani K. M, it is well known fact that connecting rod is the important intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. Existing Bearing of connecting rod is manufactured by using nonferrous materials like Gunmetal, Phosphor Bronze etc.. This paper describes modeling and analysis of connecting rod bearing for small end using ProE Wildfire 4.0.A two dimensional drawing is drafted from the calculations. A parametric model of bearing is modeled using PRO-E 4.0 software. Analysis is carried out by using Pro-mechanica software. Static structural analysis of Bearing for small end of connecting rod is done by considering three different materials. The best combination of parameters like Von misses stress; Maximum shear stress and weight reduction for Four stroke diesel engine were studied in ProE software. In the paper by Tukaram S. Sarkate, Sachin P. Washimkar, Sachin S. Dhulekarssss, it is concluded that The stress analysis of connecting used in engine has been presented and discuss in this paper. The results obtain by FEA for both Aluminum 7068 alloy and AISI 4340 alloy steel are satisfactory for all possible loading conditions. By using Aluminum 7068 alloy instead of AISI 4340 alloy steel can reduce weight up to 63.95%. Also equivalent stresses for Aluminum 7068 alloy is less by 3.59%. The factor of safety of connecting rod will reduce by 9.77% in case tensile load applied at crank end but it will increase in all other load conditions if Aluminum7068 alloy is used instead of AISI 4340

IV. METHODS GENERALLY USED FOR MANUFACTURING THE CONNECTING ROD

1 Wrought Forged Connecting Rods

It is unclear when the first wrought forged connecting rod was produced but the wrought forged connecting rod has long been the “standard” for the automotive industry. Plain carbon steel forgings were the initial material of choice. Since a finished connecting rod cannot be formed in one blow, the forging dies for connecting rods have several impressions, each step moving progressively toward the final shape. The metal billet, or starting material, is transferred from one impression to another between successive blows. Figure 6 shows a set of forging dies and the main steps in forging a connecting rod. Often, the cap part and lower rod part are forged separately, or forged slightly oblong and sawed in two pieces. After the part has been forged it must be heat treated to reach the desired properties and then straightened after the heat treating operation. To ensure proper weight and balance of the finished rod, the rod is forged with extra weight in the form of balancing pads on both ends of the rod These balancing pads are then machined during10 the finishing operation to obtain a well balanced connecting rod. The rod and cap are finish machined using several operations including broaching, milling, boring, honing, fringing and other finishing steps.

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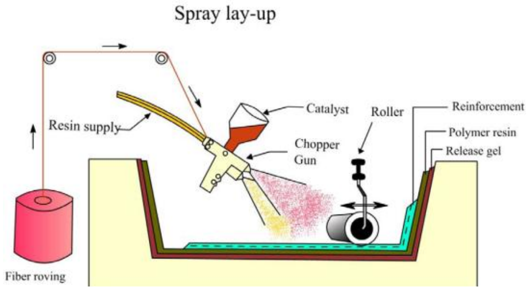

Fig 1: Resin Film Infusion Process and Fiberglass Spray Lay-up Process

2 Fiberglass Spray Lay-up Process

Is very different from the hand lay-up process .The difference comes from the application of the fiber and resin material to the mold. Spray-up is an open-molding composites fabrication process where resin and reinforcements are sprayed onto a reusable mold. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam, or other core material may then be added, and a secondary spray-up layer embeds the core between the laminates. The part is then cured, cooled, and removed from the mold.

3 Hand Layup Method For Composite Material.

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after Perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribedhardener (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The time of curing depends on type of polymer used for composite processing. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, daises board, deck etc.

V.EXPERIMENTAL WORK

The LML freedom 2002 edition bike connecting rod was taken up as a project to be replaced by aluminum and carbon fiber. The connecting rod of the bike had broken due to the wear and tear of the rod since 11 years when used under regular maintenance

Fig 2:Actually Broken Connecting Rod Of The Bike

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The models where prepared by taking the dimension from the parts which were available when the engine was deconstructed for removing and studying the connecting rod and other components.

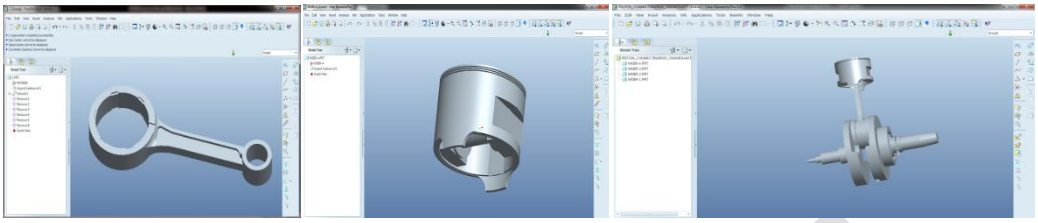

Fig 3: The Connecting Rod Model, Piston Model and Assembly

The materials chose for manufacturing the connecting rod Aluminum alloy 6061, Aluminum , 075, Aluminum 2014, Carbon fiber 280gsm bidirectional, The materials where tested using ansys software for the stress and strain and other forces acting on the connecting rod.

Table: MATERIAL PROPERTIES

	Aluminum alloy 6061	Aluminum alloy 7075	Aluminum alloy 2014
Aluminum, Al	95.8 - 98.6 %	87.1 - 91.4 %	90.4 - 95 %
Chromium, Cr	0.04 - 0.35 %	0.18 - 0.28 %	0.10 %
Copper, Cu	0.15 - 0.40 %	1.2 - 2.0 %	3.9 - 5.0 %
Iron, Fe	0.70 %	0.50 %	0.70 %
Magnesium, Mg	0.80 - 1.2 %	2.1 - 2.9 %	0.20 - 0.80 %
Manganese, Mn	0.15 %	0.30 %	0.40 - 1.2 %
Silicon, Si	0.40 - 0.80 %	0.40 %	0.50 - 1.2 %
Titanium, Ti	0.15 %	0.20 %	0.15 %
Zinc, Zn	0.25	5.1 - 6.1 %	0.25

VI. STRUCTURAL ANALYSIS OF CONNECTING ROD

Table: Material Properties of Different Materials used in manufacturing of connecting rod

	Aluminum alloy 6061	**Aluminum alloy 7075**	**Aluminum alloy 2014**	**Carbon fiber**
Young modulus	68.9GPa	71.7GPa	72.4GPa	
Poisson's ratio	0.33	0.33	0.33	
Density	2.1g/cc	2.81g/cm³	2.80 g/cm³	1.6Kg/mm^3
Shear Modulus	26 GPa	26.9GPa	26.5GPa	0.6 Msi
Tensile Strength, Ultimate	290MPa	572 Mpa	220Mpa	75-85N/mm^2
Shear Strength	186MPa	331MPa	124MPa	600MPa

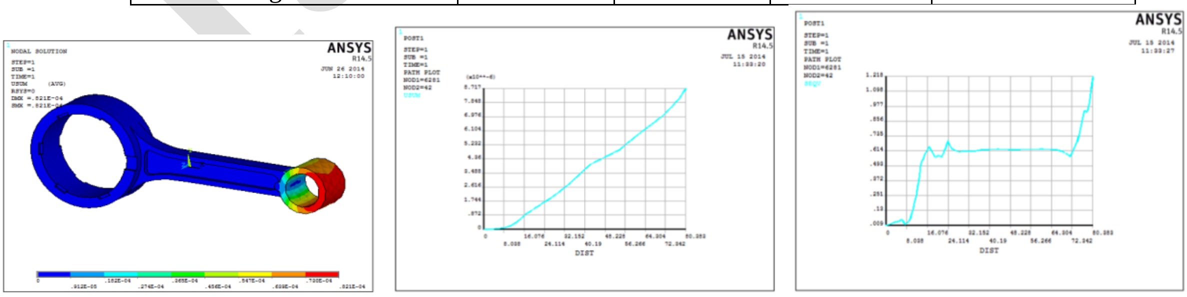

Fig 4: Displacement and Stress on Connecting Rod Of Al6061

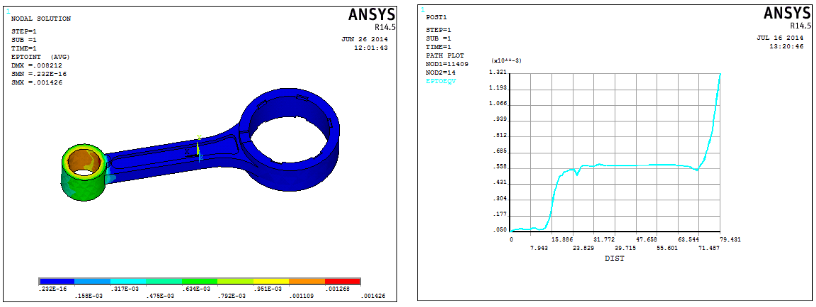

Fig 5: Strain induced .001426 On The Connecting Rod Of Al2014 and Starin On Connecting Rod Of Al2014

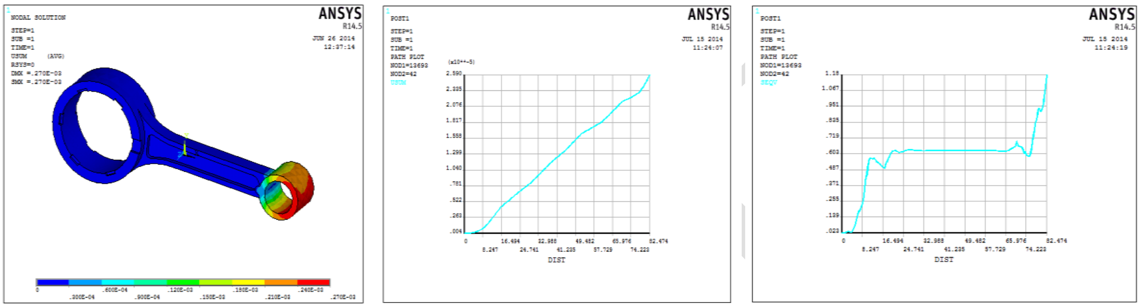

Fig 6: The Displacement and Stress induced on Connecting Rod Of Carbon Fiber

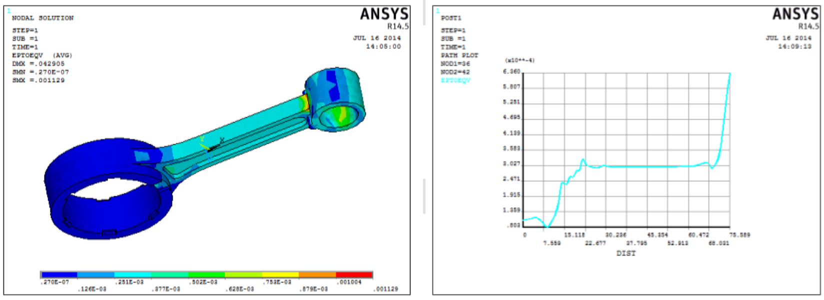

Fig 7:Strain induced .001129 On The Connecting Rod Of Al7075 and Starin On Connecting Rod Of Al7075

Table 6.2.4Table of Results for Stress And Strain

	Aluminum 6061	Aluminum 7075	Aluminum 2014	Carbon Fiber
Displacement (mm)	0.821E-04	0.845e-04	0.008212	$0.2701e^{-03}$
Stress (N/mm^2)	71.5632	72.2133	71.5869	72.5887
Strain	0.43E-04	0.147E-04	0.001425	0.484E-04
Ultimate tensile strength	117 MPa	221 MPa	220 MPa	

Table 6.3: Modal and Harmonic Analysis For Aluminum Alloy Connecting Rod

Mode displacement	Aluminum alloy 2014	Aluminum alloy 6061	Aluminum alloy 7075	Carbon fiber
Mode 1 Hz	16.0473	159.125	141.203	113.183
Mode 2 Hz	36.3806	360.749	320.012	256.224

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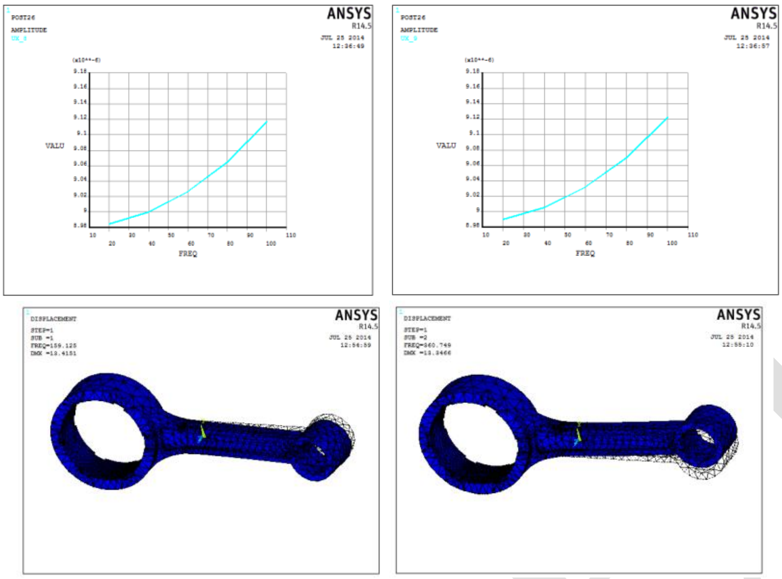

Fig 8: Model Analysis for Al 6061

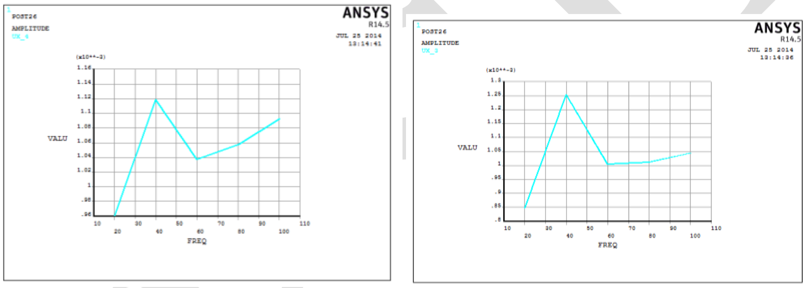

Fig 9: Harmonic Analysis for Al 2014

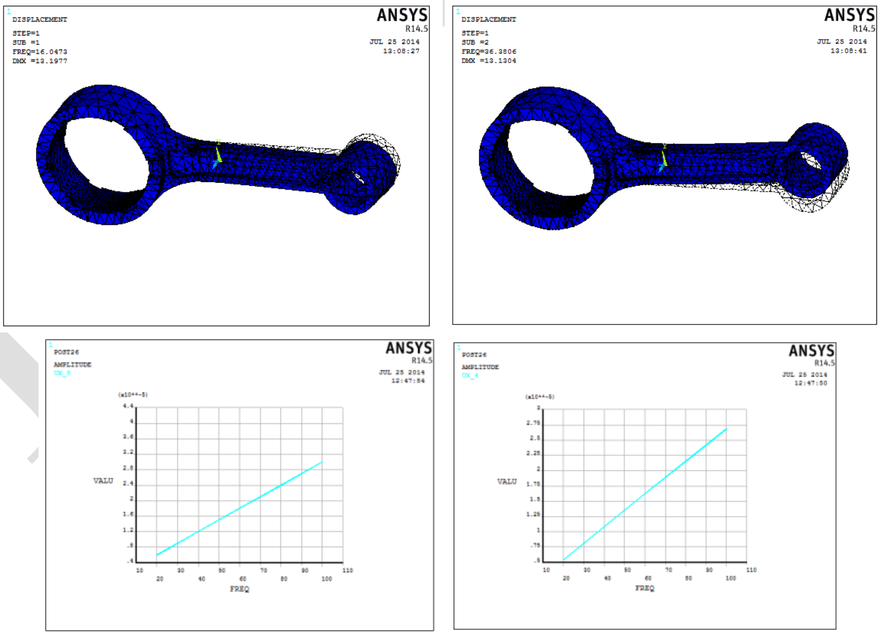

Fig 10: Harmonic Analysis for Carbon Fiber

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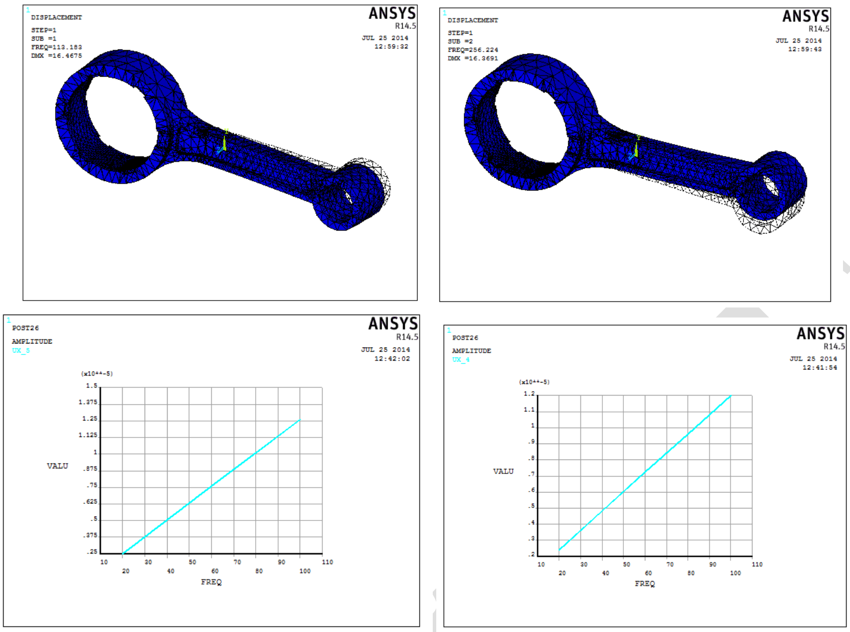

Fig 11: Harmonic Analysis For Al 7075

The forces where applied on the piston head and the effect of it on the connecting rod was studied in this analysis. The piston connecting rod and the crank shaft comprise of a system all together. The pressure developed in the chamber first affects the piston top and then form there pass to the connecting rod through the gadget pin to the small end of the rod and then through the steam to the big end of the rod and then to the crank shaft which rotates and converts the reciprocating motion into rotary motion.

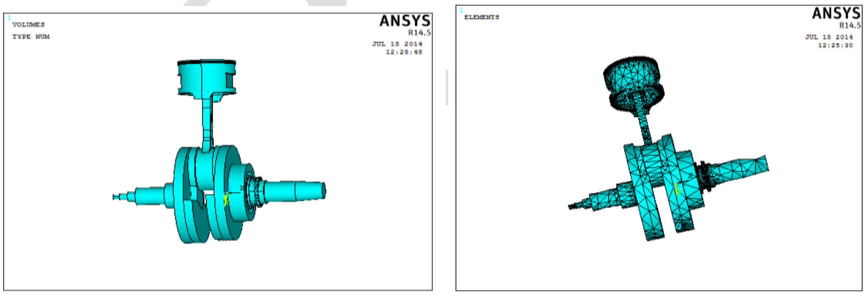

Fig 12: Imported model in ANSYS and Mesh Model for Carbon Fiber Connecting Rod in Assembly

VII. STRUCTURAL ANALYSIS OF CARBON FIBER FOR CONNECTING ROD

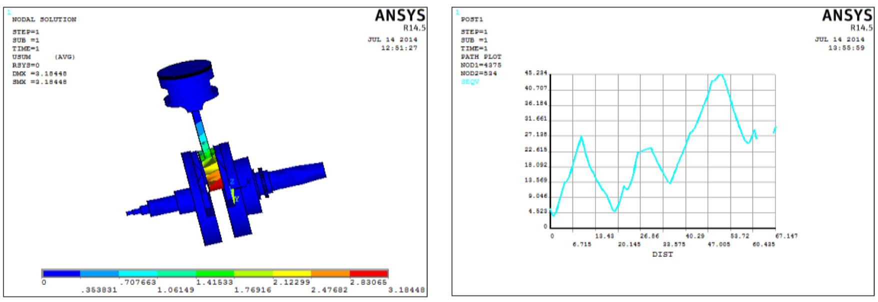

Fig 13: Displacement Induced 3.18448 In Assemblies For Carbon Fiber Rod

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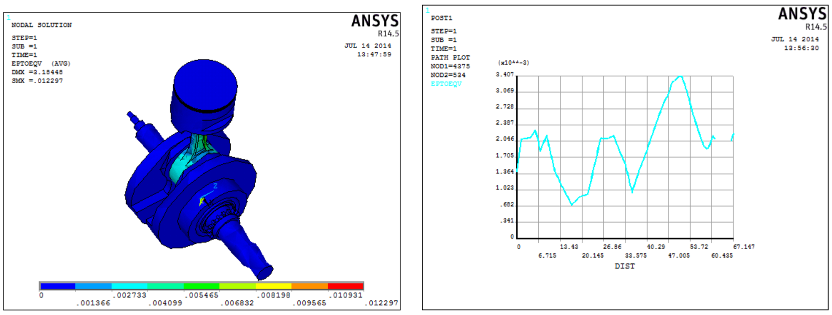

Fig 14: Strain on Carbon Fiber Rod In Assembly

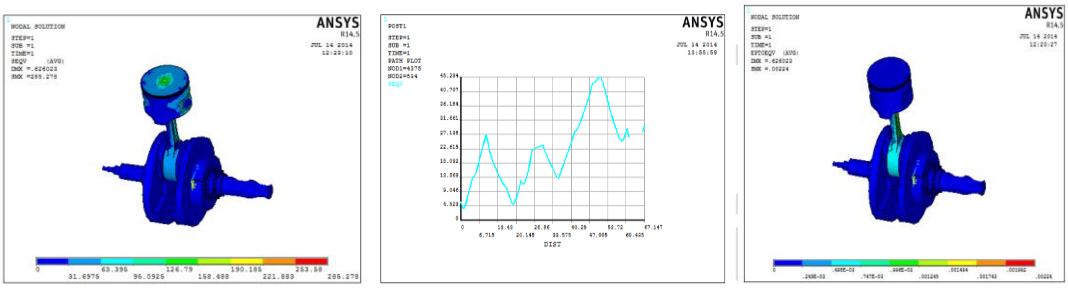

Fig 15: Stress Graph on Al6061 Rod In Assembly

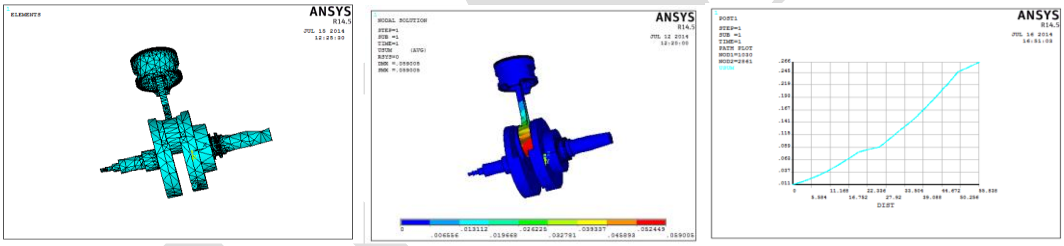

Fig 16: Mesh Model for Al2014 Assembly and Displacement on Al2014 Rod In Assembly

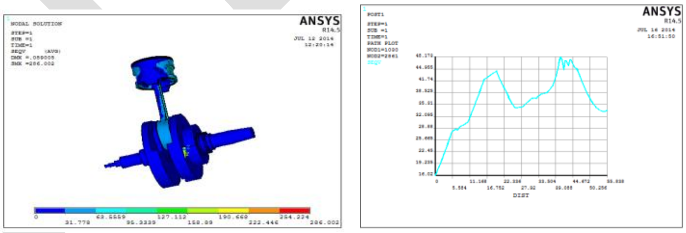

Fig 17: Stress Induced on Al2014 Rod In Assembly and Stress on Al2014 Rod In Assembly

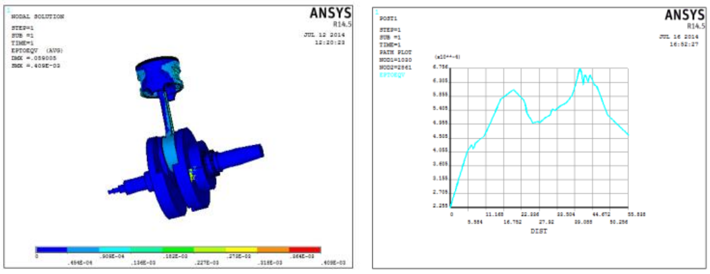

Fig 18 Strain Induced on Al2014 Rod In Assembly and Strain on Al2014 Rod In Assembly

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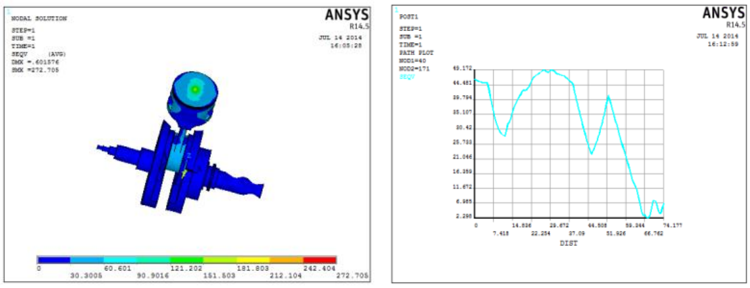

Fig 19: Stress Induced on Al7075 Rod In Assembly and Stress on Al7075 Rod In Assembly

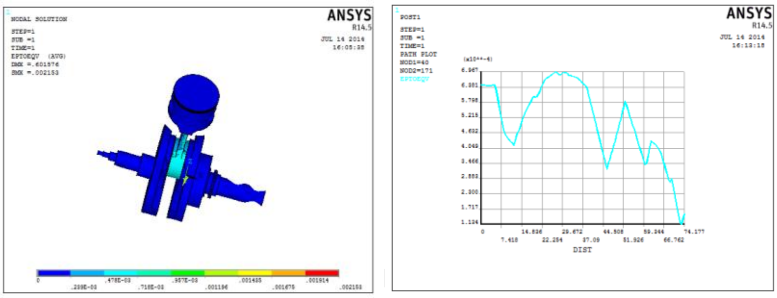

Fig 20: Strain Induced on Al7075 Rod in Assembly and Strain on Al7075 Rod In Assembly

Table 6.4.6: Results for Displacement Stress And Strains

MATERIALS	RESULTS		
	DISPLACEMENT (mm)	STRESS N/mm^2	STRAIN
ALUMINIUM2014	0.059605	286.002	0.409E-03
ALUMINIUM6061	0.626023	285.278	0.00224
ALUMINIUM7075	0.601576	272.705	0.002153
CARBON FIBER	3.18448	277.723	0.012297

The materials were chosen and the connecting rod was manufactured by the two processes respectively. The ingot of the specified material where purchased from the dealers of the required materials.The ingots where machined using the CNC machine by the model modeled on Pro-Engineer and it was transferred to the machine. The work piece on the table was clamped with bench wise again fixed to the table in the T slots. The cutter was aligned properly by once setting the co- ordinates. The bores are precision honed. All corners where blended to eliminate stress at corners.

Fig 21: CNC machining of aluminum block

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Fig 22: Mold Preparation

The carbon fiber connecting rod was produced using hand layup method First the half mold was made by making a wooden pattern around the half periphery of the rod. The holes were also covered with the wooden pattern and screws were fit into them to pull them out after the half mold is built. The releasing agent was then applied so that when the mold is ready after drying it is easily removed from the pattern and doesn't stick to it. The realizing has to be applied properly otherwise the mold may break while separating. The half mold was prepared by using the fiber glass material which was placed by hand layer after layer and applying the general purpose resin mixed with the accelerator copaland then the catalyst methyl-ethyl copal is added while layers are added and left for drying.

Fig 23: Fiber Glass Mold Preparation

The fiber glass mold of one side was ready after drying and then the other side of the pattern was used and the other half of the mold was prepared. The other half mold was also prepared the same way. The other half is also made the same way by removing the wooden pattern from the middle. The mold is ready now the carbon fiber is laid in the mold layer by layer and applying the epofine 1556 and fine hard 951 simultaneously by hand and the final product is obtained. The connecting rods of the aluminum alloy where solution heat treated to increase their strength and mechanical properties at temperatures of around 480c and was held in water for 30 minutes. The rods after solution heat treatment and stress revealing operation. The aluminum connecting rods where then fit in the engine step by step as shown in the following figures.

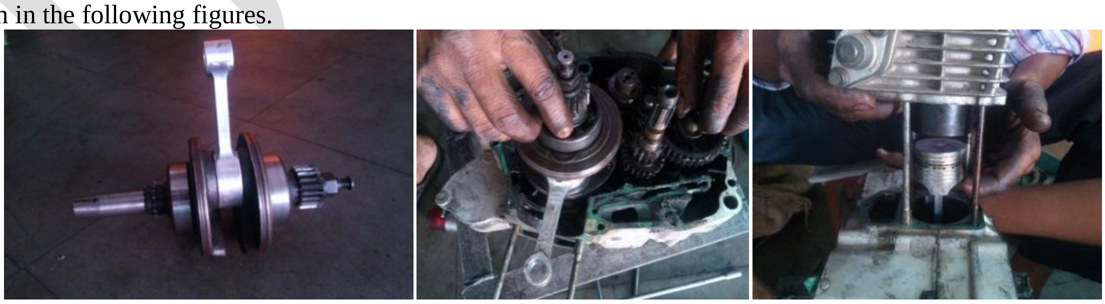

Fig 24: Solution Heat Treated Rod

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Table 8.1: Result Table for Analysis of Connecting Rod

	Aluminum 6061	Aluminum 7075	Aluminum 2014	Carbon Fiber
Displacement (mm)	0.821E-04	0.845e-04	0.008212	0.2701e^{-03}
Stress (N/mm^2)	71.5632	72.2133	71.5869	72.5887
Strain	0.43E-04	0.001129	0.001425	0.484E-04
Ultimate tensile Strength, MPa	117	221	220	

By observing the results of Aluminum Alloy 6061, the displacement 0.821e^{-4} is more at the small end and decreasing towards the big end, the stress 71.5632 is more at the small end and decreasing towards the big end. Aluminum alloy 7075, the displacement 0845e-04 is more at the small end and decreasing towards the big end stress 72.2133. is more at the small end and decreasing towards the big end. The Aluminum Alloy 2014 displacement is 0.008212 more at the small end and decreasing towards the big end the stress 71.5869is more at small end and decreasing towards the big end. The carbon Fiber displacement 0.2701E-03 is more at small end and decreasing towards the big end stress is 72.5887 is more at small end and decreasing towards the big. By comparing all the materials, Carbon Fiber is better since its stress is within the limits and has more strength than all other materials. The values for ultimate tensile strength are compared with the respective material to check if the material with stands the load.

Table 8.2 Result Table for Model Analysis

Mode displacement	Aluminum alloy 2014	Aluminum alloy 6061	Aluminum alloy 7075	Carbon fiber
Mode 1 Hz	16.0473	159.125	141.203	113.183
Mode 2 Hz	36.3806	360.749	320.012	256.224

The modal analysis gives us deflection against frequency and from the above values we can see that aluminum alloy 2014 has the frequency values from 16.0473 and 36.3806 and deflection values from 13.1977 and 13.1304, aluminum alloy 6061 has frequency values from 159.125 and 360.749 and deflection values from 13.4151 and 13.3466, aluminum alloy 7075 has frequency values from 141.203 to 30.012 and deflection values form12.2071 and 12.1999and carbon fiber frequency values form113.183 and 256.224 and deflection values from16.4675and16.3691and the deflection increases with increases in the frequency values after a certain period of time hence we can say that the vibration limit of the elements are in the range we got.

Table: Results Table For Analysis Of Assembly

MATERIALS	RESULTS		
	DISPLACEMENT (mm)	STRESS (N/mm^2)	STRAIN
ALUMINIUM2014	0.059605	286.002	0.409E-03
ALUMINIUM6061	0.626023	285.278	0.00224
ALUMINIUM7075	0.601576	272.705	0.002153
CARBON FIBER	3.18448	277.723	0.012297

By observe the result of aluminum alloy 2014 displacement is 0.059005 is more at the big end of connecting rod, The stress is 286.002 is more at big end of connecting rod and piston head. The aluminum 6061 displacement is 0.626023 is more at the big end of connecting rod the Stress is 285.278 more at piston head. Aluminum alloy 7075 displacement is more at big end of connecting rod and the stress is 272.705 is more at big end of connecting rod and piston head. Carbon Fiber displacement is 3.18448 is more at big end of connecting rod and stress is 277.723 is more at head of the piston. Hence we see that the rods do with stand the loads after further treatment.

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VIII. MILEAGE RECORDED

Sr. No	MILAGE
SAE 8620	60kmpl
AL7075	63kmpl
AL6061	62kmpl
AL 2014	62kmpl

The mileage was calculated of all the connecting rod and they were to be found out as tabulated above. The mileage was calculated by keeping the bike on for a while and then by running it with the mileage meter calibrated for noting the reading for petrol consumed. The calibration is in ml per litter that is the bike goes 6 km for every100 ml on the whole the meter reading for the kilometer where tabulated as 60 for 1 litter. As we can see that there is a change in the mileage of the bike is due to the reduced weight of the connecting rod. The carbon fiber connecting rod did not work for a long time and broke at the big end bearing. It even melted due to the heat of the engine and the oil rotating inside the engine.

IX. CONCLUSION

In this thesis, a broken connecting rod made of forged steel is replaced with Aluminum alloys and Carbon Fiber. The materials are changed so that the weight of the connecting rod is less when aluminum alloys and carbon fiber are used than Forged Steel. The connecting rod is modeled in Pro/Engineer, forces are calculated. Analysis is done on the connecting rod using materials aluminum 6061, aluminum 7075, aluminum 2014 and carbon fiber 280 GSM bidirectional. By observing the analysis results of aluminum 6061 as 71.5632N/mm^2 aluminum 7075 as72.2133N/mm^{2}Aluminum 2014 as 71.5869N/mm^2 and carbon fiber as 72.5887N/mm^2 which are very much less than their respect yield strength values. Analysis is also done on the assembly of piston, connecting rod and crankshaft. The material used for piston is LM6, for crankshaft is Carbon Steel. By observing the analysis results for aluminum 2014 as 286.002 N/mm^2, aluminum 7075 as 272.705 N/mm^2, aluminum 6061 as 285.278 N/mm^2 and carbon fiber as 277.723 N/mm^{2}the stresses on the connecting rod are within the limit. After validating the analysis results, two different material connecting rods are manufactured. One is the aluminum connecting rod using machining process and the other is Carbon Fiber connecting rod using hand lap method. The connecting rod was successfully tested in the bike and 3of the rods performed to the level of expectation as they should have performed. The rods where tested in ideal condition and also by changing the gears at regular intervals of time and speed which let the rod undergo loads at different speed at different gear shifts. The rods where tested to their maximum capacity and they have performed well. The carbon fiber rod did with stand the forces for a while but the epofine used failed over 450c melted and caused the rod to melt as the flash point of the epofine was around 200c The aluminum 7075 and carbon fiber connecting rod are the best to be used as they with stand the forces but epoxy in carbon fiber melts due to heat. The aluminum connecting rods can be made with the new method mentioned above the forged ingot method which reduces the forging cost. The steel connecting rods in the average bikes can be replaced for lighter and better performance. The composite material like carbon fiber has good strength and can be used for connecting rod but with a better epoxy which can withstand the heat inside the chamber. The crank shaft if replaced with aluminum will give good results and induce much less pressure on the aluminum connecting rod and help increase its life.

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