

A Review on “Application of composite materials for Weight Optimization of Connecting Rod”

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ABSTRACT: This study demonstrates the need of composite materials over common materials. Using different molding methods, composite components are manufactured in different sectors. The primary advantage of composite is lightweight, relative stiffness and strength properties. The key concepts of composites are its physical properties, material properties, tooling, design, inspection and repair. Military vehicles, such as airplanes, helicopters, and rockets, placed a premium on high-strength, light-weight materials. While the metallic components that had been used up to that point certainly did the job in terms of mechanical properties, the heavy weight of such components was prohibitive. Polymer industries were quickly growing and tried to expand the market of plastics to a variety of applications. The emergence of new, light-weight polymers from development laboratories offered a possible solution for a variety of uses, provided something could be done to increase the mechanical properties of plastics. In an internal combustion engines and compressors, connecting rod is a high volume production, critical component which is periodically subjected to high tensile, compressive and bending loads caused by the thrust and pull on the piston and by the centrifugal force of the rotating crankshaft. The connecting rods can be manufactured using variety of methods and variety of materials but it depends on application case, which technology and material to use. Existing connecting rods are mostly manufactured by using carbon steel. Aluminium and titanium alloys are strong and light weight alloys known. Titanium finds its application in high performance automotive where light weight but strength of components is needed. ANSYS is the analysis tool to calculate Von-mises stress, Von-mises strain and deformation etc.

KEYWORDS: ANSYS, composite materials, Connecting rods, weight optimization, Ceramics, Fatigue, Monomers, polymers.

I. INTRODUCTION

Most of human needs lead to inventions. At first, he used only the materials which surrounded him in nature. Wood and stone are used as tools and animal skin for clothing. Then he learnt to weave natural fibers, like cotton and silk to make cloth. Later he discovered the use of iron and copper to make different hunting implements. Man's scientific understanding has greatly increased in the last two centuries, which have witnessed a revolution in technology. Scientists have discovered how to make special synthetic materials like plastics. Plastic can be inorganic or organic, natural or synthetic. But increasingly, the word has come to denote synthetic organic plastics, essentially polymers [9]. Polymers, means many parts are composed of giant molecules or units called monomers [18]. Each monomer is composed essentially of carbon and hydrogen. Sometimes, they may contain other elements like oxygen, nitrogen, chlorine, silicon, etc. Most polymers are immensely long chains; sometimes linear, sometimes branched. This

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is possible because carbon atoms can combine very easily with one another and with many other kinds of atoms. They have the ability to form strong bonds in long chains.

A composite can define as “Two inherently different materials that when combine together produce a material with properties that exceed the constituent materials”. In other words Composite material can be defined as a combination of a matrix and a reinforcement, which when combined gives properties superior to the properties of the individual components. The reinforcement fibers can be cut, aligned, placed in different ways to affect the properties of the resulting composite. The matrix, normally a form of resin, keeps the reinforcement in the desired orientation. It protects the reinforcement from chemical and environmental attack, and it bonds the reinforcement so that applied loads can be effectively transferred.

Connecting rod is integral component of internal combustion engine; it acts as a linkage between piston and crankshaft which is subjected to high tensile, compressive and bending loads during internal combustion engine operation. It converts reciprocating motion of piston into rotary motion of the crank. It has three main zones, the small end, the central shank and the big end. The small end is the piston pin end, the big end is the crankshaft end and the central shank is of I-cross section. Connecting rod is a pin jointed strut in which more weight is concentrated towards the big end. In that point of view the location of the CG point of connecting rod lies more towards the big end. Connecting rods are most made of steel for production engines, but can be made of Aluminium (for lightness and the ability to absorb high impact at the expense of durability) or titanium (for combination of strength and lightness at the expense of affordability) for high performance engines, or of cast iron.

Connecting rods of automobiles should be lighter, should consume less fuel and at the same time they should be durable, which unfortunately leads to increase in weight. This tendency in automobile construction led the invention and implementation of quite new materials which are light in weight and meet design requirements [1]. They can be produced either by casting, powder metallurgy or forging.

However, connecting rods could be produced by casting, the difference between others and it usually, they have blown holes which are adverse from durability and fatigue points of view. The fact that forgings produce blow hole free and better rods gives them an advantage over cast rods. Powder metal manufactured blanks have the advantage of being near net shape, reducing material waste. However, the cost of the blank is high due to the high material cost and sophisticated manufacturing techniques [2].

II. NEED OF COMPOSITES & BENEFITS

In comparison to common materials used today such as metal and wood, composites can provide a distinct advantage. The primary advantage in composites is the light weight, relative stiffness and strength properties. In transportation, less weight equates to more fuel savings and improved acceleration. In sporting equipment, lightweight composites allow for longer drives in golf, faster swings in tennis, and straighter shots in archery. While in wind energy, the less a blade weighs the more power the turbine can produce. Rubber tiers replacing wooden wheels; bright nylon or polyester dress materials becoming more popular than cotton; tennis rackets made of lighter materials being preferred over the old, heavy wooden one. Composite materials are generally costlier as compared to conventional materials, but still their use is becoming increasingly popular because of their significant properties.

- Non corrosive
- Non conductive
- Long Life
- Design flexibility
- Low maintenance
- Flexible, will not dent

For example, carbon-fiber reinforced composite can be five times stronger than 1020 grade steel at one fifth of the weight. Though Aluminum (6061 grade) is much nearer in weight to carbon-fiber composite, but the composite can have twice the modulus and up to seven times the strength. Materials are classified into different categories like Metals, Polymers, Ceramics and inorganic glasses and composites. At high temperature metals lose their strength. High-Polymeric materials in general can withstand still lower temperatures. Ceramics and polymers are able to withstand at

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high temperatures, good strength and thermal expansion properties, but due to brittleness they are not as structural materials. Basically composites are grouped into the following categories - Fiber Composites: The fibers reinforce along the line of the length.

Particle Composites: P Particles used to strengthen a matrix. Spread at random throughout a matrix, particles tend to reinforce in all directions equally. Ex cement and plastics.

Flake Composites: Flakes, because of their shape usually reinforced in two dimensions. Common flake materials are glass and mica.

Laminar Composites (layered): laminar composites involve two or more layers of same or different materials. The layers can be arranged in different directions to give strength.

Combined Composites: It is possible to combine several different materials into a single composite. It is also possible to combine several different composites into single product.

III. APPLICATION OF COMPOSITES

As composite materials possess a unique combination of properties such as

- High strength to weight ratio, i.e., lightness in weight
- Better toughness, fatigue and stiffness
- Functional superiority, i.e., better corrosion,
- weathering and fire resistance, electrical insulation and anti-friction properties
- Ease of fabrication or versatility of fabrication methods
- Better durability and low maintenance cost
- Great Importance is given to the composites as raw material for various Industries.

Sector-wise Composite Demand



Figure 1. Sector-Wise Composite Demand

IV. USE OF COMPOSITES IN AUTOMOBILE AND TRANSPORTATION INDUSTRY

The potential for increasing fuel economy by reducing the vehicle's weight has stimulated tremendous interest for composite materials in automobile and transportation industry. As a result, industrially developed countries like Japan are extensively using graphite dispersed aluminum composites for automobile parts where friction is involved.

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The applications of composite materials in railways and road transports are well established all over the world. Glass fibre-polyester epoxy composites are the usual materials for the production of three-wheeled vehicles for invalids, commercial vehicles (cabs and trucks), car bodies, sporting cars, buses, ambulances, caravans, mobile shops, etc. in foreign countries. GRP is also used in motor cycle and scooter industry mainly due to weight saving and the need to obtain an inexpensive weather-resistant Streamlined fairings. The other various industries are Marine Industry, Chemical Industry, Mechanical, Civil, Electrical and Electronics industries used very widely.

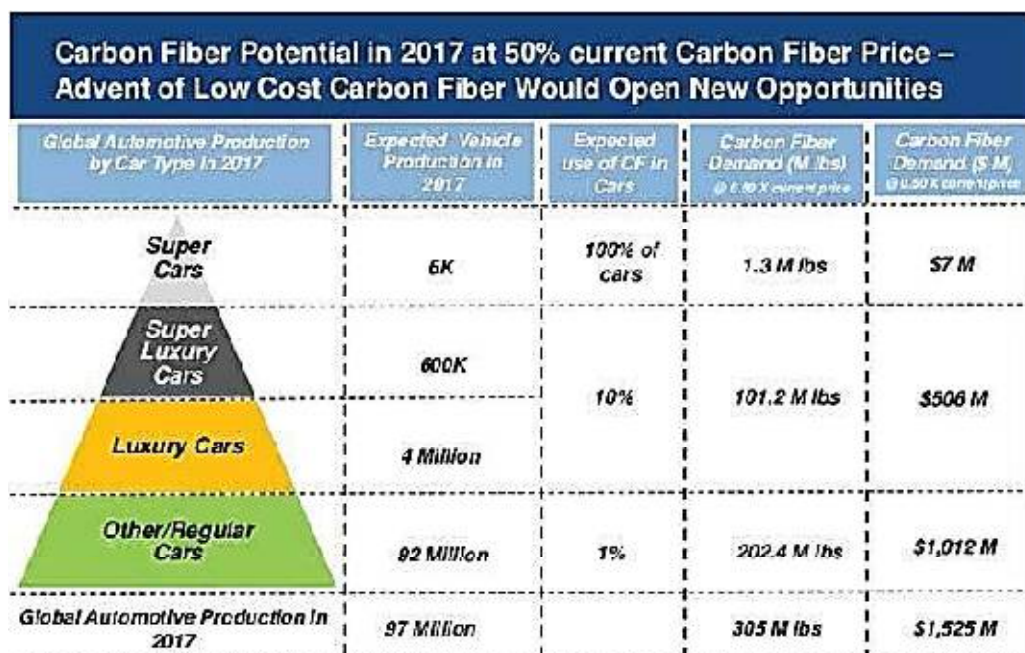


Figure 2. Carbon Fiber Potential in 2017

V. LITERATURE REVIEW

VenuGopalVegi and Leela Krishna Vegi [3] in their paper describe designing and analysis of a connecting rod. Currently existing connecting rods are made of carbon steel. The model of connecting rod is modelled using CATIA software and analysis is carried out on ANSYS software. Finite element analysis is carried out on a connecting rod made of forged steel. The parameters like Von mises stress, strain, deformation, factor of safety etc. were calculated and found that forged steel have more factor of safety, reduced weight, greater stiffness than carbon steel.

Vikas Gupta [4] in his research work altered the dimensions of already existing design of a connecting rod of a tractor engine. This analysis was done under static and fatigue loading. Optimization was done under same boundary and loading conditions for validation in few stress and fatigue parameters. The critical regions under both static and fatigue analysis are identified and improved. The connecting rod was modelled and optimized for the reduced weight, improved life and manufacturability. The material was kept same and a significant change was observed in Von mises stress. 9.4% less stress was observed at critical point under static load conditions. Only 5 gm. of weight was reduced which is very low. From this we can conclude that not only materials but also design parameters can be considered for optimization.

The comparison of fatigue behaviour of forged steel and powder metal connecting rods was discussed by A. Afzal et al. [5]. The experiments included strain controlled specimen testing with specimen obtained from the connecting rods as well as strain controlled connecting rod bench testing. Monotonic and cyclic deformation behaviour and strain controlled fatigue properties of two materials are evaluated and compared. The stress concentration factors were obtained from FEA, and modified Goodman equation was used to account for the mean stress effect. The connecting

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Vol. 6, Issue 7, July 2017

rod is a most stressed part in internal combustion engine. During its operation various stresses are acting on it. The effect of compressive stress is more due to gas pressure and whipping stress. Fanil Desai and all [6] compared two samples of connecting rod made of forged steel. Static analysis was done using ANSYS software and experimental analysis with Universal Testing Machine (UTM). Experimental results were verified with the numerical results. To reduce weight and cost of forged steel connecting rod, Ambrish Tiwari et al. [2] extremely used the numerical tools during the development phase. Therefore, to complete understand the mechanisms involved as well as the reliability of the numerical methodology are extremely important to take technological advantages, such as, to reduce project lead time and prototypes cost reduction. The work shows complete FEA methodology to explore weight and cost reduction opportunities for production of forged steel connecting rod. Considering the modified Goodman diagram, fatigue study based on stress life theory was also performed.

Kuldeep B. replaced the conventional materials of connecting rod by aluminium based composite materials reinforced with silicon carbide and fly ash. The comparative study between conventional materials and new materials found that new materials have less weight and better stiffness. It resulted in reduction of 43.48% of weight with 75% reduction in displacement [1].

Ramanpreet Singh in his study used isotropic and orthotropic composite materials. The modelling of connecting rod was done using CATIA v5 and stress analysed in MSC. PATRAN. Linear static analysis was carried out for both materials with tetrahedron with element size of 4mm to obtain stress results. Comparison of both materials was done keeping the boundary conditions same. Author concluded that there was a reduction of 33.99% of stresses when isotropic material (i.e. steel) is replaced with orthotropic material (i.e. E-glass/Epoxy). Also there was reduction in displacement of about 0.026% [7].

G.M. Sayeed Ahmed [8] et al. In their work, a broken connecting rod made of forged steel is replaced with aluminium alloys and carbon fiber. By doing so, the authors found that weight of connecting rods was reduced and all performed to the level of expectation. The carbon fibers have good strength and are light in weight. The rods were tested in ideal condition and also by applying variable loads. The rods tested to their extreme capacities and they performed well. The analysis also carried out on the crankshaft of aluminium which gave good results and pressure induced on connecting rod was less.

Existing connecting rod is manufactured using ferrous alloys. Authors S. Vijaya Kumar et al. Replaced material of connecting rod with chrome steel and titanium. Modelling is done using Creo Parametric 2.0 software and analysed over ANSYS. Composites used for manufacturing helped optimizing weight and cost and improved its life span than the original design. The maximum stress was within the allowable stress limit for chrome steel and titanium [9].

VI. CONCLUSION

Connecting rods are being manufactured by conventional method of forging. Steel can be replaced by aluminium and titanium alloys on a cost of affordability. Weight optimization is possible using composite materials without varying the allowable stresses and boundary conditions.

Extant studies show the advantages like:

1. Resistance to a wide range of chemical agents including acid rain and salt spray, conditions under which metal parts would suffer. This results in much reduced maintenance and repair costs.
2. Resilience – the ability to deform and spring back to their original shape without major damage. Shape memory and impact tolerance are two of the biggest advantages of composites, particularly within the transport industry.
3. Low weight – with substantial savings in weight over similar metal parts (25% the weight of steel, 30% lighter than aluminum) cost savings are noticeable with installation, handling and particularly fuel consumption, when in service. Even greater weight savings are achieved when two components, previously manufactured out of steel or aluminum, are combined in one composite structure. This also gives savings in the installation process.
4. Adhesive and coating compatibility – since composites and adhesives/coatings share a similar polymeric make-up, they are widely compatible with one another.
5. Thermal properties – composite structures act as very good insulators, whilst retaining their shape while not becoming brittle in cold temperatures.

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6. Strength – comparable to aluminum and steel, strength characteristics of many materials can be reproduced through research and development with reinforcements, e.g. Glass.
7. Innovative designs which were previously impractical can be achieved with composites with no loss in performance or strength.
8. Safety – fiber-reinforced composites are low in electrical conductivity and are efficient fire retardant, which makes them a good choice for covering electrical parts.
9. Reduced cost – effective techniques have been developed which produce a post-mould paint-finish type surface which requires no further processing, thus eliminating the need for time consuming and expensive finishing. For composites which have been designed to be painted, the part manufacture can include allowances for a surface finish suitable for the keying-in and adhesion of the finish.

The above merits clearly indicate the necessity of the composites than common materials.

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