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COMPARATIVE ANALYSIS BETWEEN FORCES ACTING ON A CARBON STEEL AND METAL MATRIX CONNECTING ROD.

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ABSTRACT

The purpose of this research is to compare the results of the common forces acting on metal matrix composite connecting rod and the Regular (carbon steel) connecting rod and use the value of the result obtained to advance reasons why automotive application especially connecting rods are made by metal matrix composite materials. Metal-matrix composites (MMCs) have emerged as a class of materials widely used in the engineering field. The general characteristics possessed by metal matrix composites are found to be the reason for using it in the automotive application in preference to high energy intensive metals. The research work commenced with casting of the metal matrix composite sample connecting rod by stir-casting method and purchasing the Regular (carbon steel) connecting rod. The two types of connecting rods were earlier tested on a Toyota starlet of 12 valve model E series live engine. Theoritical calculation of forces acting on the two types of connecting rod,ie, Regular (carbon steel) connecting rod, and MMC connecting rod was carried out and the result obtained are: 23760N,12672N,$3.14x10^{-6} N/m^2$,and84.7Mpa: 10464.8N,1358.53N,$2.84x10^{-6} N/m^2$,and 81.7Mpa respectively, show that stress induced in metal matrix connecting rod is lower than that of the regular(carbon steel connecting rod. Hence the replacement of connecting rod material with MMC will give improved strength and reduce induced stress in the structure.

Keywords: *Connecting rod, MMCs, Stiffness. Stir- casting, Whipping stress.*

Introduction

Metal-matrix composites (MMCs) have emerged as a class of materials for advanced structural, aerospace, automotive, electronic, thermal management, and wear applications. The general characteristics possessed by the composite materials are found to be the reason for using it in the automotive applications such as the connecting rod. The automobile engine connecting rod is a high volume production, critical component. It converts the reciprocating motion of the piston into rotary motion of the crankshaft. Lighter connecting rods helps to decrease load caused by forces of inertia in engine as it does not require big balancing weight on crankshaft (Kuldeep etal,2013).The reduction in weight, increased in stiffness and increase in strength of a metal matrix composite (MMC) connecting rod when compared to the conventional steel connecting rod have motivated researchers in this area in recent times, but the current cost to produce a metal matrix connecting rod still makes this technology unfeasible for mass production (Aigbodion,etal,2016).

The connecting rod has sometimes been described as one of the most important components in a conventional engine design. Here, the alteration from a stepped to a generously radiused shoulder of the connecting rod at the junction of the shank to big-end bolt lugs significantly reduced stress concentration in the connecting rods and is one of the important modifications that ultimately made possible a safe doubling in power output(Nunney,1998).

The automobile engine connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces to a complex state of loading. It undergoes high cyclic loads of order of 10^8 to 10^9 cycles which range from high compressive loads due to combustion to high tensile loads due to inertia ,it is the intermediate member between the piston and 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.

The nature of the loading on the connecting rod is that it is subjected to a combination of axial and bending stress and, the former arising from reciprocating inertia forces and cylinder gas pressure and the loss from centrifugal effects as it transmit the push and pull from the piston pin to the crank pin. “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.

Materials and Method

Materials

The experimental material used for the research is metal matrix composite connecting rod produced by stir-casting method, and purchasing the regular carbon steel connecting rod to serve as control.

Methods

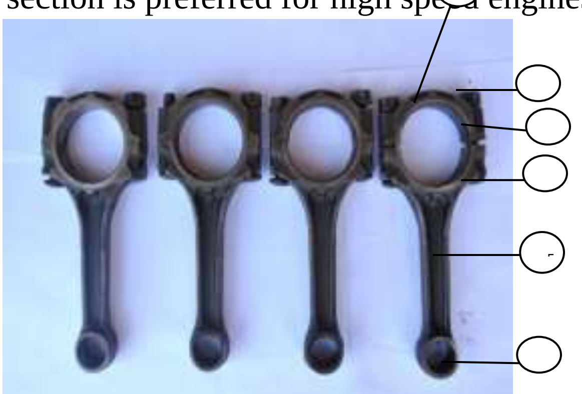
The two types of connecting rods were earlier tested on a Toyota starlet of 12 valve live engine model E series of Single overhead camshaft (SOHC) = 1.3L. It is a four stroke, four cylinder compression ignition engine with the following parameters.

Bore x stroke; 73.0mm x 77.4mm
Displacement; 1,295cc
Compression ratio; 5:1

Standard output range of the engine is from 65hp (48kw) to 82hp (61kw) at 600 rpm with a torque of 98N-m at 3000 rpm to 7716ftlb 104N-m) at 5,200 rpm.

Theoretical analysis.

A connecting rod consists of a long shank a small end and a big end. The cruoss-section of the shank may be rectangular, circular, tubular "I section and H section". Generally circular sections are used for low speed engines while I section is preferred for high speed engines (Dharun and Arun, 2013)



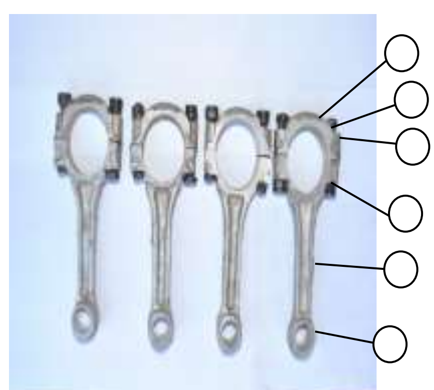


Plate1aPhotograph of Regular connecting rod. Plate1b Photograph of MMCs connecting rod

Forces acting on connecting rod

A connecting rod is subjected to the following forces;

1. Force due to gas or steam pressure and inertia of reciprocating parts.
2. Inertia bending force, and
3. Force acting on a horizontal plane

Experimental calculation on Regular (carbon steel) connecting rod.

Engine specifications:

Single overhead camshaft (SOHC) = 1.3L

Diameter of the piston = 110mm

Mass of the reciprocating parts = 2kg

Length of the connecting rod from centre to centre = 325mm

Length of stroke = 150mm

R.P.M = 2500

Compression ratio = 5:1

Maximum force on the piston due to pressure

$F_L = \frac{\pi}{4}$ x D^2 x pressure

$= \frac{\pi}{4}$ $(73)^2$ x 2.5 $\frac{N}{mm2}$ x mm x mm = 10464.8 N

Force in the connecting rod: FC=FL=23760N.

Inertia force of reciprocating parts is maximum, when the crank is at the inner dead centre, i.e. when θ = 0

Therefore $F_I = M_R\ (\omega max)^{2r}\left(1 + \frac{1}{n}\right)$

$= 2\ (261.8)^2$ x 0.075 $\left(1 + \frac{1}{4.3}\right)$ = 12672N

Experimental calculation on MMCs connecting rod.

Available Data:

Diameter of piston = 73mm

Mass of reciprocating parts = 2kg

Length of connecting rod from centre to centre = 120mm

Length of stroke = 77.4mm

RPM = 1100

Compression ratio = 5:1

Taking density P = 2.86g/cm^3 = 0.00286kg/cm^3

Maximum explosion pressure = 2.5 N/mm^2

Maximum bending or whipping stress due to inertia bending forces

$\sigma_{c(max)} = \frac{M_{max}}{Z_{xx}} = \frac{138.3}{4.4 \times 10^{-6}} = 31.4 \times 10^6 \text{ N/m}^2$

Maximum compressive stress in the connecting rod will be,

$\sigma_{c(max)} = \frac{320}{6} + 31.4 = 84.7\text{MPa}$

Maximum force on the piston due to pressure

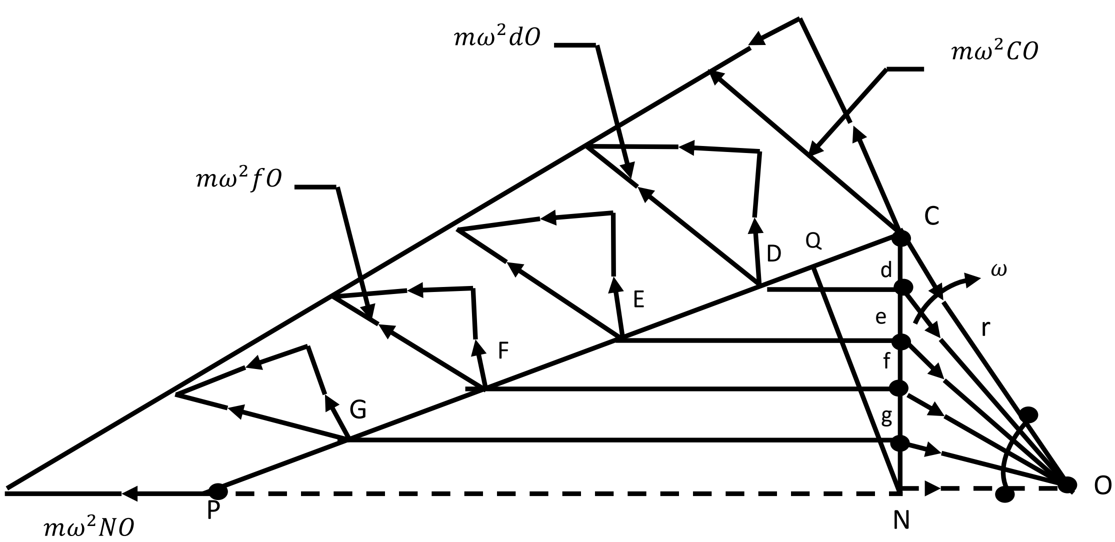
$F_L = \frac{\pi}{4} \times D^2 \times \text{pressure}$

$= \frac{\pi}{4} (73)^2 \times 2.5 \frac{N}{mm2} \times mm \times mm = 10464.8 \text{ N}$

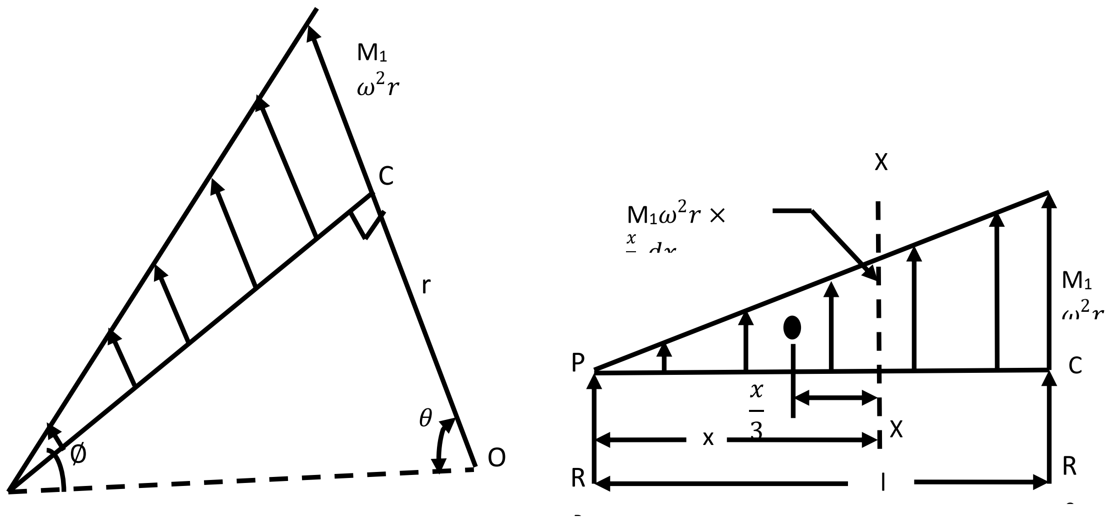
Discussion and Results

Theoretical calculation of forces acting on the two types of connecting rod, ie, Regular (carbon steel) connecting rod, and MMC connecting rod was carried out. As the connecting rod perform its primary function to transmit the push and pull from the piston pin to the crank pin and converting the reciprocating motion of the piston into rotary motion of the crank, gudgeon pin position at each stage and resultant inertia forces (parallel and perpendicular) components acting on the connecting rod, Fig. 3.0, i.e. :

In the connecting rod PC, a crank OC, rotates with a uniform angular velocity ω rad/s. Also in CQNO as shown in fig.3.0



(a)



(b) (c)

Fig. 3.0: Inertia bending forces (Khurmi and Cupta, 2010).

(i) Parallel (or longitudinal) components on the connecting rod. (FC)

(ii) Perpendicular (or transverse) component produces bending action (also called whipping action), or known as the whipping stress. Thus the value of the forces are : 23760N,12672N, 3.14x10 $^{-6}$ N/m^2 ,and 84.7Mpa: 10464.8N,1358.53N,2.84x10 $^{-6}$ N/m^2 ,and 81.7Mpa respectively, show that stress induced in metal matrix connecting rod is lower than that of the regular(carbon steel connecting rod.

Table: 1 Summary of result of forces acting on the connecting rods

S/No	Description	Regular connecting rod	Produced MMCs connecting rod
1.	Maximum force on the piston due to gas pressure F_L	23760N	10464.8N
2.	FC = F_L	23760N	10464.8N
3.	Maximum inertia force of reciprocating parts F_I	12672N	1358.53N
4.	Maximum bending or whipping stress due to inertia bending forces σ_b (max)	3.14 x 10^{-6} N/m^2	2.84 x 10^{-6} N/m^2

5.	Maximum compressive stress in the connecting rod σ_c (max)	84.7 MP_a	81.7 MP_a
6.	Maximum bending moment M_{max}	138.3 N-m	124.76 N-m
7.	Maximum angular speed W_{max}	261.8 rad/s	115.2 rad/s
8.	Ratio of the length of connecting rod to the radius of crank	4.3	3.1

Comparison of Results

The summary of result of forces acting on the two types of connecting rod i.e. Regular and MMCs connecting rod is displayed in Table 1.The experimental result obtained show that the forces acting on the carbon steel connecting rod is higher in magnitude, intensity, and has maximum stress. Accordingly, a maximum force of 23760N as against 10464.8N, a compressive stress of 84.7MPa as against 81.7MPa and a maximum bending moment of 138.3N-m as against124.76N-m respectively. This clearly confers that MMCs connecting rod has lower induced stress on application than the Carbon steel connecting rod. Similarly, from literature review, for automotive application especially connecting rods are made by metal matrix composite materials.

CONCLUSIONS:

- The following conclusions can be drawn from this study:
- The results obtained show that the forces acting on the Regular (carbon steel) connecting rod is higher in magnitude intensity and has maximum induced stress.
- It is clear that the stress induced in the metal matrix composite connecting rod is found to be lower than that of regular connecting rod.
- Lighter connecting rods help to decrease load caused by forces of inertia in engine.
- Replacement of connecting rod material with MMC will give good strength, reduced weight, and induced stress in the structure, hence its usage for connecting rod material is highly recommended.

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