N GOVINDRAJ
and
S. SURESHA

Static structural and linear buckling analysis of diesel generator connecting rod

Connecting rod is one of the major components in an internal combustion (IC) engine which provides reciprocating motion from the rotary motion to the piston. In an IC engine the high combustion gas will produce, due to which high loads will developed in the connecting rod. It is very important to study the behaviour of connecting rod in an IC engine for diesel generator due to high pressures on connecting rod. It is also important to study the buckling load of the connecting rod which may reduce the failure of connecting rod. Hence in the project the static structural and linear buckling analyses have been conducted on a connecting rod for a diesel generator, resembling an exact diesel generator connecting rod. Estimation like the maximum stresses, maximum deformation, buckling load factor and critical buckling load are determined for different materials like aluminum alloy 6061, titanium alloy, magnesium alloy and aluminum boron carbide and new modified design. CAD model of connecting rod has been generated by using industrial CAD tool solid works and analysis has been done by using industrial CAE tool Ansys Workbench. In this project the results of static and buckling analysis has been compared and presented the suitable design of connecting rod for better performance. Finally, the results are justified by suggesting why Al alloy holds better replacement that other mentioned alloys.

Keywords: Internal combustion, alloys, CAE, buckling, connecting rods, dynamic.

1.0 Introduction

A connecting rod is an engine component that transfers motion from the piston to the crankshaft and functions as a lever arm. Connecting rods are commonly made from cast aluminium alloy and are designed to withstand dynamic stresses from combustion and piston movement [5]. The small end of the connecting rod connects to the piston with a piston pin. The piston pin, or wrist pin, provides a pivot point between the piston and connecting rod. Spring clips, or piston pin locks, are used to hold the piston pin in place [1]. The big end of the connecting rod connects to the crankpin journal to provide a pivot point on the crankshaft. Connecting rods are produced as one piece or two-piece components [7]. A rod cap is the removable section of a two-piece connecting rod that provides a bearing surface for the crankpin journal. The rod cap is attached to the connecting rod with two cap screws for installation and removal from the crankshaft [9]. The most common application of connecting road is IC engines and steam engines, Farm equipment, cars and trucks, construction equipment and in other type of vehicle with an internal combustion engine uses some type of connecting rod [6].

1.1 History of connecting rod

Evidence for a connecting rod appears in the late 3rd century hierapolis (Asia Minor) sawmill. It also appears in two 6th centuries saw mills excavated at Ephesus, Asia Minor, and Gerasa, Jordan.

In China, a crank and connecting rod machine appeared in the 5th century, followed by a crank and connecting rod machine with a piston rod in the 6th century [13]. Sometime between 1174 and 1206, the Arab inventor and engineer Al-Jazari invented a machine which incorporated the connecting rod with a crankshaft, for the first time, to pump water as part of a water-raising machine [10].

In modern diesel generator internal combustion engines, the connecting rods are most usually 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 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 [14]. 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 [4].

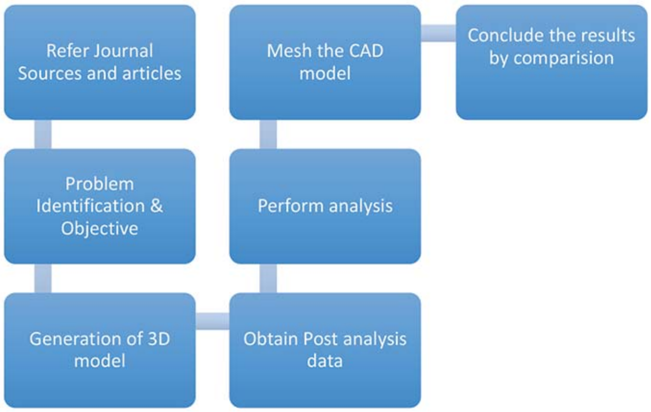
The small end attaches to the piston pin, gudgeon pin (the usual British term) or wrist pin, which is currently most often press fit into the con rod but can swivel in the piston, a "floating wrist pin" design.

Messrs. N Govindraj, PG Student Machine Design and S. Suresha, Assistant Professor School of Mechanical Engineering, REVA University, Bangaluru 560064, India. E-mail: sureshpoojar95@gmail.com

2.0 Objectives

- The primary objective of the current work is to optimize the weight, strength and buckling factor of the connecting rod with the different MMCs of alloys for better performance for lower CC diesel generator engine.
- Conduction of linear static and buckling analysis of the connecting rod to optimize the design of connecting rod.
- Determination of maximum stresses, deformations and buckling factor of the connecting rod with existing material and different composite materials to find out the better design of the connecting rod.
- Determination of the buckling factor of the connecting with different materials and design to estimate the critical buckling load.
- Optimization of the connecting rod with appropriate material chosen.

2.1 Methodology (flowchart)



3.0 Numerical formulation

3.1 Engine configuration of diesel generator connecting rod

Table 1 shows the engine configuration of the diesel engine for the crankshaft.

Table 1: Engine specifications

Capacity	450CC
No. cylinders	1
Compression ratio	22:1
Max power	8.1 HP@3600RPM
Max. torque	15.7 N.m@2200RPM
Bore dia × stroke	78mm × 68mm

Static structural and linear buckling analysis of diesel generator connecting rod has been conducted for different materials as under:

- Aluminum alloy 6061
- Titanium alloy
- Magnesium alloy
- Aluminum boron carbide

As the generator engine operates majorly under stationary platform condition unlike the automotive engines are attached to a rigid frame under motion. A major amount of work needs to be performed on the fatigue analysis, modal analysis and stationary analysis. Since the diesel generator regular operates under elevated temperature with minimal fins for cooling, the materials chosen must be of at lower density. Due to accumulation of heat momentum around the region of working space.

3.2 3D CAD Model Generation

After extensive research from analyzing the data, changes were made alongside the diesel generator connecting rod. The 2D designs of the parts were initially modelled in AutoCAD. Once the feasibility of the drawing were verified, the same data were taken in for 3D CAD model.

The tool used for modelling is CATIA_V5. It was later procures for assembly section and saved in ".CATproduct." for future references. The assembled sections were later saved for in various format as ".stp" has to be compatible for further ANSYS software for meshing and analysis. The files prepared for drafting are saved in as .dwg and .pdf formats for future references.

Fig.1 shows 3D model of ideal diesel cenerator connecting rod generated by using CAD tool software.

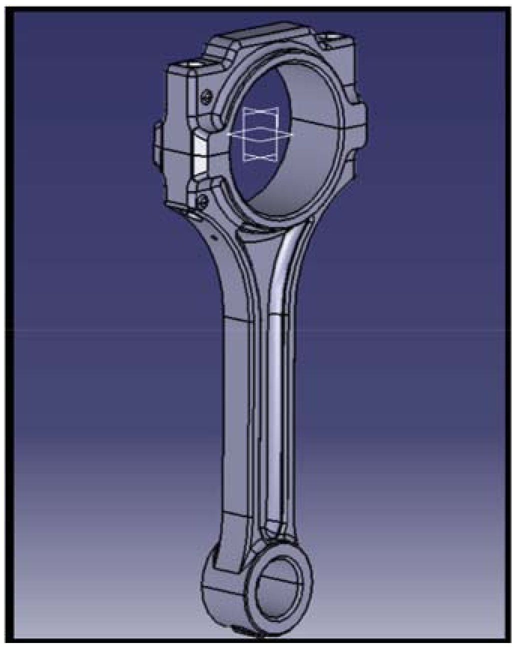


Fig.1: 3D model view of diesel generator connecting rod

4.0 Meshing CAD model

The tools used for meshing the modelled assembly are ANSYS Workbench 17.1. Refined meshes were taken into consideration with nearing irregulated geometry regions. The refinements of the meshed were controlled by automatic programme controlled by the software.

In case of the irregular structure of the shapes in the geometry of the model the relevance center were considered to be coarse with smooth and transition rate. As per the geometry dimensions the optimum edge length is taken as 1.03 mm. As seen in Fig.2 the meshes are refined finitely when approaching curvatures. There are several types of element shapes which are further divided into various classes depending on their use. Major use of hexa-dominant elements is undertaken along with tetrahedral along the curvature proximities. As the property of contact region holds good for interaction property between various geometry. The main agenda of this project is to procure the study and interaction of loads/forces.

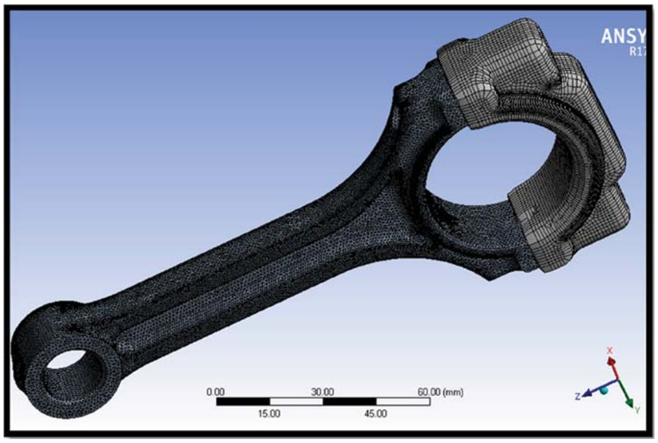


Fig.2: Finite mesh of conceding Rod

5. Results and discussions

5.1 Linear static and buckling analysis of connecting rod with aluminum alloy 6061 has been conducted

- Maximum stress of 97.7 MPa has got at the time of combustion pressure.
- The maximum stress is within the allowable stress, hence the design is safe.
- Maximum deformation of 0.0641 mm has achieved at the time of combustion pressure.

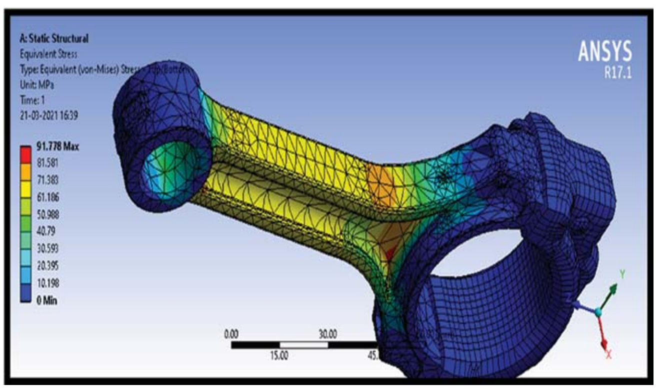


Fig.3: Von-mises stress plot of aluminum alloy 6061 (left image) and zoomed up view (right image)

5.1.1 Results of buckling load factor and critical load of connecting rod with aluminum alloy 6061

- Fig.4 Shows the buckling load factor plot of aluminum alloy 6061
- Buckling load factor of 13.132 has got at the time of maximum load

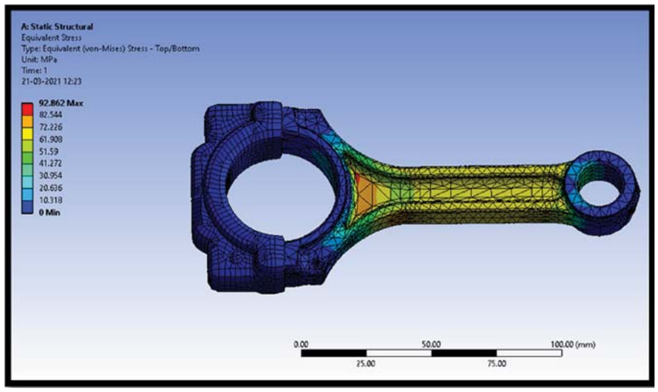


Fig.4: Static structural representing Von Mises stress for Ti Alloy at different orientations front view

The connecting rod with aluminum alloy 6061 can withstand 13 times the load applied.

Critical buckling load (F_c) = applied load (F_a) × load factor/ multiplier (λ)

$F_c = 10000 \times 13.132$

$F_c = 131.3$ KN

5.2 Linear static and buckling analysis of diesel generator connecting rod with titanium alloy

- Fig.5 shows the von-mises stress plot of titanium alloy.
- Maximum stress of 92.86 MPa has got at the time of combustion pressure.

5.2.1 Linear buckling analysis of diesel generator connecting rod with titanium alloy

- Buckling load factor of 17.74 has got at the time of maximum load

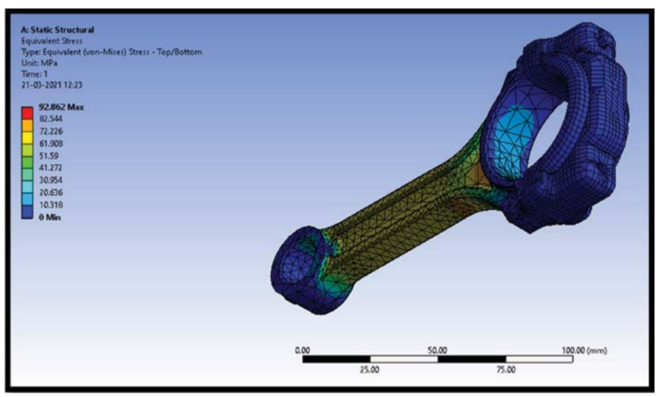


Fig.5: Static Structural representing Von Mises stress for Ti Alloy at different orientations at side view

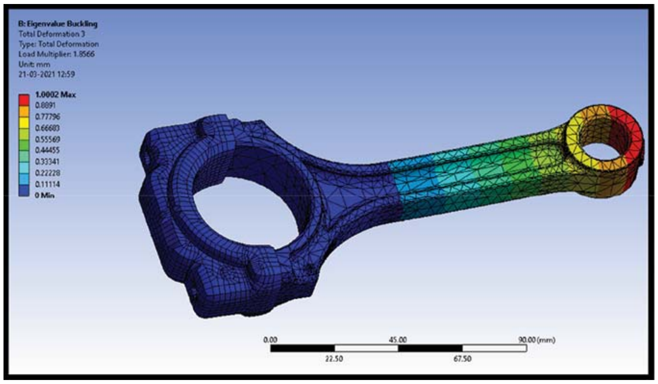


Fig.6: Buckling load factor plot and front view of buckling load factor plot ti alloy

- The connecting rod with titanium alloy can withstand 17 times the load applied critical buckling load (Fc) = applied load (Fa) × load factor/multiplier (λ)

  Fc = 10000 × 17.74

  Fc = 177.4 kN

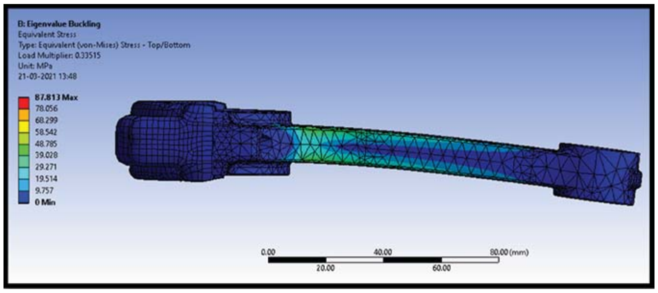


Fig.7: Von-mises stress plot and zoomed in view of maximum stress plot mg alloy (side view)

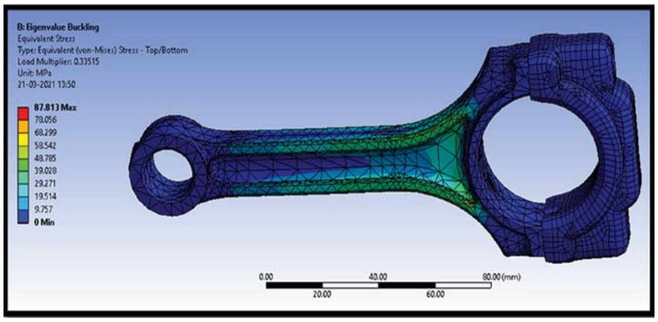


Fig.8: Von-Mises stress plot and zoomed in view of maximum stress plot mg alloy (front view)

The critical load for the connecting rod with titanium alloy is of 177.4 kN

5.3 Linear static and buckling analysis of diesel generator connecting rod with Magnesium Alloy

- Maximum stress of 87.81 MPa has got at the time of combustion pressure
- The maximum stress is within the allowable stress, hence the design is safe

6.0 Comparison study

Table 2: Results of Von-Mises stress and max. deformations for different material of base design

Material	Von-Mises stress (MPa)	Maximum deformation (mm)	Weight (gms)
Aluminum alloy 6061	100.3	0.0771	110.9
Titanium alloy	99.77	0.0569	184.9
Magnesium alloy	92.86	0.1215	73
Aluminum boron carbide	98.60	0.032	118.12

Table 3: Results of buckling analysis for different material of base design

Material	Buckling Load factor	Buckling load (critical load)	Eigen value buckling (total deformation) mm
Aluminum alloy 6061	7.5	75.75 KN	0.08
Titanium alloy	10.21	102.1 KN	1.0002
Magnesium alloy	4.79	47.9 KN	1.02
Al Br C	21.29	212.9 KN	2.9

7.0 Conclusions

- The maximum stresses and maximum deformations generated are less in the connecting rod with the aluminum boron carbide compared to other materials like aluminum alloy 6061, titanium alloy and magnesium alloy.
- From the buckling analysis it is clear that the connecting rod with aluminum alloy can withstand the almost the same as even for Al Br C or Ti alloy.
- From the bucking analysis it is also clear that the critical buckling load is more in the connecting rod with aluminum boron carbide compared to other material and the Al alloy.
- Since under all the aspect the Al alloy simply competes best among the other materials, with values varying only marginally across other materials.
- Since the availability of Al alloy is abundantly available and used extensively, it is a wiser choice to recommend from cost point of view.
- Finally, it can be concluded that the connecting rod with material aluminum alloy can be replaced with existing material like aluminum boron carbide, titanium alloy and magnesium alloy for better efficiency in lower cc diesel generator engine.

8. References

[1] Alejandro Esteban Rodriguez Sanchez, et. al., – “Determination of the Side and Front-rear Buckling Loads for a Connecting-rod” - Schematic Scholar, Published 2017

[2] Manish Kumar, et.al., (2017): “Design, Buckling and

Fatigue Failure Analysis of Connecting Rod” – *IJAERS*, Vol-4, Issue-7, July

[3] BorraRameshbabu, et.al., (2016): “Design and Buckling Analysis of Two-Wheeler Connecting Rod Using Different Materials” – *IJMER*, Volume 3, Issue 6, June.

[4] M.S. Shaari1, et. al., (2010): “Design of Connecting Rod Of Internal Combustion Engine: A Topology Optimization Approach”, NCMER 2010

[5] Utkarsha U. Patil, et. al., (2018): “Buckling Analysis of Connecting Rod for Different Materials”- Published 2018. Materials Science *International Journal of Advance Research and Innovative Ideas in Education*

[6] Anil Kumar Vishwakarma et. al., (2016): “Study and Analysis of Connecting Rod Parameters Using Ansys” – *International Journal of Mechanical Engineering and Technology* (IJMET) Vol.7, Issue 4, July–Aug. pp.212–220, Article

[7] Arvind Dave1, et. al., Study of Connecting Rod to the Shank Sectional Area Reduction of Variable Cross Section by using Finite Element Method

[8] Nagaraju K L1 et. al., (2016): “Buckling Analysis of Connecting Rod”, *IRJET* Volume: 03 Issue: 08 Aug.

[9] Prof. N.P. Doshi, et. al., (2013): “Analysis of Connecting Rod Using Analytical and Finite Element Method” - *IJMER* Vol.3, Issue.1, Jan-Feb. pp-65-68

[10] Sourabh Jain et. al., - Finite Element Analysis of Connecting Rod to determine the Critical Buckling Stress and Factor of Safety.

[11] Zhi-wei Yu, et., al., (2015): “Fatigue Fracture of Truck Diesel Engine Connecting-Rods”, Springer, *Journal of Failure Analysis and Prevention*, volume 15, pages 311–319.

[12] Kalenda Mutombo, et, al., (2018): “Research and Development of Ti and Ti alloys: Past, present and future”, IOP Conf. Ser.: Mater. Sci. Eng. 430 012007, Volume 430

[13] Jiangfeng Song, et. al., (2020): “Latest research advances on magnesium and magnesium alloys worldwide”, *Journal of Magnesium and Alloys*, Volume 8, Issue 1, March, Pages 1-4

[14] Venkatesha B K, et.al., (2017): “Review on Mechanical properties and Fatigue life of E-Glass/ Bamboo Fiber Reinforced Polymer Composites”, *International Journal of Engineering Sciences & Management*, ISSN 2277-5528, Special edition, pp. 52-57.

[15] Venkatesha B K, et.al., (2014): Investigation of Fatigue Crack Growth Rate in Fuselage of Large Transport Aircraft using FEA Approach, *Global Journal of Research in Engineering*-USA, ISSN: 2249-4596, 14(1), pp.11-19.