International Journal of Scientific Research & Engineering Trends
Volume 9, Issue 2, Mar-Apr-2023, ISSN (Online): 2395-566X

A Review On Analysis Of Connecting Rod Using Finite Element Method

Pradeep Kumar Dwivedi, Prakash Kumar Pandey
Department of Mechanical Engineering, VITS-Bhopal

Abstract- The connecting rod belongs to the group of critical components of piston engines. The connecting rod transfers loads from the piston onto crankshaft. In modern diesel engines the large value of torque achieved at low speed of rotation causes high stresses in pistons, crankshafts, connecting rods and another engine components. Amplitude of operational stresses has significant in- fluence on the fatigue life of the connecting rod. Additional factors which limit its fatigue strength are: incorrect shape (design), material defects or technological errors (defects created during the production process).The failure analysis of the connecting rods of piston engines was described in many publications. Several typical and uncommon failure modes in connecting rods of combustion engines were reported in work. The author's attention is focused on description of failure mode and the stress analysis of investigated connecting rod.

Keywords- Connecting rod, finite element method, stress, deformation.

I. INTRODUCTION

Connecting rod is an engine component that connects the piston to the crankshaft. It converts the linear and down movement of piston into circular motion of crankshaft.The connecting rod joins the piston to the crankshaft of a reciprocating piston engine, converting the piston's reciprocating action to rotary motion for the crank. A piston pin, also known as a gudgeon pin, secures it to the piston at its small end. The crankpin journal connects the large end to the crankshaft. They form a basic mechanism with the crank that turns linear motion into rotational motion. A connecting rod's job is to allow fluid movement between pistons and the crankshaft.During the combustion cycle, the connecting rod must be strong enough to sustain the piston force. It will be subjected to a lot of tensile and compressive loads during the course of its life.

A connecting rod can be made out of a variety of materials, including carbon steel, iron base sintered metal, micro-alloyed steel, and graphite cast iron. Steel connecting rods are most typically used in mass- produced car engines. In most high-performance applications, billet connecting rods, which are machined from a solid billet of metal rather than being cast or forged, are used.

Every vehicle that uses an internal combustion enginerequires at least one connecting rod depending upon the number of cylinders in the engine. The automobile engine connecting rod is a high volume production, critical component. It is the intermediate component between crank and piston. The objective of the connecting rod is to transmit push & pull from the piston pin to the crank pin and then converts reciprocating motion of the piston into the rotary motion of crank. The main components of a connecting rod are big shank, a small end and a big end. There are different types of materials and production methods used in the creation of connecting rods. The most common types of material for connecting rods are steel and aluminium. The most common types of manufacturing processes are casting, forging and powdered metallurgy.
Other materials include aluminium alloy, which can be used for lightweight while also absorbing heavy impact without sacrificing durability. Titanium, on the other hand, is a more expensive alternative that is found to reduce weight, whilst cast iron, on the other hand, is found to be less expensive and has extremely low performance applications such as scooters.Due to its large volume of 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, reducingengine weight and improving engine performance and fuel economy.

The connecting rod is a connection between the piston and a crankshaft. It joins the piston pin with the crankpin. The small end of the connecting rod is connected to the piston pin and the big end to the crank pin.The purpose of the connecting rod is to convert the linear motion of the piston into the rotary motion of the crankshaft.The connecting rod consists of an I-beam cross-section and is made of forged steel. Aluminum alloy is also used for connecting rods. They are precisely matched in sets of similar weight in order to maintain engine balance.The lighter the connecting rod and piston, the greater the resulting in power and the lesser the vibration because the reciprocating weight is less.The connecting rod carries the power thrust from piston to the crankpin and hence it must be very strong, rigid and also as light as possible.

Fig. 1: Connecting rod.

II. RESEARCH METHODOLOGY

Research methodology regarding the static analysis and design optimization of connecting rod is accomplished in four steps which are as follows:

Step 1: Design of connecting rod

Design ofconnecting rod plays a major role as it is subjected tocyclic loading. As the compressive forces are significantly higher than the tensile strength, the cross-section of the connecting rod is considered as a strut and the formula of Rankine is used. A connecting rod, which is exposed to the load W of the axis of the connecting rod, buckled around the x axis as a neutral axis in the moveable plane of the connecting rod. The connecting rod is regarded as both ends hinged and buckles around x-y-axis. The buckling of a connecting rod on either axis should be strong.

Step 2: 3D modelling of connecting rod in solid works

The 3D CAD model of the connecting rod was prepared using the SOLIDWORKS for the IC engine whose dimensions are given in previous chapter, as per the design of experiment using Taguchi's orthogonal array.

Step 3: Meshing of connecting rod in ANSYS

In pre-processing, the CAD model was meshed using tetrahedron elements.

Step 4: Applying boundary conditions for static analysis

The big end of the connecting rod was constrained whereas the force, were applied at the small end for static analysis.

Step 5: Results

The results were observed in the post-processor. Contour plots were obtained in terms of maximum principal stressand deformation.

1. FEM modelling of Connecting Rod

FEM is an approximation approach at its most simplistic form that divides a complex problem space or domain into several smaller and simpler parts (finite elements), which can be represented in relatively simple equations. FEM has been designed for the engineering study of electronic, civil and aeronautical engineering structures to model and analysis complex. It has the fundamental principles of physics, such as Newton's laws of movement, mass preservation, energy conservation, balancing, and thermodynamics laws. The FEM may be used to evaluate for example the structural dynamics of the various sections of a bridge, heat transfer through a motor component, or the dispensing of the electromagnetic radiation from an antenna under different loading conditions.

The subdivision of the domain is an essential feature of FEM. Computer-aided program (CAD) is helpful in this respect since it determines an object's three-dimensional form, conveniently split up to the desired net or three-dimensional grid of items of the required sizes. The mesh can describe elements of the same size and shape (such as cubes or pyramids) in different shapes or sizes in different sections of the domain, depending on the problem to be solved. It is necessary to select the right mesh or element model: The findings with a more coarser mesh (larger subdivisions), but a thinner mesh that produces further components which requires further power to solve. The results are less exact. Therefore it's helpful to specify a mesh which vary throughout the domain; a grosser mesh may be set in less interesting places, and a finer mesh in areas with a heavy effect on the structure.

It is therefore essential to be aware of the material properties of the components being studied while modeling a particular domain. In order to reach correct performance, physical elements including coefficient of thermal expansion, conductivity of electrical and thermal power, friction, dielectric constants, tensile strength and compressive force, yield tension, and more need to be integrated into the model.

2. D Modelling of Connecting Rod

Solid Works is indeed a 3D solid modeling tool that enables users to create comprehensive, solid models of design and analysis in a virtual environment. At SolidWorks they build 3D models by drawing concepts and experimenting with various designs. SolidWorks produces basic and complicated components, assemblies and drawings for designers, engineers and other practitioners. It is useful to develop a simulation model such as SolidWorks, and therefore it saves time, effort and resources to develop the design.

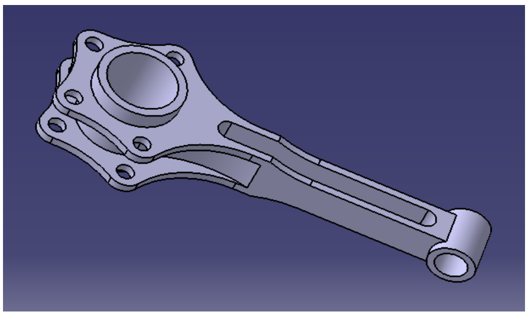

Fig.2:CAD model of connecting rod

After creating CAD model of connecting rod, it is imported in ANSYS in IGES format for static analysis.

3.Mesh model of connecting rod

Breaking of design into smaller aspects to assess each element is called meshing [39]. It is a distinct framework realization of structure that helps to solve the particular design solutions. The smaller the mesh size, the more time and precision the results are computed[40]. The meshing size is set in program ANSYS as default. A completely free mesh form is taken into consideration both the time of arranging and the computational costs, the rate and even simplification of use. The default mesh control has a +100 value with a medium smoothing iteration number. The CAD model has been meshed with tetrahedron element in pre-processing.

4.Boundary Conditions

Another key and important phase in the study after the meshing method is the fixation of supports and applied load in such a way that meets the real-life circumstances[39][34]. Fixed support and load are the boundary condition used in this static evaluation. The fixed support prevents the geometry from moving or twisting. In the next part of this study the complex loads resulting from: pressure of gas in cylinder, inertial forces and pretension of bolts were defined. Mentioned loads were used in order to one load case definition. The maximum pressure of exhaust gases in cylinder occurs when the crankshaft has an angle α=6O after top death centre (TDC) (Fig. 3a). The maximum pressure acting on the piston (12.895 MPa) was taken from indicator plot of the engine (Fig. 3b).

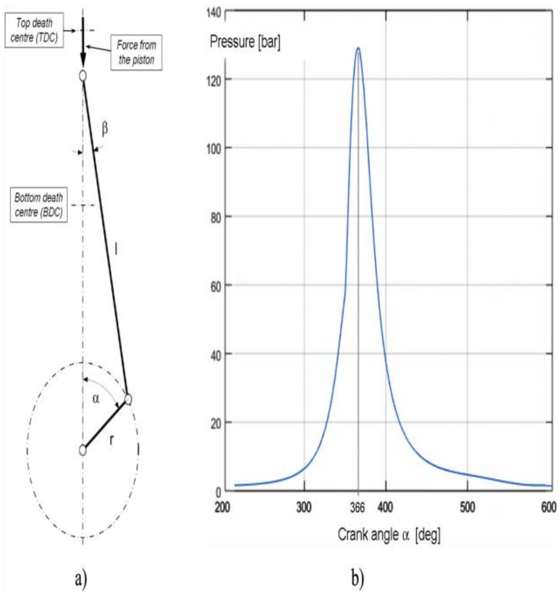

Fig. 3. Position of crankshaft and connecting rod during work of the engine (a). Indicator plot for investigated diesel engine (a) [19].

5.Material property

The material properties that may be linear or non-linear, isotropic or orthotropic, constant or temperature-dependent must be precisely described for effective and qualitative study of the material. Mechanical attributes, such as density, intensity and thermal expansion definition coefficient are optional, based on an analysis goal[36][39]. It is highly helpful for the construction assessment purpose to recognize as well as proclaim the property's right worth. The Young's product module named the elasticity module is a statistical constant, which explains the resilience and tests a solid's capacity to stand up to adjustments in a certain direction whether under tension or compression.

The bigger the Young's modulus, the more rigidly the system, i.e. only how it spreads under loads, would surely need a much greater amount of deforming loads. The ratio of Poisson to material expansion combined with Young's modulus (tension to strain proportion) shows both the hardness and nature of the deformity of the material structure, depending on a particular limitation. Both the bulk and the shear module describe the deformation of the due constant volume and the opposing powers. The yield and the tensile strength are specifically two different critical elements that can be used as such materials lose their versatile behaviour and optimum tension[39][38]. After the geometry has been imported into the program with the properties shown in Table 2.2, the structural material is described. Three materials have been arranged for comparison (1) first structural steel (2) second Al alloy and (3) Ti alloy.

III. RESULTS AND DISCUSSION

In this section the results for total deformation and maximum principal stressare presented and compared.

1.Total Deformation

The figures below shows the deformation due to applied pressure as per the boundary condition applied. After comparing the deformation in different models it is noticed that aluminium alloy hasmaximum deformation.

2.Structural steel

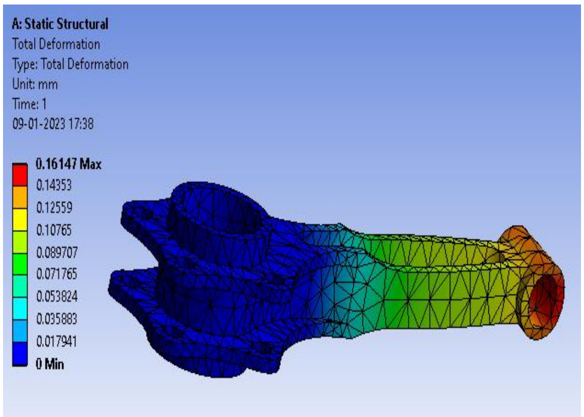

Fig. 4 Deformation in structural steel.

3.Al Alloy

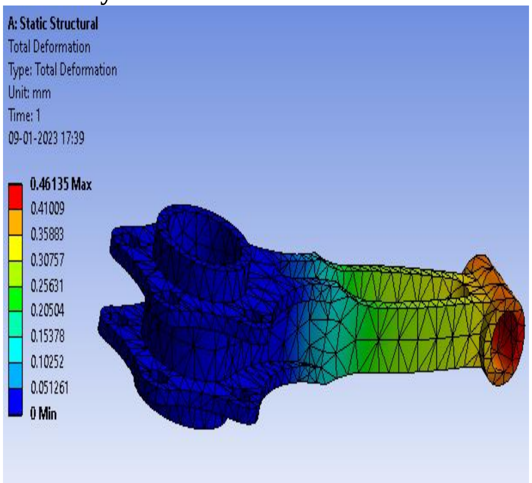

Fig. 5: Deformation in Al alloy

4.Ti alloy

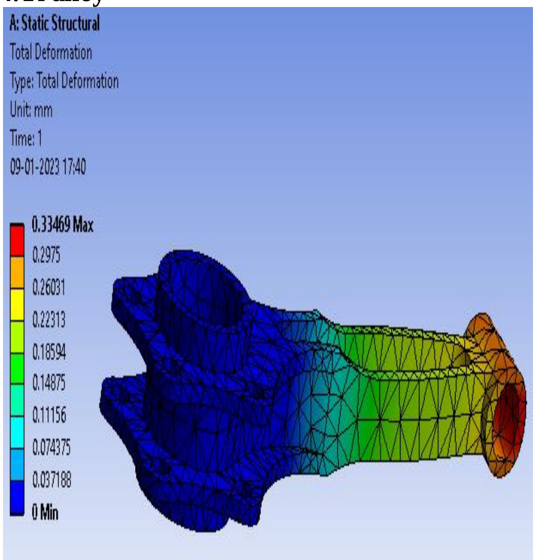

Fig. 6: Deformation in Ti alloy

5.42CRMo4 steel

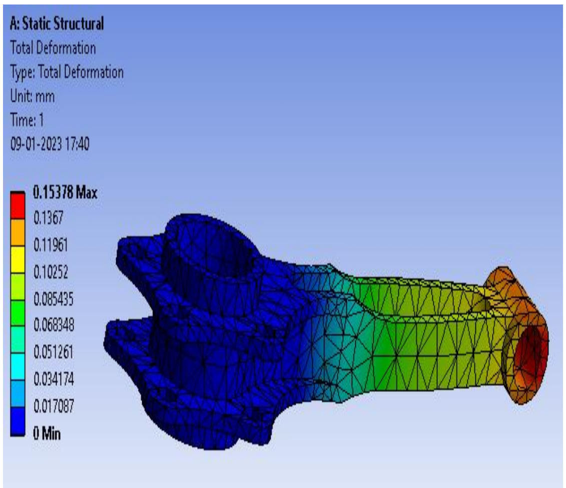

Fig. 7: Deformation in 42CRMo4 steel

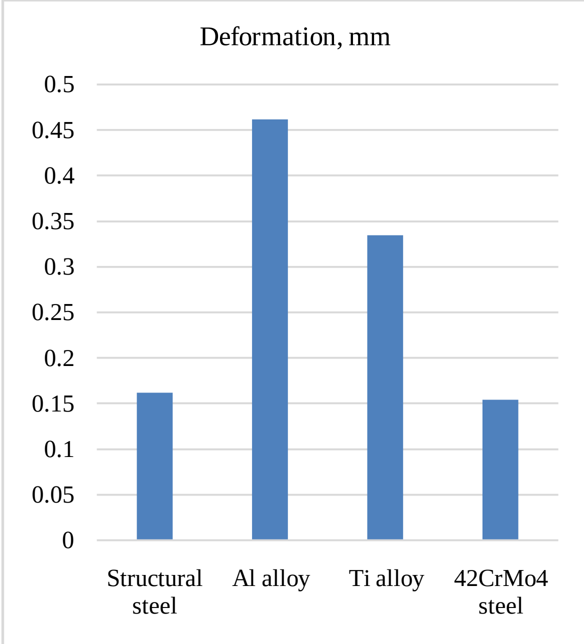

Fig. 8 Deformation comparison

1.Maximum principal stress

The stress analysis of the connecting rod was made using the ANSYS software [16]. To solve the problem, the nonlinear staticanalysis was utilized. As a result of numerical calculations the maximum principal (σ1) stress distributions were obtained for theconnecting rod subjected to the operational loads. This stress is important in fracture analysis because the tensile σ1 stress has a largeinfluence on both the fatigue crack initiation and the crack propagation process.

2.Structural steel

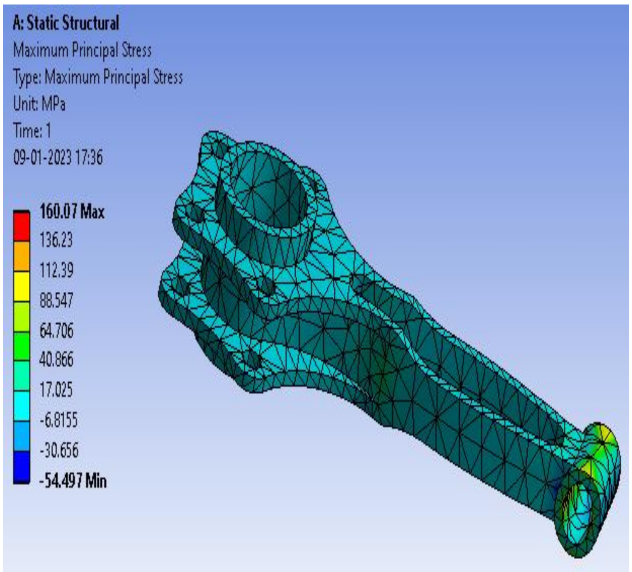

Fig. 9: Max. principal stress in structural steel
Al Alloy

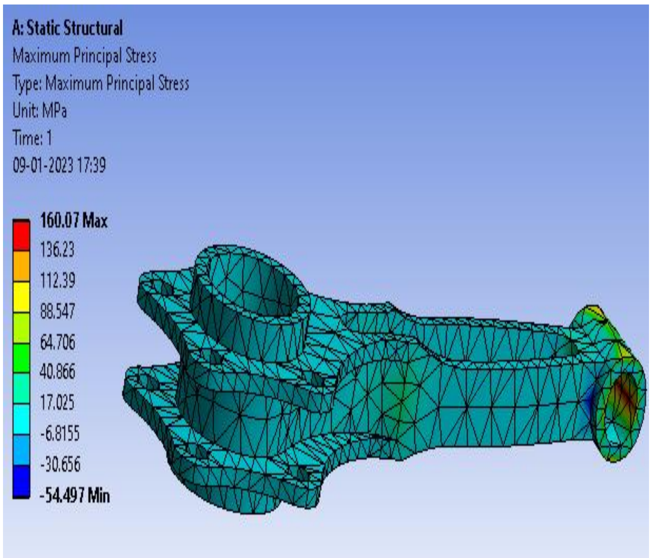

Fig. 10: Max. principal stress in Al alloy

Ti alloy

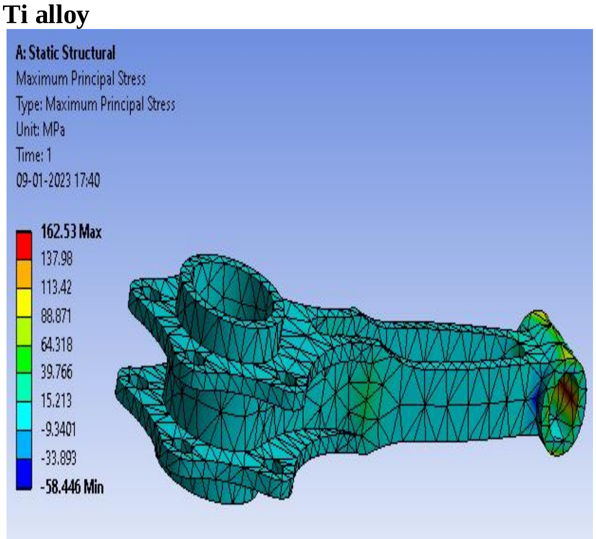

Fig. 11: Max. principal stress in Ti alloy

CR

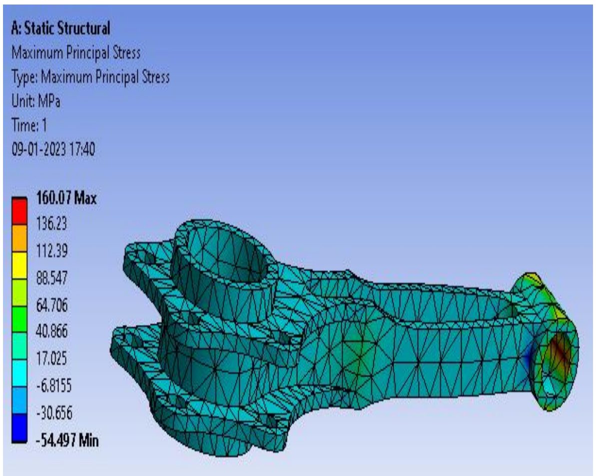

Fig. 12: Max. principal stress in 42CRMo4 steel

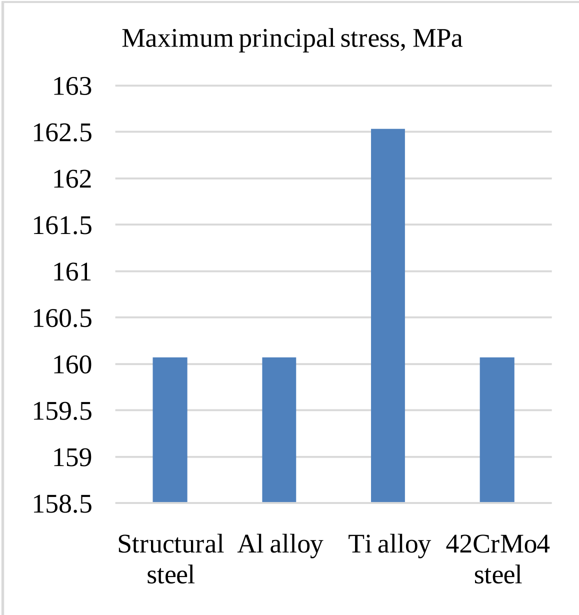

Fig. 13: Max. principal stress comparison

Results of nonlinear finite element simulation showed that during work of the engine the maximum stress zones (162.53 MPa) are observed in the connecting rod, close to the small end. During work of the engine the big hole of the connecting rod is subjected to large deformations.

IV. CONCLUSION

The connecting rod belongs to the group of critical components of piston engines.

The connecting rod transfers loads from the piston onto crankshaft. In modern diesel engines the large value of torque achieved at low speed of rotation causes high stresses in pistons, crankshafts, connecting rods and another engine components . Amplitude of operational stresses has significant influence on the fatigue life of the connecting rod. Additional factors which limit its fatigue strength are: incorrect shape (design), material defects or technological errors (defects created during the production process). The failure analysis of the connecting rods of piston engines was described in many publications. Several typical and uncommon failure modes in connecting rods of combustion engines were reported in work. The author's attention is focused on description of failure mode and the stress analysis of investigated components. The interpretation of the fractures was supported by traditional calculations and advanced analytical models. The analyzed failures in connecting rods showed that the most common failure modes.

In this study the failure and stress analysis of the connecting rod of turbocharged diesel engine was performed. In order to explain the reasons of connecting rod damage, an advanced stress analysis using the finite element method (FEM) was utilized. In order to solve the problem the geometrical models of connecting rod, piston and adjacent components were created. Next the complex loads resulting from both the pressure of gas in cylinder and the inertial forces were defined. The contact between all touching surfaces of considered components was defined. Results of nonlinear finite element simulation showed that during work of the engine the maximum stress zones (162.53 MPa) are observed in the connecting rod, close to the small end. During work of the engine the big hole of the connecting rod is subjected to large deformations.

REFERENCES

1. Sathish, T., S. Dinesh Kumar, and S. Karthick (2020). Modelling and analysis of different connecting rod material through finite element route. Materials Today: Proceedings, 21, pp 971-975.
2. Sudeep Jhain Automobile Engineering, Connecting Rod: Definition, Parts, Types, Function, Material https://themechanicalengineering.com/connecting-rod/
3. Things you must know about connecting rod, July 12, 2020, https://studentlesson.com/connecting-rod-definition-functions-types-parts-problem/,
4. Sathish, T., S. Dinesh Kumar, S. Karthick (2020). Modelling and analysis of different connecting rod material through finite element route. *Materials Today: Proceedings* 21, pp 971-975.
5. Muhammad, Aisha, Mohammed AH Ali, and Ibrahim Haruna Shanono (2020). Design optimization of a diesel connecting rod. *Materials Today: Proceedings*, 22 pp.1600-1609.
6. Muhammad, A., M. A. H. Ali, and I. H. Shanono (2020). Finite Element Analysis of a connecting rod in ANSYS: An overview. *IOP Conference Series: Materials Science and Engineering*, vol. 736, no. 2, pp. 022119
7. Chari, Addanki Dharma Linga. Modeling and Analysis Of Connecting Rod Using Various Materials With Fem.
8. Saheb, Shaik Himam (2020). Design and analysis of connecting rod with different materials for high fatigue life. *AIP Conference Proceedings*, vol. 2283, no. 1, pp. 020027.
9. Seralathan, S., Sai Viswanath Mitnala, RV Sahith Kumar Reddy, Inturi Guru Venkat, Dadi Reddy Tejeswar Reddy, V. Hariram, and T. Micha Premkumar (2020). Stress analysis of the connecting rod of compression ignition engine. Materials Today: Proceedings.
10. Pani, Amiya Ranjan, Ritesh Kumar Patel, and Gaurab Kumar Ghosh (2020). Buckling analysis and material selection of connecting rod to avoid hydro-lock failure. Materials Today: Proceedings, 27, pp. 2121-2126.
11. Abraar, SA Muhammed, N. Suresh, and M. Rameeza (2020). Stress analysis of connecting rod for 1500 hp engine. *AIP Conference Proceedings*, vol. 2283, no. 1, pp. 020004.
12. Muhammad, Aisha, and Ibrahim Haruna Shanono (2019). Static analysis and optimization of a connecting rod. Int. J. Eng. Technol. Sci.6, no. 1, pp 24-40.
13. Natrayan, L., E. Aravindaraj, M. S. Santhosh, and M. Senthil Kumar (2019). Analysis And Optimization Of Connecting Tie Rod Assembly in Agriculture Application. Acta Mechanica Malaysia 3, no. 1, pp. 06-10.
14. Mahfouth, Altayeb. Analysis and Optimization of Connecting Rod.
15. Valero-Páez, L. B., J. L. Chacón-Velasco, and O. A. González-Estrada (2019). Optimization of the connecting rod of a two-stroke engine using finite element analysis. Journal of Physics: Conference Series, vol. 1386, no. 1, pp. 012114.
16. Muhammad, Aisha, and Ibrahim Haruna Shanono (2019). Design optimization of a diesel engine connecting rod. International Journal of Engineering Technology and Sciences, 6, no. 1, pp. 24-40.
17. Pandiyan, A., G. Arunkumar, G. Prem kumar (2019). Design, Analysis and Topology Optimization of a Connecting Rod for Single Cylinder 4–Stroke Petrol Engine. International Journal of Vehicle Structures & Systems, 11, no. 4, pp 439-442.
18. Guadiamos, Lucas Emilio (2019). High Performance AM Connecting Rod Design and Optimization." Master's thesis, NTNU.
19. Kumar, A. Vijay, K. Mihir, M. Mrudul, and P. Pavan Kumar (2019). Design and Analysis of Connecting Rod of Diesel Engine.
20. Kar, Anurag. (2019). Connecting Rod Manufacturing. Available at: https://www.researchgate.net/publication/330183972_Connecting_Rod_Manufacturing/citation/download.
21. Patel, Ritesh Kumar (2018). Finite element analysis of connecting rod using CAE tools.
22. Chumbre, Vinayak, Vinayak Kallannavar, AnilkumarShirahatti, Ratan Patil, and Shirish M. Kerur (2018). Design and Comparative Analysis of Connecting Rod using Finite Element Analysis. Young 1, no. 1.2, x10-5.
23. Kaliappan, S., S. Mohanamurugan Dr PK Nagarajan, MD Raj Kamal (2018). Analysis Of An Innovative Connecting Rod By Using Finite Element Method. Taga Journal Of Graphic Technology, 14, pp 1147-1152.
24. Prakash, Om, M. Natrayan, R. Dinesh Kumar (2018). Optimization of Connecting Rod for Weight Reduction by Finite Element Analysis. International Research Journal of Automotive Technology, 1, no. 6, pp. 80-87.
25. Xu, C., Bowen, L. (2018). Finite Element Analysis of Static Linkage of Engine Connecting Rod Based on

Algor. IOP Conference Series: Materials Science and Engineering, vol. 382, no. 4, pp. 042061.

26. BiradarAkshaydattaVinayakrao, Swami M. C. (2017). Analysis and Optimization of Connecting Rod used in Heavy Commercial Vehicles, International Journal of Engineering Development and Research, 5(3), 684-707.
27. Ruchir Shrivastava (2017). Finite Element Analysis Of Connecting Rod For Two Wheeler And Optimization Of Suitable Material Under Static Load Condition, 4(2), 538-543.
28. Bulut, Mehmet, and ÖmerCihan (2017). Stress and deformation analysis of a connecting rod by using ANSYS. International Journal of Automotive Engineering and Technologies, 9, no. 3: 154-160.
29. Sen, Binayak, Pushparenu Bhattacharjee, Uttam Kumar Mandal (2016). A comparative study of some prominent multi criteria decision making methods for connecting rod material selection. Perspectives in Science, 8, pp: 547-549.
30. Shweta Ambadas Naik (2014), Design & Shape Optimization of Connecting Rod using FEA: A review, International Journal of Engineering and Technical Research, 2(8), 95-100.
31. https://themechanicalengineering.com/connecting-rod/
32. Connecting rod. Cylinder Components (2010), 69–93. doi:10.1007/978-3-8348-9697-1_4