Design and Analysis of Aluminum Silicon Carbide Connecting Rod of Light Motor Vehicle

[1]*Dr.Suri Srinivas,* [2]*Pasam Satya Sri Chakravarthi, Shyamalapelli Durga Prasad, Madala Sri Hari*

[1]*Assistant Professor, Department of Mechanical Engineering, M.V.S.R Engineering College, Nadergul, Hyderabad, Telangana, India*

[2]*UG Students, Department of Mechanical Engineering,M.V.S.R Engineering College, Nadergul, Hyderabad, Telangana, India*

***Abstract*—The connecting rod plays a crucial role in the functioning of internal combustion engines. Engines are exposed to high pressures and forces. This work aims to Analysis of a lightweight engine connecting rod using Aluminum silicon Carbide (Al-Sic) composite material. The Al-sic composite Provides enhanced durability, resistance to corrosion, and has good Thermal Conductivity to Conventional materials. This will involve a detailed model of the connecting rod and its features, which is created to accurately measure the Stress concentration, endurance, and structural integrity. The simulations will be based on the engine's performance under different operating conditions. The performance of the connecting rod made of aluminum silicon carbide will be weighed against that of a similar conventional steel rod. This work aims to decrease the engine's weight, while maintaining strength, leading to improved fuel efficiency and performance. The goal is to create and evaluate an Al-Sic connecting rod.**

Key Words- Aluminum Silicon Carbide, Composite, Durability.

1. INTRODUCTION

Connecting rods always serve as a link between the shaft and the reciprocating piston. The smaller end is joined with the piston using a gudgeon pin while the larger end is attached to the crankshaft. There are both axial and bending stresses that the rod has to cope with while in operation. Calorific pressure of the gas in the cylinder, along with the inertia force resulting due to reciprocating motion, gives rise to axial stresses. In order to provide the connecting rod with greatest rigidity while making it as light as possible, it has an I-section cross portion while the ends of the rod take the form of a solid eye or split eye, which holds the piston pin. The split end is where the crank pin is connected and is always exposed. A few connecting rods have a channel drilled through them, connecting the two ends to allow lubricating oil to flow freely. This enables lubrication of the piston and pin, causing axial stresses on the piston pin. To consider the problems of studying the crank end of the connection rod, strain intensity, stress concentration and deformation issues are studied first with respect to the chosen the vehicle and set up the working Here the design parameter or size of the connecting rod is computed, and from the results obtained, we anticipate achieving the necessary work outcomes.

1.1. Connecting rod

The connecting rod in a reciprocating piston engine links the piston to the crankshaft or crank. The connecting rods of modern automotive internal combustion engines are generally constructed from steel for standard production engines; however, they may also be manufactured from aluminum for enhanced impact absorption and reduced weight at the cost of durability, titanium for high-performance engines (which offers a combination of strength and light weight at the sacrifice of cost-efficiency), or cast iron for applications like motor scooters. Connecting rods are occasionally called "billets," especially in racing engines.

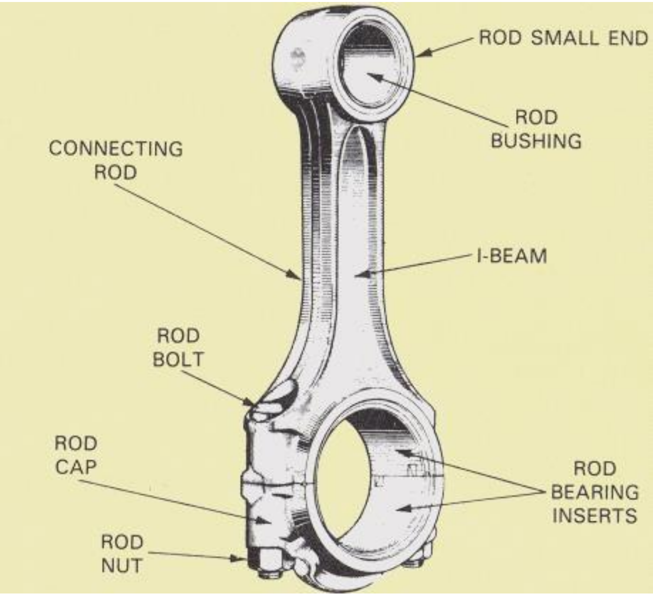


Fig 1- Connecting Rod

It's due to a defect, incorrect tightening, or re-use of previously used (stressed) bolts where not advised. This is due to the fact that production auto parts possess a much higher factor of safety, and usually more systematic quality control. Usually, connecting rods are manufactured from stainless steel and Aluminum alloy using the forging process, as this process offers high productivity and that too at a lower cost of production. Forces induced on the connecting rod are usually by weight, and burning fuel within the cylinder acts upon the piston and then upon the connecting rod, hence giving rise to both the bending and axial stresses. The connecting rod or crank couples the piston to the crankshaft in a reciprocating piston engine. With the crank, they make a simple mechanism that couples reciprocating motion to rotating motion. Connecting rods can also transform rotating motion into reciprocating motion. In the past, prior to the invention of engines, they were utilised in this manner. A connecting rod is rigid; it can transmit a push or a pull, and therefore the rod can turn the crank through both halves of a revolution, i.e. piston pushing and piston pulling. Earlier mechanisms, like chains, could only push. In some two-stroke engines, the connecting rod is only needed to push. Anyway, today's connecting rods are known best through internal combustion piston engines, i.e., automotive engines. They are of a fundamentally different construction from those in previous configurations of connecting rods, which were found in steam engines and steam locomotives.

2. Literature survey

Quite a few papers were referred on the area of present work, out of those papers, these papers Were relevant

B. Anusha, Dr. C. Vijaya Bhaskar Reddy et al. “Comparison of Materials for Two-Wheeler Connecting Rod Using ANSYS.” The connecting rod model was imported into the analysis software known as ANSYS. A static analysis is carried out to ascertain von Mises stresses, strain, shear stress, and total deformation under the specified loading conditions using the analysis software, i.e.. , ANSYS. In this analysis, two materials are chosen and examined. The results from the software for the two materials are compared and used for the design of the connecting rod.

Ravi et. al [1]Paper presents a study about exploring load and cost reduction, but we have selected forged steel for comparison as the preferable material for handling substances in the connecting rod. The paper has been subjected to a comprehensive evaluation of the connection pole through a dynamic examination of the linking bar considered. The analysis of the first part deals with the observation of static load analysis and the materials that are selected and subsequently taken into account while considering production factors. Then, this paper addresses the design of the connecting rod through CATIA, after which the connecting rod is imported into the ANSYS workbench, and an analysis is conducted. Results are obtained by comparing experimental outcomes.

Mr. H. B. Armani et al. “Analysis of Connecting Rod under Different Loading Conditions Using Ansys Software” In this research, an in-depth load analysis was conducted on the connecting rod, followed by the finite element method using Ansys-13 software. In this context, to compute stress in various parts of the connecting rod, the total forces acting on the connecting rod were calculated. Afterward, it was modeled, meshed, and loaded into the Ansys software. The analysis identified the maximum stresses in different sections of the connecting rod. The greatest pressure stress was located between the pin end and rod linkages as well as between the bearing cup and connecting rod linkage. The highest tensile stress was found in the lower portion of the pin end and between the pin end and the rod linkage. It is recommended that the results obtained can aid in modifying the design of the connecting rod.

The study by Ramasubramanian et al. examines the design, production, and analysis of aluminum/silicon carbide (Al/SiC) metal matrix composites (MMCs) for connecting rods in internal combustion engines. The main objective is to assess the viability of Al/Sic MMCs as an alternative to conventional C70 steel. The study includes mechanical testing, finite element analysis (FEA), and a comparison of different Al/Sic.

3. Objectives

Designing and analysing the connecting rod according to the input parameters, and subsequently modeling it in SOLIDWORKS software. Material and model input for FEM tool software ANSYS is provided based on parameters derived. In order to determine Von Mises stresses, Strain Intensity, Total Deformation and optimisation in the present Connecting rod design. To calculate stresses in the critical regions and to determine the locations in the connecting rod where there are greater possibilities of failure. To minimise the weight of the current connecting rod on the basis of the size of the output of the analysis. The prime objective of the project is to calculate the Von-Mises stress-strain employed for the connecting rod. Based on this, the new material may be compared with the current materials employed for connecting rods.

4. Material and its properties

Properties of Aluminum Silicon Carbide

Aluminum Silicon Carbide (Al-Sic) is a lightweight, high-performance metal matrix composite (MMC) that combines the ductility and heat conductivity of aluminum with the hardness, strength, and low thermal expansion of silicon carbide. Al-Sic composite material possesses a higher strength-to-weight ratio, thermal properties, and is used in automotive, aerospace, and electronic applications. With extensive use in components like connecting rods, pistons, heat sinks, and structural parts, AL-Sic reduces weight while increasing strength, performance, and enhanced durability. However, its high production cost, hardness in machining, and the need for uniform dispersion of Sic in the aluminum matrix are still major disadvantages. In spite of all these drawbacks, Al-Sic has great promise as a material for advanced engineering applications where light-weight, high-strength, and heat-resistance are of prime importance. In this paper, the Aluminum reinforced with SiC ratios are set at Al 60% / SiC 40%, Al 75% / SiC 25%, and Al 70% / SiC 30%. Evaluation and assessment are done with regard to the evaluation and common physical properties listed below.

Properties of forged steel

Forged steel and other forged steel versions are commonly used to manufacture connecting rods and some Aluminum alloys. Forged steel is a high-strength material known for its superior mechanical properties, making it suitable for applications in industries such as aerospace, automotive, and heavy machinery. The process of forging involves shaping the steel by applying high-pressure forces, which results in material with improved structure and enhanced performance. So here are the properties of Forged Steel mentioned below

Material properties of Forged Steel 4340

Property	Typical Value
Density	7.8 g/cm³
Tensile Strength	~800-1200 MPa
Elastic Modulus	200 GPa
Thermal Conductivity	50 W/m·K
Coefficient of Thermal Expansion	12.3 µm/m C
Fatigue Strength	~860-1850 MPa
Specific Strength	High
Wear Resistance	Excellent
Corrosion Resistance	Good

Table 1- Material Properties of Forged Steel 4340

Material properties of Aluminium Silicon Carbide Physical Properties of Al-Sic

Description of Properties	Quantity
Density (kg/m^3)	2784
Young's Modulus (MPa)	99974
Poisson Ratio	0.292
Co-efficient of thermal expansion (C^{-1})	16.002
Tensile Strength (MPa)	615.63
Compressive Strength (MPa)	400.3
Thermal Conductivity ($Wm^{-1}K^{-1}$)	130
Specific Heat ($Jkg^{-1}k^{-1}$)	919

Table 2- Physical Properties of Al-Sic

Mechanical Properties of Al-Sic (MMC)

Composition (Vol.%)	Al75-Sic25	Al70-Sic30	Al60-Sic40
Density ($g/cm3$)	2.8	2.8	2.9
Young's Modulus (GPa)	115	125	150
Co-efficient of thermal expansion (C^{-1})	15	14	13
Thermal Conductivity ($Wm^{-1}K^{-1}$)	145	150	155

Table 3- Mechanical Properties of Al-Sic Composition

5. Modeling of the connecting rod

Two parts were molded for a connecting rod using the dimensions of existing light motor vehicle. The SolidWorks software was utilised for the modeling phase. A connecting rod exists to relay the motion and force between the piston and the crankshaft. One end of the rod is attached to the piston, enabling the motion and force to be applied easily. The other two ends are etched separately, and they join the crankshaft for easy assembling and disassembling. This design enables better service and improves efficiency in the engine. The model complies with the most common engineering standards to ensure effectiveness, reliability, and durability while it is being used.

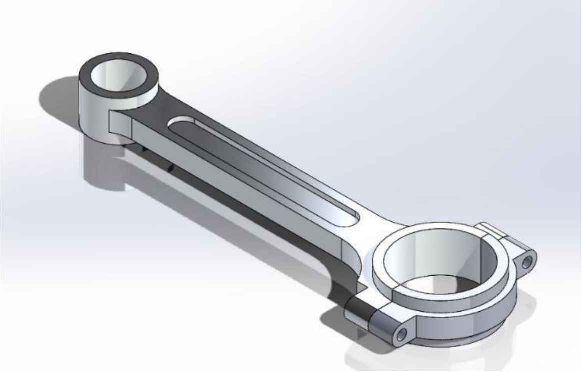


Fig 2- Modeling of Connecting Rod

6. Analysis of the connecting rod

The analysis section involves stress, strain, and deformation of the given connecting rod. First, we must analyze the conventional material to check the total stress, strain, and deformation. The data produced are compared with the data from the Al- Sic material

Finite Element Method in Structural Analysis

The Finite Element Method is commonly known for its various forms of application areas. The term structural, therefore, does not pertain to civil engineering structures like bridges and buildings. It includes structures like ship hulls, aircraft bodies and machine housings, not limited to civil engineering, but also includes naval, aeronautical and mechanical structures. Besides those, it includes a large number of mechanical components such as pistons, machine parts and tools.

Various types of Structural Analysis

Structural analysis is carried out using a wide variety of ANSYS products. The most fundamental unknowns are then used to derive other important quantities such as strains, stresses, or reaction forces. Structural analysis features are available in ANSYS/Multiphysics, ANSYS/Mechanical, ANSYS/Structural, or ANSYS/Linear Plus. The different types of structural analysis performed in ANSYS include:

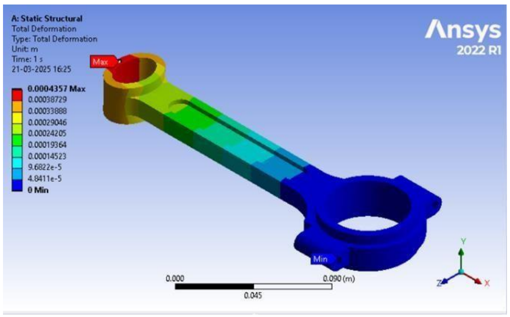
Static Analysis: Used when displacements, stresses, and other responses are obtained under conditions of static loading.

We conducted the Analysis on four different materials they are Forged Steel, Al75-SiC25, Al70-SiC30, and Al60-SiC40. The connecting rod was modeled and then brought into ANSYS for appropriate meshing. Various boundary conditions were set for different analyses.

Static structural analysis involves applying a force at the piston end while the crankshaft side has a fixed support. In modal analysis, the piston end is also fixed but the crankshaft end has a cylindrical support with a temperature value applied. For buckling analysis, the piston end is under pressure and the crankshaft side is fixed.

MATERIAL: -Forged steel

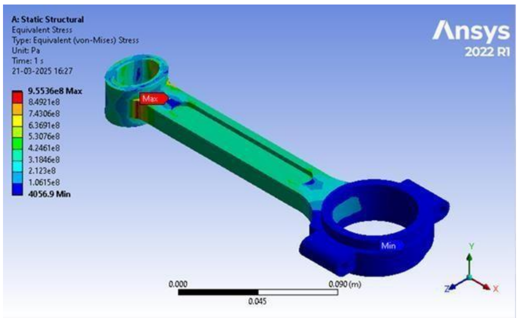
Total Deformation:



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1 s
21-03-2025 16:25

Fig 3- Total Deformation of connecting Rod (Forged Steel)

Equivalent Stress:



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: Pa
Time: 1 s
21-03-2025 16:27

Fig 4- Equivalent Stress of connecting Rod (Forged Steel)

Equivalent Strain

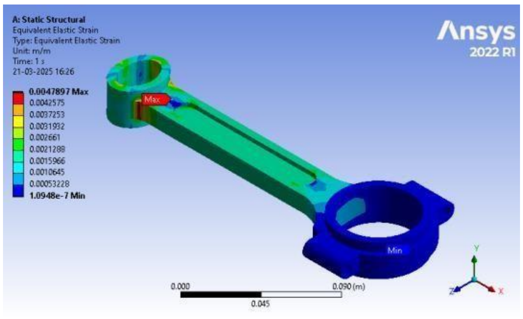


Fig 5- Strain of connecting Rod (Forged Steel)

Modal Analysis

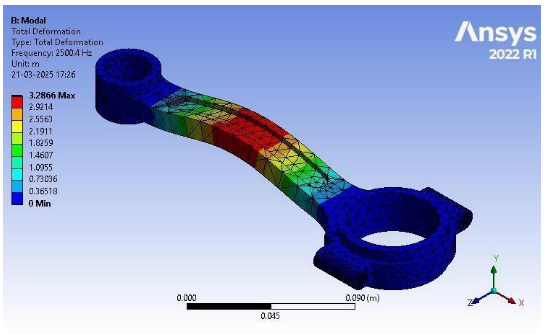


Fig 6- Modal Analysis of connecting Rod (Forged Steel)

Buckling Analysis

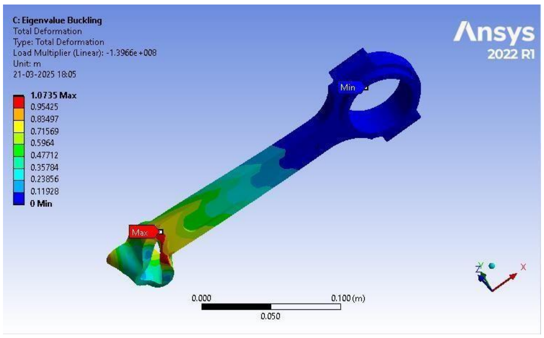


Fig 7- Buckling Analysis of connecting Rod (Forged Steel)

Results of Forged Steel Connecting Rod

Material	Deformation (m)	Stress (Pa)	Strain	Modal (m)	Buckling (m)
Forged Steel 4340	4.357e-004	9.5536e+008	4.7897e-003	3.2866	1.0735

Table 4- Analysis Results of Connecting Rod (Forged Steel 4340)

MATERIAL: -Aluminum Silicon Carbide (Al60-SiC40)

Total deformation

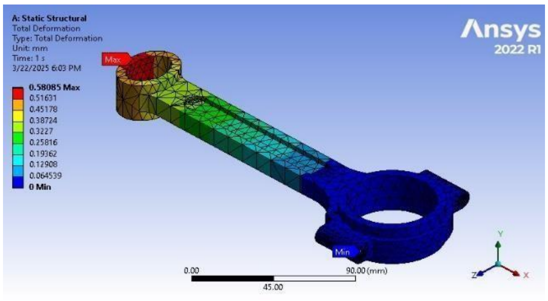


Fig 8- Deformation of connecting Rod (Al60-Sic40)

Equivalent Stress

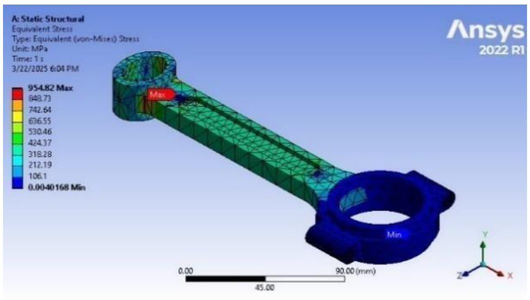


Fig 9- Stress of connecting Rod (Al60-Sic40)

Equivalent Strain

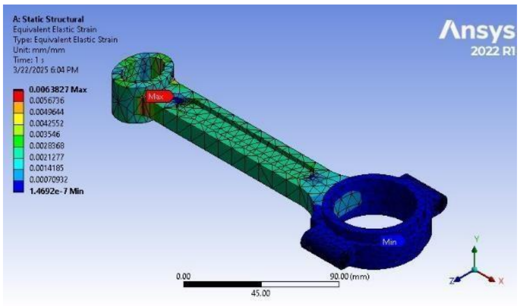


Fig 10- Strain of connecting Rod (Al60-Sic40)

Modal Analysis

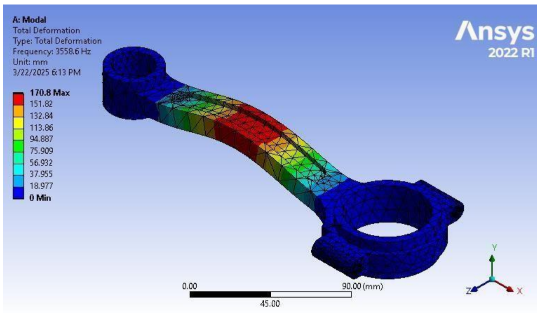


Fig 11- Modal Analysis of connecting Rod (Al60-Sic40)

Buckling Analysis

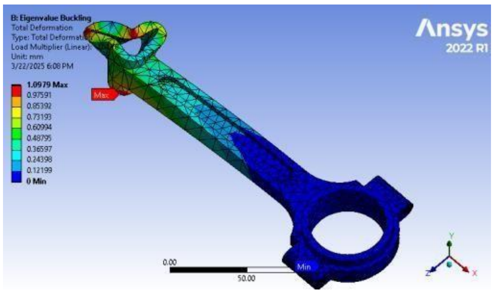


Fig 12- Buckling Analysis of connecting Rod (Al60-Sic40)

Results of Aluminum Silicon Carbide (Al60-SiC40) Connecting Rod

Material	Deformation (mm)	Stress (MPa)	Strain	Modal (mm)	Buckling (mm)
Al60-Sic40	0.58085	954.82	6.3827e-003	170.8	1.0979

Table 5-Analysis Results of Connecting Rod (Al60-Sic40)

MATERIAL: -Aluminum Silicon Carbide (Al75-SiC25)

Total deformation

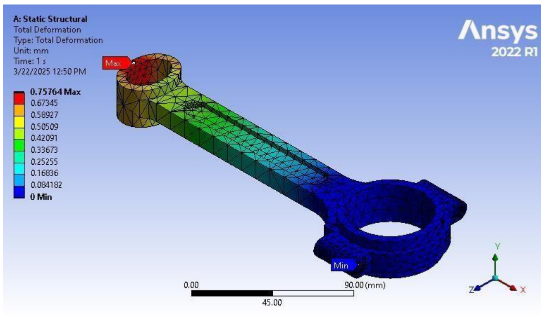


Fig 13- Deformation of connecting Rod (Al75-Sic25)

Equivalent Stress

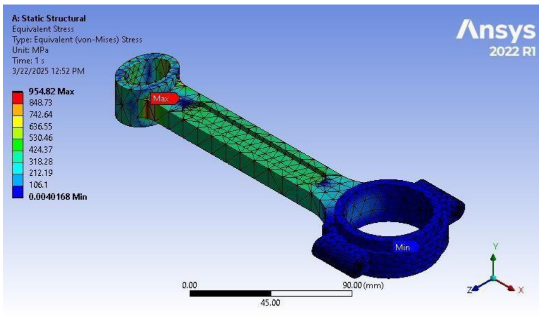


Fig 14- Stress of connecting Rod (Al75-Sic25)

Equivalent Strain

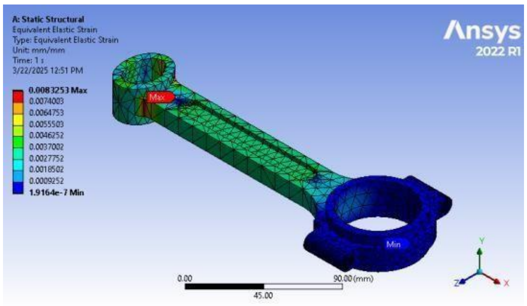


Fig 15- Strain of connecting Rod (Al75-Sic25)

Modal Analysis

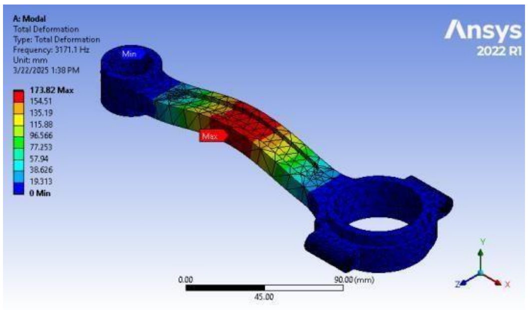


Fig 16- Modal Analysis of connecting Rod (Al75-Sic25)

Buckling Analysis

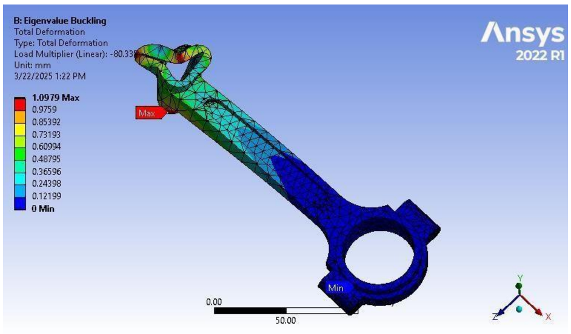


Fig 17- Buckling Analysis of connecting Rod (Al75-Sic25)

Results of Aluminum Silicon Carbide (Al75-SiC25) Connecting Rod

Material	Deformation (mm)	Stress (MPa)	Strain	Modal (mm)	Buckling (mm)
Al75-Sic25	0.75764	954.82	8.3253e-003	173.82	1.0979

Table 6-Analysis Results of Connecting Rod (Al75-Sic25)

MATERIAL: -Aluminum Silicon Carbide (Al70-SiC30)

Total deformation

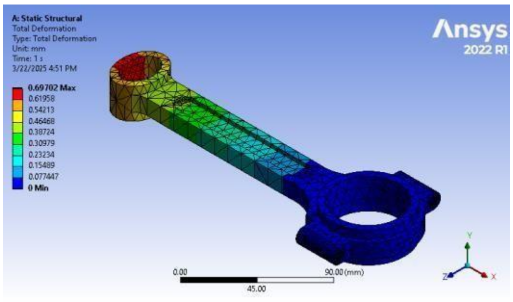


Fig 18- Deformation of connecting Rod (Al70-Sic30)

Equivalent Stress

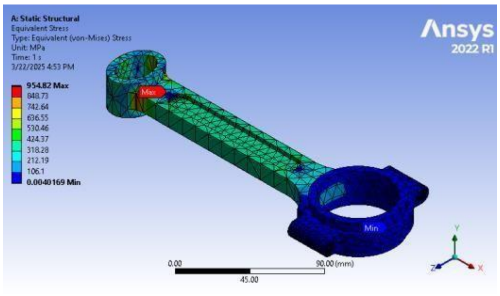


Fig 19- Stress of connecting Rod (Al70-Sic30)

Equivalent Strain

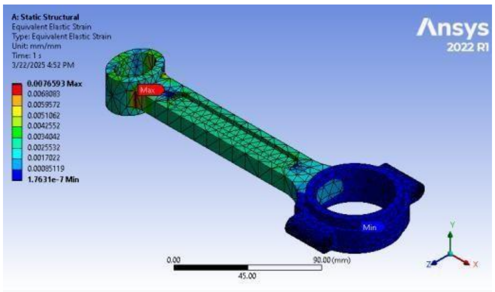


Fig 20- Strain of connecting Rod (Al70-Sic30)

Modal Analysis

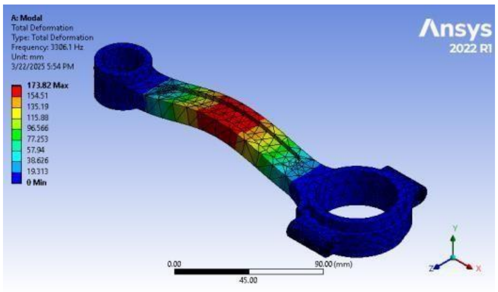


Fig 21- Modal Analysis of connecting Rod (Al70-Sic30)

Buckling Analysis

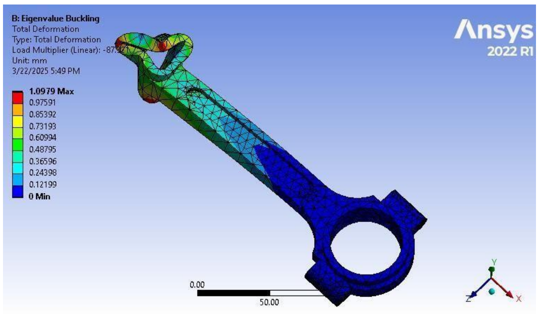


Fig 22- Buckling Analysis of connecting Rod (Al70-Sic30)

Results of Aluminum Silicon Carbide (Al70-SiC30) Connecting Rod

Material	Deformation (mm)	Stress (MPa)	Strain	Modal (mm)	Buckling (mm)
Al70-Sic30	**0.69702**	**954.82**	**7.6593e-003**	**173.82**	**1.0979**

Table 7-Analysis Results of Connecting Rod (Al75-Sic25)

COMPARISON OF RESULTS

Properties	**Forged steel**	**Al60-SiC40**	**Al74-SiC25**	**Al70-SiC30**
Deformation(mm)	0.4357	0.58085	0.75764	0.69702
Stress (Mpa)	955.37	954.82	954.82	954.81
Strain	4.7897e-003	6.3827e-003	8.3253e-003	7.6593e-003
Modal(mm)	3286.6	170.8	170.83	173.82
Buckling(mm)	1073.25	1.0979	1.0979	1.0972

Table 8- Results Comparison of Material

The mechanical characteristics of various aluminum silicon carbide (Al-SiC) composites and forged steel are thoroughly compared in this table. It shows attention to important variations in structural stability, stress, strain, and deformation. Both materials' elasticity and strength are examined in order to determine how well they function under mechanical loads. While Al-SiC composites provide superior strength-to-weight ratio and wear resistance, forged steel usually has higher toughness and ductility. The effect of loading circumstances and temperature on material behavior is also compared.

7. Conclusion

According to the results, Al-SiC composites—in particular, Al70-SiC30—offer a well-balanced combination of stress management and deformation resistance, which makes them desirable substitutes for conventional forged steel in applications where durability and weight reduction are crucial. Performance could be improved for specific engineering requirements with additional SiC content optimization.

Forged Steel is the preferred material for applications requiring high strength, stiffness, and minimal deformation, such as in high-performance engines. On the other hand, Al-SiC composites, with their lighter weight and competitive buckling resistance, are suitable for applications where weight reduction is critical, provided that higher deformation and lower stress tolerance are acceptable. The choice between these materials ultimately depends on the specific engineering requirements and trade-offs between weight, strength, and durability.

These findings suggest that Al-SiC composites, particularly Al70-SiC30, offer a balanced combination of deformation resistance and stress management, making them viable alternatives to traditional forged steel in applications where weight reduction and durability are critical. Further optimization of SiC content could enhance performance for specific engineering requirements.

REFERENCES

[1] Dynamic Load Analysis and Optimization of Connecting Rod By Pravardhan S. Shenoy, thesis page 2 – 5.

[2] Design And Optimization of Connecting Rod For 4 – Stroke Petrol Engine By Using Finite Element Analysis S. Aishwarya And E. V. V. Ramanamurthy, Department Of Mechanical And Production, Sathyabama University Page 1.

[3] Study And Analysis Of Connecting Rod Parameters Using Ansys Anil Kumar Vishwakarma, Pawan Kumar Singh, Vicky Lad Research Scholar, Department Of Mechanical Engineering.

[4] International Journal Of Scientific & Engineering Research, Volume 6, Issue 8, August-2015 Issn 2229- 5518ijser © 2015 Http://Www.Ijser.Org Parameters Influencing Connecting Rod A Review Shubham Tiwari, Ajay Kumar Kaviti.

[5] International Journal Of Engineering Trends And Technology (Ijett) – Volume 4 Issue 9- Sep 2013 "Comparison Of Materials For Two-Wheeler Connecting Rod Using Ansys" B. Anusha#1, Dr.C.Vijaya Bhaskar Reddy.

[6]. Solid Works. Manual.

[7]. Ansys Workbench 13 Manual.

[8]. G.M Sayeed Ahmed, Sirajuddin Elyas Khany, Syed Hamza Shareef "Design, Fabrication And Analysis Of A Connecting Rod With Aluminum Alloys And Carbon Fiber "International Journal Of Innovative Research In Science, Engineering And Technology, Issn: 2319-8753, Vol. 3, Issue 10, October 2014.

[9]. Aniket B. Phatangare, Prof. M.S. Mhaske, Prof. S.B.Belkar, Swapnilkulkarni "Using Finite Element Analysis For Determining Fatigue Life Of Connecting Rod As Used In A Motor-Bike" International Journal Of Advanced Engineering Research And Studies E-Issn: 2249–8974.

[10]. Ram Bansal "Dynamic Simulation Of A Connecting Rod Made Of Aluminium Alloy Using Finite Element Analysis Approach" Iosr Journal Of Mechanical And Civil Engineering (Iosr-Jmce) Eissn: 2278-1684 Volume 5, Issue 2 (Jan. - Feb. 2013), Pp 01-05.

[11]. Abhinavgautam, K Priyaajit "Static Stress Analysis Of Connecting Rod Using Finite Element Approach" Iosr Journal Of Mechanical And Civil Engineering (Iosr-Jmce) Eissn: 22781684, P-Issn: 2320-334x, Volume 10, Issue 1 (Nov. - Dec. 2013), Pp 47-51

[12]. Pravardhan S. Shenoy And Ali Fatemi" Connecting rod Optimization For Weight And Cost Reduction" Sae Technical Paper 2005-01-0987, 2005, Doi: 10.4271/2005-01-0987.

[13]. Gvss Sharma And P Srinivasarao "Process Capability Improvement Of An Engine Connecting Rod Machining Process" Journal Of Industrial Engineering International 2013, 9:37 Doi: 10.1186/ 2251-712x-9-37.

[14]. K. Sudershn Kumar, Dr.K. Tirupathi Reddy, Syed Altaf Hussain "Modeling And Analysis Of Two-Wheeler Connecting National Journal Of Modern Engineering Research (Ijmer),