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# CAD Modelling and Comparative Deformation Analysis with Different Materials of Automatic Crank Shaft

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**ABSTRACT:** The connecting rod is a critical component in an engine assembly, functioning as the link between the piston and the crankshaft. It endures substantial tensile and compressive forces throughout its operational life. This paper aims to explore and compare the properties of various materials used in the manufacture of connecting rods. Specifically, we examine connecting rods made from Aluminium 360, ALFA SiC (an aluminium composite reinforced with silicon carbide), magnesium alloy, and beryllium alloy. Our goal is to evaluate their mechanical properties in terms of weight reduction, stress, strain, and displacement while ensuring or enhancing the strength of the connecting rod.

## I. INTRODUCTION

A connecting rod serves as the vital link between the piston assembly and the crankshaft, transforming the piston's reciprocating motion into the crankshaft's rotary motion. Globally, connecting rods are mass-produced and must endure significant tensile and compressive loads. The automotive industry demands lighter components to improve fuel efficiency while maintaining passenger comfort and safety. However, achieving this balance often increases vehicle weight. This challenge has driven the development and adoption of new, lightweight materials that meet stringent design criteria. Lighter connecting rods reduce the inertia forces within the engine, eliminating the need for large balancing weights on the crankshaft. Consequently, a connecting rod must be robustly designed to withstand high stresses, necessitating thorough analysis.

The connecting rod comprises three main parts: the pin end, which connects to the piston assembly; the shank region; and the crank end, which connects to the crankshaft. Stress analysis can be efficiently conducted by modeling the connecting rod in CAD software and utilizing finite element analysis (FEA). Advancements in techniques for reducing weight, stress, and strain are crucial for enhancing engine performance and efficiency.

AISI 4615 alloy steel, a nickel-molybdenum steel, falls under the category of low alloy steels, offering enhanced mechanical properties over presence like molybdenum, nickel, and chromium. Dynamic analysis and simulations using ANSYS have been performed to validate these properties. The optimization process involved refining geometry, materials, and manufacturing techniques, taking into account various constraints, feasibility, and cost factors. Deformation analysis pinpointed areas of maximum stress and critical points on the crankshaft, while modal analysis assessed the vibration characteristics of the structure, crucial for the dynamic evaluation of the crankshaft.

## II. LITERATURE SURVEY

1. **Farzin H. Montazersadgh et al. (2007):** The crankshaft, a critical component in internal combustion engines, transforms the piston's reciprocating motion into rotary motion through four-bar linkage mechanism. It undergoes numerous load cycles, necessitating careful consideration of its fatigue performance, durability, and service life during the design process. The goal in crankshaft design and development is to produce a component that is lightweight, cost-effective, has good fatigue strength, and enhances fuel efficiency and power output.

2. **Meng et al. (2011):** This study conducted static structural and modal analysis on crankshafts of four-cylinder engines, identifying the areas of maximum stress, maximum deformation, and potential failure points.

3. **V. C. Shahane et al. (2016)**, a comprehensive analysis was performed on the crankshaft of a single-cylinder four-stroke diesel engine, focusing on both static structural and dynamic aspects. A 3D CAD model of the crankshaft was created

4. **V. Sowjanya et al. (2016)**: This study investigated the dynamic characteristics of a crankshaft by analyzing its vibration modes and frequencies through modal and harmonic analyses using ANSYS software. A detailed 3D model was generated using Pro-E software, enabling Finite Element Analysis (FEA) to identify stress variations at critical locations. The research aimed to achieve weight reduction through reverse engineering techniques, optimize material selection, and parametrically enhance the crankshaft's design. These efforts were directed towards improving engine performance, enhancing the strength-to-weight ratio, and lowering production costs.

5. **Thirunavukkarasu et al. (2016)**: The paper investigated several strategies for reducing the weight of a crankshaft, including optimizing the web design and decreasing the bearing diameters. The research showed that by incorporating hollow crank pins and journals, it is possible to achieve a 22% reduction in crankshaft weight while simultaneously increasing the safety factor by two times compared to a traditional solid crankshaft design.

6. **Paolo Citti et al. (2018)**, the authors emphasize that the crankshaft, as a crucial element of internal combustion engines, demands meticulous attention in terms of material selection, heat treatments, manufacturing techniques, and cost management. This work examined current and future material choices for high-performance engine crankshafts, focusing on materials like 38MnVS6 and 48MnVS3, along with surface hardening techniques and thermal treatments to enhance quality and cost efficiency.

7. **Vijaya Ramnath et al. (2018)**: The objective of this paper was to comprehensively address all aspects of crankshaft design, manufacturing, maintenance, and serviceability. Employing a Coordinate Measuring Machine (CMM) for reverse engineering, CATIA for computer-aided modeling, and ANSYS for optimization analysis, the study conducted a comparative analysis of fatigue performance among crankshafts fabricated from forged steel, ductile cast iron, and aluminum alloy.

8. **K. Satyanarayana et al. (2017)**: This study investigated stress induced in AISI 4340 forged steel crankshafts. It included kinematic and dynamic analysis, and FEA stress analysis. Using experimental data from a variable compression ratio diesel engine, equations of equilibrium were developed for stress analysis. The study applied these forces and boundary conditions to identify von-Mises stresses and deformations, assessing the crankshaft's safety factor. The paper highlighted traditional manufacturing methods (forging, casting, machining) and their drawbacks, emphasizing the need for weight reduction, material selection, and parametric optimization to improve performance and reduce costs.

9. **Sarihan and Song (1990)**: For optimizing the wrist pin end, this study used a fatigue load cycle including compressive gas loads (for maximum torque) and tensile loads (for maximum inertia). The design for fatigue involved the modified Goodman equation with alternating and mean octahedral shear stress. An approximate design surface was generated for optimization.

10. **Yoo et al. (1984)**: This research applied variational equations of elasticity, the material derivative concept from continuum mechanics, and an adjoint variable technique to calculate shape design sensitivities of stress. An iterative optimization algorithm, specifically the steepest descent algorithm, solved the optimal design problem, focusing on shape design sensitivity for a connecting rod under principal stress constraints from inertia and firing loads.

### III. OBJECTIVE OF THE STUDY

- Develop a 3D CAD model of the crankshaft using SOLIDWORKS 2017.
- Analyze the impact of various loads on the crankshaft under specified loading conditions.
- Utilize the FEM tool in ANSYS to compare different materials and determine the optimal material for the crankshaft.

### 3.1 MATERIALS AND METHOD:

#### Engine specification:

This study centers on the crankshaft, emphasizing that its design and characteristics are tailored specifically to the engine it operates within. The presence of chromium in the material composition enhances hardness penetration, while molybdenum contributes to consistent hardness and increased strength. AISI 4140 chrome molybdenum steel can achieve substantial hardness levels through the process of oil hardening. Detailed engine specifications and the chemical composition of the materials utilized are provided in Table 1.

Engine type	4 stroke, Single cylinder, Air cooled engine
Bore x Stroke	68 X 45 mm
Displacement	163 cm <sup>3</sup>
Rated Output	2.83 KW @ 3,600 rpm
Maximum Torque	10.3 Nm @ 2,500 rpm
Compression Ratio	9.0:1
Weight	15.1 Kg

Table 3.1 Specification of the engine

### 3.2 CRANKSHAFT:

#### 3.2.1 Material

For internal combustion (IC) engine components, compact weight and high structural rigidity are essential attributes. AISI 1040 carbon steel, due to its high carbon content, can be hardened through heat treatment followed by quenching and tempering, achieving tensile strengths between 150 and 250 ksi. On the other hand, AISI 1045 steel, a medium tensile steel, is typically provided in either a black hot rolled or normalized state. It boasts a tensile strength of 570 to 700 MPa and a Brinell hardness ranging from 170 to 210. Known for its good weldability, excellent machinability, and high strength and impact properties in both normalized and hot rolled conditions, AISI 1045 steel, however, has a shallow depth of hardness penetration. These properties underscore the importance of balancing weight and structural rigidity in the design of IC engine components.

Designation	MATERIALS			
	AISI 1040	AISI 1045	AISI 4140	AISI 4615
Elements	Content (%)	Content (%)	Content (%)	Content (%)
Iron (Fe)	98.6-99	98.51-98.98	96.785-97.77	96.495-97.42
Manganese (Mn)	0.60-0.90	0.60-0.90	7.5-1.0	0.45-0.65
Carbon (C)	0.370-0.440	0.420-0.50	0.380-0.430	0.13-0.18
Sulfur (S)	≤ 0.050	≤ 0.050	≤ 0.040	≤ 0.040
Phosphorous (P)	≤ 0.040	≤ 0.040	≤ 0.035	≤ 0.035
Chromium (Cr)	-	-	0.80-1.10	-
Molybdenum	-	-	0.15-0.25	0.20-0.30

um (Mo)				
Silicon (Si)	-	-	0.15-0.30	0.15-0.30
Nickel (Ni)	-	-	-	1.65-2

**Table 3.2** Chemical composition of selection materials % by weight

**AISI 1040 carbon steel features:**

- Its high carbon content enables hardening through heat treatment, followed by quenching and tempering, reaching tensile strengths of 150 to 250 ksi.
- It has limited hardening potential, suitable for sections up to approximately 60 mm in size for effective tempering and through hardening.
- In normalized or hot rolled conditions, it can be flame or induction hardened efficiently, achieving surface hardness levels between Rc 54 and Rc 60, depending on section size, setup type, and quenching medium.
- It does not contain the necessary alloying elements for the nitriding process.

**AISI 1045 steel:**

- Medium tensile steel, available in black hot rolled or normalized condition.
- Tensile strength ranges from 570 to 700 MPa with Brinell hardness between 170 and 210.
- Known for good weldability, machinability, and high strength and impact properties in both normalized and hot rolled conditions.
- Low depth of hardness penetration, but can achieve surface hardness through flame or induction hardening.

**AISI 4140 chromium molybdenum alloy steel is characterized by several key properties:**

- Chromium contributes to good hardness penetration, while molybdenum ensures uniform hardness and high strength.
- It can be oil hardened to achieve a high level of hardness.
- When quenched and tempered, it provides excellent toughness, good ductility, and superior wear resistance.
- The alloy can be heated using various methods to obtain a broad range of properties, making it an ideal choice for forging stock due to its self-scaling nature.
- It resists creep at temperatures up to 538°C (1000°F) and maintains its properties even after prolonged exposure to high temperatures.
- AISI 4140 is also available as cold rolled rounds in the 41L40 variant, which contains 0.15 to 0.35% lead to enhance machinability, although this can alter other properties.

A chemical composition test performed using a vacuum optical emission spectrometer confirmed that the material adheres to AISI 1040 standards, according to the American Iron and Steel Institute (AISI).

**AISI 4615 Alloy steel:**

- Classified into low alloy and high alloy steels.
- Low alloy steels, enhanced with elements like molybdenum, nickel, and chromium, have superior mechanical properties compared to plain carbon steels.
- High alloy steels provide high strength at elevated temperatures, suitable for aggressive environments.

The optimized crankshaft model exhibits a weight reduction compared to the original design, achieving an optimal configuration. These optimizations focus on identifying the most efficient design and shape to improve performance, especially at key points. Tables 2 and 3 provide detailed information on the chemical composition and the physical and mechanical properties of the crankshaft materials used in this study.

**3.3 REVERSE ENGINEERING:**

Reverse Engineering (RE) involves creating a detailed computer-aided design (CAD) model from precise measurements obtained using non-contact scanning techniques on an actual physical object. The process, as described by Bopaya, B.I. et al. (1994), includes several systematic steps: data acquisition, pre-processing, triangulation, feature extraction, segmentation, and finally, surface fitting using CAD/CAM/CAE tools. This methodology finds wide application across various industries such as automotive, aerospace, marine, medical life sciences, and software

development.

In this study, reverse engineering techniques were employed, leveraging the high-resolution capabilities of the Steinbichler Comet L3D scanner, which boasts a resolution of 2 megapixels (1600 x 1200 pixels). The goal was to accurately capture and recreate an existing physical model in digital form.

To simplify calculations without compromising accuracy, engineers assume that bending forces do not propagate beyond two adjacent bearings where forces are applied. This approach helps in determining the necessary dimensions of the crankpin. One crucial consideration is ensuring that the projected bearing area (calculated by multiplying the diameter by the length) is sufficiently large. This ensures the crankpin can safely endure the loads imposed by gas pressure, inertia forces, and centrifugal forces during engine operation.

Designation	MATERIALS			
	AISI 1040	AISI 1045	AISI 4140	AISI 4615
Density(Kg/M <sup>3</sup> )	7845	7870	7850	7850
Coefficient of Thermal Expansion (µm/M)(°c)	11.3	11.5	12.2	11
Young's Modulus (GPa)	210	206	210	205
Poisson's Ratio	0.26	0.29	0.30	0.29
Bulk Modulus (GPa)	140	163	175	162
Shear Modulus (GPa)	80	79	80.7	79
Isotropic Thermal Conductivity @ 0°c (W/Mk)	51.9	51.9	42.6	44.5
Yield Strength (MPa)	415	450	415	350
Ultimate Strength (MPa)	620	580	655	650

**Table 3.3** Physical and mechanical properties

### III. ALUMINIUM BASED COMPOSITE MATERIAL REINFORCED WITH SILICON CARBIDE

Aluminum and silicon carbide (SiC) powders, with mesh sizes of 300 microns and 75 microns respectively, were sourced from F.S Corporation in Lahore. The aluminum powder, serving as the matrix, consisted of 98 wt.% aluminum, with minor elements including silicon (Si), zinc (Zn), and iron (Fe).

The experimental procedure for this study involved creating composite samples. Four tablet samples, each with a diameter of 20 mm, were prepared. One sample consisted of pure aluminum powder, while the other three composite samples were reinforced with varying weight percentages of silicon carbide (SiC). the table below comprises the details:

(1)

$$D_g = \frac{A\rho_w}{B - F}$$

Name of constituent	Wt. %	Sample ID
Aluminium	90	A
Silicon Carbide	10	
Aluminium	85	B
Silicon Carbide	15	
Aluminium	80	C
Silicon Carbide	20	

**Table-4.1:** Shows samples

The powders were first sieved using a mechanical sieve shaker in accordance with ASTM B 214-99 standards to achieve the desired small particle size. Smaller particles have a larger pore/solid interfacial area, which increases the driving force for sintering. Both silicon carbide and aluminum powders were then heated to 120°C for 2 hours in a vacuum to remove any moisture. After this, they were mixed in specific weight ratios, with 0.5 wt.% magnesium added to each mixture to act as a sintering aid for aluminum.

The mixed powders were subjected to ball milling in a nitrogen atmosphere at 350 rpm for 6 hours. Following milling, the powders were compacted using a uniaxial compaction machine under a load of 40 MPa and then sintered in a nitrogen environment at 630°C for 6 hours.



**Fig. 4.1:** Showing prepared composites samples after sintering and Heat treatment.

After sintering, only a slight variation in diameter was observed, with the samples measuring approximately 18-19 mm in diameter compared to the initial 20 mm. Density measurements were conducted following the ASTM B962-15 standard, which is based on Archimedes' principle. To measure the green density of the composite tablets, the tablets were first weighed in air (mass A). They were then impregnated with silicone oil at 85°C for 4 hours to seal the surface pores. After cooling to room temperature, excess oil was removed using a lint-free cloth, and the samples were weighed again (mass B). The samples were then weighed in water using deionized water at a temperature of approximately 28-32°C. The density of each sample was determined using the following formula:

#### 4.2 DENSITY:

The density measurements of the prepared composites followed ASTM B962-15 standard test method, revealing a significant increase in density from the unsintered to the sintered state as silicon carbide (SiC) particles were added. This increase continued with higher weight percentages of SiC, attributed to pore shrinkage during sintering. Figure 2 illustrates that the addition of SiC particles led to higher densities, reaching a maximum of 2.4 g/cm<sup>3</sup> with 20 wt% SiC content.

Regarding hardness, the AL-SiC composites exhibited an increase with higher wt% of SiC particles. This enhancement is due to the hard nature of SiC particles, which are well-bonded within the aluminum matrix. These particles hinder the movement of dislocations, leading to increased hardness. The maximum hardness value observed was 51 HV-3 in the composite reinforced with 20 wt% SiC, highlighting the beneficial effect of SiC in enhancing the hardness of aluminum-based metal matrix composites

#### 4.3 POROSITY CONTENT:

The study noted the presence of porosity in parts produced using powder metallurgy, a characteristic also observed in the Al-SiC composites examined in this research, as detailed in Table-2. The table clearly illustrates that porosity

content was notably reduced after the sintering process. The most substantial reduction in porosity was observed in composites containing 20 wt% SiC reinforcement. This reduction is attributed to the phenomenon where small particles settle into interstitial sites during the sintering process.

**4.4 SEM ANALYSIS:**

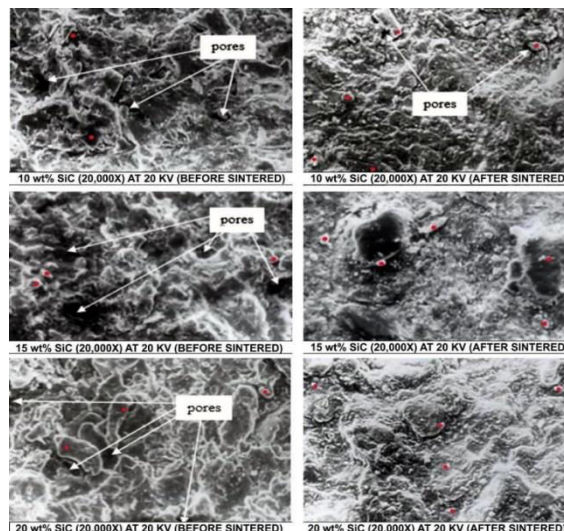
In this study, the distribution of reinforcements within the matrix of composites prepared via powder metallurgy was investigated using SEM (Scanning Electron Microscopy) analysis. The results revealed that the particles were uniformly distributed throughout the matrix. Furthermore, significant reduction in porosity was observed in the sintered samples compared to the unsintered ones. This reduction in porosity is a key outcome of the sintering process, where particles bond together to form a denser structure.

SEM micrographs also showed that the morphology of the SiC particles exhibited irregular shapes before sintering. However, after sintering, these particles tended to agglomerate. This phenomenon was attributed to liquid phase sintering facilitated by the addition of magnesium (Mg) as a sintering aid. The liquid phase helps in improving particle rearrangement and densification during sintering, leading to enhanced mechanical properties in the final composite.

Regarding the finite element analysis (FEA) used in the study, solid elements, specifically tetrahedrons, were employed to describe the geometry of the CAD model. Tetrahedral elements are characterized by nodes at their corners, connected by straight edges. The study compared linear tetrahedral elements, which have four corner nodes, with parabolic tetrahedral elements that include additional mid-side nodes along the edges.

Sample condition	Porosity Content			
	Pure Aluminum	10wt%	15 wt. %	20wt%
Un sintered	40.07	42.35	42.39	42.44
Sintered	18.38	17.88	15.21	14.02

**Table-4.2:** Table showing porosity content in un-sintered and sintered Al-Sic composites

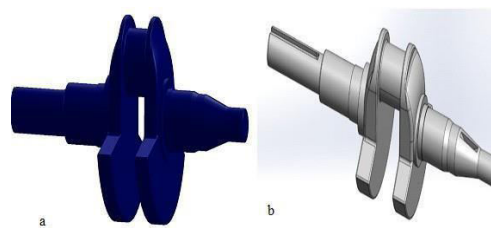


**Fig. 4.2:** Showing SEM micrographs of Al-Sic reinforced MMCs. The Sic particles are highlighted with red dots to show their appearance



#### 4.5 INITIAL MODELING:

The study utilized the advanced capabilities of the Stencher Comet L3D scanner, known for its high-resolution performance with 2 megapixels and an image resolution of 1600 x 1200 pixels. This scanner can effectively capture detailed data within a measuring field of 400 mm, enabling precise measurements in a volume of 400 x 300 x 250 mm<sup>3</sup>. With a point-to-point distance accuracy of 259  $\mu$ m, the scanner ensures meticulous capture of physical models, such as the crankshaft that was analyzed in this research.



**Figure 4.3** Crankshaft: (a) Digitally scanned representation and (b) Computer-aided design (CAD) model.



**Figure 4.4** View of Crank shaft

This project centers on designing and optimizing a crankshaft specifically for a single-cylinder, 4-stroke spark ignition engine. The impetus for redesigning the crankshaft is inspired by Honda's recent advancements, created in partnership with Autodesk. The analysis of the forces impacting the crankshaft is based on the principles of the slider-crank mechanism, a foundational concept that dates back to 1209.

A critical aspect of the project involves understanding the forces generated during the engine's power stroke, calculated based on the compression ratio within the cylinder. Approximately 4600 N of total force is produced during this phase, emphasizing the significant mechanical stresses experienced.

The crankshaft is essential for transforming the piston's reciprocating motion, via the connecting rod, into rotational motion that powers the engine. To enhance its design, a comprehensive model was created using Fusion 360 software. This software was selected due to its intuitive interface and powerful features, which allow for accurate geometric input crucial for computer-aided engineering (CAE) analysis.

## V. METHODOLOGY

1. Crankshaft Design
2. Material Selection
3. Structural Design
4. CAD Modeling
5. Export to IGES Format.
6. Import to ANSYS.
7. Mesh the Solid Model

8. Select the Analysis Method.
9. Input Material Properties.
10. Solve Analysis
11. Retrieve Results.

In our methodology, composite element structural members are employed to simulate the complex behavior of the crankshaft accurately. ANSYS allows us to create a detailed structural model, assign material properties, and apply loads as per operational conditions. This approach ensures that the simulated responses closely mirror real-world scenarios, providing insights into stress distribution and deformation patterns.

The selection of the best material for the crankshaft is determined through a comparative analysis of results obtained from ANSYS simulations. Graphical representations of stress levels, deformation characteristics, and other performance metrics aid in making informed decisions regarding material selection. This process ensures that the chosen material offers optimal strength, durability, and reliability under operational loads.

## **5.1 GEOMETRIC MODELING AND FINITE ELEMENT ANALYSIS:**

Sketching is a fundamental technique used for creating intricate shapes or tracing with a digitizer. Before starting a sketch, it's essential to define the type of object (whether it's a line, polyline, or spline), its scale, and its flexibility. These parameters ensure that the sketch accurately captures the intended design or outline, maintaining consistency and precision throughout the drawing process. By establishing these factors beforehand, sketching becomes a methodical and effective tool for visualizing and creating complex designs.

## **5.2 MODELING:**

### **5.2.1 DESIGN CALCULATIONS:**

In the design of crankshafts, engineers treat them as beams supported at multiple points. Each crankshaft undergoes rigorous analysis considering two critical positions: one where bending moments are at their maximum, and another where twisting moments reach their peak. These calculations are essential to ensure the crankshaft can withstand the various forces it encounters, including those from the flywheel weight, belt tension, and other operational factors.

To simplify calculations without compromising accuracy, engineers assume that bending forces do not propagate beyond two adjacent bearings where forces are applied. This approach helps in determining the necessary dimensions of the crankpin. One crucial consideration is ensuring that the projected bearing area (calculated by multiplying the diameter by the length) is sufficiently large. This ensures the crankpin can safely endure the loads imposed by gas pressure, inertia forces, and centrifugal forces during engine operation.

## **5.3 CRANK SHAFT:**

The crankshaft is a critical component in an internal combustion engine, responsible for transforming the piston's reciprocating motion into rotational motion through the connecting rod.

It comprises three primary sections:

1. Crank Pin
2. Crank Web
3. Shaft

Types of crankshafts:

- **Side Crankshaft:** Also known as an 'overhung' crankshaft, it has one crank web and requires two bearings for support. It is used in medium and large horizontal engines.
- **Center Crankshaft:** This type has two webs and three bearings for support. Commonly found in radial aircraft engines, stationary engines, and marine engines, it is widely used in automotive applications.

Crankshafts are further classified based on the number of crank pins:

- **Single-Throw Crankshafts:** Have one crank pin and are depicted in Fig. 1. They are typical in smaller engines.

- Multi-Throw Crankshafts: Used in multi-cylinder engines, they feature multiple crank pins to accommodate each piston's motion.

Design considerations:

- Strength: Crankshafts must withstand bending and twisting moments under operation.
- Rigidity: They need sufficient stiffness to limit lateral and angular deflections within acceptable limits.
- Endurance: Due to fluctuating stresses, crankshafts require high endurance limit stress to ensure durability.

Manufacturing:

- Crankshafts are typically manufactured through the drop forging process, ensuring robustness and reliability in operation.

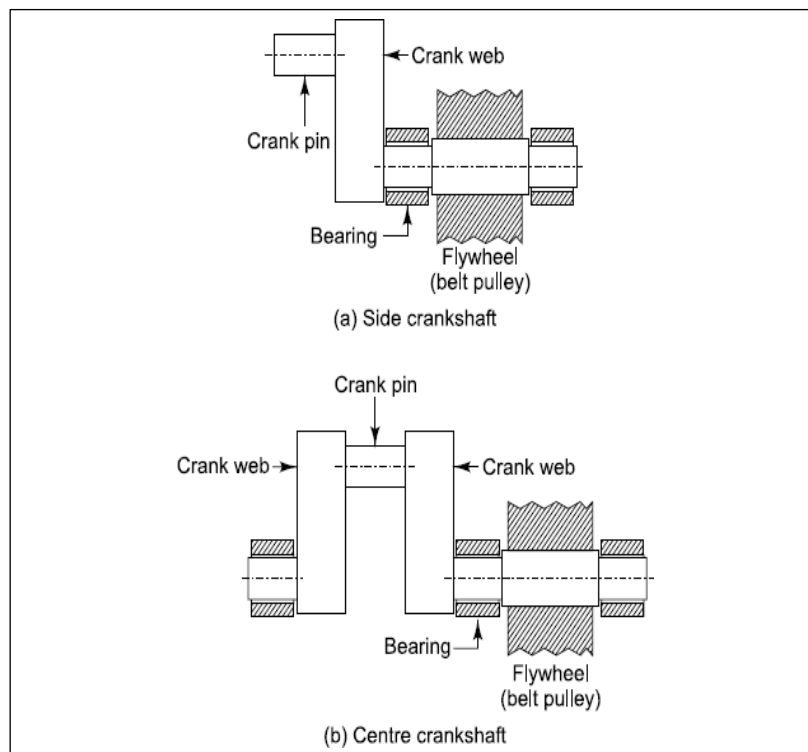


Figure 5.1 type

#### 5.4 MATERIALS USED FOR CRANKSHAFTS:

Designing a center crankshaft involves consideration of various forces and moments acting upon it during engine operation. These include:

1. **Force from the Connecting Rod:** This force acts on the crank pin and is responsible for transferring the reciprocating motion of the piston to rotational motion.
2. **Weight of the Flywheel (w):** The flywheel exerts a downward force due to its weight, affecting the vertical load on the crankshaft.
3. **Belt Tensions (P<sub>1</sub> + P<sub>2</sub>):** These forces act horizontally due to the tension in the belts that drive external components such as generators or pumps.

In the design process of a center crankshaft, two critical cases are analyzed:

**Case I:** The crankshaft is at the top dead center position. Here, it experiences maximum bending moment but no torsional moment. This scenario focuses on ensuring the crankshaft's ability to withstand the maximum bending stress without yielding.

**Case II:** The crankshaft is at an angle away from the dead center positions. In this case, it experiences maximum torsional moment due to the twisting forces applied by the connecting rod and other components. The design here focuses on ensuring the shaft's torsional rigidity and strength

**Assumptions:**

- (i) Engine Orientation and Crank Position.
- (ii) Horizontal Belt Drive.
- (iii) Support and Bearing Configuration.

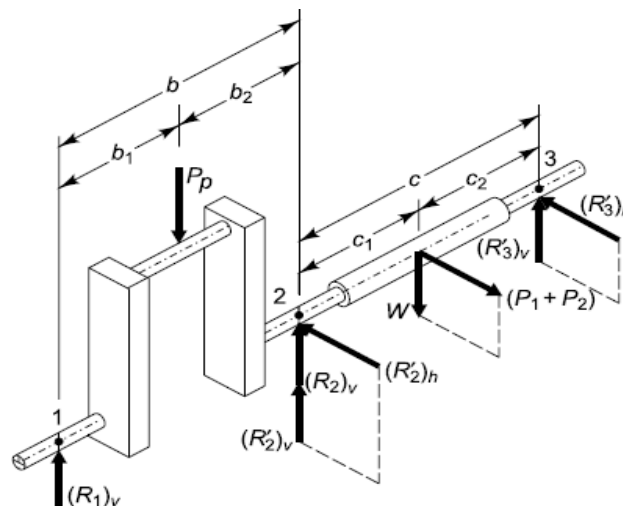


Figure: 5.2 Centre Crankshafts at Dead Centre

**5.5 DESIGN OF CRANK PIN:**

In design of crank pin, the central plane identified as the location where it experiences the highest bending moment. This critical section must be carefully engineered to withstand the forces and stresses imposed during engine operation. Here are the key parameters and considerations:

- $d_c$  (diameter of crank pin)
- $l_c$  (length of crank pin)
- $\sigma_b$  (allowable bending stress)

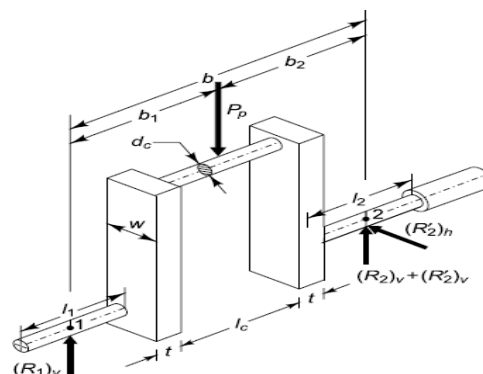


Figure. 5.3, the central plane of the crank pin is subjected to maximum bending moment

### **5.6 INTRODUCTION TO CAD:**

Computer-aided design (CAD), or computer-aided design and drafting (CADD), refers to the use of computer technology in the creation and documentation of designs. It revolutionizes traditional drafting by employing specialized software that enhances efficiency across design, drafting, and manufacturing processes. CAD software provides tools to streamline tasks like drafting technical drawings and generating manufacturing instructions. Outputs from CAD include electronic files used for printing or machining.

CAD environments vary based on their intended applications. For industries like construction and manufacturing, CAD software typically uses vector-based environments for precise, scalable drawings. Graphic-based software, on the other hand, utilizes raster-based environments that handle pixelated graphics effectively.

In addition to basic shapes, CAD allows intricate design of curves, surfaces, and solid objects in both 2D and 3D spaces. The process of designing geometric models for these objects is often termed computer-aided geometric design (CAGD). Modern CAD systems are versatile, supporting features like 3D solid and surface modeling and dynamic mathematical modeling. This capability enables designers to visualize and manipulate objects from various perspectives, including internal views.

## **V. FINITE ELEMENT ANALYSIS**

The finite element method (FEM) is a computational technique used in engineering and applied physics to solve complex problems related to structural analysis, heat transfer, fluid dynamics, mass transport, and electromagnetic fields. These problems typically involve solving boundary value problems for partial differential equations. In FEM, the problem domain is discretized into smaller, simpler elements known as finite elements. Each finite element is defined by a set of mathematical equations that approximate the behavior of the unknowns (such as displacement, temperature, velocity, etc.) across the domain. These equations are then assembled into a larger system of equations that represents the entire problem. By subdividing the domain into finite elements, FEM allows for the accurate approximation of the unknowns over complex geometries and under varying physical conditions.

### **6.1 MESH GENERATION:**

ANSYS Meshing is a highly advanced and automated tool within the ANSYS software suite, designed for creating precise and efficient meshes for complex simulations involving multiphysics phenomena. It simplifies the process of generating meshes by offering intelligent defaults that can be tailored with detailed user controls as needed.

The software optimizes mesh generation through parallel processing, significantly reducing the time required to create meshes for simulations. It adapts to different analysis types and geometry complexities, ensuring that the mesh configurations are suitable for the specific simulation requirements.

ANSYS Meshing seamlessly integrates with all solvers within the ANSYS Workbench environment, enhancing its versatility and usability across various engineering applications. Whether for experienced users needing fine-tuned control or new users requiring straightforward operation, ANSYS Meshing facilitates the creation of meshes with minimal effort, selecting optimal settings based on the simulation type and model geometry.

### **6.2 CAD MODELLING AND ANALYZING PROCEDURE MATERIAL SELECTION:**

1. Aluminium Alloy
2. Stainlesssteel

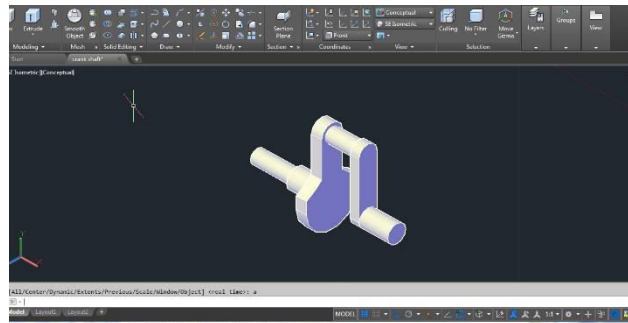


Figure 6.3: ISOMETRIC VIEW:

VII. ANALYSIS WORK BENCH

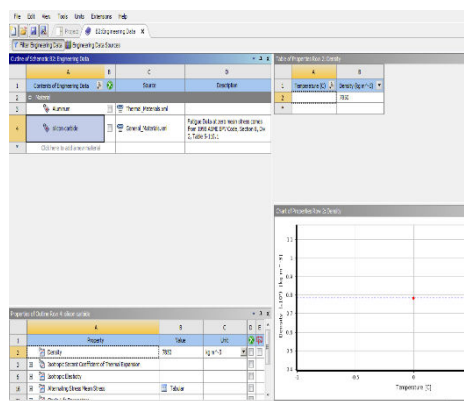


Figure 7.1: MATERIAL SELACTION: ALUMINIUM ALLOY

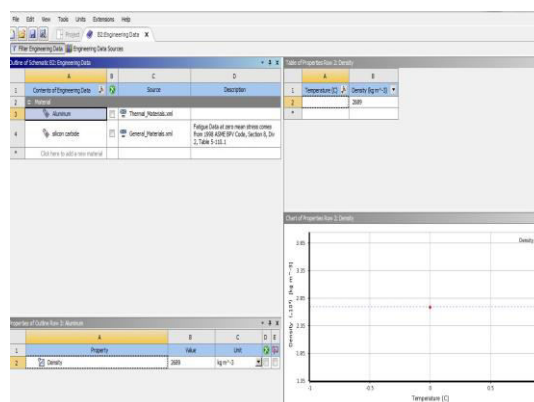


Figure 7.2: SILICON CARBIDE:

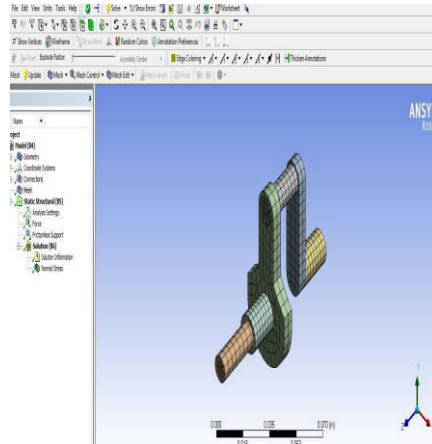
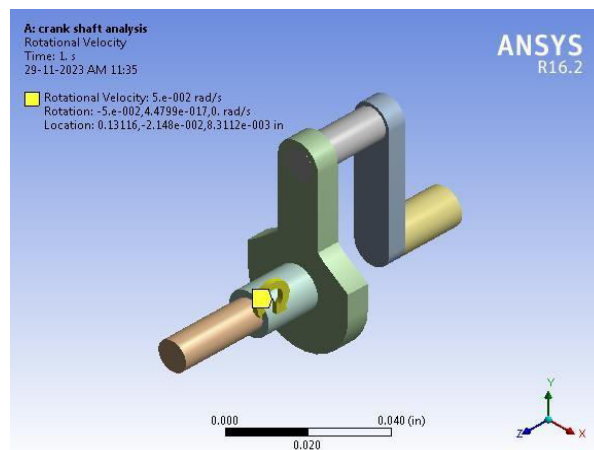
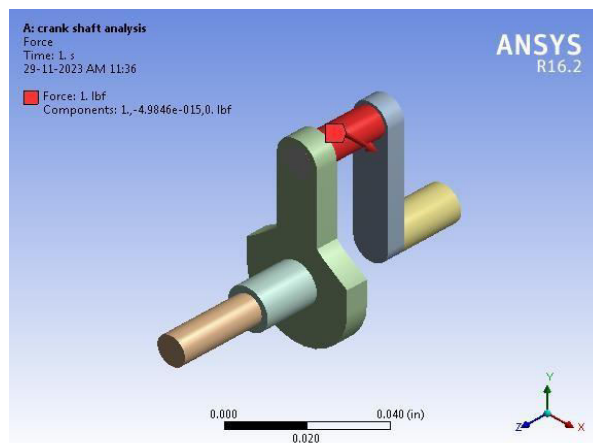


Figure 7.3: MESH:



Rotational Velocity:



Frictional Force:

**Contents**

- [Units](#)
- [Model \(A4\)](#)
- [Geometry](#)
- [Material Data](#)
- [Structural Steel](#)

**Units**

**TABLE 1  
Model (A4)**

Unit System	U.S. Customary (in, lbm, lbf, s, V, A) Degrees rad/s Fahrenheit
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Fahrenheit

*Geometry*

**TABLE 2  
Model (A4) > Geometry**

Object Name	<i>Geometry</i>
State	Fully Defined
<b>Definition</b>	
Source	D:\2022-2023\paavai ME project\CRANK SHAFT\crank shaft.igs 1.igs
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
<b>Bounding Box</b>	
Length X	3.4023e-002 in
Length Y	6.3459e-002 in
Length Z	9.2583e-002 in
<b>Properties</b>	
Volume	2.1198e-005 in <sup>3</sup>
Mass	6.0119e-006 lbm
Scale Factor Value	1.
<b>Statistics</b>	
Bodies	6

**Material Data**



*Structural Steel*

TABLE 3  
Structural Steel > Constants

Density	0.2836 lbm in <sup>-3</sup>
Coefficient of Thermal Expansion	6.6667e-006 F <sup>-1</sup>
Specific Heat	0.10366 BTU lbm <sup>-1</sup> F <sup>-1</sup>
Thermal Conductivity	8.0917e-004 BTU s <sup>-1</sup> in <sup>-1</sup> F <sup>-1</sup>
Resistivity	8.5235 ohm cmil in <sup>-1</sup>

VIII. CONCLUSION

The research aims to investigate fatigue failure in crankshafts using finite element analysis (FEA). A linear stress-strain relationship was utilized to ensure that the maximum stress experienced remains within safe yield limits. The analysis revealed that failure initiation occurred specifically at the fillet region of the crankshaft made from SiC material, primarily due to concentrated bending stresses. This study focused extensively on identifying and understanding zones of high stress concentration, particularly at the crank and corners, which are critical areas prone to fatigue failure.

REFERENCES

1. **Farzin H. Montazersadgh et al. (2007):** The crankshaft, a critical component in internal combustion engines, transforms the piston's reciprocating motion into rotary motion through a four-bar linkage mechanism. It undergoes numerous load cycles, necessitating careful consideration of its fatigue performance, durability, and service life during the design process. The goal in crankshaft design and development is to produce a component that is lightweight, cost-effective, has good fatigue strength, and enhances fuel efficiency and power output.
2. **Meng et al. (2011):** This study conducted static structural and modal analysis on crankshafts of four-cylinder engines, identifying the areas of maximum stress, maximum deformation, and potential failure points.
3. **V. C. Shahane et al. (2016):** Static structural and dynamic analysis was performed on a single-cylinder four-stroke diesel engine crankshaft. A 3D CAD model was created using Pro/Engineer based on 2D drawings of the existing crankshaft. Finite Element Analysis (FEA) using ANSYS software revealed stress variations at critical locations under different conditions. The study aimed to optimize crankshaft geometry and shape without altering the engine block and cylinder head, achieving a 4.37% weight reduction and improving engine performance.
4. **V. Sowjanya et al. (2016):** This research explored the relationship between frequency and vibration modes through modal and harmonic analysis of a crankshaft using ANSYS. The study focused on weight reduction via reverse engineering, material selection, and parametric optimization to enhance engine performance, improve strength-to-weight ratio, and reduce production costs.
5. **Thirunavukkarasu et al. (2016):** This paper explored various methods to reduce crankshaft weight, such as optimizing web design and reducing bearing diameters. The study demonstrated that using hollow crank pins and journals could reduce crankshaft weight by 22% while doubling the safety factor compared to a solid crankshaft design.
6. **Paolo Citti et al. (2018):** The crankshaft, a key component in internal combustion engines, requires careful material selection, heat treatments, manufacturing processes, and cost considerations. This work examined current and future material choices for high-performance engine crankshafts, focusing on materials like 38MnVS6 and 48MnVS3, along with surface hardening techniques and thermal treatments to enhance quality and cost efficiency.
7. **Vijaya Ramnath et al. (2018):** This paper aimed to derive all parameters related to designing, manufacturing, maintaining, and servicing crankshafts. Using a CMM device for reverse engineering, CATIA for computer-aided modeling, and ANSYS for optimization analysis, the study compared the fatigue performance of crankshafts made from forged steel, ductile cast iron, and aluminum alloy. Deformation analysis identified maximum stress regions, and weight reduction was explored, showing the feasibility of using forged steel.
8. **K. Satyanarayana et al. (2017):** This study investigated the stresses induced in AISI E 4340 forged steel crankshafts. It included kinematic and dynamic analysis, and FEA stress analysis. Using experimental data from a variable compression ratio diesel engine, equations of equilibrium were developed for stress analysis. The study

applied these forces and boundary conditions to identify von-Mises stresses and deformations, assessing the crankshaft's safety factor. The paper highlighted traditional manufacturing methods (forging, casting, machining) and their drawbacks, emphasizing the need for weight reduction, material selection, and parametric optimization to improve performance and reduce costs.

9. **Sarihan and Song (1990):** For optimizing the wrist pin end, this study used a fatigue load cycle including compressive gas loads (for maximum torque) and tensile loads (for maximum inertia). The design for fatigue involved the modified Goodman equation with alternating and mean octahedral shear stress. An approximate design surface was generated for optimization.
10. **Yoo et al. (1984):** This research applied variational equations of elasticity, the material derivative concept from continuum mechanics, and an adjoint variable technique to calculate shape design sensitivities of stress. An iterative optimization algorithm, specifically the steepest descent algorithm, solved the optimal design problem, focusing on shape design sensitivity for a connecting rod under principal stress constraints from inertia and firing loads, without addressing fatigue strength.



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