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DESIGN AND DEVELOPMENT OF CRANKSHAFT MODELLING AND STRESS ANALYSIS USING ANSYS

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ABSTRACT

The reliability of a system that converts linear piston displacement into shaft rotation largely depends on the crankshaft, a critical component whose failure can disrupt the entire mechanism. As a high-volume production part with complex geometry in internal combustion engines (ICE), the crankshaft plays a key role in converting the reciprocating motion of the piston into rotational motion, thereby harnessing the power generated during combustion in the cylinder. Analysing the stress experienced by the connecting rod under different load conditions is essential for efficient power transmission. This is typically done by creating 3D models in CATIA V5 and performing stress analysis in ANSYS. Evaluating crank throw distortion and stress distribution helps optimize the design by reducing weight without compromising strength. This study focuses on developing a 3D model of the crankshaft system in CATIA V5 and conducting a detailed analysis in ANSYS to understand its motion and load behavior. Topology optimization is employed to minimize weight while maintaining functionality. Testing under three loading conditions (22624 N, 32624 N, and 42624 N) identifies Model 3 as the most efficient design, showing the lowest stress, minimum deformation, and reduced weight. The topology optimization process successfully decreases material usage while preserving performance and reliability.

Keywords: Crank, Shaft, CATIA, ANSYS, Performance And Optimization.

1. INTRODUCTION

Various mechanical engineering applications, the most widely used machine elements is Shaft. The crankshaft, impeller shaft, propellor shafts, camshafts etc. use shaft. Crankshaft is one among the most vital moving elements consisting of 2 web sections and one crankpin that convert the piston reciprocator displacement to a rotation with a four-link mechanism. Crankshaft experiences massive forces from gas combustion. This force is applied to the highest of the piston and since the connecting rod connects the piston to the crank shaft, the forces are transmitted to the crankshaft. The magnitude of the forces depends on several factors that include crank radius, connecting rod dimensions, and weight of the rod, piston, piston rings, and pin. Since the crankshaft experiences an outsized range of load cycles throughout its service life, fatigue performance and durability of this element needs to be thought of within the style method. That the lifetime of internal combustion engine and reliability depend upon the strength of the crankshaft mostly and because the engine runs, the power impulses hit the crankshaft in one place so another. Failures of shafts not only end in cost, however additionally in method period. The one among the most common causes of shaft failure is break. Fatigue failures are vital issues in mechanical styles. to determine the stress, geometry and dimensions Analysis, evaluations and engineering principles are utilized within the style. to confirm the lifetime of engine, strength calculation of crankshaft becomes a key issue. historically beam and area frame model were used to calculate the stress of crankshaft however in these models the number of nodes is restricted. With the development of computer, additional and additional design of crankshaft has been used finite element methodology (FME) to calculate the stress of crankshaft. as shown in figure 1.

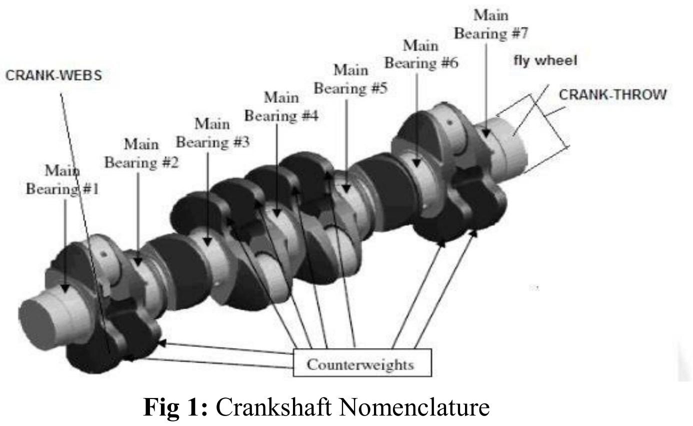

Fig 1: Crankshaft Nomenclature

2. LITERATURE SURVEY

Literature reviews are integral components of academic research papers, theses, dissertations, and scholarly articles. They serve to situate the research within the existing body of knowledge, demonstrate the researcher's familiarity with prior work, and justify the need for new investigations.

Thejasree, Dileep Kumar and Leela Prasanna Lakshmi (2023) presented analysis the effect of gas forces was analyzed at crankpin and main journals of the crankshaft. The maximum load acting on the crankpin was found to be 22163 N for the bench mark model whereas for the developed concepts 1, 2 and 3, it was found to be 22624 N, 22066 N and 22303 N respectively. The maximum stress for the bench mark model was found to be 67 MPa and whereas for the developed concepts 1, 2 and 3, it was found to be 80MPa, 71 MPa and 79 MPa respectively. Structural static analysis shows that the stress concentration regions are located at the fillets of crank pin and main journals. Dynamic stress and strain analysis has been carried to determine the stress and deformation of the crankshaft in a working cycle. The weight of the crankshaft for concept-2 has been reduced by 1.6 kg which is a 12.8% reduction in weight without much increase in the stress.[1]

Ahmad and Gurlal et.al. (2023) Crankshaft is one amongst the most vital moving elements in combustion engine. Crankshaft could be a massive part with a complex geometry within the engine that converts the mutual displacement of the piston into a rotation. It should be strong enough to require the downward force throughout power stroke while not excessive bending. That the reliability and lifetime of combustion engine depend upon the strength of the crankshaft mostly. Maximum deformation produced in the crankshaft before optimization 0.11265 and after optimization 0.11189. Maximum stress produced in the crankshaft before optimization 269.2 and after optimization 257.71. [2]

R.Raju et.al. (2023) observed that there has been considerable increase in the von mises stress (max.) for Grey Cast Iron. We can also derive that the maximum deformation value is 5.572e-3mm for Grey Cast Iron as compared to 5.821e-3mm with Steel. Hence, fatigue life will be more for Grey Cast Iron than that of Steel.[3]

Reddy, Prasad and Reddy (2023) discussed the crankshaft model was created by Pro/ENGINEER software. Then the created model was imported to ANSYS software. After structural analysis of crankshaft, the maximum stress value on forged steel is 150 MPA and on composite material is 146 MPA. So, the composite materials have better performance than forged steel. But the manufacturing cost of composites is higher than the forged steel so due to the low cost of forged material, it's almost used for crankshaft.[4]

Karandikar et al. (2023) observed from the stress analysis using ANSYS software, maximum deformation or displacement in crankshaft happens at the top central portion of the crankpin. The maximum stresses befall in the regions where there is quite a sudden change in the geometry of the crankshaft. This area is the junction where the crank web connects the shaft. This is a natural because the stress lines suddenly change themselves. This leads to the accumulation of high stresses over there, making the material weak. These fillets should be designed such that the crankshaft is least affected by these high stresses.[5]

Yashik-Ramprasanth et.al. (2022) The conventional crank shaft used in the engines was replaced with a Composite crank shaft. The conventional crank shaft and the Composite crank shaft were analyzed by finite element methods. From the results, it is clear that the stress induced in the Composite crank shaft is found to be lower than that of the conventional crank shaft. Composite crank shaft material is replaced for good fatigue strength, minimizing weight and without violating the limiting constraint formed by induced stress. A reduction of 37.5% weight is achieved when a conventional crank shaft is replaced with Composite crank shaft under identical conditions of design parameters.[6]

Randhavan et.al. (2022) conclude that to reduce the weight of the crankshaft it should use aluminum alloy without compromising the properties of the existing material. By using FEA results we can analyse the von misses' stresses, max principal stress and deformation when load is applied considering boundary conditions. Experimental performances will help to analyze the new material.[7]

Pandiyan et al. (2022) studied topology optimization in Crank case cover reduced a net mass of 0.737kg from the initial design. This could lead to a better performance of the engine. While achieving this reduction in mass, necessary precaution is to be taken to ensure the factor of safety is still in the industry standards. The advanced and High-Performance Computing with ANSYS Topology improvement formed a stronger result than the conceptual designs. There are 2 issues to be mentioned and solutions ought to be suggested. The primary one high localized stress at the fastenings, by increasing space by providing fillets or offer much length for the fastening support this drawback will be resolved.[8]

Sowjanya V et. al. (2022) discussed the crankshaft model is created by Pro/ENGINEER software. Then the model created by pro/Engineer was imported to ANSYS software. The maximum deformation seems at the center of crankshaft surface. The most stress seems at the fillets between the crankshaft journal and crank cheeks, and close to the central point. The edge of main journal is high stress space. The crankshaft deformation was principally bending deformation under the lower frequency. and therefore, the most deformation was set at the link between main bearing journal and crankpin and crank cheeks. [9]

Shelke-Dhamejani et. al. (2022) The comparison between baseline and optimized style of the crankshaft for von-Mises stress shows higher enhancements. the stress raised from 204 MPa to 241 MPa however, the stress values invariably stay among yield criteria of fabric. The deflection in crankshaft for baseline style and optimized style are 0.0182 millimetre and 0.018 millimetre severally. the overall mass of the baseline model was 3.5 kilogram that is small up to 2.95 Kg. the proportion reduction in mass of the crankshaft determined up to 19. The baseline analysis is compared with the testing of the baseline specimen. The maximum variation determined between simulation and testing is up to 18.64% that is appropriate.[10]

Problem Formulation: As crankshaft is generally made of ferrous material, it has high density the crankshaft become bulky. Because of bulky crankshaft weight of the engine is increases, hence selecting a new material to reduce the weight of the crankshaft without compromising on the properties of the material.

Objectives: The following as under

- To model a crankshaft on software
- To perform static analysis of crankshaft
- To optimize the crankshaft design using topology optimization method.
- To reduce the overall weight of crankshaft implementing the new optimised design.

3. METHODOLOGY

Proposed methodology to be adopted while performing the design, optimization and analysis on crankshaft design:

1. Design parameters in the present design were obtained by study of previous paper.

2. After obtaining the desired dimensions further the model in CATIA V5 will be created.

3. After the modelling part the design of crankshaft model will be further imported in Ansys static structural analysis workbench to perform the static structural analysis on it.

4. After the static analysis areas having higher and lower stress will be evaluated to perform the topology optimisation on it.

5. After the evaluation part further the model is imported in topology optimization work bench to have the areas which can be removed from the model having less stress values to have the weight reduction in overall crankshaft.

6. After the topology optimization again the model will be recreated in CATIA V5 and further static analysis will be performed.

7. After the analysis both the conventional and optimized model will be compared and evaluated to suggest the overall improvement in the crankshaft design.

4. RESULT AND DISCUSSION

The topology optimization in Crankshaft is help to reduce the net mass of crankshaft in initial design. This could lead to a better performance of the engine. While achieving this reduction in mass, necessary precaution is to be taken to ensure the factor of safety is still in the industry standards. The innovative and High Performance Calculating with ANSYS Topology Optimization designed an improved result than the conceptual designs. In the simulation result there are three parameters are measured and three cases are considered for the simulation. The following parameters were measured during the experiment:

- Deformation
- Stress

Case-1 In this case the maximum force acting on the crankpin is 22624 N.

(Model -1) Deformation: After applying 22624N force in crankshaft the maximum crankshaft is deformed in top of journal which is shown in figure 4.1. In this figure the following result is obtained, the blue legend shows the minimum deformation and red legend show maximum deformation in crank shaft. In this case the maximum deformation is 0.011156mm.

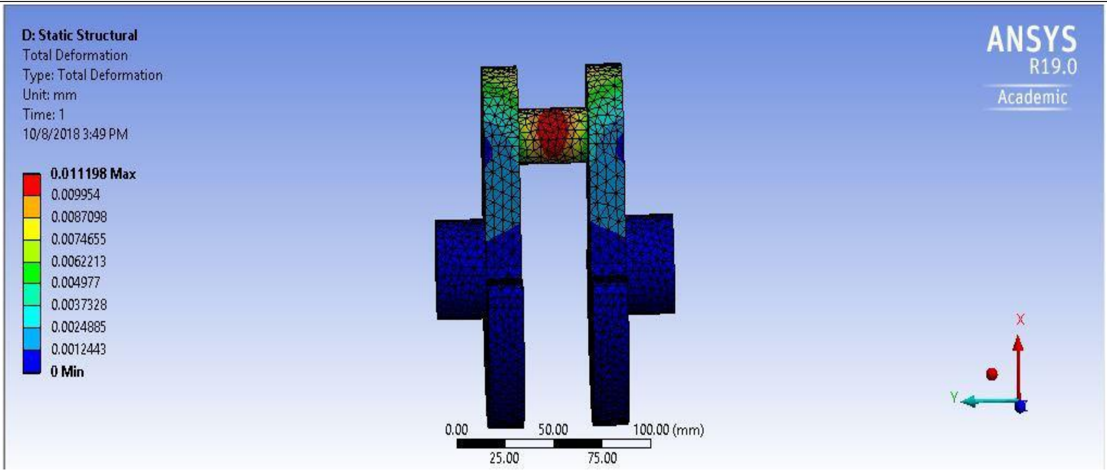

Fig 2: Total deformation in Case-1 for model 1

(Model-1) Equivalent Stress: After applying 22624N force in crankshaft the maximum stress is present in top of journal which is presented in figure 4.2. In this figure the following result is obtained, the blue legend shows the minimum stress value and red legend show maximum stress value in crank shaft. In this case 68.42 Mpa maximum stress is obtained.

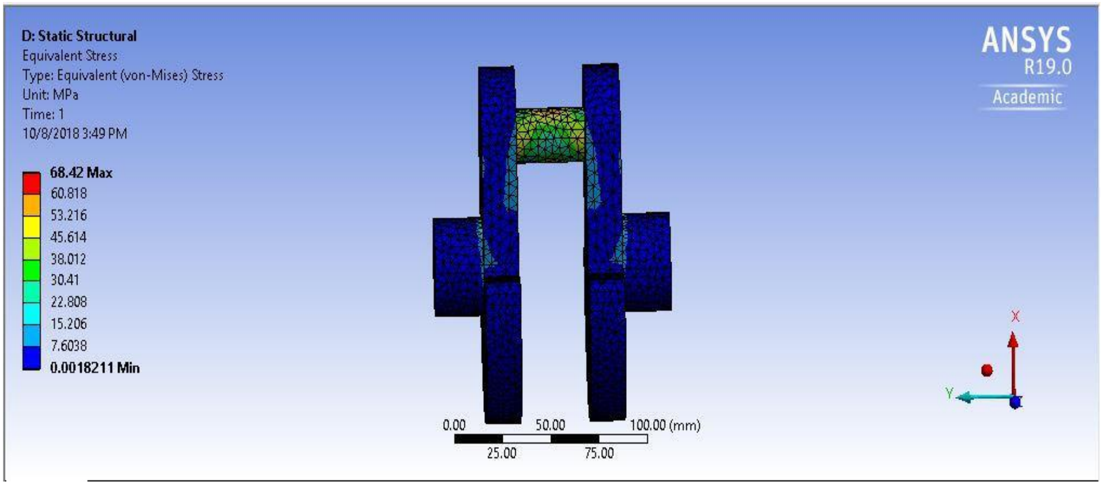

Fig 3: Equivalent stress in Case-1 for model 1

5. CONCLUSION

Topology optimization is help to optimize the performance of any machine. Some conclusions following are:

- Topology optimization helps to optimize the performance of any machine. In these research three new models is proposed.
- In previous research it is seen that the maximum stress for the bench mark model was found to be 67 MPa and whereas for the developed concepts 1, 2 and 3, it was found to be 80MPa, 71 MPa and 79 MPa respectively.
- The present model is test in three different loading conditions 22624N, 32624N and 42624N load is applied in crank shaft.

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