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Design and analysis of connecting rod-A RSM approach

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Abstract- Connecting rod was an element found within a combustion engine. By way of the connecting rod, the piston is attached to the crankshaft and transfers forces there. Depending on the number of cylinders in the engine, any automobile with an internal combustion engine requires at least one rod. In other words, a connecting rod is a stiff part that connects the piston and crankshaft of a reciprocating engine. Together with the crank, it creates the fundamental mechanism that converts reciprocal motion into rotational motion. In this FEM analysis of connecting rod using ANSYS has been done.

Keywords-Connecting rod, RSM, ANSYS, optimisation

I. INTRODUCTION

The connecting rod is an essential component found within internal combustion engines, serving as the link between the piston and the crankshaft. Its primary function is to transmit power from the piston to the crankshaft, making it a critical factor in terms of structural stability and performance. Manufacturers have focused on reducing the weight of the connecting rod by optimizing its form and minimizing the use of materials, although this approach is not always feasible. The production of lightweight connecting rods is therefore a key objective.

Additionally, the connecting rod plays a vital role in high-volume production outputs. Each internal combustion engine, depending on the number of cylinders, requires at least one connecting rod. Consequently, optimizing the design of the connecting rod is a rational pursuit. This optimization process aims to reduce the weight of engine components, resulting in decreased inertia loads,

lower overall motor weight, improved motor efficiency, and energy savings. To achieve this, a study has been conducted on the design optimization of connecting rods using the Response Surface Methodology (RSM). Specifically, the width and height of the section were selected as parameters for optimization. The initial step involved creating a 3D model of the connecting rod using SolidWorks software. Subsequently, the model was imported into ANSYS in IGES format for static structural analysis. Simulation and geometry optimization were carried out using Taguchi's L9 orthogonal array. The simulation plan enabled the acquisition of stress, deformation, and mass data. Finally, the obtained results were imported into Minitab software for parameter optimization using the RSM technique.

II. LITERATURE REVIEW

Sathish et al. (2020) “It was ultimately determined that AA2014, AA6061, and AA7075 are two distinct materials. Shear stress and overall deformation were collected from the ANSYS program, and the software also performed a FEA assessment for the three materials and for missing stress. The AA2014 is the most lightweight and rigid of the three materials”.

Muhammad et al. (2020)optimized diesel engine uses and rod connection topology were identified. Weight reduction and cost savings may be achieved without compromising durability or strength by optimizing the weight of the link rods with targets of 20%, 30%, 40%, 50%, and 60% under a 100N static stress. The static deformation, tension, elastic strain, and protection component of Von Misses structure are compared both before and after optimization. The results suggest that ANSYS Tools may be used by industrial companies to reduce resource waste while boosting output quality and productivity.Muhammad et al. (2020) The stress and optimization of a connecting rod, with a focus on key characteristics such as deformation, stress, fatigue and stress, factor protection, and life values. The performance of a connecting rod in a car engine is determined by its construction and its weight. As a result, developing a connecting rod that is strong, inexpensive, and lightweight necessitates study and improvements.

Linga et al. (2020) This connecting rod for two wheels serves as an improvised empirical tool. CATIA V5 is used to create a physical prototype of the intended product. The FEA method was applied to examine the rod connection mechanism employed in the structure. The FEA application ANSYS WORKBENCH 14.5 is used to assess stresses under a variety of loading scenarios.

Forged steel and Al-360, two similar materials, have identical functional properties. Results acquired from testing the prototype component in 3D printing under conditions of varying tension, shear stress, and fatigue life are compared.Saheb, Shaik Himamet al. (2020)I investigated how much lightweight and less expensive some compression ignition motors might be if they used connecting rods that were tuned for weight reduction. Due to the whipping stress experienced by the connecting rod, several pressures and forces might be explored to ensure that the rod does not fail in operation. The evaluation is useful for making design tweaks by taking into consideration all these strengths.

Bulut, Mehmet et al. (2020) The critical stress areas were located using a numerical rod joining analysis. Connection rod stress and deformation values were calculated based on a theoretical static implementation of the load at varying motor speeds. Inputs to the static simulation model included numbers for engine power and torque as well as geometric measurements of the rod connection and its material qualities. At different motor speeds, stress and deformation tests confirmed that the connecting rod would not break under the external load. Pani, Amiya Ranjan et al. (2020)found that the buckling resistance of the alloy's aluminum rod was much less than the steel rod forged, and that the merchant-rankine solution was inadequate in the case of a hydro lock failure on the connecting pin. This also won't be utilized in conjunction with diesel-powered semis. Important information on the buckling failure of rod configuration in large diesel engines is provided by the results of this study.

III.RESEARCH METHODOLOGY

The following are the four stages of development that complete the static analysis and design optimization of the connecting rod:

Step 1: Design of connecting rod

Design of connectingrod plays a crucial part because it's loaded and unloaded often. The connecting rod's cross section is treated as a strut and the Rankine formula is applied since the compressive forces are much greater that the tensile strength. A connecting rod bent about its neutral x-axis inside the connecting rod's movable plane when subjected to the load W along its axis. The rod is considered to be hinged at both ends and to buckle along the x-y plane. Connecting rod buckling throughout both axes must be robust.

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

For the IC engine, the specifications of which were previously provided, a 3D CAD model of the connecting rod was constructed in SOLIDWORKS in accordance with the design of experiment utilizing Taguchi's orthogonal array.

Step 3: Meshing of connecting rod in ANSYS

The CAD model was meshed with tetrahedron components in the pre-processing stage.

Step 4: Applying boundary conditions for static analysis As an the static analysis, the connecting rod was securely anchored at its large end, while the forces were exerted at its small end.

Step 5: Results

The effects might be seen in the final product. Taguchi's orthogonal array was used for experimental design, and contour plots for stress, mass, and deformation were generated.

Step 6: Optimization using RSM technique

Minitab is used to apply the RSM approach to the data that was obtained in step 5.

Step 7: Optimum parameters

Optimum parameters were obtained in terms of minimum mass, stress, and deformation.

Step 8: Optimum design

Here, the minimal possible mass, stress, and deformation are attained in the connecting rod's design.

3D Modelling of Connecting Rod

Creating detailed, analyzed virtual models of design is possible using Solid Works, which is a 3D solid modeling program. At SolidWorks, 3D models are constructed via the use of conceptual drawings and iterative design testing. For designers, engineers, and other professionals, SolidWorks creates both simple and complex parts, assemblies, and drawings. Building a simulation model in SolidWorks or another program is beneficial and may help save time, energy, and money throughout the design process. Dimensions of the connecting rods, including their width and height, are displayed in Table 1.

Table 1:Parameters range settings

	Parameters/Factors	level		
		1	2	3
A	Width of section (mm)	12	14	16
B	Height of section (mm)	16	18	20

Table 2 displays the results of nine simulations based on two parameters with three levels each, generated in Minitab using Taguchi's orthogonal array.

Table 2 Design array

S.no	Width of the section, mm	Height of the section, mm
1	12.81	16
2	12.81	18
3	12.81	20
4	14	16
5	14	18
6	14	20
7	16	16
8	16	18
9	16	20

Figure1:CAD model of connecting rod

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

Mesh model of connecting rod

Mesh analysis involves dissecting a design into its component parts for closer inspection. It's a unique structural framework produced to aid in the solution of certain design problems. The time and accuracy required to compute the results increase as the mesh size decreases[40]. ANSYS has a default setting for the meshing size. The time spent on setup as well as the computational expenses, the processing speed, and the ease of usage are all factors in determining the optimal mesh shape to utilize. The default setting for the mesh's smoothing iteration control is +100, which is considered medium. The CAD model has been pre-processed by meshing it using a tetrahedron element. In all, there are 487160 elements and 690521 nodes.

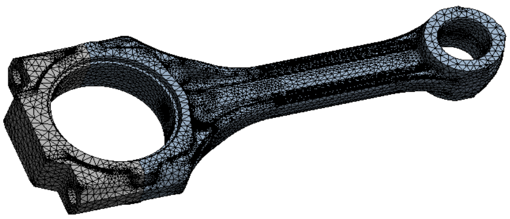

Figure2: Boundary Conditions

Material property

For efficient and qualitative analysis for the material, its properties—which may be linear or non-linear, isotropic or orthotropic, constant or temperature-dependent—must be defined correctly. Depending on the purpose of the investigation, mechanical properties including density, intensity, and thermal expansion defining coefficient may or may not be included. Table 3 details the parameters that must be entered with the geometry before the software may define the structural material.

Table 3 Material property (Structural steel)

Young's Modulus	200GPa
Density	7850 kg/m^3
Poisson's ratio	0.30
Bulk modulus	1666.7GPa
Shear Modulus	76.923G Pa
Tensile strength	0.25GPa
Ultimate shear strength	0.46GPa

IV. RESULTS AND DISCUSSION

Total deformation, equivalent stress, and mass findings for nine different connecting rod models are provided and compared in this section.

Total Deformation

The figures below display the shape change induced by the boundary pressure. Simulation 9 has the greatest amount of deformation compared to the other models' simulations.

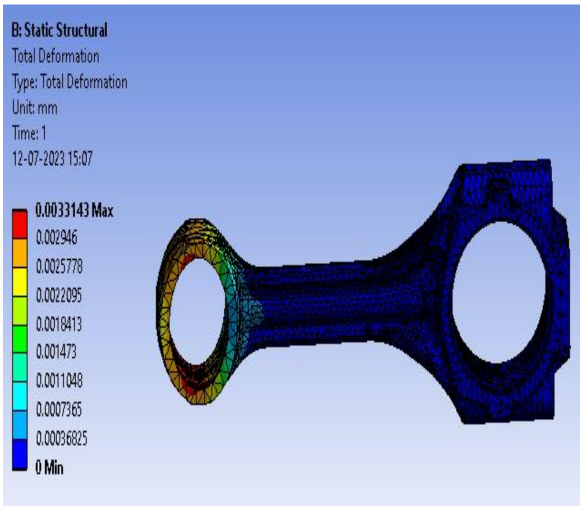

Figure 4: Deformation results.

The above figure 4shows that the maximum total deformation is found to be 0.0051mm when the width of section is 16 mm and height of section is 20 mm.

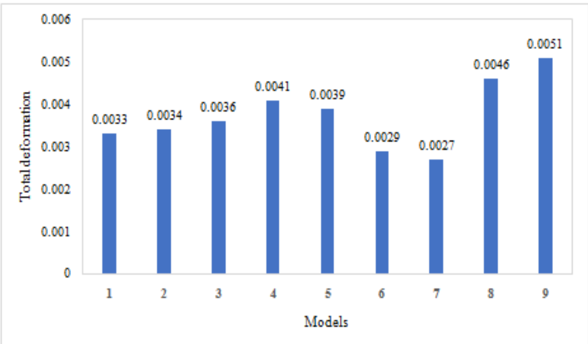

Figure 5: Variation of deformation in nine models of connecting rod Equivalent stress

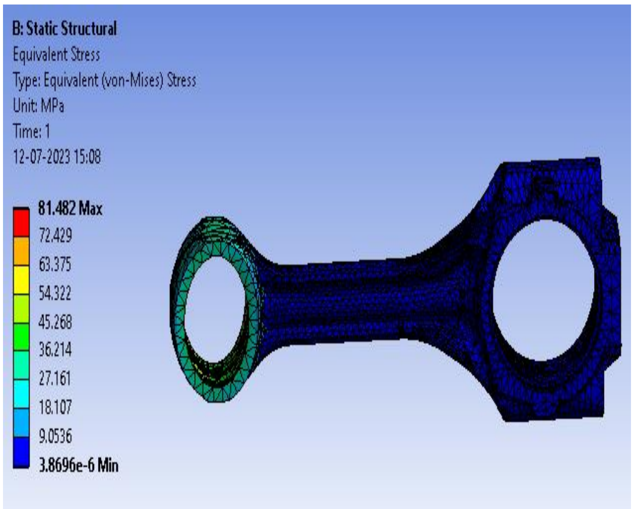

Figure 6: Stress distribution in connecting rod.

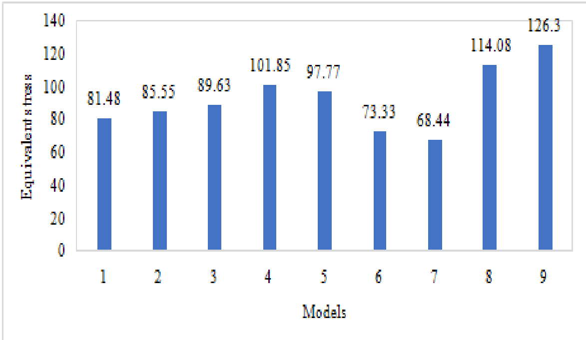

Figure 7: Variation of equivalent stress in nine models of connecting rod

When the cross-section is 16 mm wide and 20 mm height, as shown in Figure 4.3, the maximum stress is determined to be 126.3 MPa. Mass of connecting rod The connecting rod's mass was calculated using ANSYS after the CAD file was imported. Connecting rod masses for each model are listed in fig.8

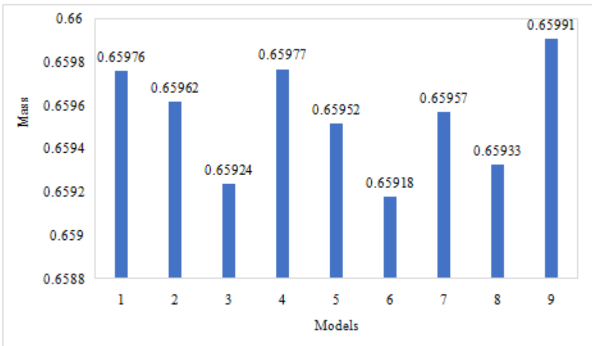

Figure 8: Variation of mass of nine models of connecting rod

Design optimization of connecting rod using Response Surface Methodolog. It was found that there is a sweet spot when the values of some parameters are at their lowest. Each variable was analyzed using a second-order polynomial model with towards the finding of optimal parameters.

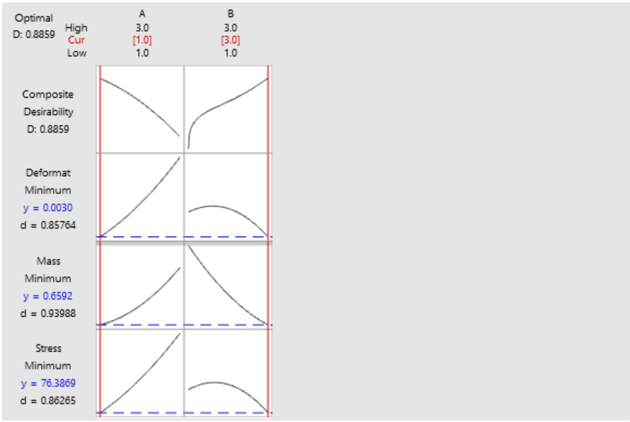

Figure 1: Optimization plot.

Table 4. displays the optimized results achieved by setting the width and height of the section to 12.81 mm (level 1) and 20 mm (level 3), respectively, from the optimizer plot.

Table 4 Optimized Solution

Solution	A	B	Mass, Kg Fit	Stress, MPa Fit	Deformation, mm Fit	Composite Desirability
1	12.81	20	0.6592	76.38	0.003	0.8859

Polynomial functions of the second order the research have used every possible reaction to arrive at the optimal state. The desirability method has been utilized for multi-parameter optimization.

VI. CONCLUSION

In this analysis, the connecting rod was optimized using the RSM method and Minitab statistical software. Solid works program was initially used for 3D modeling. Then, ANSYS is used to do a static structural analysis on the model that was imported in IGES format. The L9 orthogonal array proposed by Taguchi has been accepted for use in simulations and the optimization of geometries. The simulation plan yielded results for stress, deformation, and mass. Minitab is used to import the final findings and optimize the settings using the RSM method. The above discussion leads to the following conclusion:

a.With R2 values of 0.9789 for the "deformation" and 0.9812 for the response "stress," "a satisfactory fit of the model to the simulation data" is guaranteed. Adjusted R2 values for 'deformation' are 0.9242, while for 'stress' they are 0.9217. The calculated R2 values for 'deformation' are 0.9827, and for' stress' they are 0.9778. The data variability was well explained by the link between deformation and the process factors. “High adjusted R2 and forecasted R2 values suggested there was a strong relationship between the two sets of data”.

b.The model has statistically fit the data as seen in the above table. Fisher's F-Test results are statistically significant (F value= 18.29 for deformation, 10.47 for stress, and 42.27 for mass) yet the probability value is extremely small (p= 0.05), indicating that this is the case which is significant.

c.The optimal conditions presented here were utilized to create second-order polynomial models for each response type. Several responses have been optimized using the Desirability approach.

d.Optimized values are mass of connecting rod = 0.6592 kg, Stress = 76.38 MPa, and deformation = 003 mm. The ideal choice of width and height of section is determined as 12.81 mm (level 2), and 20 mm (level 3).The findings imply that the models employed in this work may potentially specify what parameters or outcomes are optimal. In addition, the research presented here is useful for designers and academics since it illustrates how the RSM approach may be used to optimize designs.

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