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Design optimisation of connecting rod using RSM Technique

Gaurav Sankhian
M.tech ME 2019
1901106001
gaurav.19-m-0738@rayatbahrauniversity.edu.in

Harpreet Singh
(Astt. Prof.)
Department of USET-ME
harpreetsingh.11995@rayatbahrauniversity.edu.in

Abstract: Connecting rod is a component inside of an internal combustion engine. The piston is connected to the crank by connecting rod and it is the principal part to transmit power from the piston to the crankshaft. In terms of structural stability and performance, it is considered a critical factor. The main effort in reducing weight has been to optimize the form and remove materials, which is not often possible.In this study, attempts have been made towards the design optimisation of connecting rod using Response Surface Methodology (RSM). Width and height of section have been selected for that purpose. First, 3D modelling was done using Solid works software. After that model is imported in IGES format in ANSYS for static structural analysis. Using Taguchi's L9 orthogonal array has been adopted for simulation purpose and geometry optimization. Stress, deformation and mass have been obtained under simulation plan. Final results are imported in Minitab software for optimization of parameters using RSM technique.

Keywords: Connecting rod, internal combustion engine, Response Surface Methodology, Minitab

1.Introduction

Connecting rod is a component inside of an internal combustion engine. The piston is connected to the crankshaft by connecting rod and transmit forces from the piston to the crankshaft. Any car using an internal combustion engine needs at least one rod, based on the number of motor cylinder[1]. In other terms, a connecting rod is a rigid component that joins a piston in a reciprocal engine to a crankshaft. It forms a basic mechanism along with the crank that transforms the reciprocal motion into rotary movement [2]. During the operation connecting rod (CR), cyclic loading have been acting and transmit to crankshaft.It is loaded under compressive stress (under the prevalent gas pressure) (primarily due to inertia force). Owing to its swiveling

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movement, the bending rod is often strained. It should be as light as possible and strong enough as a moving engine part. There must also be adequate part and structural strength.

"Through lubricating the connecting rod, control is transferred from the pump and the piston through the connecting rod to the crankshaft". Therefore, the stress applied to the rod depends on "the pressure distribution of the lubricant. In turn, the rigidity of the connecting rod" end drills may impact this. The lubrication friction between the crankshaft and the bearing box on the top-side holds the inertia force in balance. CR bolts provide for the joint continuity between the CR and the cap. The CR ovalize under the influence of friction and the bolts are externally curved. The connecting rod bolted joint will open to the pin side of the cord [5] if the bolt force is inadequate. CR shank, therefore, presses the crank log into the hydrodynamic boundary layer under maximum gas strain. Connecting rod is ovalized and the bolts curve into the inner side of the rod. The linking rod end is caused by significant bending tension. In comparison to the bolt threads, filets on the shaft transfer to the big and small end are the most strained places in "straight split connecting rods." The downside of angle split rods is that the top section of the "blind hole thread" is placed immediately in the most stressful direction.

"In order to help decrease fuel usage and mitigate friction agitation", moving masses as minimal as is practicable should be held in general. One such part, the rod, influences the weight of its parts – a lighter connecting rod will cause the piston, balancer, bearing and shaft mass to be reduced. A lower deck height may also be reduced by decreasing the rod connection length. However, it must take into account variations in lateral forces in the skirt of the piston. The spinning and oscillating masses can align as precisely as possible in order to preserve a quiet activity and low vibration levels. On the side of the piston there is a swinging mass part, and the spinning portion on the side of the crankshaft[5]. The sintering process permits raw component tolerances of less than 1 percent in a tolerance range. The oscillating and rotational weights are calculated by the finished rods and the rods are separated into separate weight groups. In this respect, two weights, one at the middle of the small end and the crank finish, measure the connecting rod horizontally. The value in the small end bore is the oscillating mass and the value in the end crank is the moving mass.

2. Literature review

Sathish et al. (2020) "two separate materials such as AA2014, AA6061 and AA7075 have been analyzed. FEA review for selected three materials and for missed stress has been

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carried out by ANSYS tools; shear stress and overall deformation have been obtained from the software of ANSYS. The AA2014 has fewer weight and higher rigidity compared to the three materials".**Muhammad et al. (2020)**determined topology for connecting a rod appropriate for diesel engine applications and structural optimization… The link rod weight optimisation takes place with a 20% weight reduction goal, 30%, 40%, 50%, and 60% under a 100N static loading to decide the weight to be removed to reduce weight and costs while affecting its strength and longevity. Comparison of structural static deformation, tension, elastic strain and protection component of Von Misses before and following optimization. Based on the outcome it can be inferred that manufacturing firms can use ANSYS Tools to mitigate waste of materials, while ensuring product consistency and efficiency at the same time.**Muhammad et al. (2020**) The study of stress and the optimization of a connecting rod with strong emphasis on essential parameters including deformity, stress, fatigue and stress, factor protection, and life values, among other things. A connection rod's output in an automotive motor is dependent on its design and weight. Therefore, research and optimization are important for producing a durable, cheaper and lightweight connecting rod. **Linga et al. (2020**) An empirical tool constructed is the presented connecting rod for two wheels. A physical model is built in CATIA V5 according to the design. FEA has been used to analyze the structural rod connection mechanism. Various stresses are measured using FEA program ANSYS WORKBENCH 14.5 for specific loading conditions. Similar materials perform in the same way (forged steel and Al-360). The findings obtained are compared on the basis of different performances with considerable tension, shear stress, fatigue life based on the results achieved and we prepared the prototype part in 3d printing.

Saheb, Shaik Himamet al. (2020)researched and compare the weight and price of the connecting rod optimized reduction of certain compression ignition motors. Because the connecting rod is subject to whiping stress in order to design the rod, we can investigate multiple pressures and different forces such that connecting rods do not malfunction. In taking all these strengths into account, the review is helpful to improve design.

Bulut, Mehmet et al. (2020) a numerical rod connecting analysis for the determination of essential stress regions was identified. The load of various motor speeds was supposed to be statically implemented in the study of the connection rod and its resulting stress and deformation values were evaluated. Engine power and torque values were used in static simulation model as the load border conditions, whereas the geometric measurements of the rod connector and its

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material properties were other parameters used as input values. Stress and deformation tests were assessed at the various motor speeds and showed that the connecting rod did not malfunction and fractured under the external pressure.**Pani, Amiya Ranjan et al. (2020)** concluded that in the event of a hydro lock failure on the connecting pin, the merchant-rankine solution is inadequate to buckling load measurement and the aluminum alloy rod buckling resistance even weaker than the steel rod forged. It will also not be used with diesel heavy duty engines. The findings of this project provide important details for the buckling failure of rod configuration in heavy diesel engines.

3. FEM modelling of Connecting Rod

Solid Works is indeed a 3D solid modeling tool that enables users to create comprehensive, solid models of design and analysis in a virtual environment. At SolidWorks they build 3D models by drawing concepts and experimenting with various designs. SolidWorks produces basic and complicated components, assemblies and drawings for designers, engineers and other practitioners. It is useful to develop a simulation model such as SolidWorks, and therefore it saves time, effort and resources to develop the design. Width and height of segment as shown in Table 1. Displays the specification variables, describing the connecting rod dimensions.

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

Based on two parameters with three levels, nine-simulation scenario as per Taguchi's orthogonal array have been created using Minitab software as shown in Table 2.

Table 2:Design array

S.no	**Width of the section, mm**	**Height of the section, mm**
1	12.81	16
2	12.81	18

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3	12.81	20
4	14	16
5	14	18
6	14	20
7	16	16
8	16	18
9	16	20

Fig. 2:CAD model of connecting rod

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

4. Mesh model of connecting rod

Breaking of design into smaller aspects to assess each element is called meshing [39]. It is a distinct framework realization of structure that helps to solve the particular design solutions. The smaller the mesh size, the more time and precision the results are computed[40]. The meshing size is set in program ANSYS as default. A completely free mesh form is taken into

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consideration both the time of arranging and the computational costs, the rate and even simplification of use. The default mesh control has a +100 value with a medium smoothing iteration number. The CAD model has been meshed with tetrahedron element in pre-processing.The total number of nodes is 690521 and total number of elements is 487160.

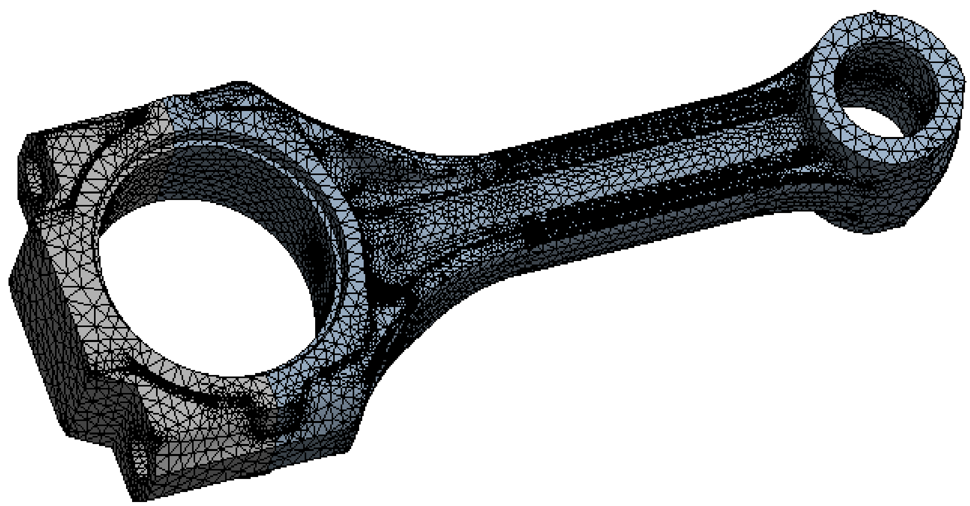

Fig.3:**Mesh model of connecting rod**

5. Boundary Conditions

Another key and important phase in the study after the meshing method is the fixation of supports and applied load in such a way that meets the real-life circumstances[39][34]. Fixed support and load are the boundary condition used in this static evaluation. The fixed support prevents the geometry from moving or twisting. A pressure of 15.5 MPa is applied at the smaller end.

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Fig.4. Boundary Conditions

6. Material property

The material properties that may be linear or non-linear, isotropic or orthotropic, constant or temperature-dependent must be precisely described for effective and qualitative study of the material. Mechanical attributes, such as density, intensity and thermal expansion definition coefficient are optional, based on an analysis goal. [36]. [39]. It is highly helpful for the construction assessment purpose to recognize as well as proclaim the property's right worth. The Young's product module named the elasticity module is a statistical constant, which explains the resilience and tests a solid's capacity to stand up to adjustments in a certain direction whether under tension or compression. The bigger the Young's modulus, the more rigidly the system, i.e. only how it spreads under loads, would surely need a much greater amount of deforming loads. The ratio of Poisson to material expansion combined with Young's modulus (tension to strain proportion) shows both the hardness and nature of the deformity of the material structure, depending on a particular limitation. Both the bulk and the shear module describe the deformation of the due constant volume and the opposing powers. The yield and the tensile strength are specifically two different critical elements that can be used as such materials lose their versatile behaviour and optimum tension. [39]. [38]. After the geometry has been imported into the program with the properties as Carbon fibers have high strength (3–7 GPa), high modulus (200–500 GPa), compressive strength (1–3 GPa), shear modulus (10–15 GPa), and low

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density (1.75–2.00 g/cm3). Carbon fibers made from pitch can have modulus, thermal, and electrical conductivities as high as 900 GPa, 1,000 W/mK, and 106 S/m, respectively.

7. Results and Discussion

The figures below shows the deformation due to applied pressure as per the boundary condition applied. After comparing the deformation in different models it is noticed that simulation 9 shows maximum deformation.

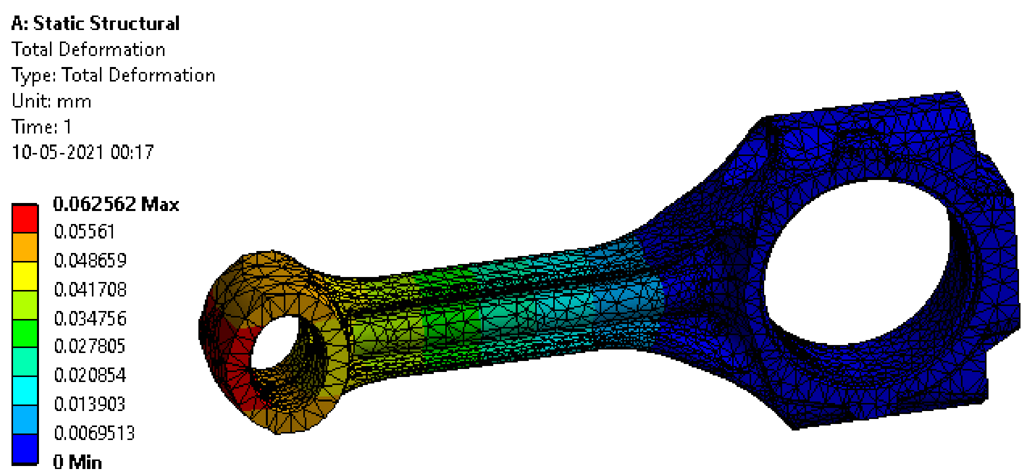

Figure 5: Deformation results

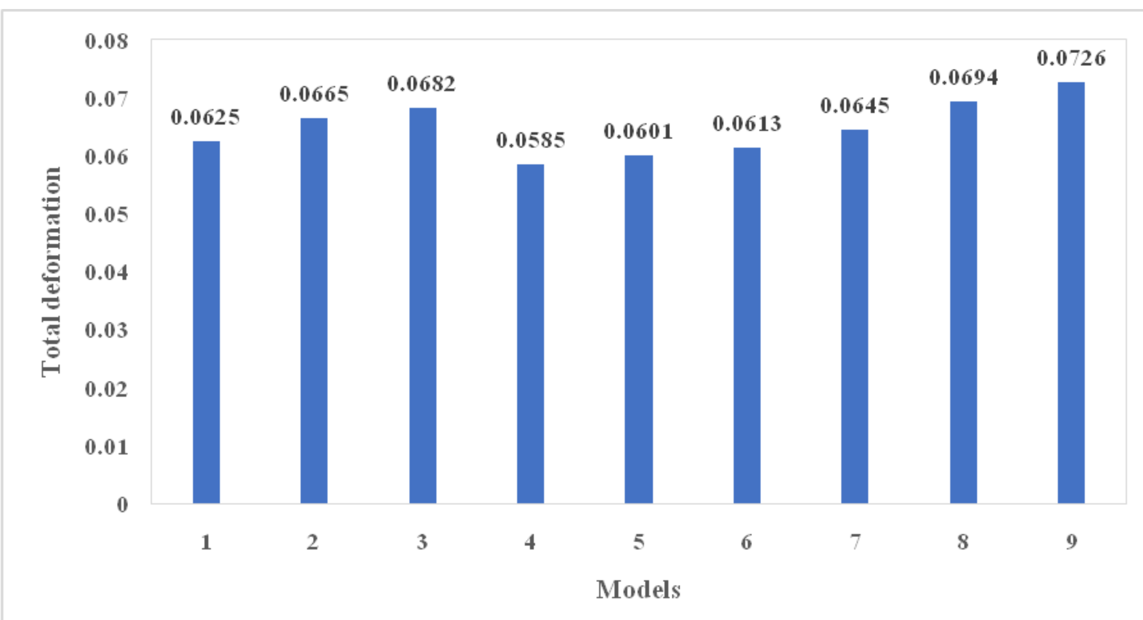

Figure 6: Variation of deformation in nine models of connecting rod

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Equivalent stress

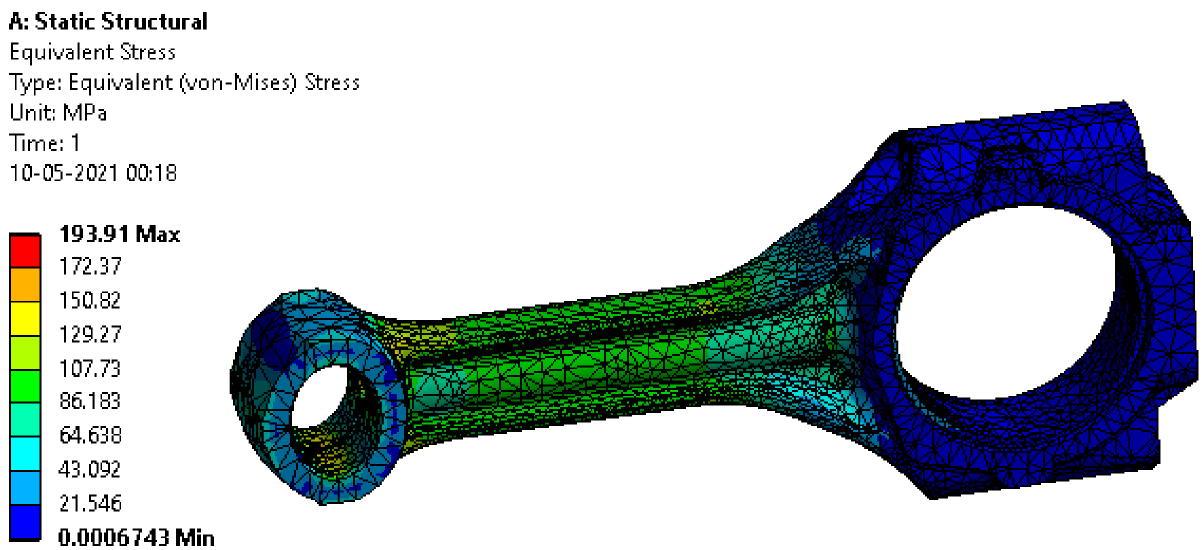

Figure 7: Stress distribution in connecting rod

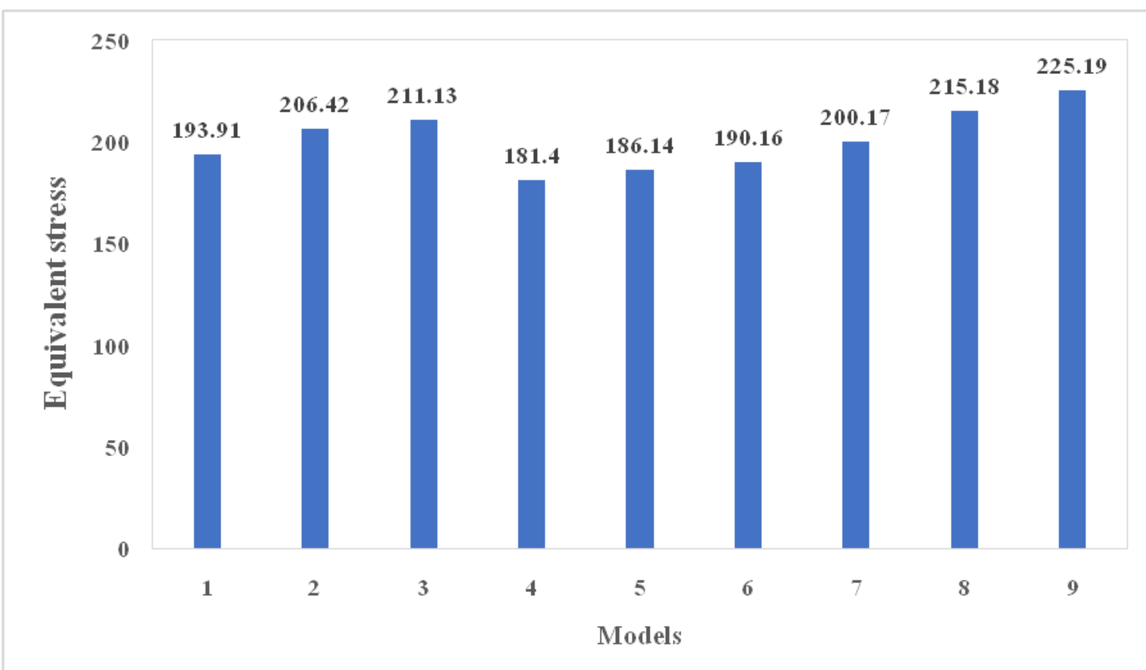

Figure 8: Variation of equivalent stress in nine models of connecting rod

The above figure 8shows that the maximum stress is found to be 225.15 MPa when the width of section is 16 mm and height of section is 20 mm.

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Design optimization of connecting rod using Response Surface Methodology

The Pareto chart shows that absolute values from of the highest effect to the smallest impact of both the standardized effects. The diagram shows a comparison line to show the statistically significant effects. The statistical importance comparison line depends upon on importance level (denoted by α or alpha). As from the fig. 3.5, the bars of factor B and AA cross the reference line that is at 3.182, shows these factors are statistically significant at the 0.05 level. Further, those factors do not cross the reference line, are statistically insignificanti.e. factor A, AB and BB.

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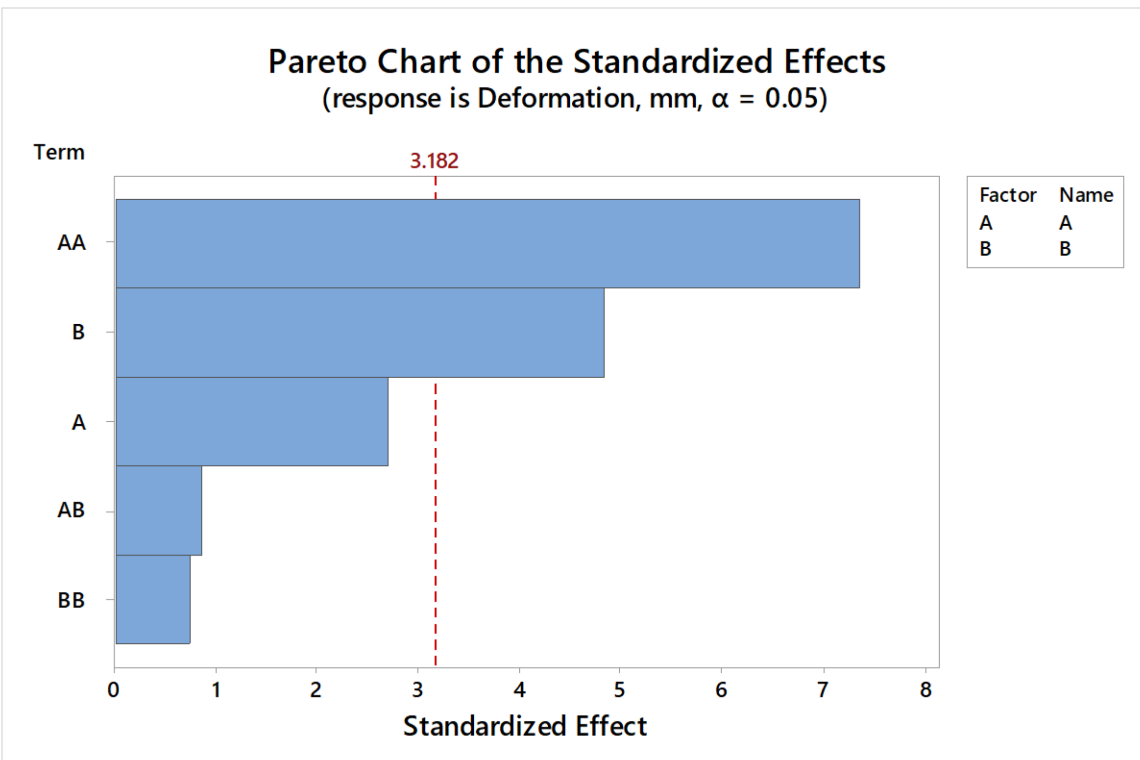

Figure 9:Pareto chart of deformation

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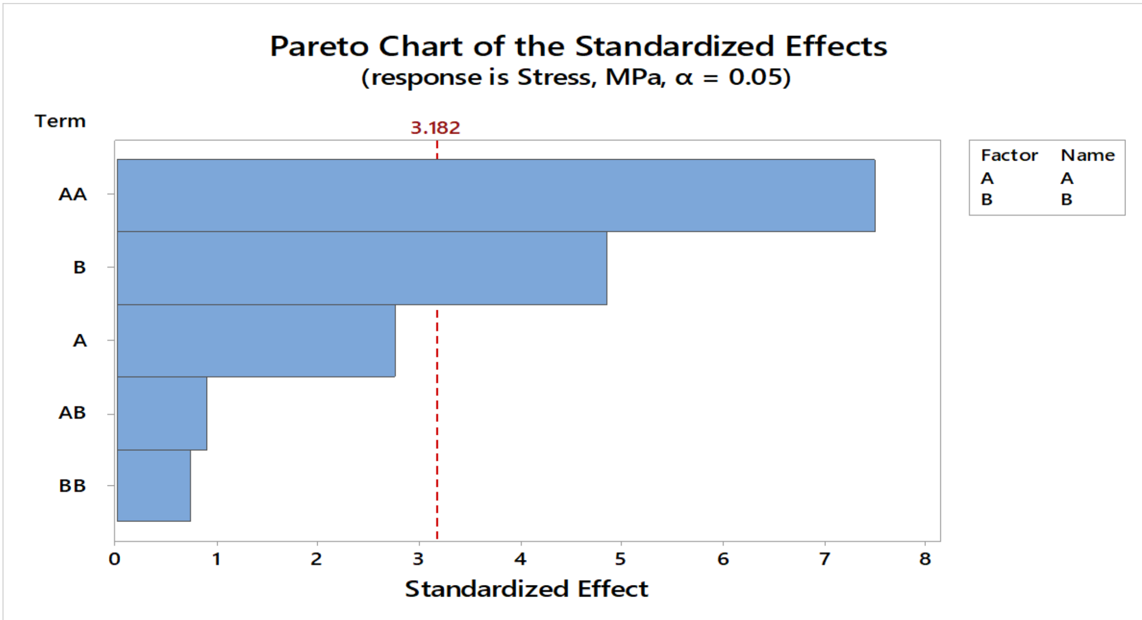

Figure 10: Pareto chart of stress

Optimal solution

An optimum condition was determined to obtain minimum values of selected parameters. Second-order polynomial models were adoptedin the perspective of each response towards optimum conditions.

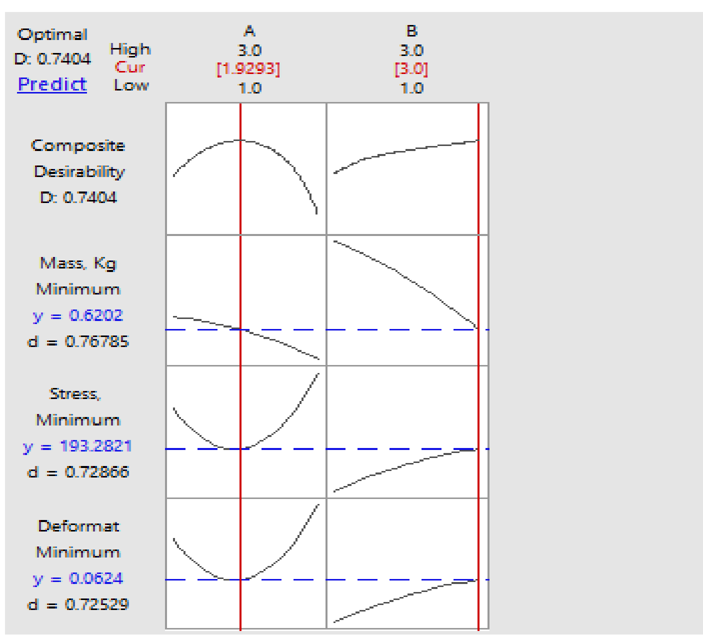

Figure 11: Optimization plot

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From the optimizer plot, optimal setting of width and height of section is obtained as 12.81 mm (level 2), 20 mm (level 3), and optimized results are shown in Table 1.

Table 1:Optimized Solution

Solution	A	B	Mass, Kg Fit	Stress, MPa Fit	Deformation, mm Fit	Composite Desirability
1	1.92929	3	0.620197	193.282	0.0623734	0.740350

Second-order polynomial models every response has been used to achieve defined optimum condition established in this analysis. For optimizing multiple parameters, the Derringer desire ability approach has been used.

8. Conclusion

In this study, optimization of connecting rod has been done using RSM technique by employing Minitab software. First, 3D modelling was done using Solid works software. After that model is imported in IGES format in ANSYS for static structural analysis. Using Taguchi's L9 orthogonal array has been adopted for simulation purpose and geometry optimization. Stress, deformation and mass have been obtained under simulation plan. Final results are imported in Minitab software for optimization of parameters using RSM technique. From the optimizer plot, optimal setting of width and height of section is obtained as 12.81 mm (level 2), 20 mm (level 3), and optimized results are mass of connecting rod = 0.620197 kg, Stress = 193.282 MPa, and deformation = 00623 mm.The results suggest which optimum parameters or results may also be defined by the models used for these work. Further, this study is beneficial for designers and researchers in the perspective of design optimization by employing RSM technique.

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