DESIGN OPTIMIZATION OF KNUCKLE JOINT USING FEA

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Abstract: The Knuckle joint is a type of joint which is used in steering system and is placed between the steering rod and pinion of the steering gear which can be easily disconnected when required. The stress developed in knuckle joint depends upon design of stub and material used for assembly components which includes knuckle, stub and arm. The current research investigates the design improvement of stub using response surface method. The CAD model of stub is developed in design modeler and analyzed FEA analysis is conducted in ANSYS FEA software package. The safety factor achieved for stub is 3.54 and for knuckle is 4.15 for base design. From response surface optimization technique, the maximum mass of stub without optimization was .61046Kg and minimum mass obtained after optimization was .59352Kg which is 2.77% reduction.

Keywords: Knuckle, Stub, FEA, Optimization

I. INTRODUCTION

A knuckle joint is used to connect two rods which are under the action of tensile loads whereas, if the joint is guided, compressive load may be supported by rods. A knuckle joint can be easily disconnected when required. Its uses are link of a cycle chain, tie road joint for roof truss, valve rod joint with eccentric rod, pump rod joint, tension link in bridge structure and lever and rod connection of various types. In knuckle join, one end of one of the rods is made into an eye and the end of the other rod is formed into a fork with an eye in each of the fork leg.

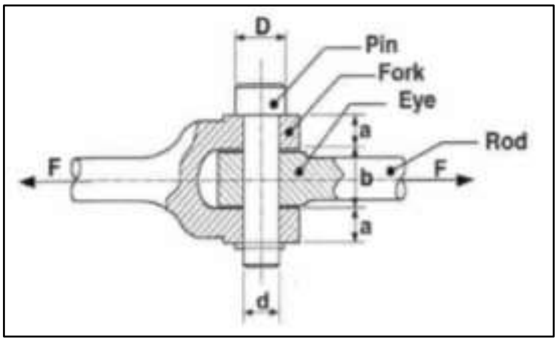


Fig 1: Knuckle joint

The knuckle pin passes through both the eye hole and the fork holes and may be secured by means of a collar and taper pin or spilt pin. The knuckle pin may be prevented from rotating in the fork by means of a small stop, pin, peg, or snug. In order to get a better quality of joint, the sides of the fork and eye are machined, the hole is accurately drilled and pin turned. The material used for the joint may be steel
or wrought iron. Knuckle joints may be cast or fabricated or forged. In the knuckle joint illustrated, the rods are integral with the eye and fork.

II. LITERATURE REVIEW

Sangamesh et al. [1] studied the stresses in Knuckle joint using analytical method. Further study in this direction can made by using various directions of the pin and the capacity to withstand load. The present work is concentrating on which type of meshing is preferable for components.

Sanjay Yadav et al [2] has done static analysis of steering knuckle component. The design of Steering Knuckle component is done with the help of Computer Aided Engineering (CAE). [2]

Mahesh P. Sharma et al. [3] has done static examination of controlling knuckle. We have structure a knuckle which suits double caliper mountings for expanding braking productivity and decreasing a halting separation of a vehicle. Computer aided design modular of knuckle was set up in CREO2.0. Static examination was done in ANSYS WORKBENCH by obliging the knuckle, applying heaps of braking torque on caliper mounting, longitudinal response because of footing, vertical response because of vehicle weight and guiding response.

Adiya Chavan et al [4] has upgrade the controlling knuckle so as to diminish the un sprung weight of a solitary seat All-Terrain Vehicle (ATV) while holding an agreeable wellbeing factor for better execution of the vehicle. A twostep procedure has been utilized for the equivalent. Initial step is demonstrating the knuckle according to the auxiliary contemplations and structure limitations set by suspension, controlling and brake congregations and assurance of burdens following up on the knuckle.

III. PROPOSED WORK

The stress developed in knuckle joint depends upon design of stub and material used for assembly components which includes knuckle, stub and arm. The current research investigates the design improvement of stub using response surface method. The CAD model of stub is developed in ANSYS design modeler and analysis is conducted using ANSYS workbench.

IV. METHODOLOGY

The CAD model of stub is developed as per dimensions shown in figure 2 below. The CAD model is developed using sketch and revolve tool of ANSYS design modeler as shown in figure 3 below.

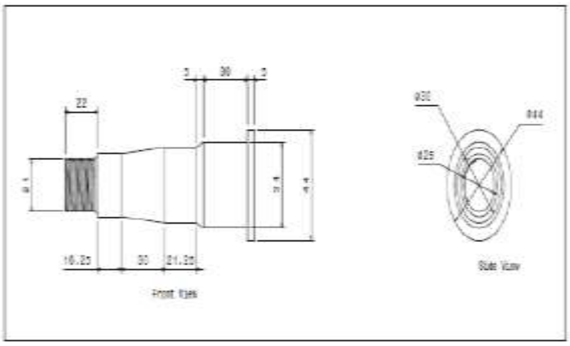


Figure 2: Front view and side view of stub

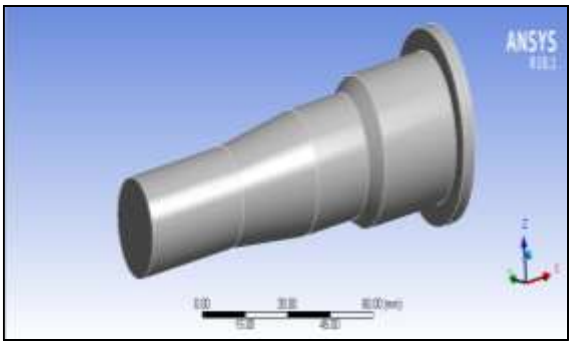


Figure 3: CAD model of stub developed in ANSYS design modeler

The model is meshed using tetra elements of appropriate size and shape. After meshing appropriate loads and boundary conditions are assigned.

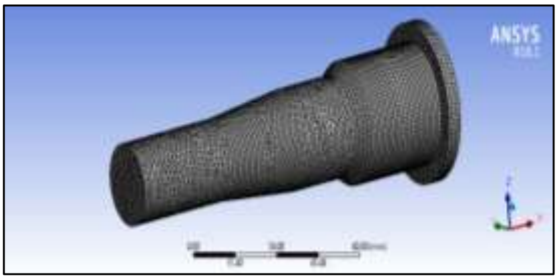


Figure 4: Meshed model of stub

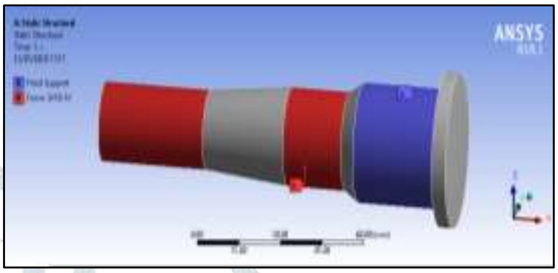


Fig 5: Element shape of tetrahedral element

The loads and boundary conditions are assigned as shown in figure 5 above. The fixed support is applied in location A and vertical force of 3210N is applied on region B as shown by red colour. The loads and boundary conditions are taken from literature.

V. RESULTS AND DISCUSSION

From the structural analysis conducted for stub, equivalent stress plot is generated. The maximum stress is generated near support feature and V shape junction with magnitude of 70.54MPa and reduces as we move away from this junction show by light blue and dark blue color contour as shown in figure 6 below.

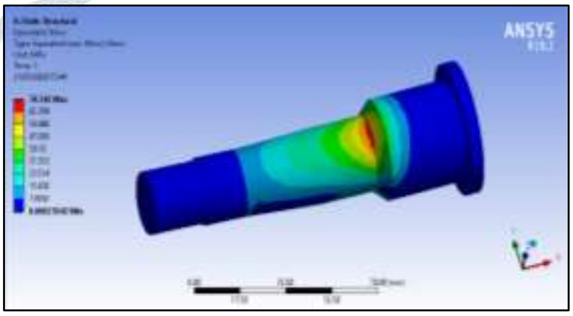


Figure 6: Equivalent stress at different regions of stub

The total deformation plot is shown in figure 7 below. The maximum magnitude of deformation is .0612mm on circular portion which is connected to arm and deformation reduces as we move away from circular zone shown by dark orange and green colors. The minimum deformation is noticed at support zones.

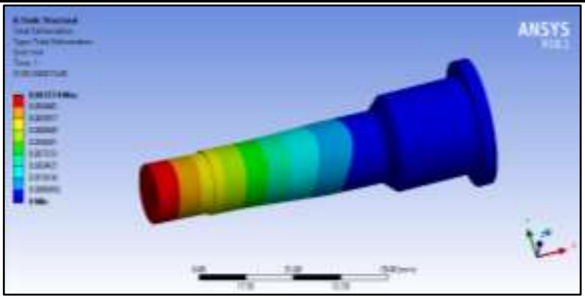


Figure 7: Deformation at different regions of stub

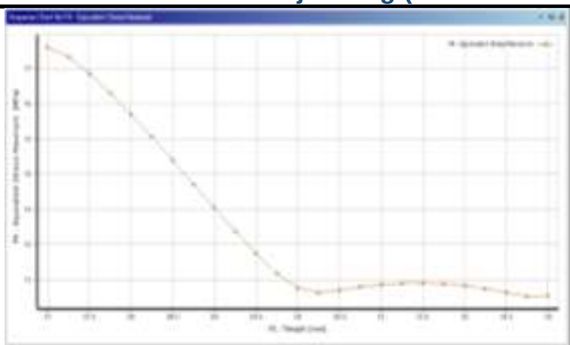


Figure 8: Equivalent stress vs Tlength

Table 1: Results for different components

Component Name	Yield Strength (MPa)	Deformation(mm)	Eq Stress (MPa)	Factor of Safety
Stub	250	.0612	70.54	3.54
Knuckle	510	.0653	122.7	4.15

The equivalent stress value decreases with increase in Tlength value linearly upto 30mm as shown in figure 5.15 above. The maximum value of equivalent stress is observed for Tlength value of 27mm and minimum is observed for Tlength value of 31.25mm.

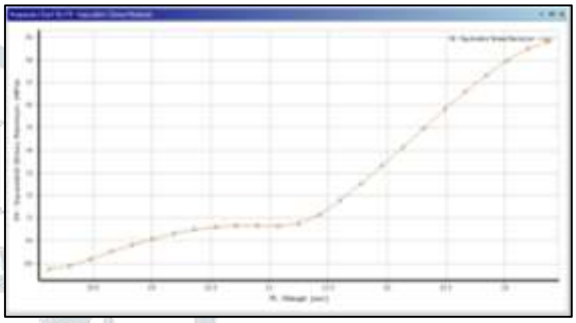
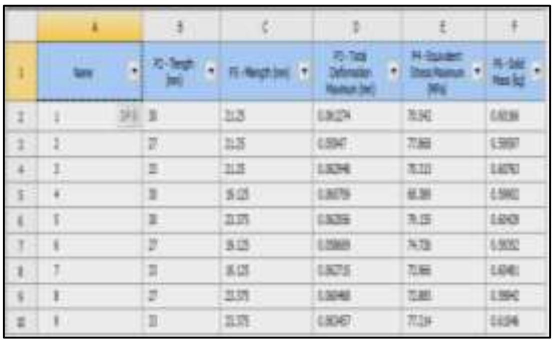


Figure 9: Equivalent stress vs Mlength

Table 1 above shows safety factor and deformation for both components i.e. stub and knuckle. The safety factor achieved for stub is 3.54 and for knuckle is 4.15. The existing design of knuckle has mass of .4561kg for 18mm thickness and further analysis is conducted with reduced thickness of knuckle. The optimization variables selected for response surface optimization of stub . The 1st optimization variable is Tlength and 2nd optimization variable is Mlength. The variables are ticked in details tab of ANSYS design modeler. The design points are generated using Taguchi design of experiments (DOE) a. The design points are generated using linear regression model. Design of experiments (DOE) is a systematic method to determine the relationship between factors affecting a process and the output of that process. In other words, it is used to find cause-and-effect relationships. This information is needed to manage process inputs in order to optimize the output. ANSYS optimization is selected is central composite design scheme.

The equivalent stress value decreases with increase in Mlength value linearly up to 23.375mm as shown in figure 9 above. The maximum value of equivalent stress is observed for Mlength value of 23.375mm and minimum is observed for Mlength value of 19.125mm. The response surface plot for equivalent stress shows that maximum equivalent stress is observed for Mlength value ranging from 23mm to 23.375mm and Tlength value ranging from 28mm to 31mm.

Table 2: Design Points generated using Taguchi DOE



	A	B	C	D	E	F
1	Name	P2 - Tlength (mm)	P3 - Mlength (mm)	P3 - Total Deformation Maximum (mm)	P4 - Equivalent Stress Maximum (MPa)	P5 - Solid Mass (kg)
2	1	30	21.25	0.06274	70.542	0.60166
3	2	27	21.25	0.05947	77.866	0.58597
4	3	33	21.25	0.06298	70.221	0.60763
5	4	30	19.125	0.06079	68.389	0.59802
6	5	30	23.375	0.06356	79.155	0.60429
7	6	27	19.125	0.05869	74.731	0.59332
8	7	33	19.125	0.06275	70.866	0.60481
9	8	27	23.375	0.06048	72.881	0.59942
10	9	33	23.375	0.06347	77.214	0.61046

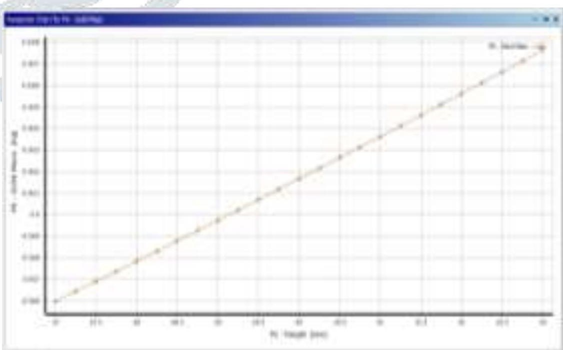


Figure 10: Solid mass vs Tlength

The mass value decreases with increase in Tlength value linearly upto 33mm as shown in figure 10 above. The maximum value of mass is observed for Tlength value of 33mm and minimum is observed for Tlength value of 27mm.

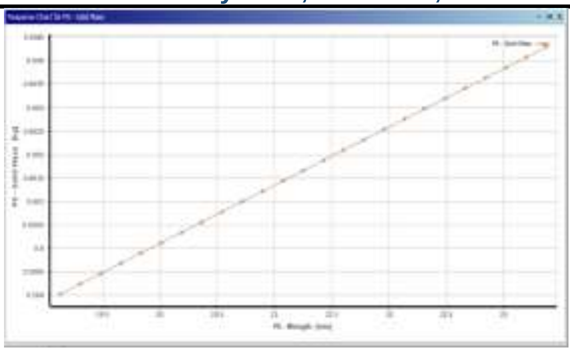


Figure 11: Solid mass vs Mlength

The mass value increases with increase in Mlength value linearly upto 23.375mm as shown in figure 11 above. The maximum value of mass is observed for Mlength value of 23.375mm and minimum is observed for Mlength value of 19.125mm. The response surface plot generated for solid mass shows the maximum value of solid mass for mlength value ranging from 21mm to 23.375mm and Tlength value ranging from 30mm to 33mm.

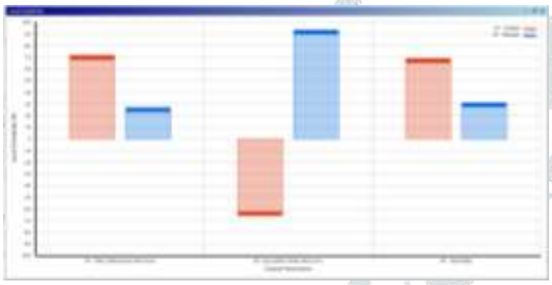


Figure 12: Sensitivity plot

For total deformation, Tlength has positive sensitivity of 71.73 and Mlength also has positive sensitivity of 26.877. Therefore, for total deformation, Tlength has higher effect as compared to Mlength. For equivalent stress, Tlength has negative sensitivity of 65.717 and Mlength also has positive sensitivity of 93.471. Therefore, for equivalent stress, Mlength has higher effect as compared to Mlength. For mass, Tlength has positive sensitivity of 68.881 and Mlength also has positive sensitivity of 31.107. Therefore, for mass, Tlength has higher effect as compared to Mlength.

VI. CONCLUSION

The FEA analysis using ANSYS software is also a viable option against experimental testing which involves costly set up and is time consuming. Response surface optimization of stub is conducted to determine the effect of various parameters on stub design and knuckle design. The detailed conclusion are as follows:

1. From response surface optimization technique, the maximum mass of stub without optimization was .61046Kg and minimum mass obtained was .59352Kg which is 2.77% reduction.
2. From response surface optimization technique, the maximum equivalent stress of stub without optimization was 79.135MPa and minimum equivalent stress obtained was 68.389Mpa which is 13.57% reduction.
3. From response surface optimization technique, the maximum deformation of stub without optimization was .0634mm and minimum deformation obtained was .0586mm which is 7.65% reduction.
4. For total deformation, Tlength has positive sensitivity of 71.73 and Mlength also has positive sensitivity of 26.877. Therefore, for total deformation, Tlength has higher effect as compared to Mlength.
5. For equivalent stress, Tlength has negative sensitivity of 65.717 and Mlength also has positive sensitivity of 93.471. Therefore, for equivalent stress, Mlength has higher effect as compared to Mlength.
6. For mass, Tlength has positive sensitivity of 68.881 and Mlength also has positive sensitivity of 31.107. Therefore, for mass, Tlength has higher effect as compared to Mlength.

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