

Design, Analysis and Optimisation of Race Car Chassis

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ABSTRACT: The project aim at the design, analysis and optimisation of the race car chassis with the intension of stress minimisation and increasing the structural performance of the car. The whole car is modelled according to the 95th percentile male who can fit inside the cock-pit of the chassis. As the race car travels at high speed, the protection has been designed to the race car for driver safty using structural members. The structural members or triangulations are designed in such a way that the stresses are reduced in the front impact, rear impact, side impact and roll over collision of the chassis. Later the dimensions are taken for optimisation. For this reason, the system is analysed almost 65 times to arrive at the final dimension of the chassis. Meanwhile, tensional rigidity has been checked for the final dimensions.

KEYWORDS: Race Car Chassis, Stress, Structural Performance, Optimisation.

I. INTRODUCTION

The design starts with the finding out the boundary condition so as chassis. Hence the conceptual design of the chassis is made in the hand and then the same has been transferred into CATIA model. After many iterations and iterations i have come with the design which has assumed to have the reduced stress. (The analysis part will concentrate on the reduction of stress).

A wheel base of 1650mm and track width of 1300 at front and 1350 mm at rare has been achieved with the wheel base to track width ratio of 1.33..

Optimisation and tried to find the solution to all the questions thus achieving the goal.

II. RELATED WORK

1 FEA package.

Calculations using classical continuum methods of the chassis are highly impossible. In fact because of the reason that it cannot be solved in the continuum method, Finite element analysis has been created. This requires the computational methods such as finite element method. Thus reducing the human efforts. in the software is one of the prominent commercial methods available for the use in the society. FEA Package is used for the analysis.

2 Design Of experiment Break-up:

In fig [1] shows during the design of the experiments, 8 inputs and 1 output are considered. For the initial iterations. Analysis and optimisation goes together. Here is an example on how these can be effectively utilised and boundary conditions are exploited for the results. Sensitivity test, results conclusion, and design of experiments has been created in the following stages in the research paper.

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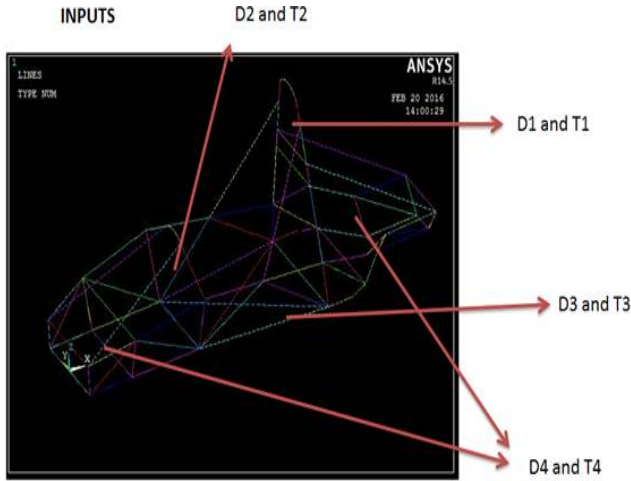


Fig 1 : Design of experiments

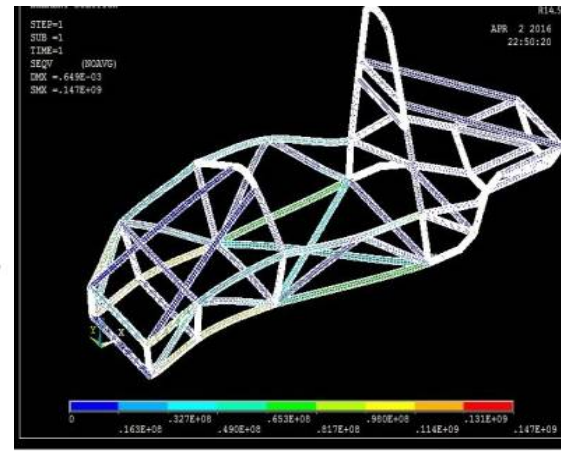


Fig 2: Von-misses stress

Von Mises stress is widely used by designers to check whether their design will withstand a given load condition.

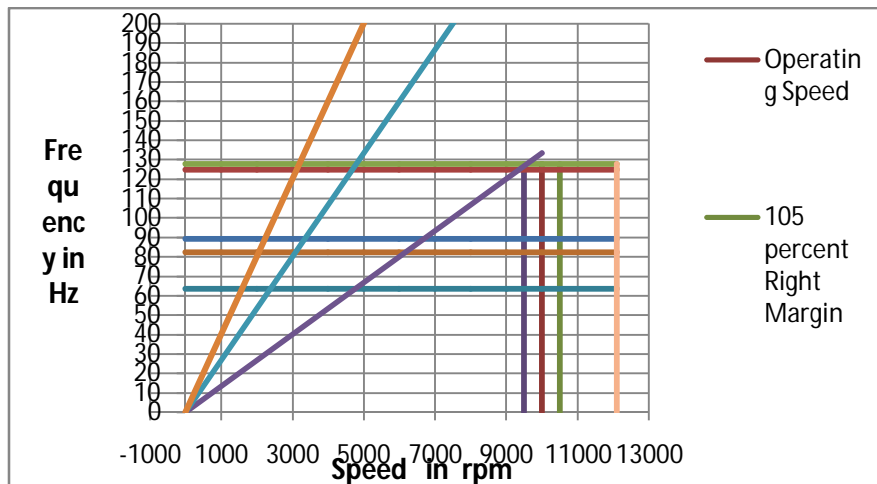


Fig 3: Campbell diagram

From the Campbell diagram it can be seen that the 1x mode is hitting the first mode at 4800rpm speed and the 5th mode at 93% of the rated speed. Also till 4X speeds there is no natural frequency hit at the running speed excepts the first mode. But the resonance is happening is less than 50% of the speed, there will be no catastrophic failures in the chassis and hence can be considered as the safe design.

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3 Torsional rigidity of chassis:

The chassis is the most important criteria for the design of the chassis. It is found using applying the couple at the front end and fixing it at the rear end as shown below.

$$\text{Torsional rigidity} = \frac{F * l}{\tan^{-1} \frac{\delta}{l}}$$

Force= 1000N

L= 450mm

The results from the FEA Package that is deflection is taken and put in the above equation to get the results. But mean deflection has to be calculated in order to get the exact results which are half of the maximum deflection. The torsional rigidity of the chassis is found to be 1381Nm/deg.

A value of 1000-2000Nm/dig would be sufficient and good enough for the proper design and we have obtained the correct results but they are not optimum.

IV. OPTIMISATION

Optimisation poses the biggest challenge in the design. Optimisation can be claimed as the best solution out of available solutions. In this project, we are concerned about reduction of stress and thus mass.

We have adopted a procedure to get DOE results and are as follows.

1. Sensitivity analysis
2. Design points(sampling points)
3. Regression analysis
4. Creation of surface response
5. Finding best solution

Each of them is discussed here.

1. orthogonal model(Minitab 17)
2. Poisons model(Minitab 17)

1 Orthogonal Regression Analysis:

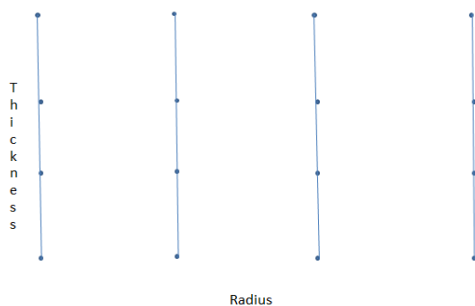


Fig 4 : vertical contunity

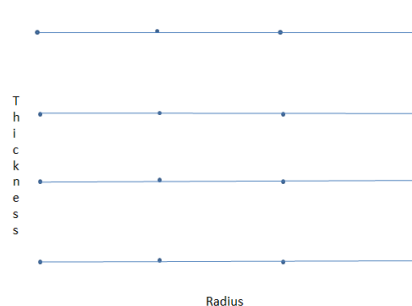


Fig 5 : horizontal contunity

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In the figure [4],[5], radius is in x axis and thickness is plotted in y axis. The results of the corresponding stresses are the dots in the figures. Taguchi methods can only pick up the dots among the above. But if the answers lies between the dots then we need to create the relation between them in terms of inputs and output.

2 Poisons Regression Model:

Orthogonal regression model which we did previously considers the linear function for the optimisation, but poisons regression models, exponential function is considered. These exponential functions are evaluated instead of the linear functions. These also can be inferred as the log-log functions

3 Sensitivity analysis:

The optimisation can only be done when we are well aware of the factors affecting the design. As mentioned earlier in the analysis section, 8 inputs and 1 outputs are considered namely R1, R2,R3,R4, T1, T2, T3, T4.

Sensitivity analysis is a iterative process, instead of doing for a large number of times, the least time possible is by changing the inputs 5 times and monitoring the von-misses stress as the output. Whenever there is deviation of stresses are seen, those are called as the sensitive parameters. A common 12.7 mm radius and 1.4mm thickness is considered for the sensitivity. By changing the 1.4mm thickness to 1.7mm thickness, the sensitivity is captured.

Sensitivity Analysis									
Front Impact Analysis Sensitivity									
Section 1		Section 2		Section 3		Section 4			
R1(mm)	T1(mm)	R2(mm)	T2(mm)	R3(mm)	T3(mm)	R4(mm)	T4(mm)	Stress(Mpa)	
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.4	147	
12.7	1.7	12.7	1.4	12.7	1.4	12.7	1.4	147	
12.7	1.4	12.7	1.7	12.7	1.4	12.7	1.4	147	
12.7	1.4	12.7	1.4	12.7	1.7	12.7	1.4	147	
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.7	125	

Table3.1: Front Impact Sensitivity Analysis

It is very clear from the table that the section 4 is more sensitive in the front impact analysis.

Sensitivity Analysis									
Side Impact Analysis Sensitivity									
Section 1		Section 2		Section 3		Section 4			
R1(mm)	T1(mm)	R2(mm)	T2(mm)	R3(mm)	T3(mm)	R4(mm)	T4(mm)	Stress(Mpa)	
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.4	447	
12.7	1.7	12.7	1.4	12.7	1.4	12.7	1.4	389	
12.7	1.4	12.7	1.7	12.7	1.4	12.7	1.4	447	
12.7	1.4	12.7	1.4	12.7	1.7	12.7	1.4	448	
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.7	436	

Table3.2:Side impact sensitivity analysis

From the above table it can be inferred that the section 1 is sensitive towards the side impact loads. This also means the principle stresses and the von-misses stress lies in the section 1. That is front roll hoop section

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Sensitivity Analysis								
Rear Impact Analysis Sensitivity								
Section 1		Section 2		Section 3		Section 4		
R1(mm)	T1(mm)	R2(mm)	T2(mm)	R3(mm)	T3(mm)	R4(mm)	T4(mm)	Stress(Mpa)
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.4	149
12.7	1.7	12.7	1.4	12.7	1.4	12.7	1.4	149
12.7	1.4	12.7	1.7	12.7	1.4	12.7	1.4	148
12.7	1.4	12.7	1.4	12.7	1.7	12.7	1.4	148
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.7	129

Table3.3:Rear impact sensitivity analysis

It is very clear that the section 4 is sensitive towards the side impact loads. This is same as the front impact but in the rear zone.

Sensitivity Analysis								
Roll Over Impact Analysis Sensitivity								
Section 1		Section 2		Section 3		Section 4		
R1(mm)	T1(mm)	R2(mm)	T2(mm)	R3(mm)	T3(mm)	R4(mm)	T4(mm)	Stress(Mpa)
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.4	239
12.7	1.7	12.7	1.4	12.7	1.4	12.7	1.4	239
12.7	1.4	12.7	1.7	12.7	1.4	12.7	1.4	239
12.7	1.4	12.7	1.4	12.7	1.7	12.7	1.4	237
12.7	1.4	12.7	1.4	12.7	1.4	12.7	1.7	238

Table3.4 :Roll over impact sensitivity analysis

5 Observations and inference of the sensitivity analysis:

Section 4(Front), section 4(rear), section 1 and section 3 are sensitive to the loads coming from different impacts. The tensional rigidity and the deflection is affected also by the section 2 hence a competitive dimension are to be kept. Hence according to the SAE rules, 12.7mm Radius and 1.4mm thickness is kept for section 2.

6 Design Points:

Design points are constructed as per the model requirement. Usually for the orthogonal model and the poisons models, L9, L16, L25 arrays are used. Here we have attempted the analysis using L9 array which would be sufficient for the optimisation.

R(mm)	Design Points Of Front Impact		
	10.5	12.7	14.5
T(mm)	Stess(Mpa)		
1	241	202	178
1.4	176	147	129
1.8	140	117	102

Table 3.5: Design points of Front Impact Factor

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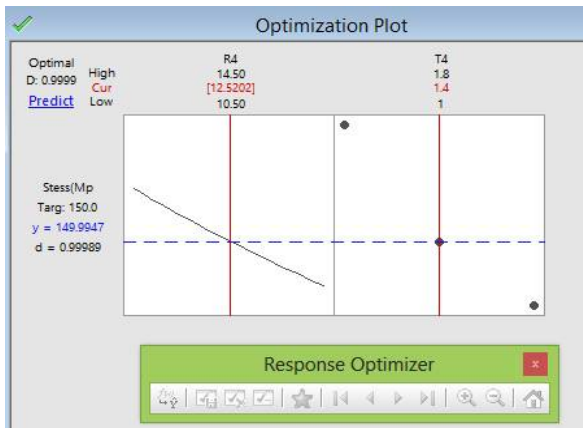


Fig 6: plot of Poison’s Horizontal continuity mode 1

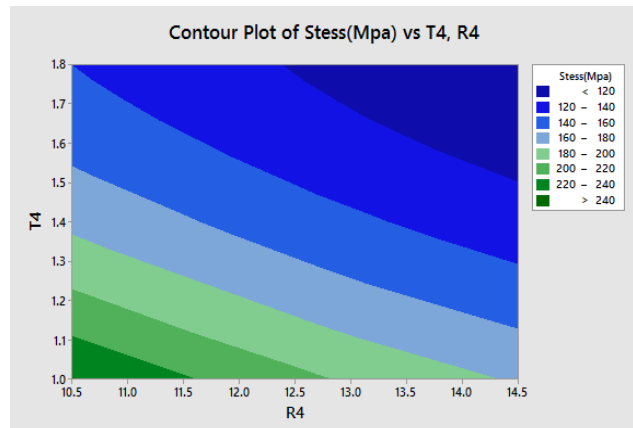


Fig7: the variation of stress with R4 & T4

In fig [6] optimisation plot in horizontal continuity modal will vary and stress reduces its perphomence will be more in fig [7] shows contour plot of stress optimisation will decreases.

3.6 Observation Table in front impact:

Model	Orthogonal Horizontal	Orthogonal Vertical	Poisons Horizontal	Poisons Vertical
R square Value	96.90%	98.82%	99.39%	99.97%
R adjusted value	95.04%	98.11%	96.27%	96.85%
Radius Value(mm)	12.7	12.6205	12.7	12.5202
Thickness Value(mm)	1.4489	1.4	1.4134	1.4

The observation from the above table clearly indicates that all R-Square values are acceptable. But the orthogonal vertical model is the most accurate results among 4. Inspire of the great goodness of fit. All 4 models calculate different results. Different values for the same target value of stress of 150Mpa. This answer leads to confusion and chaos. But from observation, It is true that all the answers are correct. Any answers can be chosen among the results.

So we have taken R4= 12.6205mm and T4=1.4mm as optimised value because of the accurate prediction.

R(mm)	Design Points Of Side Impact		
	11.7	12.7	13.7
T(mm)	Stess(Mpa)		
1.6	445	396	347
2	394	339	294
2.4	351	301	283

Table 3.7: Design points of Side Impact

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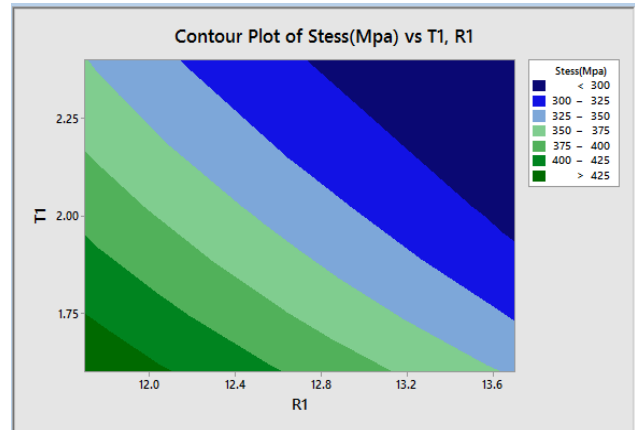
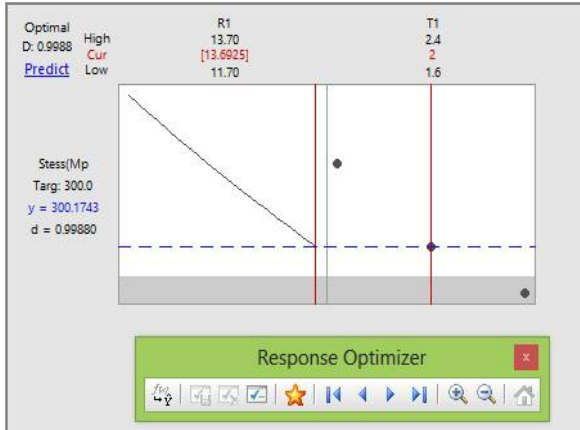


Fig 8: plot of Poisson’s Horizontal continuity model

Fig 9: contour plot of the variation of stress with R1 &T1

In side impact design points will be stress under the condition maximum orthogonal response optimisation will occurring fig [8] and also to be radius and thickness [t1]&[r1]also minimum stress will be reduces.

3.8 Observation Table in side impact:

Model	Orthogonal Horizontal	Orthogonal Vertical	Poisons Horizontal	Poisons Vertical
R square Value	97.81%	97.09%	98.61%	98.06%
R adjusted value	96.50%	95.35%	94.04%	93.49%
Radius Value(mm)	12.9632	13.7	13.6925	13.7
Thickness Value(mm)	2.4	2.07589	2	2.07064

The observation from the above table shows, R-Square values are acceptable. But the poisons horizontal model is accurate among 4. Apart from the goodness of fit. All 4 models give different results. for the same target stress of 300Mpa. It can be inferred that the results are more accurate in the poisons horizontal model and hence those values are chosen as optimum results

Now the optimum results are R1=13.6925mm and T1=2mm

R(mm)	Design points Of Rear Impact		
	10.7	12.7	14.7
T(mm)	Stess(Mpa)		
1	259	195	151
1.4	202	149	115
1.8	169	123	94.1

Table 3.9 :Design points of Rear impact

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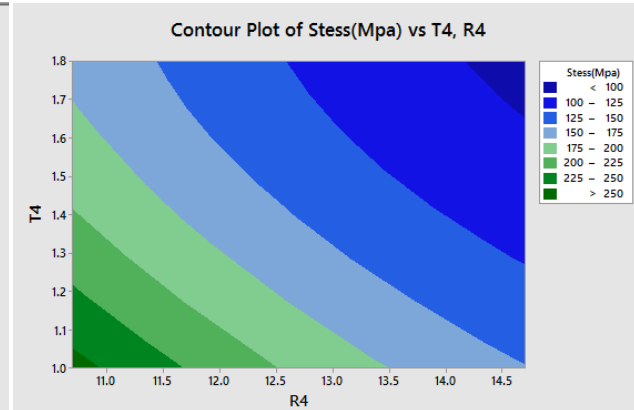
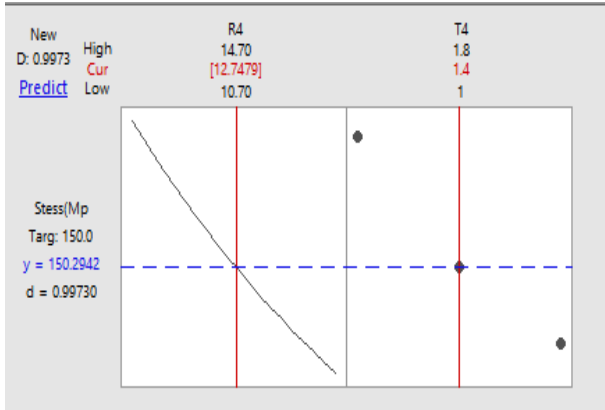


Fig 9: plot of Poisson's Horizontal continuity model.

Fig 10: contour plot of the variation of stress with R4 & T4.

In fig [10] shows optimisation plot radius[r] and [t] thickness will maximum stress variation in this modal considered in fig [9] also to be considered stress maximum optimisation reaches .

4.0 ObservationTable in rear impact:

Model	Orthogonal Horizontal	Orthogonal Vertical	Poisons Horizontal	Poisons Vertical
R square Value	97.80%	97.71%	99.83%	99.59%
R adjusted value	96.49%	96.34%	97.44%	97.20%
Radius Value(mm)	12.9371	12.7	12.7479	12.7
Thickness Value(mm)	1.4	1.46213	1.4	1.43513

The observation in the above table clearly shows that all R-Square values are acceptable. But the poisons horizontal model is the most accurate results among all 4. The results are chosen depending on the accuracy of the model. The optimum results are R4=12.7479 and the T4= 1.4. Also there exist another R4 and T4 for the front impact. Hence this value can be used for the rear side only.

R(mm)	Design Points Of Roll Over Impact		
	10.7	12.7	14.7
T(mm)	Stess(Mpa)		
1	248	242	236
1.4	244	238	232
1.8	242	235	228

Table 4.1 :Design points of roll over impact

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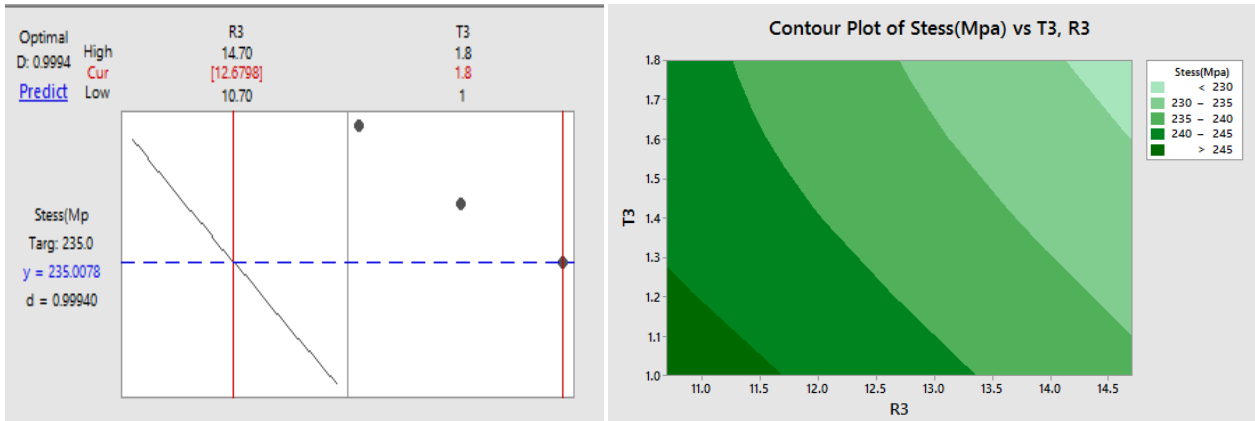


Fig 11 : plot of Poisson's Horizontal continuity model.

Fig12: contour plot of the variation of stress with R3 & T3..

The fig [11] horizontal continuity modal in the optimal solution high and fig[12] it reduces the stress in countor plot and more optimal solution will be considered

4.2 Observation Table in roll over:

Model	Orthogonal Horizontal	Orthogonal Vertical	Poisons Horizontal	Poisons Vertical
R square Value	99.58%	99.42%	99.48%	99.31%
R adjusted value	99.32%	99.07%	99.20%	99.02%
Radius Value(mm)	13.6474	12.7	12.6798	12.7
Thickness Value(mm)	1.4	1.78095	1.8	1.7838

The observation shows that all the R square values are acceptable and all the models pass the test. Nut orthogonal horizontal model has the highest accuracy and is considered for the optimisation. Hence R3=13.6474mm and the T3=1.4mm is the optimum results.

V. CONCLUSION

The optimised results are conceited in a single area here.

R1=13.6925mm and T1=2mm

R2=13.6925mm and T2=2mm

R3=13.6474mm and the T3=1.4mm

R4(Rear)=12.7479mm and the T4(Rear)= 1.4mm

R4(Front)= 12.6205mm and T4(Front)=1.4mm

All the values are well accepted and optimised. Also the stresses are well within the range. And all the values that is 8 values are optimised with the help of the analysis and the optimisation methods. Torsional rigidity is good and the Campbell diagram shows no danger in terms of the frequency.8.0



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