

# Design Analysis & Optimization of Hub Used in FSAE Cars

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**ABSTRACT:** This paper involves in detail description of overall design considerations, optimization and analysis of hub (front hub) which is a part of front wheel assembly of FSAE CAR. Formula SAE (FSAE) competitions offers a great opportunity for an engineering student where he can practice and develop various engineering skills. This increases the practical and application oriented approach towards a real engineering practice. This paper deals with the design procedure of hub used in FSAE vehicle, shape optimization for weight reduction as well as Finite Element Analysis of it. 3D cad model of hub and its shape optimization is done using AUTODESK FUSION 360 software as well as CREO 2.0 and FEA analysis is done using ANSYS 17.0

**KEYWORDS:** FSAE, Hub, Shape optimization, Finite Element Analysis, AUTODESK FUSION 360, CREO 2.0 ANSYS 17.0.

## I. INTRODUCTION

The objective of the study is to design, optimize and analyse a hub. Hub is a part of wheel assembly of a car. Here we have designed a hub of front wheel assembly. A wheel set assembly consists of a knuckle-stub-hub-brake disk-2 taper bearing-castle nut-cotter pin-lug nut and lug bolts. Hub is rotating part in the assembly where disk is mounted on one side and wheels are mounted on other side. As this part gives a motion to the wheel and affects the overall performance of the car. Hence it is important to design this part by considering various safety considerations. Proper material selection is to be taken in consideration as well as cost is also important. Design is to be done by keeping in mind the safety of the part and manufacturing point of view. As in motorsports weight of the car plays an important role in overall performance of the car. For this purpose a shape optimization of hub is done which actually gives an idea about the stresses which are induced in it and how much material we can remove so as to reduce the weight and it also gives appropriate factor of safety to the part.

After the shape optimization results we have modified the cad design with reference to the shape optimization results. Finally we have done an analysis of the part using FEA in ANSYS 17.0 software which ensures the safety of the part from failure.

## II. RELATED WORK

### A. Design Methodology

Before starting the design of hub, the knuckle and stubb dimensions must be finalised. As the hub rotates on the stubb which is completely supported by knuckle. To reduce the friction and to maintain the unobstructed motion hub two taper bearings are used. The internal diameter of bearings must be equal to the outer diameter of stubb. The bearings are cylindrical taper bearings, which are selected from the manufacturer's catalogue by considering the loads which are taken by the bearing.

After the final design of knuckle and stubb we can design the hub. As one side of hub is connected to the brake disc and other side is connected to the wheel. Hence the disc selection plays an important role for making a holes on disc side of the hub with reference to the PCD (Pitch Circle Diameter) of disc. Same as disc the PCD of rim of wheel where the hub is connected must be known.

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## Material selection:-

Material selection as it has a great impact on safety, reliability and performance. To ensure the proper selection of material market research is done. As our main aim is to provide High factor of safety to the part, lower weight and cost of the material is also considered while selection of material. As Aluminium is a metal which have less density and because of that the weight is also less. Various grades of Aluminium provides really good strength like Al 6061, Al 7075, Al 6082 etc. We have selected 2 materials which are

1. Al 6061
2. Al 7075

**Mechanical properties of Al 6061 and Al 7075**

Properties	Al 6061	Al 7075
Density (g/cc)	2.7	2.81
Young's modulus	68900 MPa	71700MPa
Poisson's ratio	0.33	0.33
Ultimate tensile strength	310MPa	276MPa
Yield strength	275MPa	145MPa

The above table shows mechanical properties of both Al 6061 and Al 7075. We can see that the ultimate tensile strength and yield strength are in same range but young's modules of Al 7075 is higher. By considering the cost of both material the cost of Al 7075 is higher than the Al 6061. Hence we have to consider the cost of the material also. Hence strength of Al 7075 is higher but cost is also high, by taking in consideration the cost of material **Al 6061** is selected of the hub.

## B. BASIC DESIGN:-

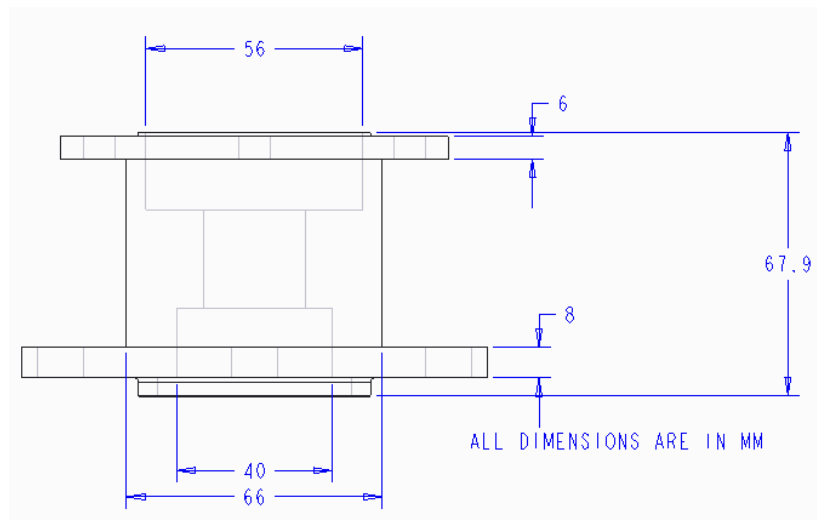
The parts of the front assembly are knuckle, stubb, brake disc, calliper, hub, taper bearings, castle nut and cotter pin. At the start of the design no optimization point is considered for the hub. Initially Hub is designed according to the requirement. In the basic design the hub it is designed according to the bearing sizes which are selected.

As well as stubb length is also to be considered. Here the stubb length is taken by considering the loads which are to be taken by the stubb, for that bending moment diagrams are drawn and final length is selected. Depending upon the stubb length the hub length is decided.

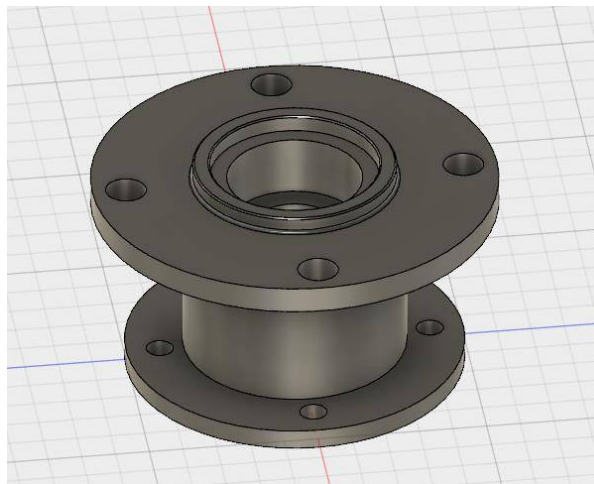
Stubb length :- 4.71 inch

Hub consists of 4 lug bolts which are connected to the rim of the wheel. Hence the holes are selected according the PCD of the rim and PCD of the brake disc.

So by considering above points the basic design of hub is done. Now further we have to do the optimization of the hub. The main objective of doing optimization is to reduce the weight as well as keeping appropriate factor of safety.



**Fig.1 Dimensions of the Hub**



**Fig.2 Isometric view of designed Hub (INITIAL)**

Fig.1 and Fig. 2 shows the dimensions and cad model of the hub which is designed at the start. As we are designing a wheel assembly of a race car so the overall weight should be less. In order to reduce the weight of the wheel assembly we have selected a hub for optimisation purpose. After initial consideration of design the weight of the hub is near about 600gram. So the question arises that how we can reduce the weight of the hub while making it safe for the use? For this purpose there are options in various FEA packages known as shape optimization, size optimization and topology optimization.

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## C. OPTIMIZATION

As we have discussed in earlier part that there are three types of optimization options available in FEA packages

1. Shape optimization
2. Size optimization
3. Topology optimization

Shape optimization- This optimization is carried out to change inner/outer shape of an object. It gives an object a particular shape depending upon the stress generated in a particular area. It takes out the material from the area where minimum amount of stress is generated. In that case the material is removed from the outer boundaries where the stresses are minimum. By doing this the weight of the object reduces without actually reducing the factor of safety.

Size optimization- This optimization is carried out to optimize the thickness, height, radius, cross section of the object. It reduces the size of the component by removal of material from the areas where the minimal stresses are induced. So this optimization takes lot of time to analyse from which portion of the object the material can be removed without reducing the specified factor of safety.

Topology Optimization- This optimization is carried out to optimize the number of holes and its configuration. It optimizes the number of holes and their configuration by considering the stress induced areas and factor of safety.

### Shape optimization-

For shape optimization purpose we have used the AUTODESK FUSION 360 software. The hub is designed is CREO 2.0 software. For further analysis the IGES file is imported AUTODESK FUSION 360.

Now for the shape optimization we have applied some moments and constraints on the hub.

The moments are applied at the bearing positions. Both the moments are applied in opposite directions. The fixed supports are given at all the holes (rim holes and disc holes)

Moment applied = 1500 N/mm

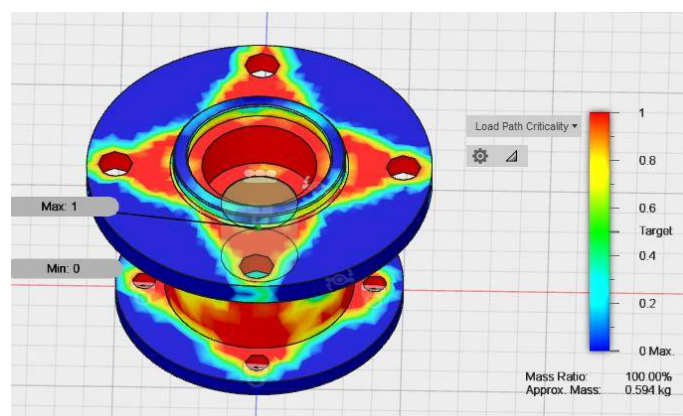


Fig.3 Analysis of hub before shape optimization

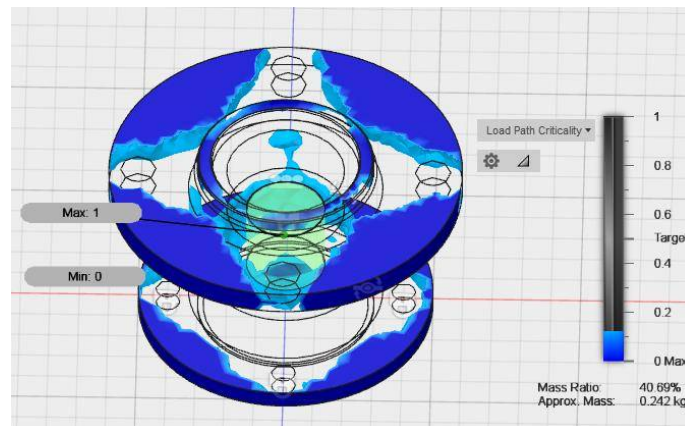
In fig.3 blue region can be seen, it shows in that area minimum/negligible amount of stress are generated. So this is the target area from where we can take out the material in order to reduce the weight.

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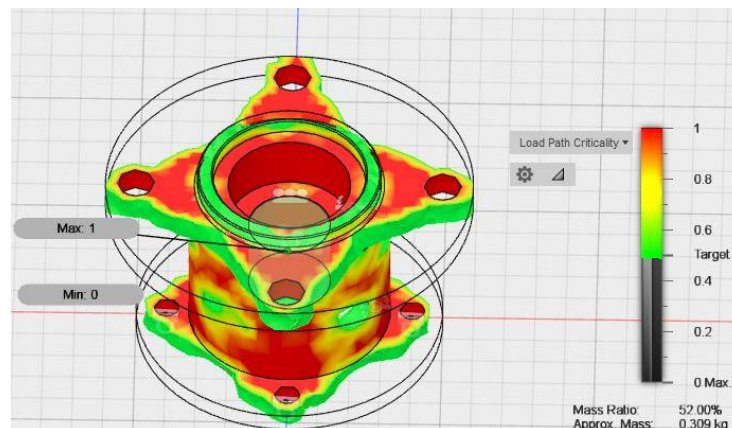
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**Fig.4 Part of hub where minimum stresses are induced**

As discussed above this is the blue area where the minimum stresses are induced and this is our target area for the optimization purpose. From the fig.4 it can be seen that 40% of weight that is about 0.242 kg can be easily reduced from the basic hub.



**Fig.5 Part of hub where considerable amount of stresses are induced**

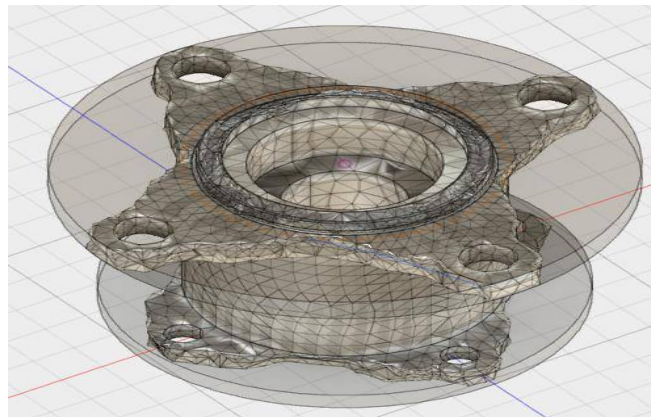
From fig.5 it can be seen that the part of the hub where actual stresses are generated. Hence while doing optimization this region is to be considered as a critical region with stresses induced. During optimization we cannot go beyond this limit as it will reduce the factor of safety of the component.

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**Fig.6 Optimized hub initial rough design**



**Fig.7 Final CAD model of optimized hub**

From fig.7 it can be seen that final CAD model of the hub is somewhat different than the optimization results we got. We have kept some extra part over the optimized limit. This is done because of the overall dynamic considerations. During the dynamic conditions there will be chances of wear. So in order to ensure the maximum safety of the component we have kept more amount of material than the optimized limit.

### **D. ANALYSIS OF HUB**

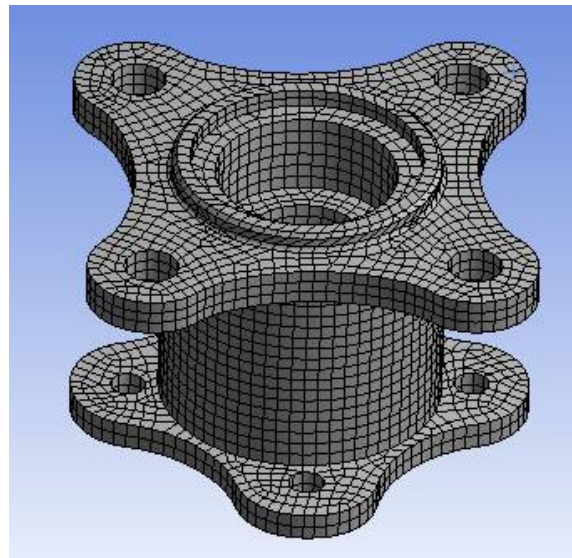
After getting the final optimization results and final CAD geometry generation analysis of hub is done using ANSYS 17.0 software.

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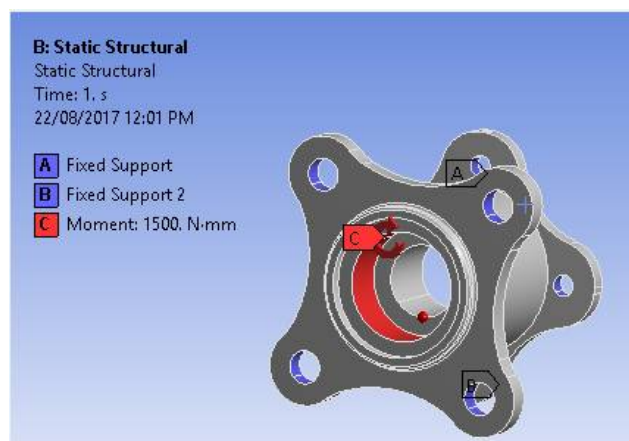
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**Fig.8 Mesh model of hub**

Meshing is done by keeping the element size as 3mm. The element size is selected according to the theory of meshing which suggests that on a smallest part of the model at least 2 elements should be present. Here the smallest hole diameter is 6mm. So we have taken the element size as 3mm.



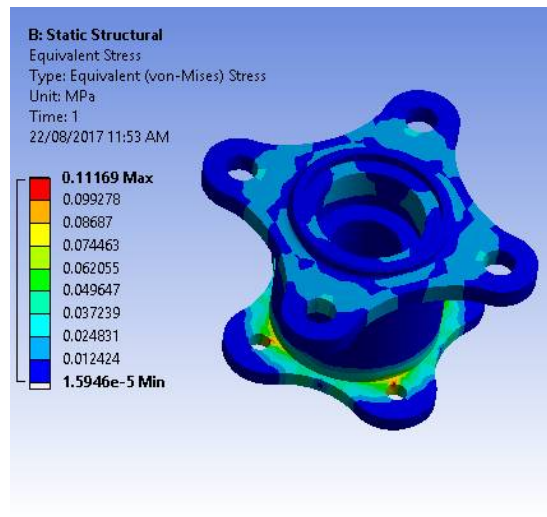
**Fig.9 Moments and constraints on the model**

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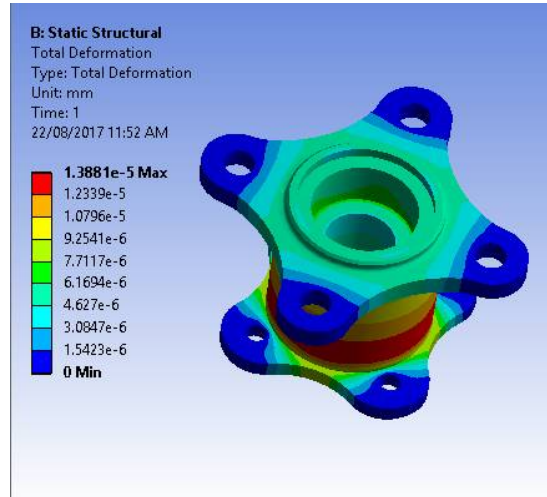
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**Fig.10 Stress induced in the Hub**



**Fig.11 Deformation in the hub**

From the Fig.10 it can be seen that the stress induced in the hub is minimum. Which means that hub is having high factor of safety. It can be used easily for front assembly of the car.

From Fig.11 it can be seen that the deformation value is also low. Hence we can conclude that by using the shape optimization technique we have reduced the weight of the hub. Initially the weight was 600 gram but after applying shape optimization the final weight is 370 gram by considering the wear tolerances. Almost we have reduced 40% of weight without reducing the limit of factor of safety for the component. Hence this hub can be used in the front wheel assembly of the car. Fig.12 shows the cad model of the complete front assembly.

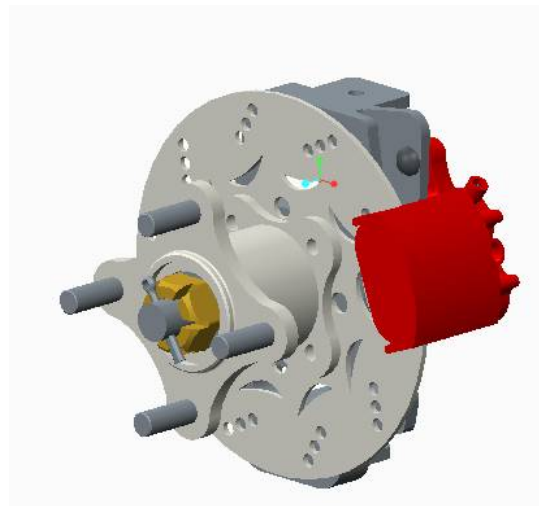


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**Fig.12 CAD model of Front wheel set of the car with optimized hub**

### E. MANUFACTURING

Manufacturing of the hub is done after the optimization and overall analysis of it.

For the manufacturing of hub 4 different operations are done

1. Lathe tuning for external and internal diameters
2. VMC (Vertical milling Centre) for giving the specified shape
3. Drilling
4. Tapping



**Fig.13 Final manufactured components (hub)**

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## III. CONCLUSION

We have implemented the shape optimization technique to optimize the design of the hub which is to be used in the front wheel set assembly of the car. The main objective of the shape optimization is to reduce the weight of the hub. As due to the reduction in the weight of the hub, the weight of the whole wheel set assembly reduces. The results have shown that for the hub we have done almost 40% weight reduction.

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