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Analysis on Stress Concentration Factors of Rapid Prototype Model Using 3D-CAD Modeling

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Abstract:-In this paper we demonstrated Design and implementation of new aerospace elements which requires the use of 3D-CAD modeling techniques and rapid prototyping, which makes it possible to significantly accelerate the deployment of new solutions. In this paper we demonstrate, one of the rapid prototyping techniques FDM is used to produce the working model of Aircraft Wheel hub. Meanwhile the task is to reduce the stress concentration in the Wheel Hub due to body weight of aircraft and other loads on the wheel hub. For design of the wheel hub Catia V5 is used. It is analysed by using the ANSYS. While analyzing the stress, stress concentration is found in the fixed regions (location of its bolts). The stress concentration is checked in three ways and selecting the one which gives the optimum stress concentration. The three ways are Design modification, Material changing without design modifications, material changing with design modification. From these three ways we will find out optimum changes in stress concentration. After selecting the best design and converting that 3D-CAD file into STL file or saving file in STL form. That STL file is used for direct developing of prototyping model by using FDM process.

Keyword: Rapid prototyping, Additive manufacturing, aerospace

1. INTRODUCTION

A wheel hub is the central portion of a wheel through which the axle passes. The wheel hub is the main part of wheel and consists of bearings and axle. The axle is connected the wheel tug.

Fig 1.1 Wheel Hubs

1.2. BASIC DEFINITIONS OF WHEEL HUB

Axle: An axle is a central shaft for a rotating wheel or gear

Bearings: A bearing is any of various machine elements that constrain the relative motion between two or more parts to only the desired type of motion.

Wheeltug: WheelTug is a fully integrated ground propulsion system for aircraft which puts a high torque electric motor into the hub of the nose wheel to allow for backwards movement without the use of pushback tugs and to allow for forward movement without using the aircraft's engines [2].

Rapid Prototyping is the term given to a set of processes that can quickly fabricate any given three-dimensional object into a model or prototype, directly from a CAD file via the additive deposition of individual cross-sectional layers of the part. Rapid prototyping was introduced in late 1980's. Rapid Prototyping can be defined as a group of techniques used to quickly fabricate a physical working model / component layer by layer (additive deposition) of a part or assembly using 3-D CAD data. Today it is very important to guide a product from concept to market quickly and inexpensively. Rapid prototyping (RP) is a method to make these prototypes much quicker and also more cost-effective. It aims to produce prototype relatively quickly for visual inspection, ergonomic evaluation, form fit analysis and as master pattern for product tool etc. in a virtual environment as if using a physical model allowing a better understanding to the designer. The application of rapid prototyping to the product manufacturing process has shown a 60% decrease in lead time over traditional method. Rapid prototyping has begun to make its way in

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to the aeronautical industry and is set to have profound implication [3].

R.P is proving its important place in aerospace industry Layer-build technology was successfully implemented on the F/A-18 by the US Navy. Using Nylon11 by SLS for a low rate production application, similarly a series of parts that formed the ductwork were built on a Vanguard SLS machine to check the flightworthiness by BAe (British aerospace), Design Verification of an Airline Electrical Generator, Engine Components for Fanjet Engine, and Prototyping Air Inlet Housing for Gas Turbine Engine Fabrication of Flight- Certified Production Castings.

Figure 1: Complete model of an aircraft made by R.P [3]

Importance of Rapid Prototyping in Aerospace Industry

The advantage of using rapid prototyping includes:

- Design freedom
- Low-quantity economy
- Material efficiency
- Predictable production
- Reduced assembly

Advancement of Rapid Prototyping in Aerospace Industry

Desirable feature of rapid prototyping in aerospace industry:

i. Low production volumes Aeronautical development has always been costly for several reasons. One of the contributing factors is ineffective amortization of tooling costs over a low production volume. In rapid prototyping such expenses are minimized.

ii. Constant design iterations Due to such a high number of iterations in design, being able to simply use a new file for the production of the part without any tooling modifications means that rapid prototyping is capable of huge time and cost savings.

iii. Geometric design complexity the aeronautical industry produces some of the most complex part geometry. As vehicles get smaller and more efficient. But it is a challenging task for the designer to combine parts together in manufacturing by traditional means much more of a than when using rapid manufacturing.

iv. Testing of new materials Rapid manufacturing has the potential of processing more exotic materials, faster and cheaper. It also allows for prototyping and small volume trials of new materials, again without the need to ever invest in tooling [3].

2. PROBLEM DEFINITION

Wheel hub is the important component of wheel, it has to with withstand to the load acting over on it. When the wheel rotating the wheel hub has to bear the load acting on the wheel hub and the torque developed by wheel while takeoff or take. By this the high stress will be developed in the wheel hub, this caucusing to breakages of wheel hub. Due to this the wheel hub is to be with stand to load acting on it.

Fig 2.1 : Position of Wheel Hub

Coming to the problem, wheel hub is made up of AZ91D material, the load acting on the wheel hub, is load of the aircraft and the torque and factors which are influencing wheel hub Specification and Loads acting on wheel hub are shown below

Wheel hub outer diameter (max) =134.049mm
Wheel hub outer diameter of base (min) = 70.775mm
Wheel hub inner diameter (max) =67.749mm
Wheel hub inner diameter (min) =40.62mm
Wheel diameter = 762mm
Input Power = 1634 kW
Speed = 18797 rpm

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Torque = 2988 N-m
Load Force = 17407 N

With respect to above values, applying all factors which are influencing on wheel hub on the Existing AZ91D material component the analysis is generated Maximum amount of Stress is 100.467Mpa. This is analysis shows Maximum amount of Stress 100.467Mpa is Concentrated at one particular curvature. The Presence of stress concentration cannot be totally eliminated but it may be reduced to some extent. So we are considering three methods to reduce stress, by design changing, material changing and both of them changing.

2.1. METHODS OF REDUCING STRESS CONCENTRATION

To reduce the stresses which are developed in the wheel hub cover three methods had considered. They are:

1. Design modification in existing model
2. Material change in existing model

Design modification and material change in existing model

Under design modification, where ever Maximum Stress is concentrated at that particular cross-section only design modification had considered. In Existing component Maximum Stress is concentrated at one particular at key hole and upper part, by modifying its thickness of hub at upper part and changing diameter of key hole gradually stress also reduce.

Under material change within the place of existing material new material had considered. This new material mechanical properties are very less compared to existing material mechanical properties. With this weight and cost of the component is reduced.

In third method above two methods had considered simultaneously[5].

By analyzing above three methods one method had considered which produce very less stress.

2.2. OBJECTIVE OF THE WORK:

The objective of the paper is design and analysis of a sarah aircraft wheel hub to with stand the loads acting on it and develop a prototype model.

- Model was created in CATIA V5 R20.
- Meshing and Analysis by using ANSYS WORKBENCH.
- Evaluation of stress, deformation, factor of safety under static analysis for Existing Wheel hub.

3. EXISTING WORKING MODEL

i. Creating 2-D Model Of Existing wheel hub

With the help of Catia software 2D representation of Existing component will takes place. In Catia, sketcher is the main tool used to represent 2D models. A sketcher is a 2D section of the feature being created. It is a basic 2D shape, and is created on a planar reference. Almost all the models designed in Catia, consist of Datum's, Sketched features, and placed features. However, in this case need a sketch to create any sketched feature, such as Extrude.

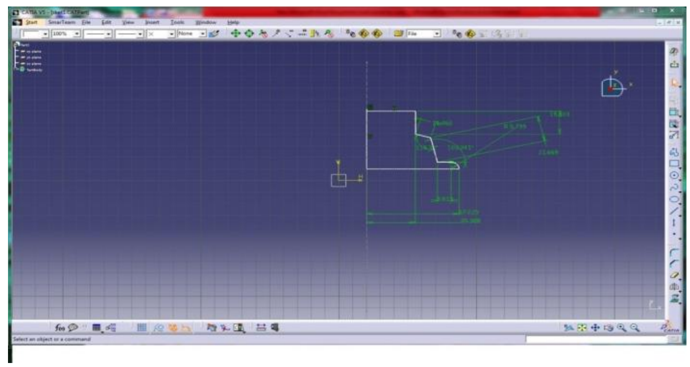

Fig 3.1 2D Drawing of wheel hub

The Existing model is shown in Fig 3.2. Inner diameter and key hole of hub modification had done. Existing Inner diameter and key hole of hub are D40.062mm and R 4.37mm. By changing Inner diameter and key hole of hub design modification had done. Inner diameter and key hole are D39.78mm-D7.5mm, 40.062mm -D8.74mm, D41.06mm- D7mm,

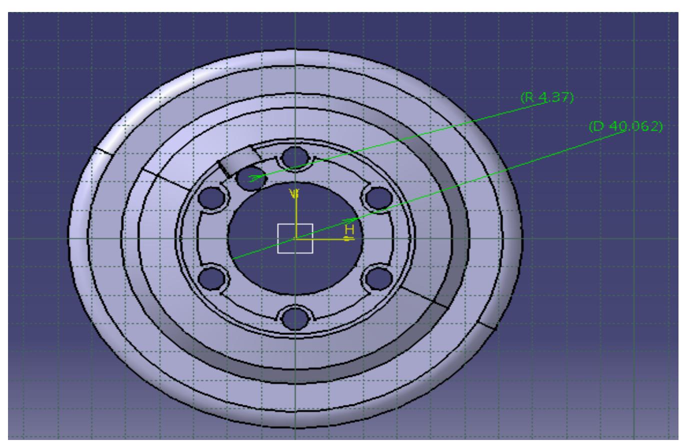

Fig 3.2 Existing model

4. PROPOSED MODEL OF WHEEL HUB

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DESIGN MODIFICATIONS FOR THE HUB:

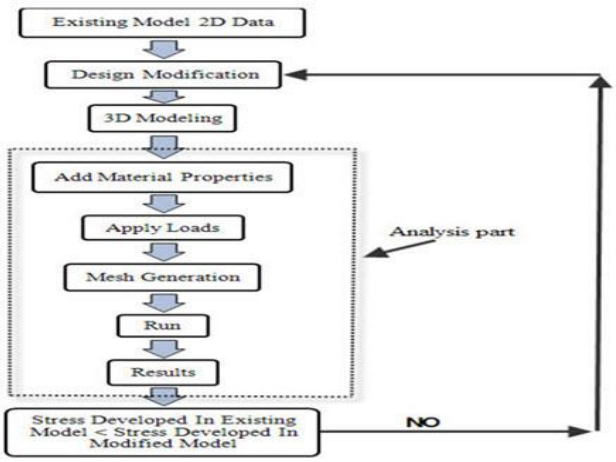

Figure 4.1: Flowchart for design modification and material change in existing model

Existing wheel hub develops Maximum amount of stress is 154.27Mpa. In Existing component Stress concentrated at one particular key hole and bolt location. To decrease this Stress two Factors had considered .By changing its key hole diameter and inner diameter of wheel hub at Stress concentrated position adding less mechanical properties material[5]

MODIFIED MODEL

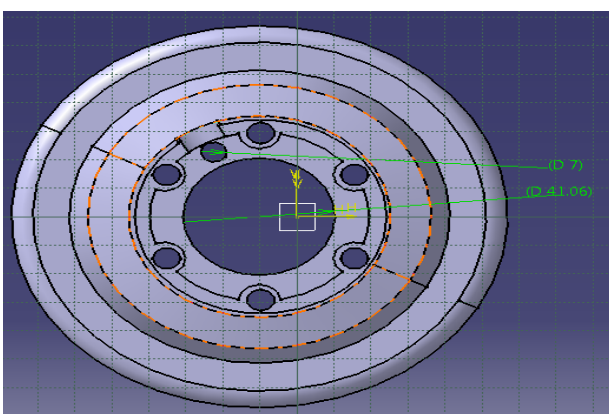

Figure 4.2 : Modified model

- **Add Material properties**

Second factor in the design modification is usage of Low properties material. In this project except existing material 3 types of materials had considered. Properties of these materials are less than Existing material AZ91D.

- **Apply loads**

Whatever the loads applied in existing wheel hub same type of lodes also used in modified mode.

- **Mesh generation**

Procedure followed in Existing wheel hub Mesh generation same procedure also followed in modified model also. But meshing parameters may vary. This is mainly depending on the model profile.

- **Run**

In this case Entire model will deflect with respect to given factors.

- **Results**

After completion of Experiment different types of results are developed, out of these results only Stress results are considered.

- **Stress developed in Existing model < Stress developed in Modified model**

After plotting results each and every stress are compared with existing model developed stress. Which design will give less stress with seatrain material that design is selected as best one.

5. DESIGN AND ANALYSIS

Initially Existing wheel hub is made up of AZ91D material. Number of steps involved in finalizing the best model with respect to its results by modifying its design. They are

ANALYSIS OF EXISTING WHEEEL HUB

Existing wheel hub model is developed in Catia software. At the time of saving this model save it format of IGES. By saving in this format at the time of analysis profiles dimensions will not disturb. Coming to the results, after completion of analysis Stress developed in the Existing wheel hub is 154.27 Mpa. This is shown in Fig 5.1.

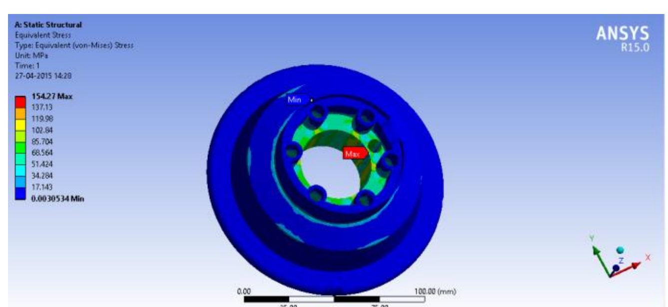

Figure 5.1 : Existing Wheel hub developed Stress distribution

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Table 1: Existing wheel hub Stress details

Name	Type	Min	Max
Stress1	VON: von Mises Stress at Step No: 154.27N/mm^2	0.0030354 N/mm^2 (MPa) Node: 4547	154.27 N/mm^2 (MPa) Node: 616

Fig 5.1 shows Stress distribution under loads are acting on the Existing Wheel hub. Red color indicates maximum amount of stress developed area. Blue color indicates less amount of stress developed in existing wheel hub. Changes in color from Blue to Red indicate increase in stress. In existing wheel hub maximum stress concentrated at one of the fixing position. This may cause sudden damage in wheel hub. To predict this failure design modification had done at that particular location.

DESIGN MODIFICATION IN EXISTING MODEL

Design modification has to be done at maximum stress concentrated location, this means at the particular key hole. This is shown in Fig 5.2.

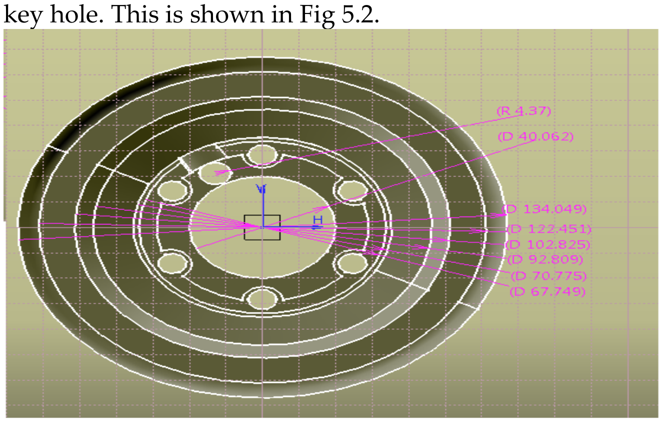
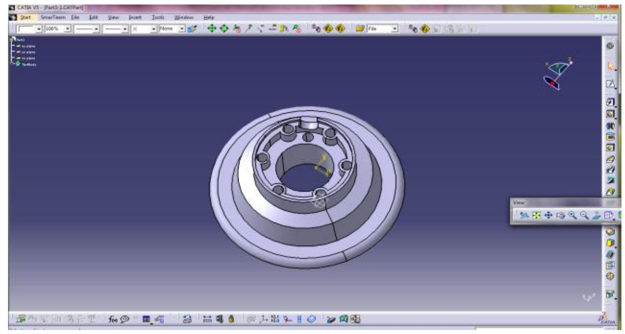


Figure 5.2: Existing model

The Existing model is shown in Fig 4.10. Inner diameter and key hole of hub modification had done. Existing Inner diameter and key hole of hub are D41.06mm and D7mm. By changing Inner diameter and key hole of hub design modification had done. Inner diameter and key hole are D39.78mm-D7.5mm, 40.062mm -D8 mm, D41.06mm- D7mm,

Modified design

Modify the inner diameter of D39.78mm-D7.5mm, then converted it into 3D model. Its 3D model is shown in Fig 5.3. Minimum and maximum stress distributed values with their nodes are shown in Table 5.2, Table 5.3. Here maximum developed stress is 139.49Mpa and fos 1.147



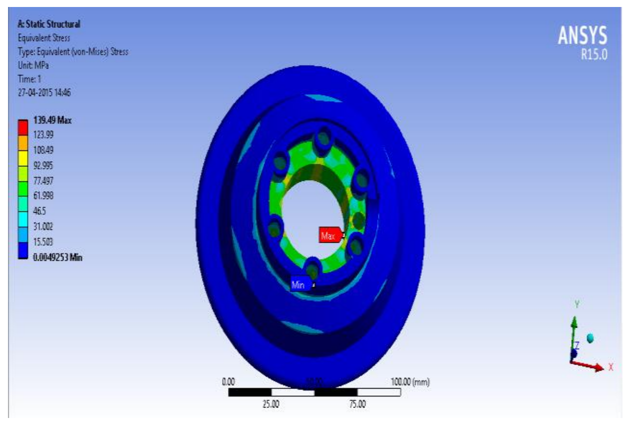


Figure 5.3: Modified Design with D39.78mm-D7.5mm 3D model

Figure 5.4: Modified Design with D39.78mm-D7.5mm stress distribution in Static analysis

Table 2: Modified Design with D39.78mm-D7.5mmStress details

Name	Type	Min	Max
Stress1	VON: von Mises Stress 139.49	0.0049253 N/mm^2 (MPa)	139.49 N/mm^2 (MPa)

FACTOR OF SAFETY:

Modified design

Modify the inner diameter of 41.06mm-D7mm, then converted it into 3D model. Its 3D model is shown in Fig 5.3. After applying static analysis Stress distribution is

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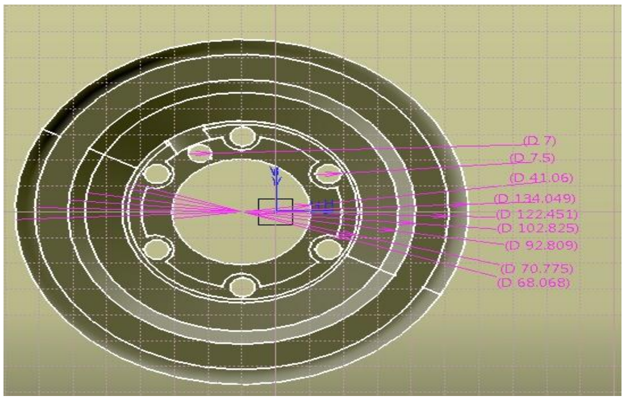
shown in Fig 5.5, Fig 5.6 Minimum and maximum stress distributed values with their nodes are shown in Table 2,Table 3. Here maximum developed stress is 135.6Mpa and fos 1.106



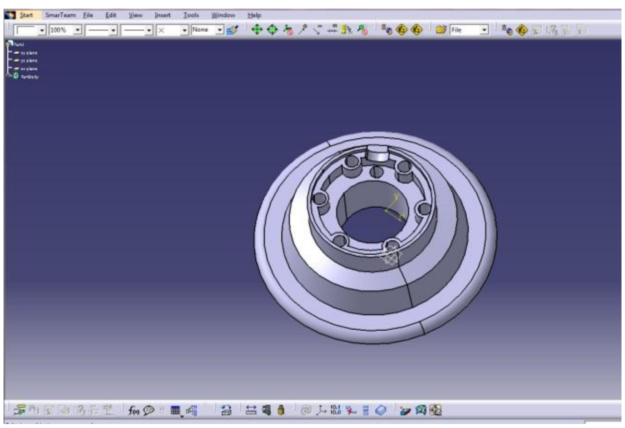


Figure 5.5 : Modified Design with 41.06 mm-D7mm

Figure 5.6: Modified Design with 41.06 mm-D7mm 3D models

Table 3: Modified Design with 41.06 mm-D7mm Stress details

Name	Type	Min	Max
Stress1	VON: von Mises Stress 135.6	0.0044 269 N/mm ^2 (MPa)	135.6 N/mm^2 (MPa)

Types of Materials vs Diameter of Wheel Hub with respective of factory of safety

Table 4. Variations in stresses and their respective factor of safety

Types of hub model different stress and		**Diameters of wheel hubs**		
factor of safety		**40.06**	**39.78**	**41.062**
AM60	Stress(MPa)	154.27	139.49	135.6
	FoS	0.972	1.07	1.1062
HK31A	Stress(MPa)	154.27	134.49	135.6
	FoS	0.713	0.788	0.81121
AZ92A-T6	Stress(MPa)	154.27	139.49	135.6
	FoS	0.81	1.06	1.1062

Above table describes the variations in stresses and their respective factor of safety

For different design modifications of Existing wheel hub model different stress and factor of safety are 135.6Mpa and 1.1799 is developed at Design modification of existing diameter with 41.06 mm-D7mm. Under design modification this is the best design which develops less stress compared to other design modified models.

6. CONCLUSION

The main constrain of this paper is minimizes of stress. To reduce this stress three methods had considered they are

- Design modification in existing model
- Material change in existing model
- Design modification and material change in existing model

Among these three methods third method had given best results. In this method out of number of design modified model is D41.062 &D7mm model with material AZ92A-T6 will had produced less stress 135.6Mpa and FOS 1.1062 compared to other materials. This material satisfies two conditions they are less weight and less cost.

The final conclusion of this paper is D41.062 &D7mm model with AZ92A-T6 material will give very less stress, and have good safety factor

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