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Design and static analysis of automobile gearbox cover

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Abstract
In this project the Gearbox cover of a 3-wheeler commercial auto is designed and fabricated. The task is to reduce the stress concentration in the Gearbox cover due to internal pressures i.e. crank pressure and gear shaft pressure.
The cover is modelling by using Pro-E tool and it is analyzed by using Solid works (COSMOS) tool. While analyzing the stress, stress concentration is found to be more at a location of its bolts. The stress concentration is checked in three ways and selected the one which gives the minimum stress concentration. The three ways are design modification, material changing without design modification and material change with design modification. Among the above three ways the material change with design modification shows the minimum stress concentration. Finally, the optimum changes in stress concentration are noted.

Keywords: Gear box cover, proE, solid works

1. Introduction

A machine consists of a power source and a power transmission system, which provides controlled application of the power. Merriam-Webster defines transmission as: an assembly of parts including the speed-changing gears and the propeller shaft by which the power is transmitted from an engine to a live axle. Often transmission refers simply to the gearbox that uses gears and gear trains to provide speed and torque conversions from a rotating power source to another device. In British English the term transmission refers to the whole drive train, including gearbox, clutch, prop shaft (for rear-wheel drive), differential and final drive shafts. In American English, however, the distinction is made that a gearbox is any device which converts speed and torque, whereas a transmission is a type of gearbox that can be "shifted" to dynamically change the speed: torque ratio, such as in a vehicle.

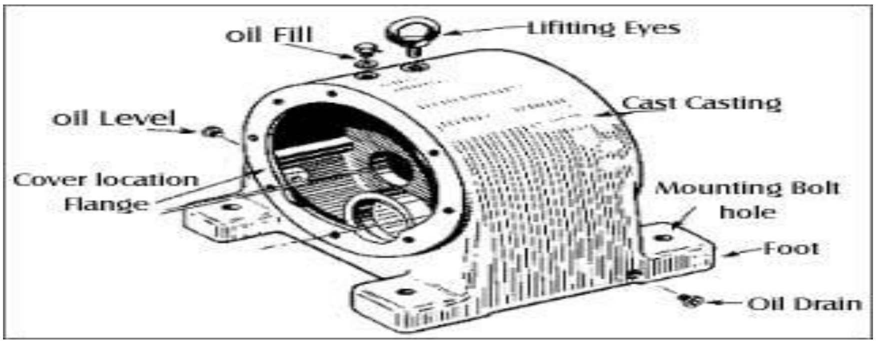

Fig 1.1: Gearbox cover

This gearbox is shown in Fig 1.1. The most common use is in motor vehicles, where the transmission adapts the output of the IC Engine to the drive wheels. Such engines need to operate at a relatively high rotational speed, which is inappropriate for starting, stopping, and slower travel. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process. Often, a transmission will have multiple gear ratios (or simply "gears"), with the ability to switch between them as speed varies. This switching may be done manually (by the operator), or automatically. Directional (forward and reverse) control may also be provided. Single-radio transmissions also exist, which simply change the speed and torque (and sometimes direction) of motor output.

1.1. Introduction to CAD and CAM

Computer-aided design (CAD), also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD - based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based (pixilated) environments.

CAD may be used to design curves and figures in two dimensional (2D) spaces; or curves, surfaces, and solids in three-dimensional (3D) objects.

The design of geometric model for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD)

1.1.1. CAD Overview

Beginning in the 1980s Computer-Aided Design programs reduced the need of draft men significantly, especially in small to mid-sized companies. Their affordability and ability to run on personal computers also allowed engineers to do their own drafting work, eliminating the need for entire departments. CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components

1.2 Important Capabilities of CAD and CAM

Amazing things with CADD, that never thought possible while creating drawings with a pen or pencil. The following are some of the important capabilities that make CADD a powerful tool:

- Flexibility in editing
- Storage and access for drawings
- Project reporting
- Engineering analysis
- Design

Computer-aided manufacturing (CAM) is the use of computer software to control machine tools and related machinery in the manufacturing of work pieces. This is not the only definition for CAM, but it is the most common; CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage. Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material consistency.

1.2.1 CAM Overview

Traditionally, CAM has been considered as a numerical control (NC) programming tool, wherein two-dimensional (2-D) or three-dimensional (3-D) models of components generated in CAD software are used to generate G-CODE to drive computer numerically controlled (CNC) machine tools. Simple designs such as bolt circles or basic contours do not necessitate importing a CAD file.

1.2.2 Geometric Modeling

Geometric modeling is a branch of applied mathematics and computational geometry that studies methods and algorithms for the mathematical description of shapes.

The shapes studied in geometric modeling are mostly two- or three-dimensional, although many of its tools and principles can be applied to sets of any finite dimension. Three-dimensional models are central to and (CAD/CAM), are widely used in many applied technical fields such as civil and mechanical engineering architecture, geology, and medical image processing.

Geometric models are usually distinguished from procedural and object oriented models, which define the shape implicitly by an opaque algorithm that generates its appearance.

Modern CAD system defines objects in 3-D thus the designer can construct 3-D model of objects conveniently and store the database of the model in the computer.

Geometric modeling can be classified into three types:

a) Wire frame modeling.
b) Surface modeling.
c) Solid modeling.

a) Wire Frame Model

A wire frame model is a visual presentation of a three dimensional or physical object used in computer graphics. It is created by specifying each edge of the physical object where two mathematically continuous smooth surfaces meet, or by connecting an object's constituent vertices using straight lines or curves.

b) Surface Modeling

Surface modeling is a widely used modeling technique in which objects are defined by their bounding faces. Surface modeling systems contain definitions of surfaces, edges and vertices. Surface modeling goes one step further than wireframe modeling

c) Solid Modeling

Solid modeling is the most powerful of the 3-D modeling technique. It provides the user with complete information about the model. Defining an object with a solid model is the easiest of the available three modeling techniques (curves, surfaces and solids). Solid models contain both geometric and topological information of the object. Some of the potential advantages of solid modeling are:

1. Mass properties such as area, volume, weight, centre of gravity and moment of inertia can be determined quickly.
2. It allows the design engineer to develop and evaluate alternative concepts for parts and assemblies while the design is still a theoretical model. Solid models are non-ambiguous.
3. Cross section can be cut through the three-dimensional models with color used to identify and highlight different materials and various other features.

2. Introductions to Pro-E

Pro/ENGINEER (Pro-E) is a feature based, parametric solid modeling program. As such, its use is significantly different from conventional drafting programs. In conventional drafting (either manual or computer assisted), various views of a part are created in an attempt to describe the geometry. Each view incorporates aspects of various features (surfaces, cuts, radii, holes, protrusions) but the features are not individually defined. In feature based modeling, each feature is individually described then integrated into the part. The other significant aspect of conventional drafting is that the part geometry is defined by the drawing. If it is desired to change the size, shape, or location of a feature, the physical lines on the drawing must be changed (in each affected view) then associated dimensions are updated. When using parametric modeling, the features are driven by the dimensions (parameters).

2.1 Engineering Design

Pro/Engineer offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

2.2 Manufacturing

By using the fundamental abilities of the software with regards to the single data source principle, it provides a rich set of tools in the manufacturing environment in the form of tooling design and simulated CNC machining and output.

3. Introduction to Fem

The basic idea in the Finite Element is to find the solution of complicated problem with relatively easy way. The Finite Element Method has been a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis of automotive, aircraft, building, defence, and missile and bridge structures to the field of analysis of dynamics, stability, fracture mechanics, heat flux, fluid flow, magnetic flux, seepage and other flow problems.

3.1 Steps Involved In FEM

The method is based on stiffness analysis. Stiffness is defined as the force required for unit displacement and is reciprocal of flexibility. In this method the structure is assumed to be built up of numerous connected tiny elements. From this comes the name "Finite Element Method". Extremely complex structures also can be simulated by proper arrangement of these elements.

Finite Element Method allows accurate modelling through the use of variety of beam plate and solid elements simultaneously. The method being essentially convergent in nature, solutions of engineering accuracy can easily be expected. The broad steps in the finite element method, when it is applied to structural mechanics are as follows.

1. Divide the continuum into a finite number of sub regions (or elements) of simple geometry such as line segments, triangles, quadrilaterals. (Square and rectangular elements are subset of quadrilateral), tetrahedrons and hexahedrons (cubes) etc.
2. Select key points on the elements to serve as nodes where conditions of equilibrium and compatibility are to be enforced.
3. Assume displacement functions within each element so that the displacements at each generic point are depending upon nodal values.
4. Satisfy strain displacement and stress – strain relationships within a typical element
5. Determine stiffness and equivalent nodal loads for a typical element using work or energy principles.
6. Develop equilibrium equations for the nodes of the discredited continuum in terms of the element contributions

4. Results and Discussion

Initially Existing gearbox is made up of LM 25 material. With the help of COSMOS software Entire Analysis part had done. Number of steps involved in finalizing the best model with respect to its results by modifying its design. They are,

4.1 Analysis of Existing Gearbox

Existing Gearbox model is developed in Pro-E 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 gearbox is 30.6 Mpa. This is shown in Fig 4.1.

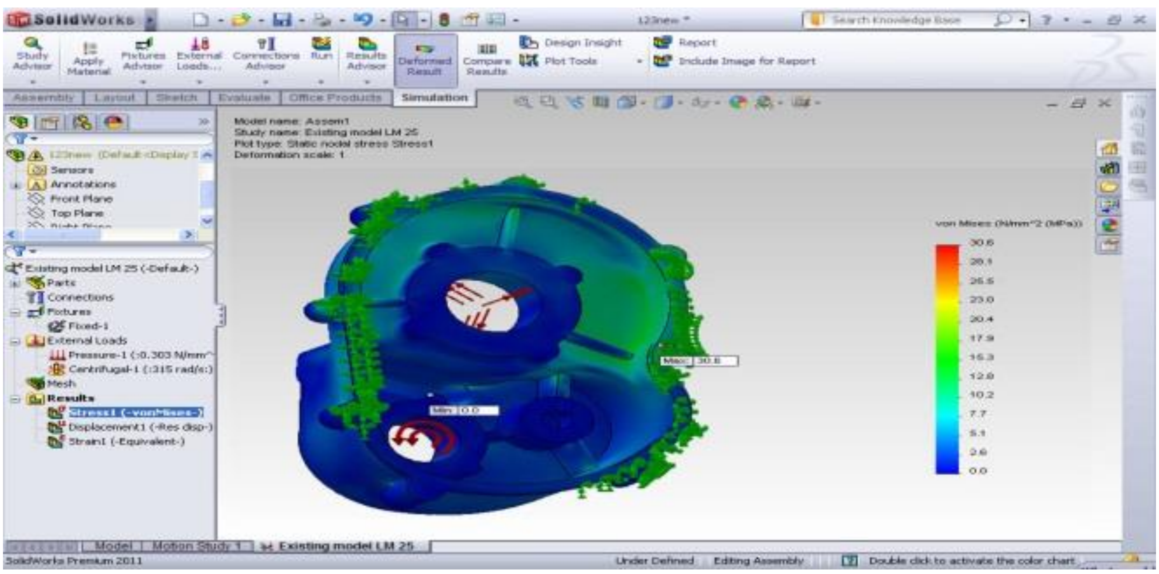

Fig 4.1: Existing Gearbox developed Stress distribution

Table 4.1: Existing Gearbox Stress details

Name	Type	Min	Max
Stress1	VON: Von Mises Stress	0.0107103 N/mm^2 (MPa) Node: 48476	30.6433 N/mm^2 (MPa) Node: 37517

4.2. Design Modification in Existing Model

Design modification has to be done at maximum stress concentrated location, this means at the particular curvature. This is shown in Fig 4.2.

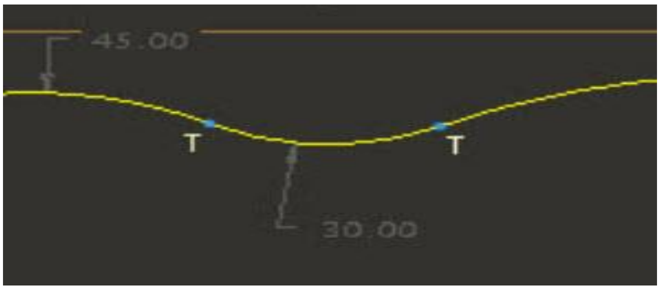

Fig 4.2: Curvature of Existing model

The curvature of Existing model is shown in Fig 4.2. From point T to T modification had done. Existing curvature consist 30mm radius. By increasing this curvature radius design modification had done. Incremental values of this curvature are shown below

60mm, 90mm, 120mm, 150mm and Tangent

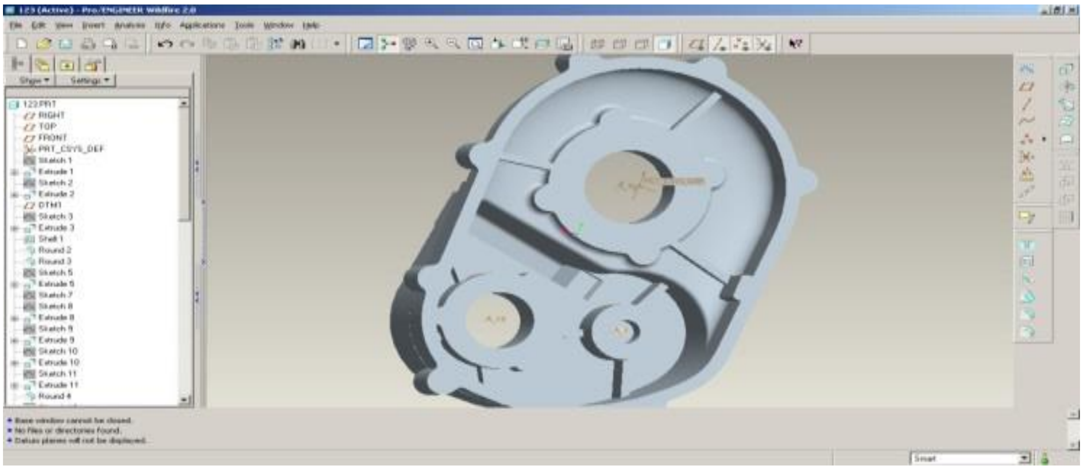

Fig 4.3: Modified Design with 60mm radius of curvature stress 3D model

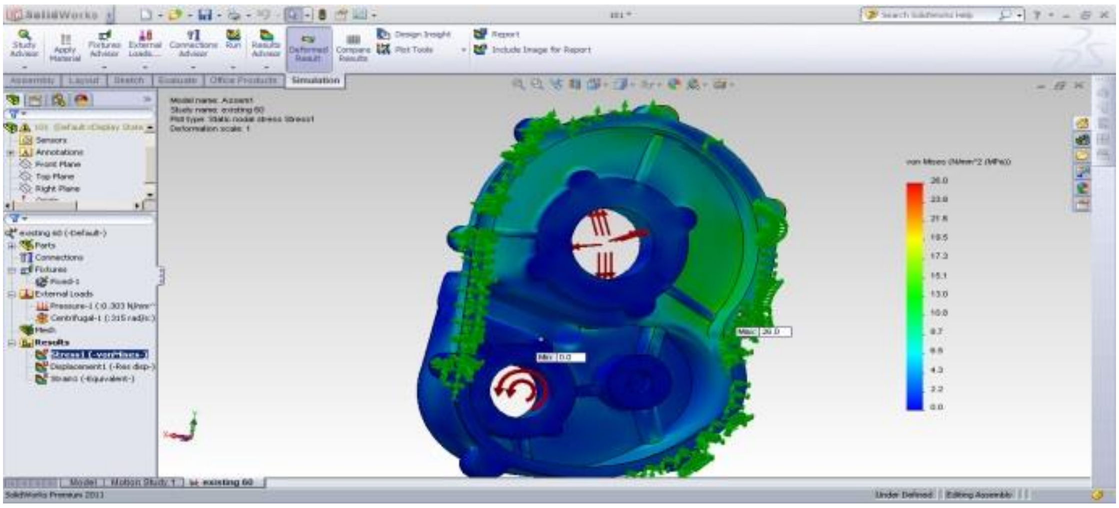

Fig 4.3: Modified Design with 60mm radius of curvature stress distribution

Table 4.3: Modified Design with 60mm radius of curvature Stress details

Name	Type	Min	Max
Stress1	VON: Von Mises Stress	0.00259962 N/mm^2 (MPa) Node: 48208	25.9676 N/mm^2 (MPa) Node: 36479

4.4. Modified design with 90mm radius curvature

Modify the curvature radius with 90mm radius, then converted it into 3D model.

This modified 2D profile is shown in Fig 4.4.1. Its 3D model is shown in Fig 4.4.2. After applying static analysis Stress distribution is shown in Fig 4.4.3 Minimum and maximum stress distributed values with their nodes are shown in Table 4.4. Here maximum developed stress is 25.4 Mpa.

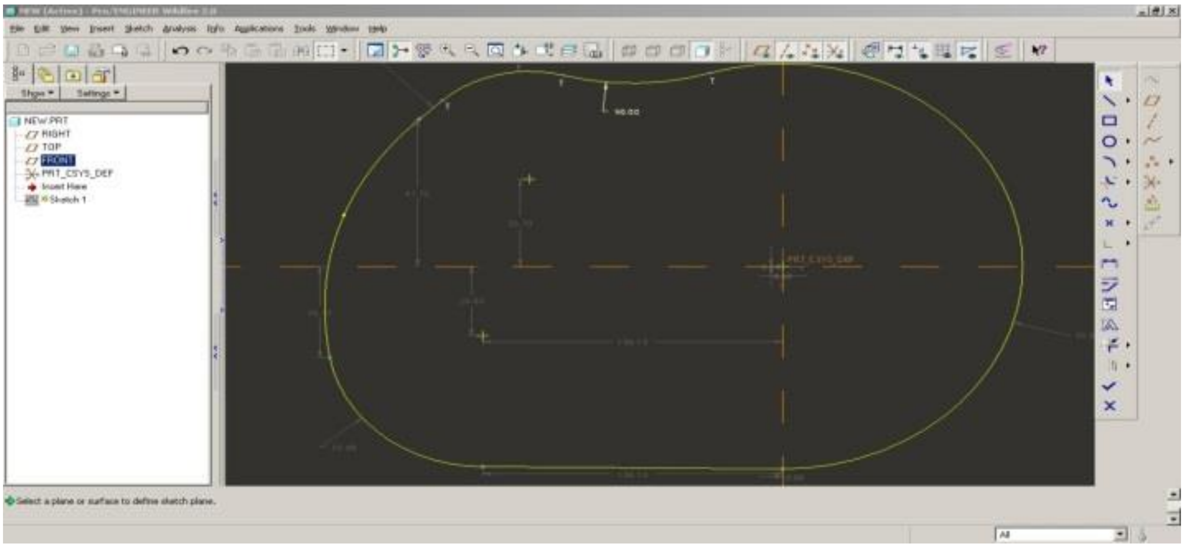

Fig 4.4.1: Modified Design with 90mm radius of curvature 2D representation

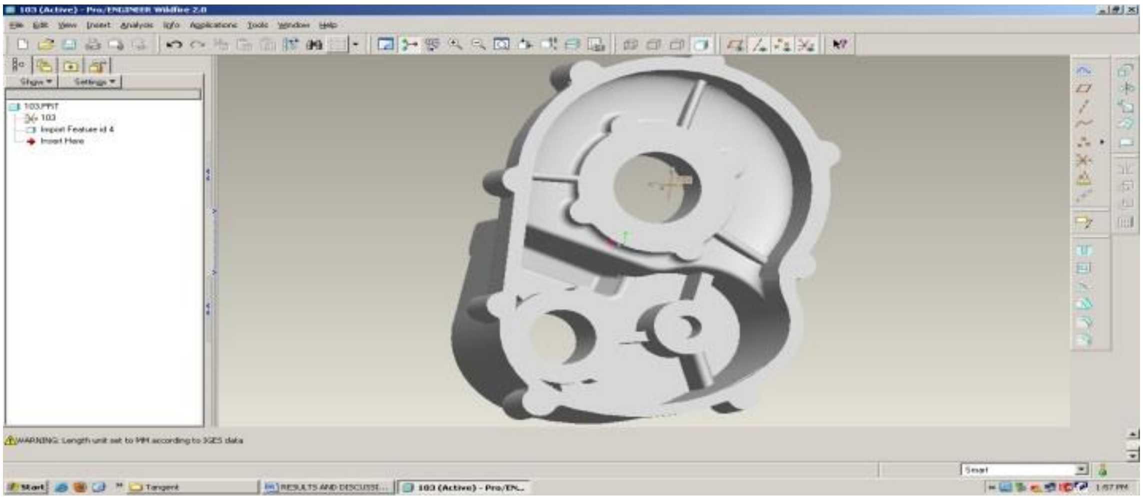

Fig 4.4.2: Modified Design with 90mm radius of curvature stress 3D model

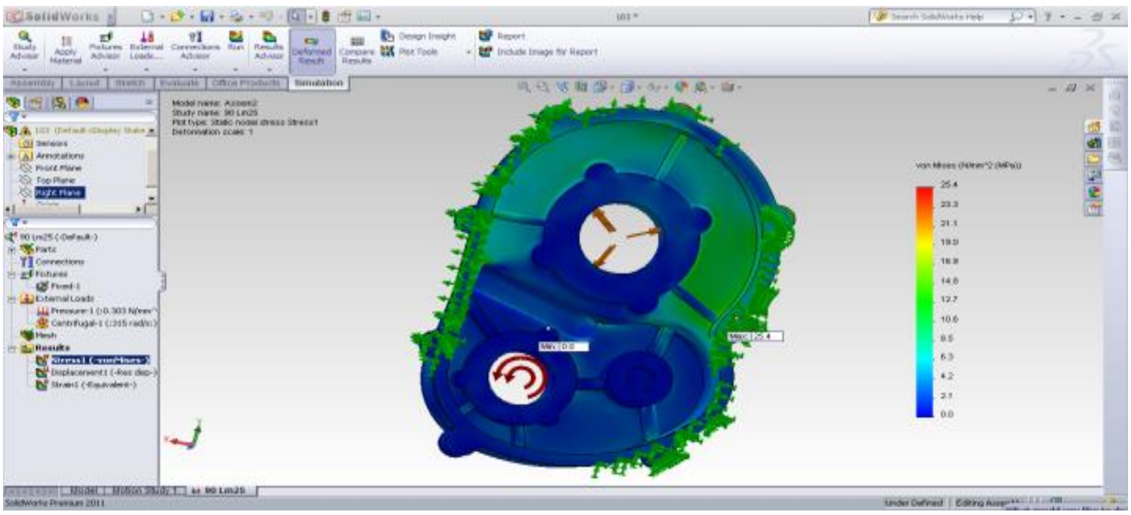

Fig 4.4.3: Modified Design with 90mm radius of curvature stress distribution

Table 4.4: Modified Design with 90mm radius of curvature Stress details

Name	Type	Min	Max
Stress1	VON: Von Mises Stress	0.00440142 N/mm^2 (MPa) Node: 8192	25.3744 N/mm^2 (MPa) Node: 36511

4.5. Modified design with tangent

Modify the curvature radius with tangent, then converted it into 3D model. This modified 2D profile is shown in Fig 4.5.1. Its 3D model is shown in Fig 4.5.2. After applying static analysis Stress distribution is shown in Fig 4.5.3. Minimum and maximum stress distributed values with their nodes are shown in Table 4.5. Here maximum developed stress is 28.4 Mpa.

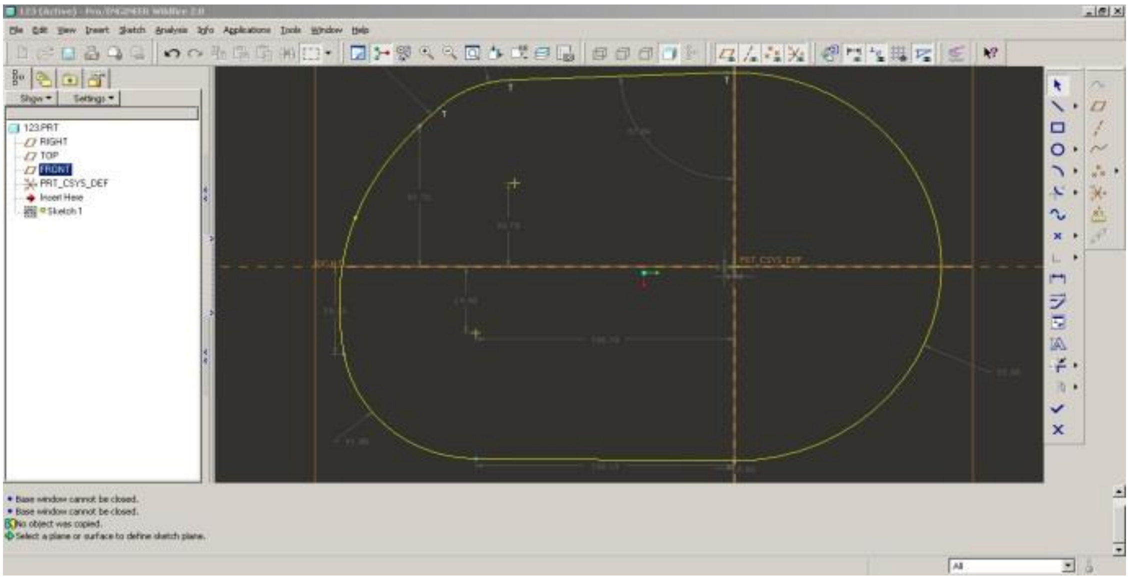

Fig 4.5.1: Modified Design with tangent 2D representation

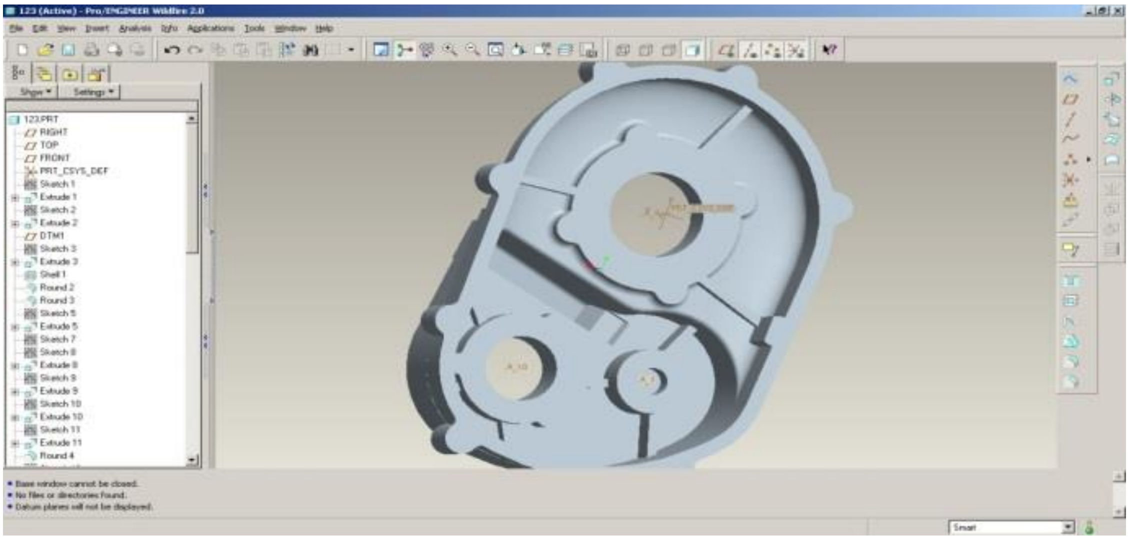

Fig 4.5.2: Modified Design with tangent stress 3D model

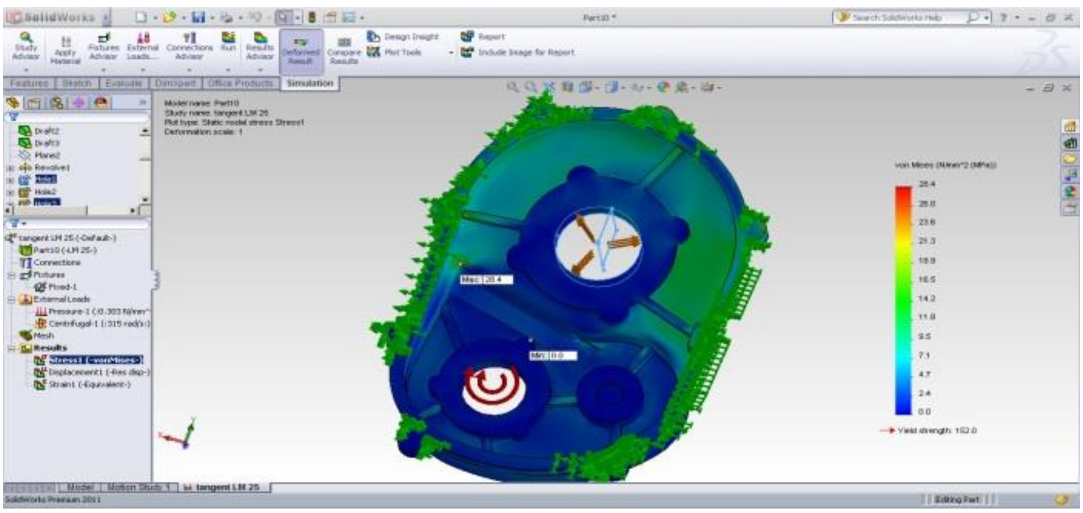

Fig 4.5.3: Modified Design with tangent stress distribution

Table 4.5: Modified Design with Tangent Stress details

Name	Type	Min	Max
Stress1	VON: Von Mises Stress	0.00878208 N/mm^2 (MPa) Node: 32023	28.3545 N/mm^2 (MPa) Node: 2818

For different design modifications of Existing Gearbox model different stress are developed, out of these stresses less amount of stress 24.2 Mpa is developed at Design modification of existing curvature with 120mm radius. Under design modification this is the best design which develops less stress compared to other design modified models.

4.6. Material Change in Existing Model

The second method is change in material type. This material should consist less mechanical properties compared existing material LM25. These material properties are shown in Fig 4.6.

2014-O Material properties   6061-O Material properties

Property	Value	Units
Elastic Modulus in X	72400	N/mm^2
Poisson's Ration in XY	0.33	
Shear Modulus in XY	28000	N/mm^2
Mass Density	2800	kg/m^3
Tensile Strength in X	185	N/mm^2
Yield Strength	95	N/mm^2
Thermal Expansion Coefficient in X	2.3e-005	/K
Thermal Conductivity in X	192	W/(m·K)
Specific Heat	880	J/(kg·K)

Property	Value	Units
Elastic Modulus in X	69000	N/mm^2
Poisson's Ration in XY	0.33	
Shear Modulus in XY	26000	N/mm^2
Mass Density	2700	kg/m^3
Tensile Strength in X	125	N/mm^2
Yield Strength	62.05	N/mm^2
Thermal Expansion Coefficient in X	2.4e-005	/K
Thermal Conductivity in X	180	W/(m·K)
Specific Heat	896	J/(kg·K)

6063-O Material properties

Property	Value	Units
Elastic Modulus in X	69000	N/mm^2
Poisson's Ration in XY	0.33	
Shear Modulus in XY	25800	N/mm^2
Mass Density	2700	kg/m^3
Tensile Strength in X	90	N/mm^2
Yield Strength	50	N/mm^2
Thermal Expansion Coefficient in X	2.34e-005	/K
Thermal Conductivity in X	218	W/(m·K)
Specific Heat	900	J/(kg·K)

Fig 4.6: Properties of different types of material

At the time of analysis applying these material mechanical properties one by one stress are developed. This analysis is shown below

4.7. Analysis of Existing Model with 2014-O Material

At the time of analysis 2014-O material properties are added for existing model. After completion of analysis distribution of stress is shown in Fig 4.7

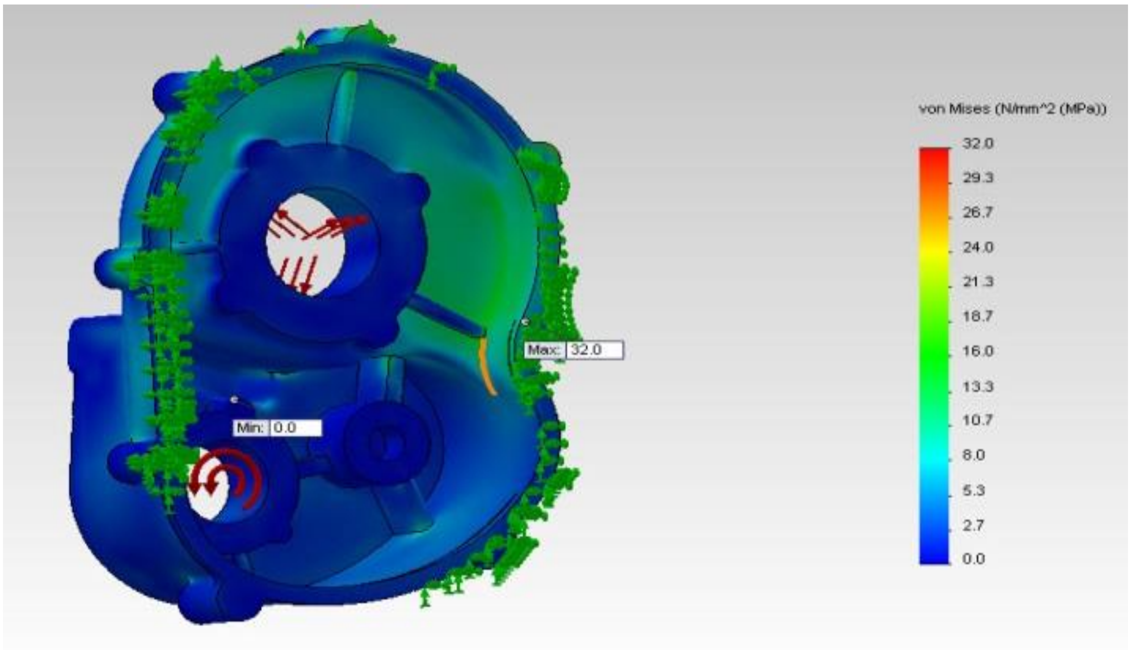

Fig 4.7: Stress distribution in Existing modified with 2014-O material

Here maximum amount of stress developed with 2014-O material is 32.0 Mpa.

4.8. Analysis of Existing Model with 6061-O Material

At the time of analysis 6061-O material properties are added for existing model. After completion of analysis distribution of stress is shown in Fig 4.8.

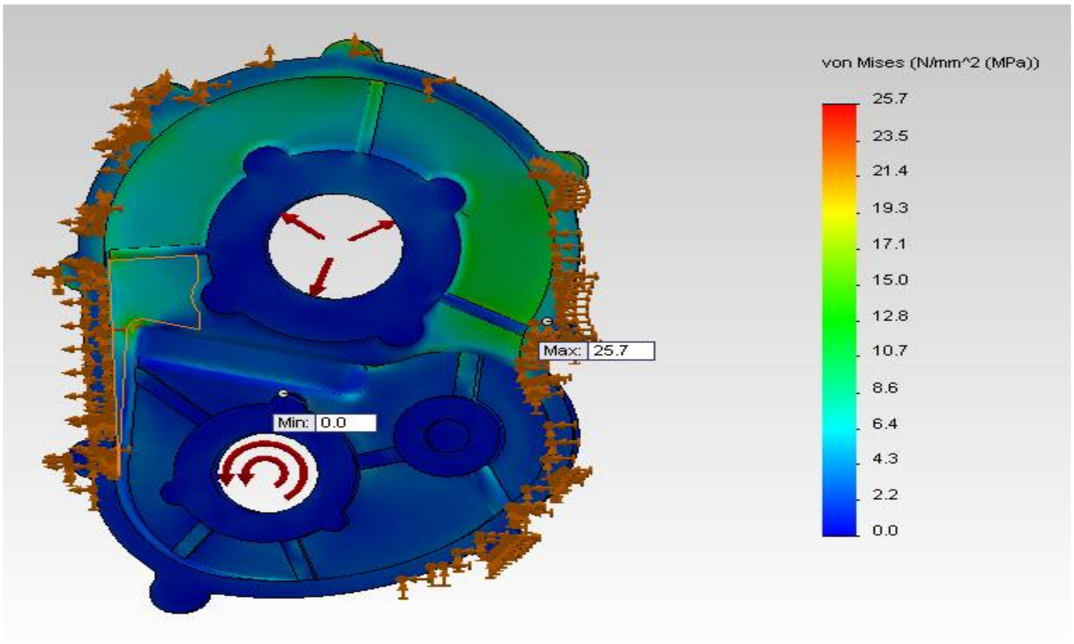

Fig 4.8: Stress distribution in Existing modified with 6061-O material

Here maximum amount of stress developed with 6061-O material is 25.7 Mpa.

4.9 Analysis of Existing Model with 6063-O Material
At the time of analysis 6063-O material properties are added for existing model. After completion of analysis distribution of stress is shown in Fig 4.9.

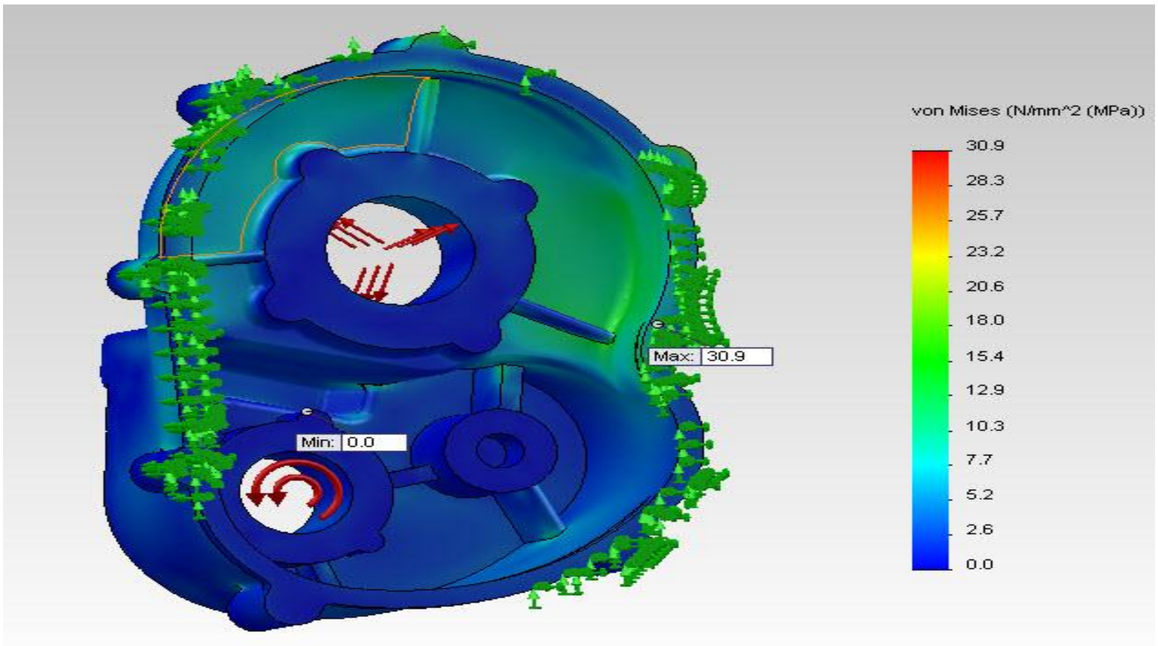

Fig 4.9: Stress distribution in Existing modified with 6063-O material

Here maximum amount of stress developed with 6063-O material is 30.9 Mpa.

5. Design Modification and Material Change in Existing Model
This method is done by adding above two methods. In this method the main criteria is applying different types of material properties in selected best model. This will produce very less stress compared to other two methods. Out of number of design modified models with 120 mm radius developed less stress. For this model analysis will takes place with different types of materials. This analysis is shown below

5.1 Analysis of Modified Design (Radius 120 mm) Model with 2014-O Material
At the time of analysis in material selection 2014-O material properties are added. After completion of analysis distribution of stress is shown in Fig 5.1.

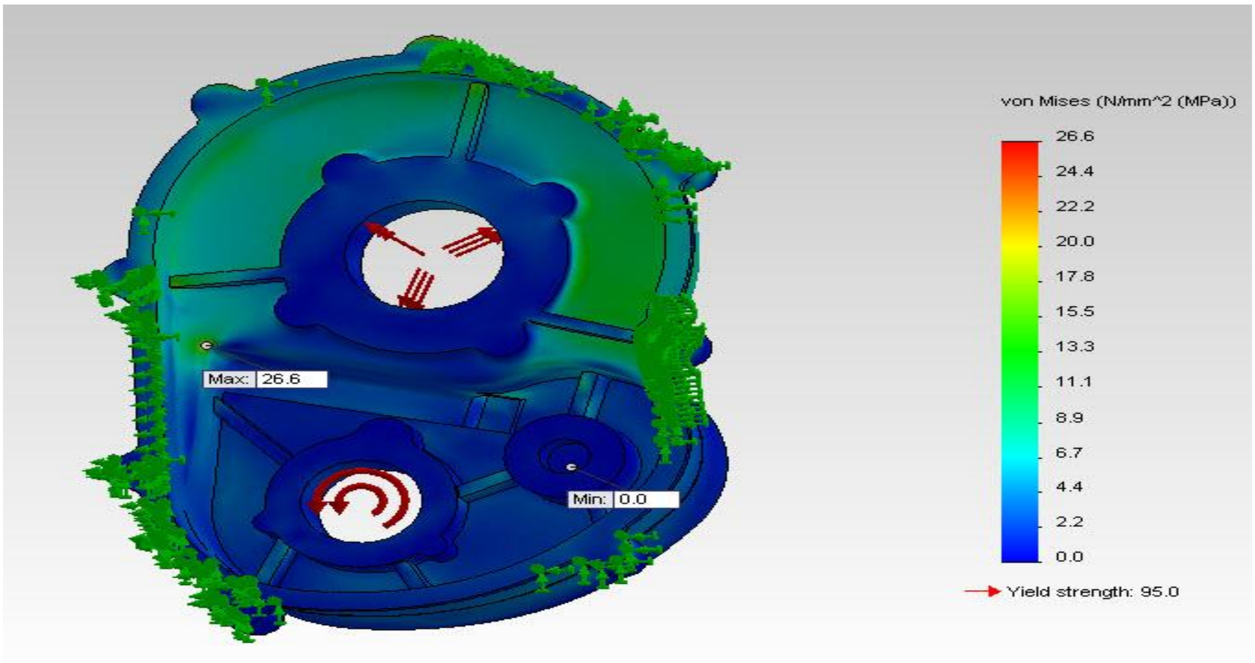

Fig 5.1: Stress distribution in design modified Gearbox with 2014-O material

Here maximum amount of stress developed with 2014-O material is 26.6 Mpa.

5.2 Analysis of Modified Design (Radius 120 mm) Model with 6061-O Material

At the time of analysis in material selection 6061-O material properties are added. After completion of analysis distribution of stress is shown in Fig 5.2.

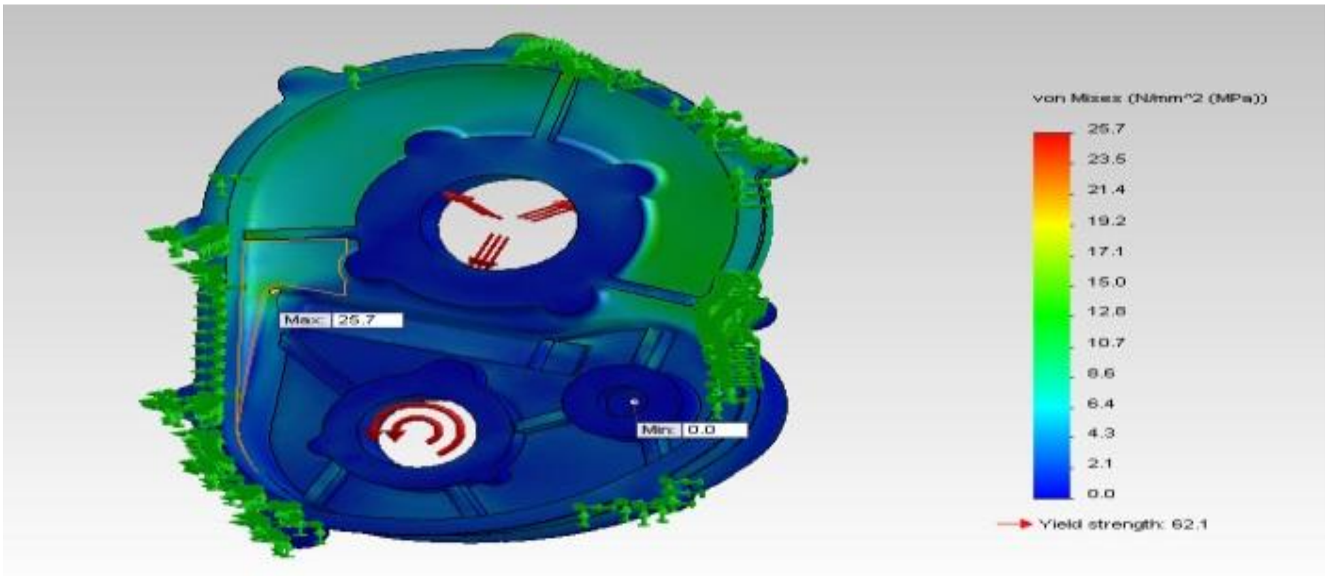

Fig 5.2: Stress distribution in design modified Gearbox with 6061-O material

Here maximum amount of stress developed with 6061-O material is 25.7 Mpa.

Table 5.3: Stress developed in different Modified Design models with its radius

Radius (mm)	60	90	Tangent
Stress (Mpa)	25.96	25.4	28.35

Table 5.4: Stress developed in Existing model with different materials

Material	LM25	2014-O	6061-O
Stress Mpa)	30.6	32	25.7

Table 5.5: Stress developed in selected Modified Design (Radius= 120mm) model with different materials

Material	LM25	2014-O	6061-O
Stress (Mpa)	24.5	26.6	25.7

By applying three materials properties to the selected 120 radius design modified model, material 6063-O material developed very less stress as 23.6 Mpa. Exact location of maximum stress concentration is shown in Fig 5.6.

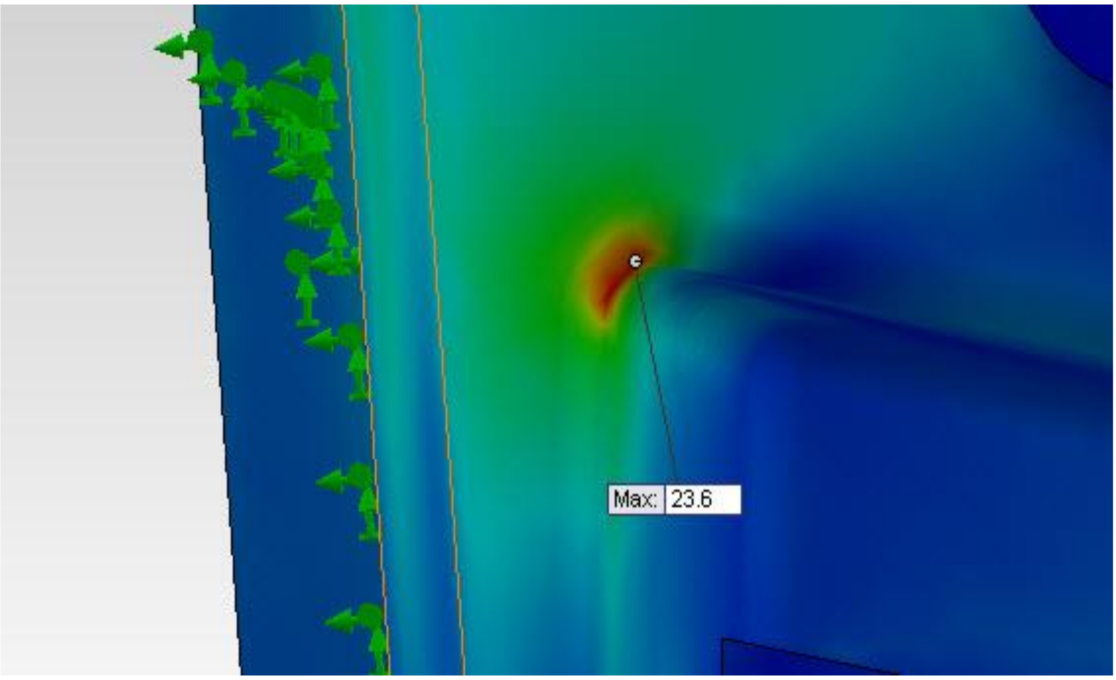

Fig 5.6: Exact location of maximum stress concentration

Conclusion

The main constrain of this project is reduction 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 models 120mm radius model with material 6063-O will had produced less stress 23.6 Mpa as compared to other materials. This material satisfies two conditions they are less weight and less cost.

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