Chapter 1

Introduction

1.1 Introduction of gear:

Gear is the most important machine elements in mechanical power transmission system. heat flux and temperature of spur gear tooth is considered to be the paramount objective of for modern spur gear design. A pair of spur gear tooth in action is generally subjected to thermal stress and temperature including fatigue. In this paper, the thermal stress analysis of a stainless steel, Gray cast iron and aluminium spur gear theoretical method using Fourier's law equation and drafting spur gear design on the NX software. The present work is an attempt to find heat flux and temperature of a stainless steel , Gray cast iron and aluminium spur gear tooth used in gear box of Maruti vehicle applications using theoretical and FEM calculations and modelling of spur gear is done in NX parametric.

A Gearbox is a device that used for transmitting power from the Power source to the output shaft. A gearbox has a set of gears that are enclosed in a casing. The gears are mounted on shafts which rotate freely about their axis. The gears are fixed on the shafts by Fits or by a key. These shafts are made to rotate freely on a support called casing. Bearings are tightly fit between the shafts and the casing. Today's cars have various sets of gears which give different speeds and torque on different Gears. A Gearbox is necessary because it is impractical to directly connect the input source to the output shaft. The power source may not have enough torque to bear the whole load at once. This will put a load on the power source which may cause overheating, more fuel consumption or even failure of the components. Gearbox gives leverage to the power source by enhancing the torque at initial gears and then delivering high speeds at final stages. This reduces the capacity of the power source required and hence less fuel consumption. Each Gearbox has its own set of Gear ratios that can be selected by the driver or just one set of universal Gear Ratio that will work with the help of a Torque converter or a Continuously Variable Transmission Major components include gears, Casing, Shafts, and Bearing.

1.2 Reduction gearbox:

A reduction gearbox is a device by which an input speed can be lowered for a requirement of slower output speed, with same or more output torque. Reduction gear assembly consists of a set of rotating gears connected to an output shaft. The high speed in coming motion from the wheel work is transmitted to the set of rotating gears, where in the motion or torque is changed. The number of gears used in the reduction gear assembly depends on the output speed requirement of the application. The reduction gear assembly is usually known as reduction gear box. Depending on the Output speed required, the reduction may have single stage or two stage reduction.

Double reduction gears are generally used in applications involving very high speeds. In this arrangement the pinion is connected to the input shaft using a flexible coupling. The pinion is connected to an intermediate gear known as the first reduction gear. The first reduction gear is then connected to a low speed pinion with the help of one more shaft. This pinion is connected to the second reduction gear mounted directly on the propeller shaft. Such arrangement facilitates the reduction of speed to a ratio as high.

- The essential part while considering a vehicle for any of the application is their moment. The required moment of a vehicle is attained due to the power which is produced by an engine.
- But the most important aspect is that the produced power should also pass to the various parts of a vehicle.
- Here we are considering two stage full depth gearbox for transmission of power from engine to the wheels. The selection of each element and their materials is characterized by the various parameters like

1. Required power
2. Ultimate Tensile Strength
3. Selection of material

1.3 Casing:

Casing is a fixture that fixes all the shafts and assembles all gears into an assembly without any interference. Casing also contains the mounting points to mount it in a powertrain Assembly. The Casing takes the load imposed by the power source. Vibrations are also transmitted in case the power source is an Engine. Intricate shape are drawn on the casing to keep it from yielding. There are bearing sockets on the casing where the bearings are fit into the casing. Then the shafts are placed in the bearing. An inlet is created in casing to pour gear oil. The casing should be air tight as it accommodates space for the gear oil for cooling. The casing is usually a symmetric two piece setup that is used to open or close the gearbox for maintenance or repairs. The casing should be manufactured with utmost precision to avoid misalignment. Over the years, Cast Iron is being used for manufacturing casing. Nowadays, casings are coming in Steels or oven Aluminium Alloys.

Chapter 2

Literature Review

2.1 Literature

The Baja Team Is discussed with us that Manual Gearboxes are complicated in design and is difficult for the users to drive the vehicle. Usage of so many components in the manual gearbox also reduced the efficiency. The team stated that it is difficult to implement manual gearbox in smaller vehicles. Hubvan Doorne of DAF has developed the concept of Continuously Variable Transmission (CVT). They have studied the concept briefly which was introduced by Leonardo Da Vinci in 14090s. They have studied the concept and its flaws discovered through 1900s and have manufactured a CVT that was implemented in cars. This resulted in the new age of Automatic Transmissions. CVTs were first tested in Volvo cars. Willis, Christopher Ryan have developed a CVT design that can be tuned to a range of Reduction ratios. Such CVTs can be tuned and can be used on any vehicle that can accommodate space for CVT. They have explained that such CVTs still need a reduction gearbox with a fixed reduction gear ratio. Polaris Automobili has successfully implemented CVT coupled with Reduction Gearbox. They have stated that the power train in their ATVs is very complicated and have studied the various complications caused due to the reduction gearbox including Noise, Vibration and the Noise produced. John M. Hawkins simplified the design of a gearbox and made it more compact for usage in low power vehicles like Mopeds and Forklifts. His design was so compact that it is being used in Helicopters to increase the torque which has reduced the start up time of the rotors. Ralph E.Taggert made a detailed experimental study on ‘Forces that affect the operation and efficiency of reduction Gearbox’ that contributes the complete information about a single stage reduction gearbox that includes dimensions of the real time gyroplane parts, the parts used in the Gearbox, assembly of individual components of the Gearbox Gearbox did not use any alloys for materials and did not consider vibrations or Thermal analysis inside the Gearbox. The basic information regarding to the issue is been collected from Team Wings from mBAJA team. We have studied the literatures available on internet Also there are lots of videos available on YouTube which really helps us to understood the problem and solution overcome that.

Sr.No	Author Name	Parameter	Finding
1	L. Karikalan, K. Mathan	Proper material selection 3D Modeling in NX Software In analysis of gears and casing done with a static structural heat flux, Stress & Strain analysis	• Equivalent stress of gears. • Total Heat Flux Of Spur Gear(W/m2)
2	V. Pranay Deepak Reddy	Static structural analysis on Pinion & Gear Vibration analysis	• Temperature Of Spur Gear(°C) • Aluminium heat flux • Gray cast Iron heat flux

2.2 Problem Statement:-

- In ATV Vehicle gearbox is failed due to the unbalanced forces exerted on the shaft. The shaft exceeded the limit due to the improper reaction force provided by the bearing
- To select the proper Material for a design of the gears and gearbox casing. To sustain the load which acted on the gears
- For a casing of gearbox have a lower thermal conductivity because of power that can be transmitted at ambient temperature without resulting in the damage of inside working of gearbox.

2.3 Objectives of the this Work :-

Objectives are

1. To have a safe design in order to attain the maximum possible output.
2. To obtained the Failure previously should avoided by using appropriate mathematical approach.
3. To reduce Weight of work should be limited up to-certain limit.
4. To Applying the sustainable mechanical elements in a previously designed system.

Chapter 3

Design & Calculations

3.1 Gear Design:-

Gear design for reduction ratio of a two-stage reduction gearbox was designed. The gears had to be light weight because heavy rotating masses have their own inertia and result into loss in overall torque. Also gear tooth must have sufficient fatigue strength and hardness to avoid failure such as abrasion wear, sudden breakage of tooth, pitting failure etc. To satisfy the above requirement EN8 alloy steel material was used, which have sufficient ultimate tensile strength after case hardening and is easily available. Following are the specifications of gearbox. Gear train has many components, such as input pinion shaft, intermediate pinion, intermediate gear and output gear etc. material which is used for gear train has following specification

There is total three types of forces are exerted on the gear train such as normal force, tangential force and radial force etc. they can be calculated using following formulae:

3.2 Calculations for Pinion 1&2

(1) Calculations for pinion 1 and 2.

Here

$N = 18$

module $= 2$ mm

$CP = \pi \times M$

$= \pi \times 2$

$= 6.283$

Here. N = No. of teeths.

CP = Circular pitch.

Now,

$PCD = M \times N$

so we have

$= 2 \times 18$

$PCD = 36$

$\because$ PCD = pitch circle diameter.

then

Diametrical Pitch $= \frac{18}{36} = 0.5$

Addendum $= \frac{CP}{\pi}$

$= \frac{6.283}{\pi}$

$= 1.999 \cong 2.$

Now

Addendum circular diameter or circle diameter

$= PCD + 2(\text{Addendum})$

$= 36 + 2(2)$

$= 40.$

Clearance $= \frac{CP}{20} = 0.1$

Tooth thickness $= \frac{CP}{2} = 3.1415$

Dedendum $=$ Addendum $+$ clearance

$= 2 + 0.1$

$= 2.1$

Dedendum circle diameter $= PCD - 2(\text{dedendum})$

$= 36 - 2(2.1)$

$= 31.8$

Calculations for Gear 1:

We have

$N = 52$

$M = 2mm$

$CP = 6.283$

$PCD = 104$

Diameter of pitch $= \frac{52}{104} = \frac{N}{PCD}$

$= 0.5$

Addendum $= 2$.

Addendum circle diameter $=$ PCD $+ 2$(Addendum)

$= 104 + 2(2)$

$= 108$.

Clearance $= 0.31415$

Tooth thickness $= 3.1415$

Dedendum $= 2.31415$

Dedendum circle diameter $=$ PCD $- 2$ (dedendum)

$= 104 - 2(2.31415)$

$= \cancel{108}.\cancel{6283}1$.

$= 99.3717$

Now,

Calculations for Gear 2.

$N = 54$
$m = 2mm$
$CP = 6.283$
$PCD = 108$ by $(M \times N)$

Diameter of pitch $= \frac{54}{108}$
$= 0.5$.

Addendum $= 1.99 \simeq 2$.

Addendum circle diameter $= PCD + 2(\text{Addendum})$
$= 108 + 2(2)$
$= 112$.

Clearance $= \frac{CP}{20} = 0.31415$

Dedendum $= 2.31415$.

Tooth thickness $= 3.1415$.

Dedendum circle diameter $= PCD - 2(\text{dedendum})$
$= 108 - 2(2.31415)$
$= 103.3717$.

From above calculations the following parameters are given.

Gear	Module	Pressure angle	No. of teeth	PCD
Input pinion	1.5	20	18	31.5
Intermediate gear	1.5	20	50	87.5
Intermediate pinion	2	20	20	40
Output gear	2	20	59	118

Table : Parameter of gears

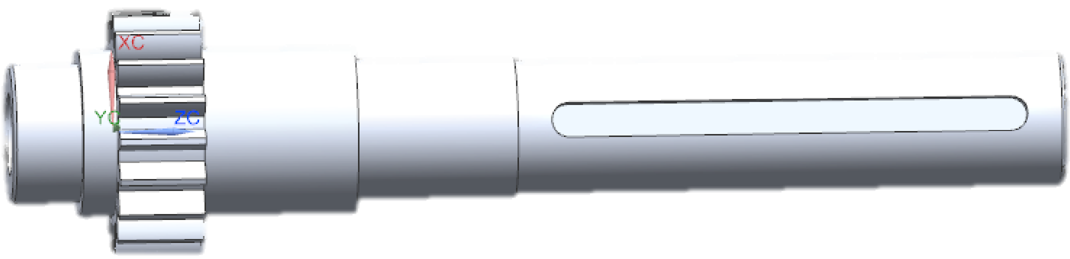


Fig. INPUT PINION

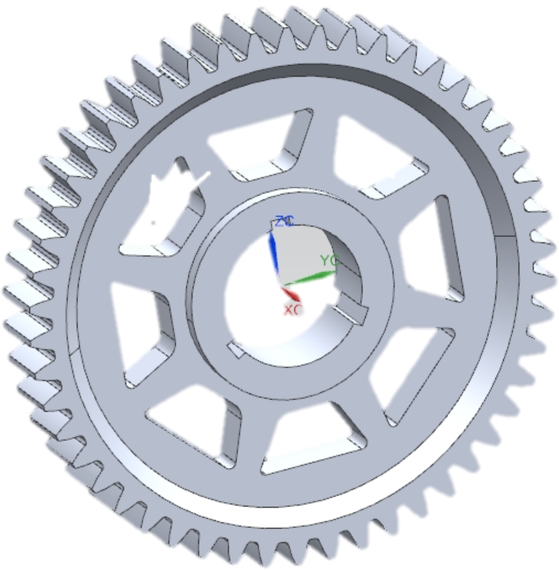


Fig. INTERMEDIATE GEAR

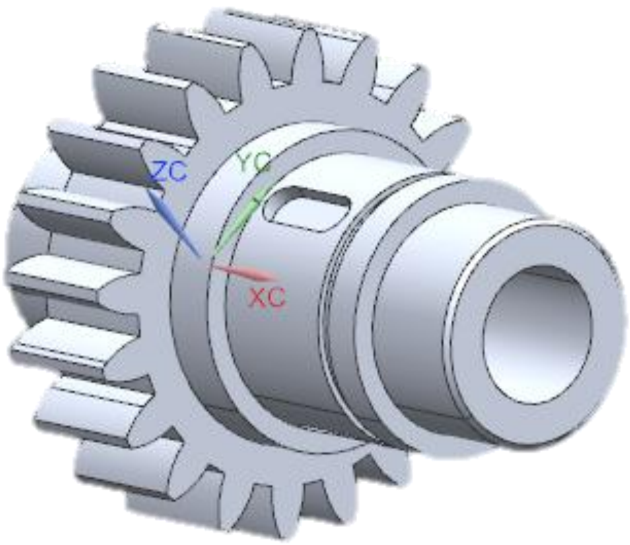


Fig. INTERMEDIATE PINION

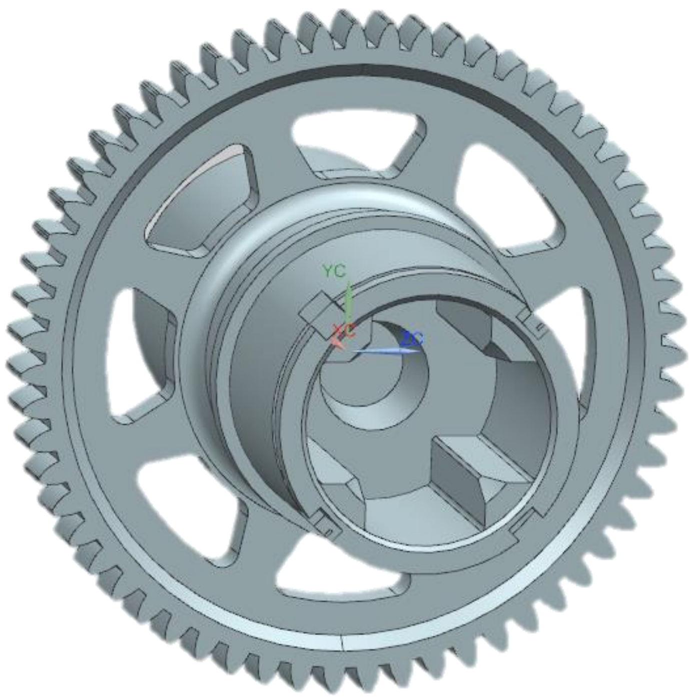
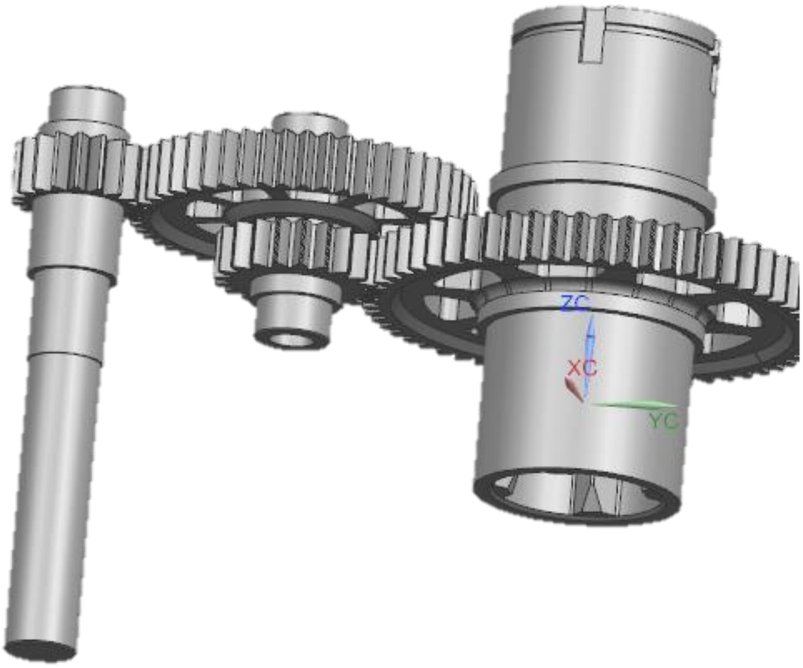
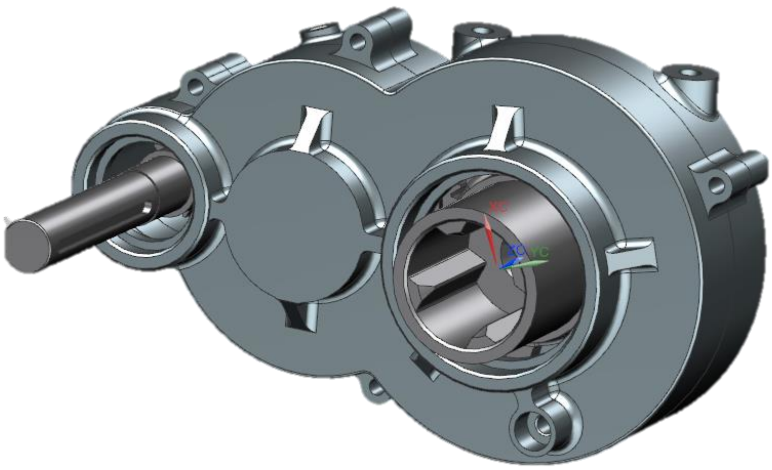


Fig. INTEGRATED SPOOL

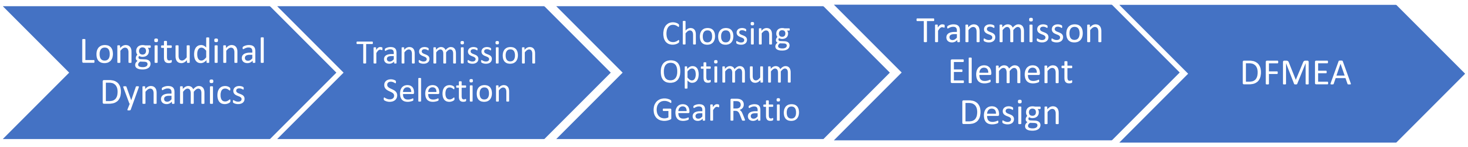
Assembly

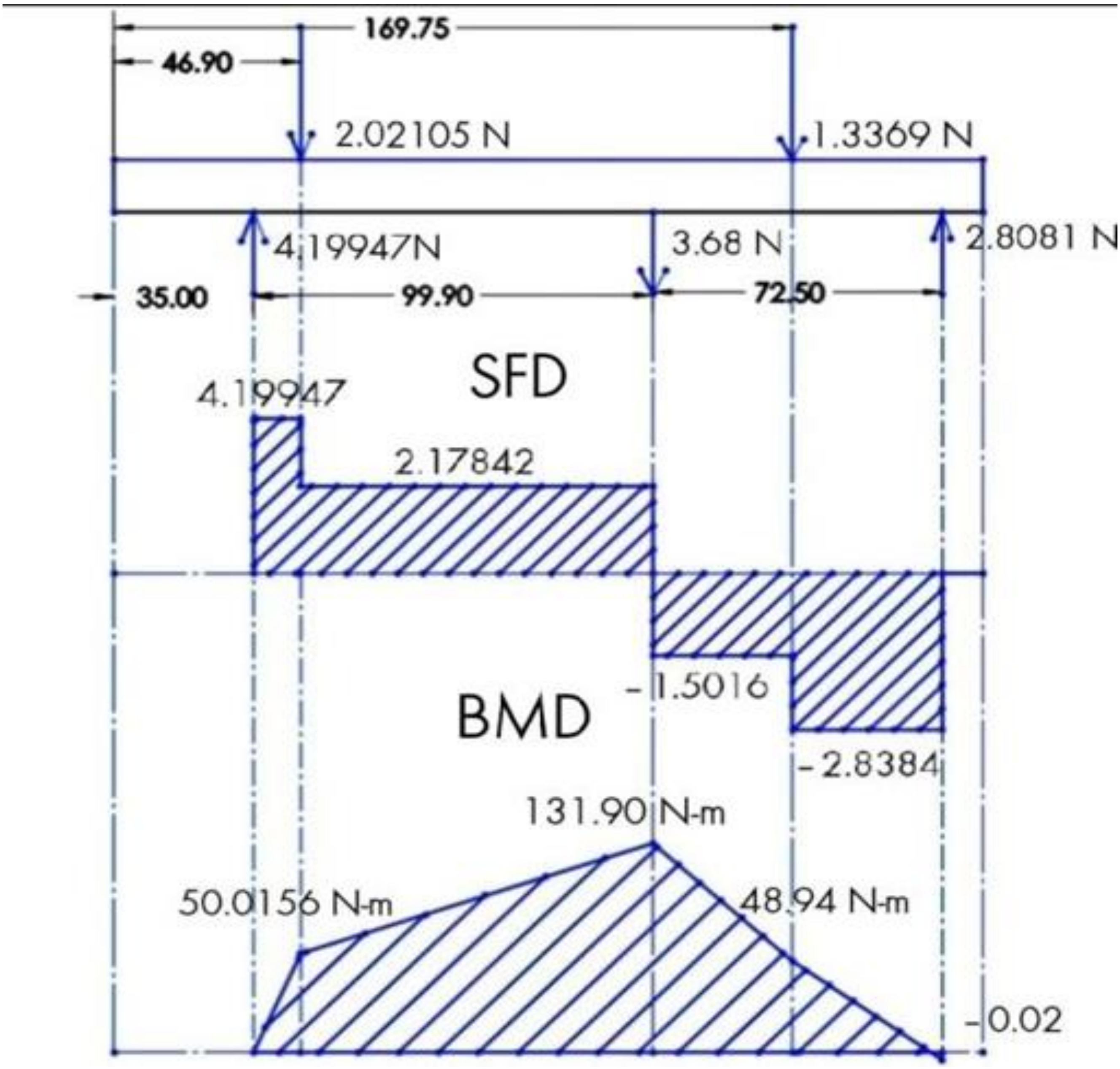




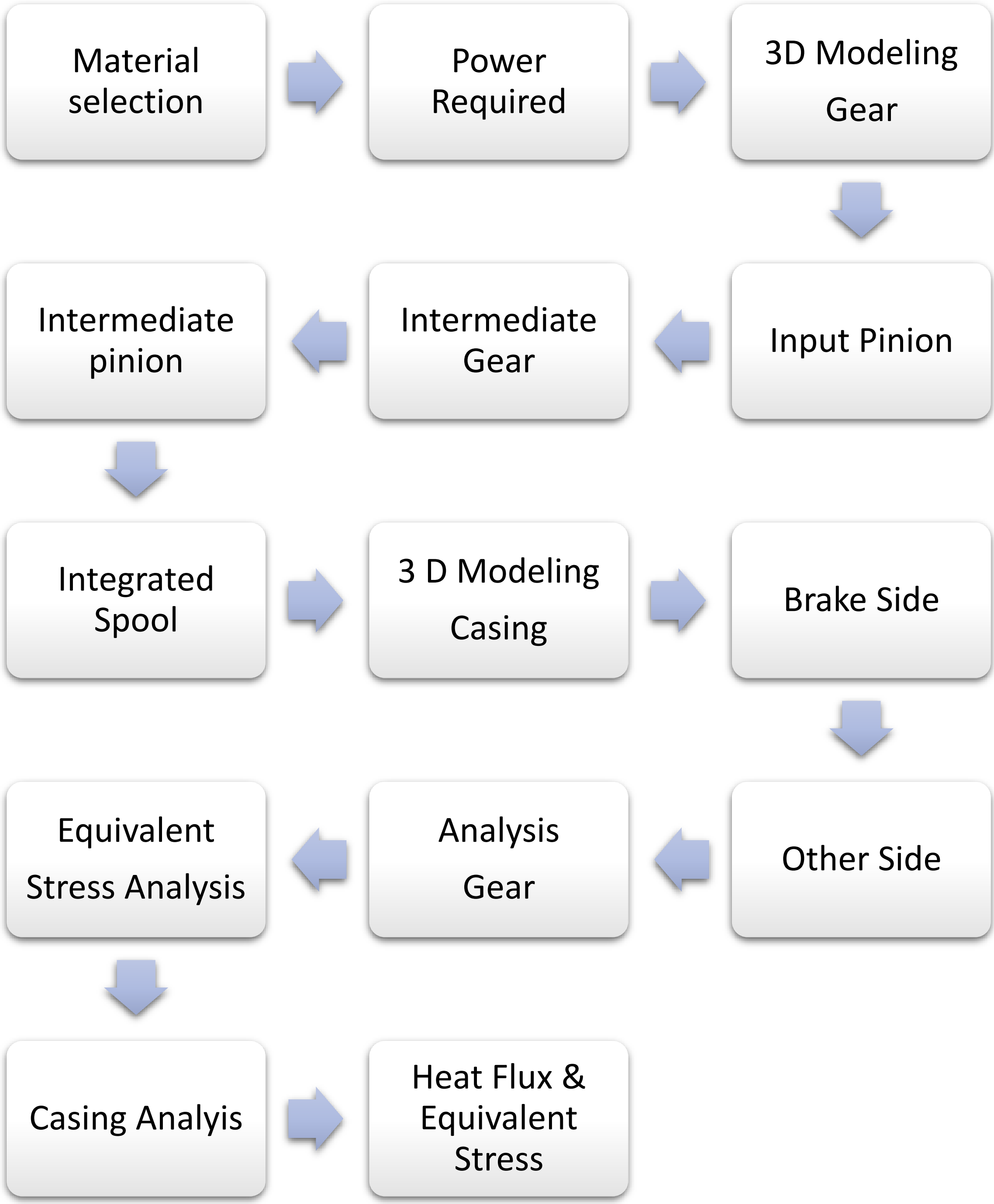
3.3 Methodology :-

As mentioned in the draft of SFD, BMD. We have noticed that the distribution of Shear force and bending moment. It is due to improper support reaction by the bearing width of bearing was 8 mm As Which wasn't sustainable. So we have considered the bearing as 12 mm by the 8 mm and then tried to solve for SFD & BMD distribution and we have observed that the distribution of SFD & BMD is uniform





3.4 Block Diagram Of Entire Process:



3.5 Application:

Gearboxes are mechanical assembly housings that are used in application from wind turbines to automobiles. The purpose of the gearbox is to increase low-speed rotational speeds from the rotor onto an electrical generator that is operating at a higher rate of speed.

tractors and snow mobiles. The main key for such vehicles is the powertrain assembly which is unique and differs from other vehicles. The power train includes Engine, Manual Gearbox, Limited slip Differential or in some cases a reduction gearbox coupled with a continuously Variable Transmission (CVT).

3.5 Advantages & Disadvantages:

Advantage	Disadvantages
Low Weight	Lower Torsional Stiffness
Compact Design	Greater Mechanical Wear
No Backlash	High speed noise vibration Happens
High Gear Ratios	It has no flexibility
High Torque	Lower Torsional Stiffness

Chapter 4

POWERTRAIN

4.1 POWERTRAIN SYSTEM ANALYSIS

In transmission system there are many components to design and analyze that are gear, gear box casing etc. in this CAE process we used 3D mesh as meshing element which has element size of 2mm, 4mm, and 6mm with different physics like thermal analysis, static analysis, bending & torsional analysis and after several iterations, we come to our final conclusion in which we finalize our final gear, axles and axles for wheels etc. In powertrain system we analyzed in two physics which are static structural analysis in which are analyzed for average deformation & stress concentration and in thermal analysis we analyzed for heat transfer from system to surrounding

4.2 Gear Train

To fulfil the required reduction ratio a two-stage reduction gearbox was designed. The gears had to be light weight because heavy rotating masses have their own inertia and result into loss in overall torque. Also gear tooth must have sufficient fatigue strength and hardness to avoid failure such as abrasion wear, sudden breakage of tooth, pitting failure etc. To satisfy the above requirement EN8 alloy steel material was used, which have sufficient ultimate tensile strength after case hardening and is easily available. Following are the specifications of gearbox. Gear train has many components, such as input pinion shaft, intermediate pinion, intermediate gear and output gear etc. material which is used for gear train has following specification as shown in table 08.

Sr no	Property	Gear material
1	Material used	EN8
2	YTS	575 MPa
3	UTS	650 MPa

Gear has following specification which are analytically calculated which are shown.

Gear	**Module**	**Pressure angle**	**No. of teeth**	**PCD**
Input pinion	1.5	20	18	31.5
Intermediate gear	1.5	20	50	87.5
Intermediate pinion	2	20	20	40
Output gear	2	20	59	118

There is total three types of forces are exerted on the gear train such as normal force, tangential force and radial force etc. they can be calculated using following formulae:

Tangential Force:

$$F_t = \frac{2 \times \text{transmitted torque}}{d}$$

Where, d = pitch circle diameter

Radial Force:

$$F_r = F_t \tan \varphi$$

Where, φ = pressure angle

Normal Force:

$$F_n = \frac{F_t}{\cos \varphi}$$

From above equation we get forces acted on the gear train for each component which are following:

For **Input pinion**:

Tangential force = 2540 N

Normal force = 2703 N Radial force = 924 N

For **Intermediate Gear:**

Tangential force = 330 N
Normal force = 351.2 N   Radial force = 120 N

For **Intermediate Pinion:**

Tangential force = 722 N
Normal force = 768.4 N   Radial force = 262.7 N

For **Output Gear:**

Tangential force = 83 N   Normal force = 88.33 N
Radial force =30.2 N

After running the simulation, we get following results as shown

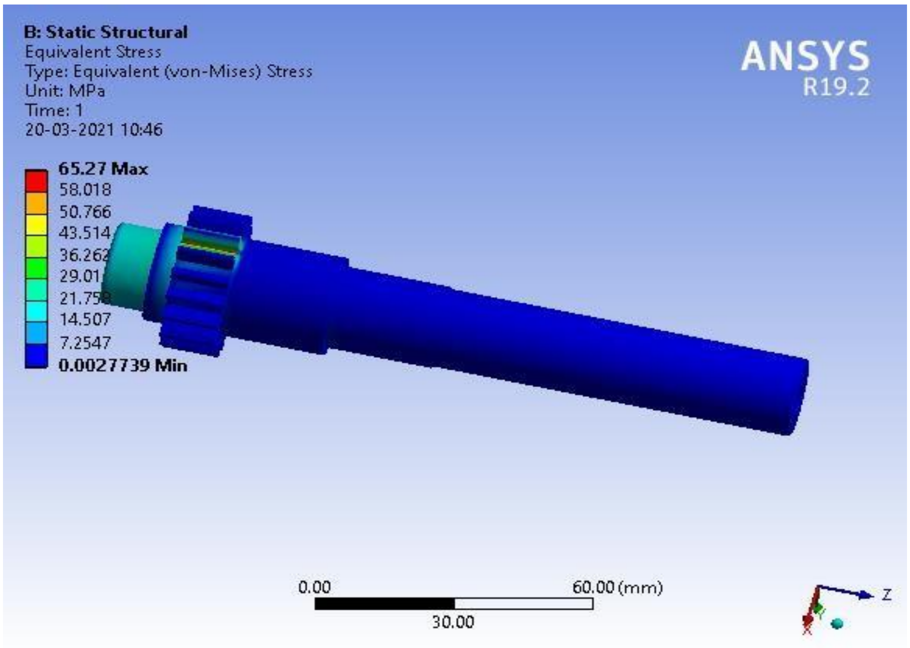


Fig. INPUT PINION

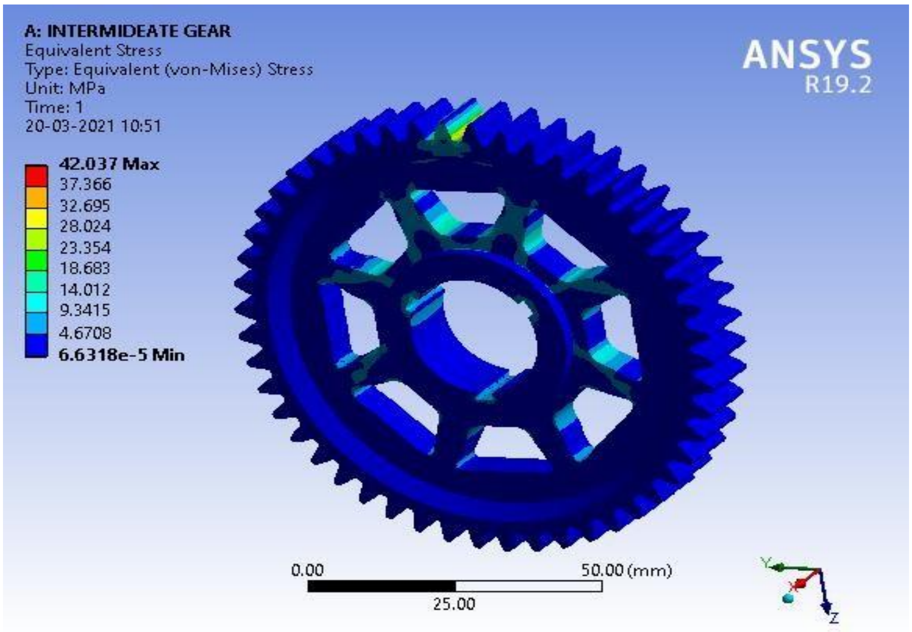


Fig. INPUT PINION

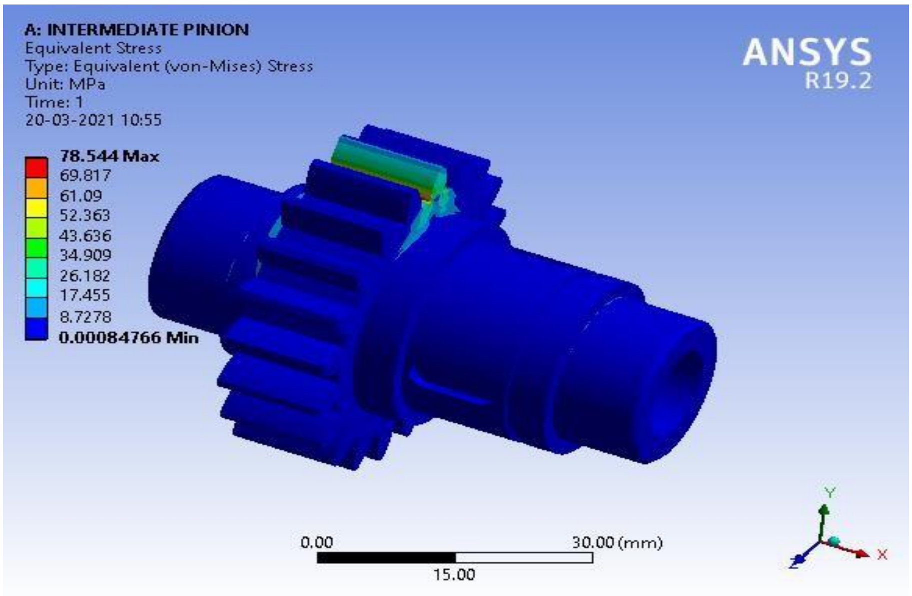


Fig. INTERMEDIATE PINION

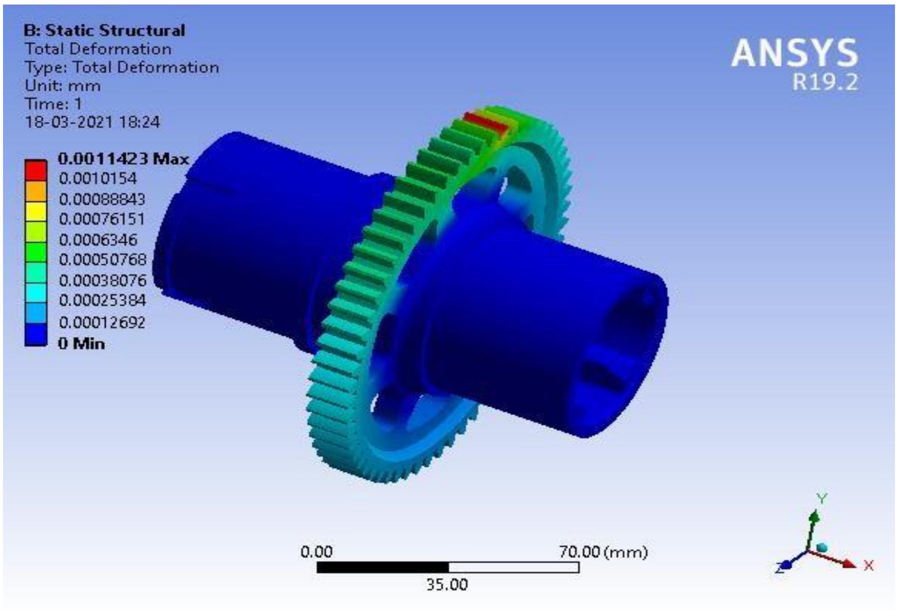


Fig. INTERMEDIATE PINION

4.3 Gear Box Casing

Gear box casing was analyzed in two types of analysis which are Static Analysis and Thermal analysis for the heat transfer and heat flux from system to surrounding. Material used for casing is Al6061 which is precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S". which has following properties:

1. coefficient of expansion = 23.4×10^{-6} / °C
2. young's modulus(E) = 69×10^{3} MPa

there are some assumptions which are consider while designing and analysis the casing which are following:

1. vehicle kept in room temperature before operation.
2. Material is homogenous in nature.

Elementary static bending analysis with Newton's second law was used to calculate bearing forces generated by the action of each shaft. These bearing forces, and their respective 3-dimensional orientations, were applied to the Solid works model of the gear casing using Solid works finite element analysis (FEA). A minimum factor of safety of 3 was used for reducing weight from less-stressed areas of the gearbox. A total of 4 pounds was reduced through this method, making the gear casing just over 10 pounds. Each of the mounting bolts is a fixed support and the bearing bores have the respective forces applied in the exact planes in which they will act.

Analysis is done in Ansys CAE software in mechanical APDL and modelling in NX12
To calculate the heat flux initial conditions are for analysis are temperature inside the casing and outside casing is 65.3 ℃ and 25 ℃ respectively, by calculation factor of safety of Casing is 1.3. Hence heat flux for the material

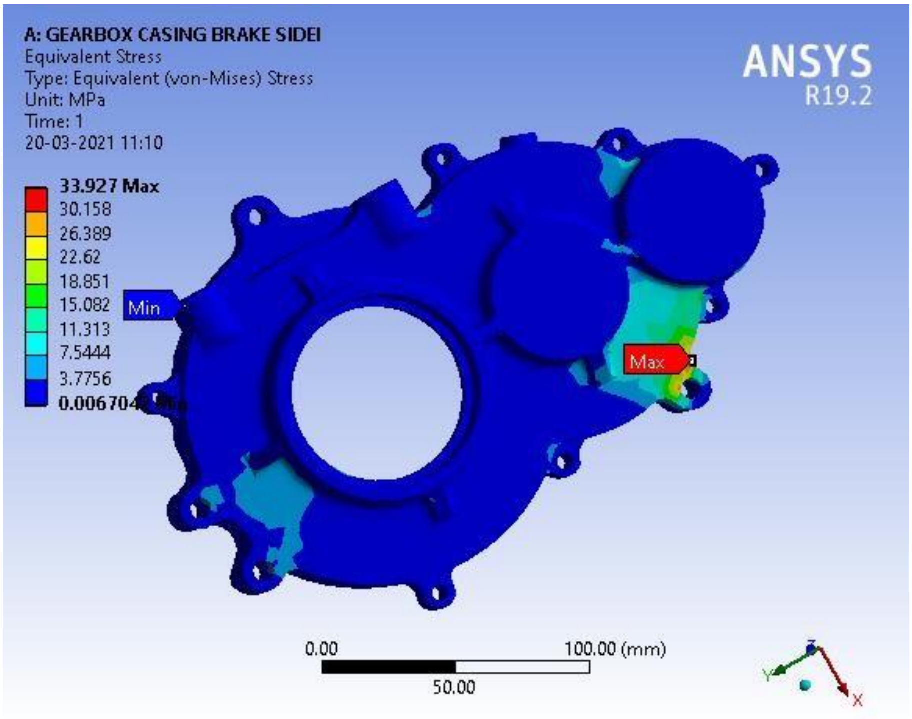


Fig. BRAKE SIDE CASING

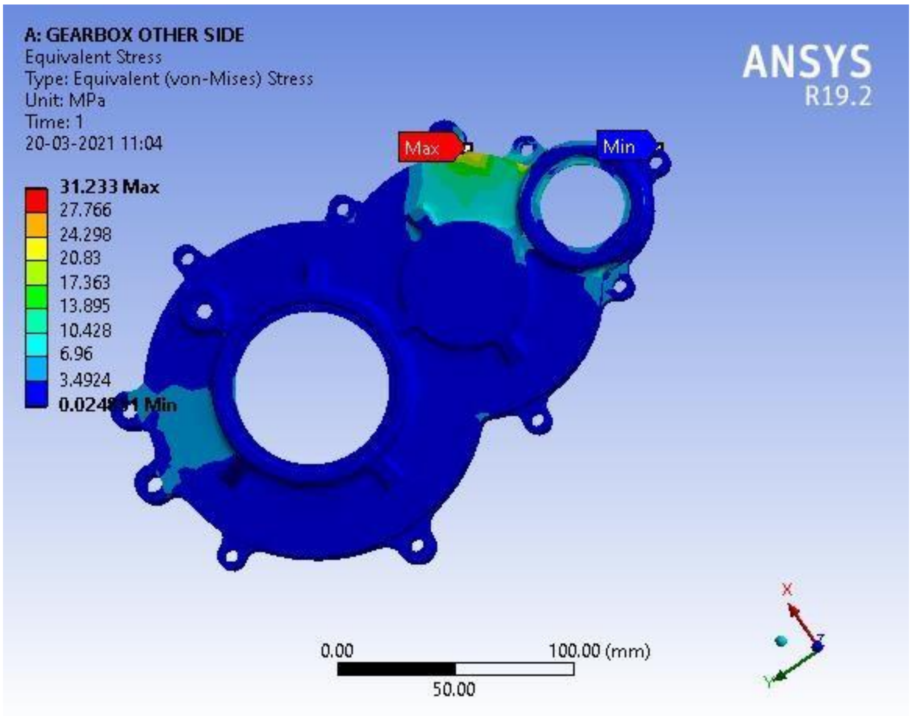


Fig. OTHER SIDE CASING

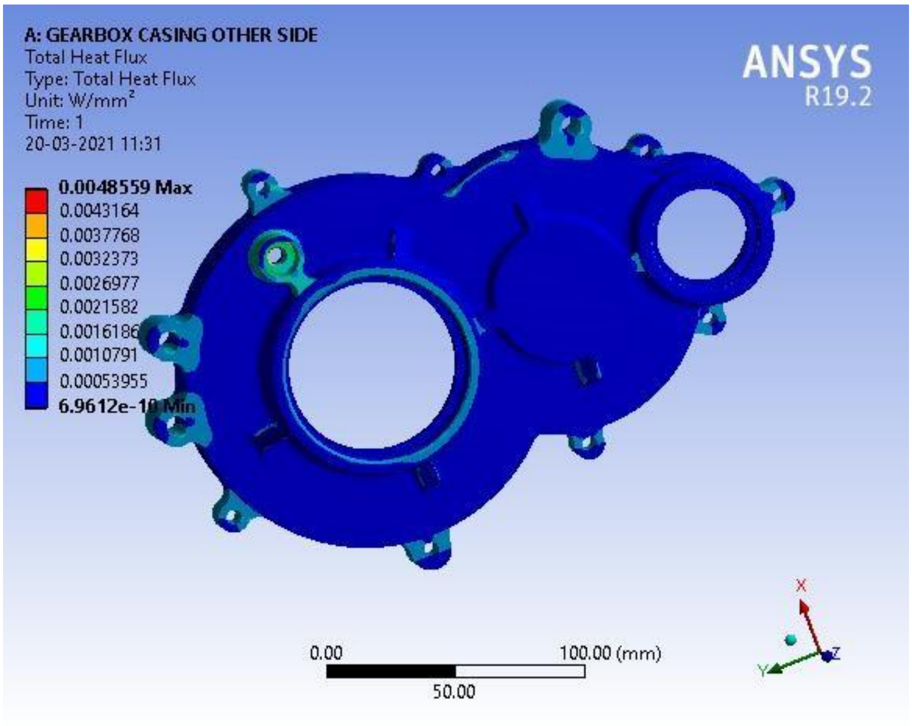


Fig. OTHER SIDE CASING

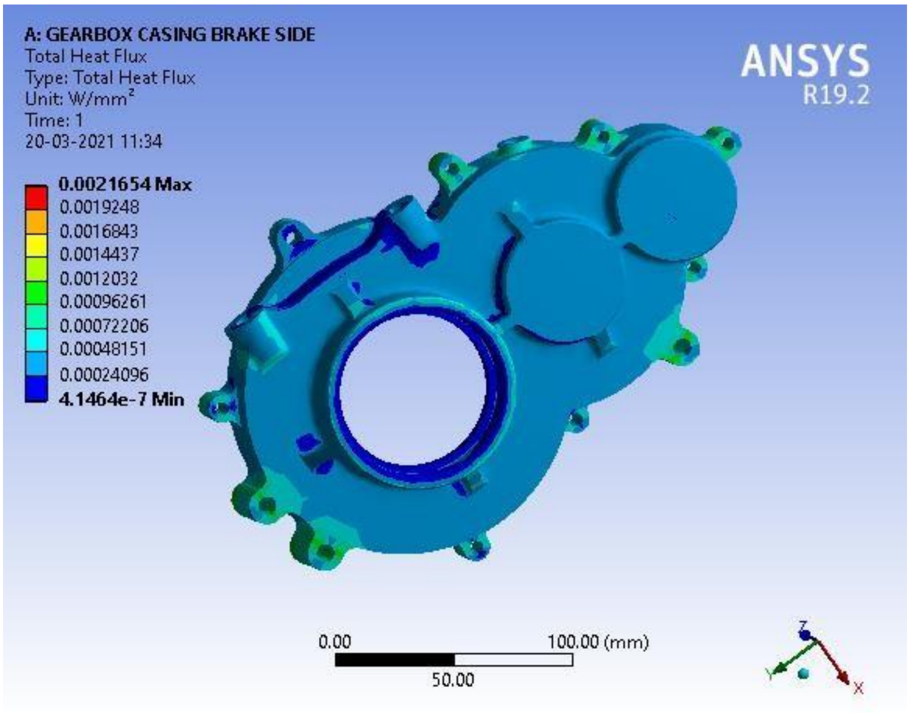
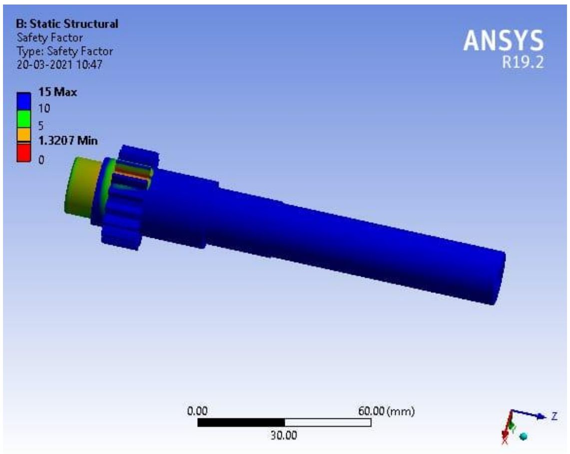


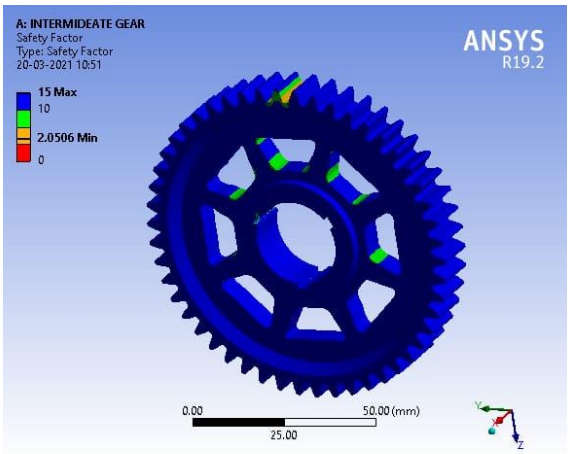
Fig. BRAKE SIDE CASING

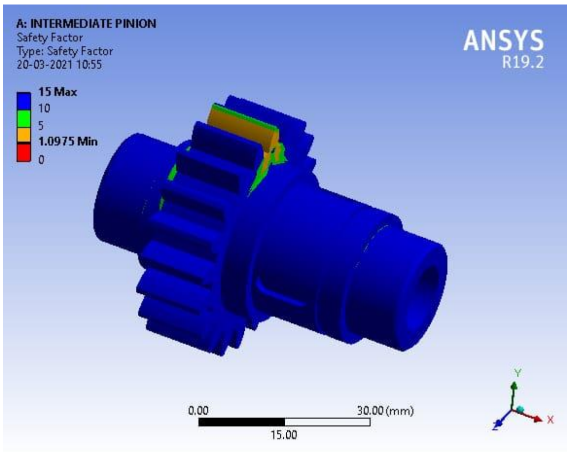
4.4 Factor of safety

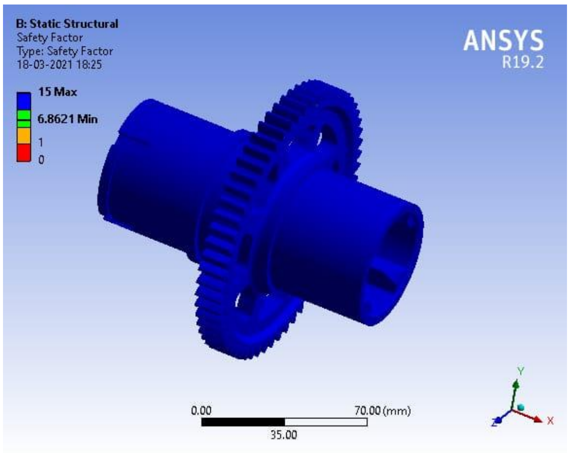
The factor of safety is the structural capacity of a system which determines the load-carrying capacity beyond its actual load. In other words, how strong the system is then what is actually required is called Factor Of Safety (FOS)

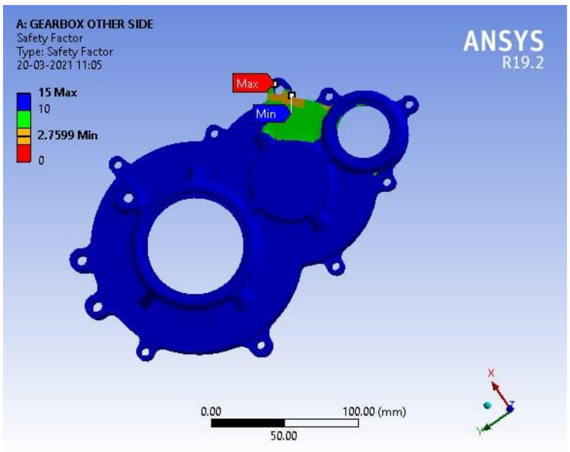
By the calculation our Factor of safety for casing is 1.3 for the both of casing

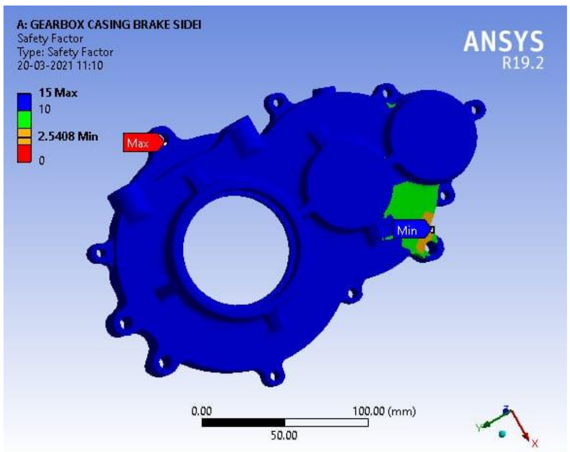












Chapter 5

Result & Discussion

5.1 Equivalent Stress :-

Equivalent stress is actually a scalar derivative of shear strain energy per unit volume measured at different points in a stressed material and helps in determining the likelihood of the failure of the said material according to the Von Mises failure criteria. It is commonly used for ductile materials. Equivalent stress allows one to view stress acting on a structure by one plot. Von Mises equivalent stress is one of the most widely used. Equivalent Von Mises stress predicts the yielding of materials under a condition of multiaxial loading with the help of the results from simple uniaxial tensile tests.

5.2 Total Deformation :-

Total deformation is the deformation option that you can see all the deformation results related to your model, in three coordinates (X, Y, and Z). Directional: In directional deformation, you can select a coordinate (X, Y, or Z) to see the deformation result of your physical model in this direction.

5.3 Total Heat Flux :-

Heat flux also named as thermal flux, is referred to as heat flux density, heat-flow density is a flow of energy per unit of area per unit of time. In SI its units are watts per square mm .

Heat flux is the thermal energy transferred from one substance to another per unit time and area denoted by temperature change measured in watts per meter squared units. In simple terms, it is the heat transferred per unit area. To obtain this value, one must obtain the change in temperature, the thermal conductivity of the medium of conduction and the direction of the heat transfer. Accurate figures are obtained when the system is in a steady state condition.

5.4 Result

Sr. No.	Component Name	Analysis	Material	FEA	
				Min	Max
1.	Input Pinion	Equivalent Stress	EN8	0.0027739 MPa	65.27 MPa
2.	Intermediate Gear	Equivalent Stress	EN8	6.6318e-5 MPa	42.037 MPa
3.	Intermediate Pinion	Equivalent Stress	EN8	0.00084766 MPa	78.544 MPa
4.	Integrated spool	Total Deformation	EN8	0 mm	0.0011423 mm
5.	Gearbox Casing Brake Side	Equivalent stress	Aluminium HE30	0.006704MPa	33.6927 MPa
		Total Heat Flux		4.1464e-7 W/mm^2	0.0021654 W/mm^2
6.	Gearbox Other side	Equivalent stress	Aluminium HE30	0.0248 MPa	31.233 Mpa
		Total Heat Flux		6.9612e-18 W/mm^2	0.0048559 W/mm^2

Chapter 6

Conclusion

We have designed a spur gear used in gear box of ATV Vehicle applications using theoretical calculations and modelling of spur gear is done in NX 12 Software.

- We have performed Structural analysis on spur gear using EN 8 .
- We are using EN 8 Material because of EN 8 has high strength levels compared to normal bright mild steel, due to thermo-mechanical rolling. EN8 is suitable for all round engineering purposes that may require a steel of greater strength.
- For safe Design we have change the teeth on the gear to get maximum possible output.
- Due to failure of previous gearbox should avoided by using appropriate mathematical approach using shear force diagram and bending moment diagram.