Design and Analysis of Nine Speed Gear Box with two Stages

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Abstract

This paper consists of designing of nine speed gearbox and the procedure for calculating the number of teeth on gear including structure and ray diagram. For analysis, the gearbox assembly is created in CATIA and Analysis is performed in ANSYS. Also, deformation is attained as the gear efficiency depends on the deformation. A mechanical device called a gearbox that transforms the torque and speed of a rotary power generator to the output shaft. The torque transferred reduces when there is a rise in shaft speed, and likewise. Multi-speed gearboxes are utilized in cases where the speed or the torque there at the output shaft must be varied often. Gearboxes operate on the idea of teeth meshing, resulting in power transfer and the motion transfer from the input source toward the outputs. To achieve the needed speed differences, a gearbox is constructed by attaching several gears in a proper speed ratio. Gearboxes often feature many groups of gears that are strategically arranged to achieve various speed variations. The synchromesh, sliding mesh, and constant mesh gearboxes are the three kinds of gearboxes. Sliding and stationary gears are the two main types of gears in a sliding mesh gearbox. Sliding gears are installed on splined shafts so that they may move along the shaft's axis and mesh with possible combinations of gear. The result shows that the deformation, maximum stresses and elastic strain are under safe limits.

Keywords: Gearbox with Nine speeds, 3D modeling, simulation, gear tooth, analysis of gearbox.

1. Introduction

The basic function of a gearbox is to transfer power out of a power supply to the intended output component as per varying requirements. A gearbox is a device that converts the torque and speed of a rotary power supply to the output shaft. The torque transferred will reduces when shaft speed rises, and likewise. Multi-speed gearboxes are utilized in situations where the speed or the torque at the output shaft must be changed often. Gearboxes function on the concept of teeth meshing, which leads to motion and power transfer from the input to the output. A transmission or gearbox uses gear ratios to convert speed and torque from a rotary power supply toward another device. The transmission shifts the greater engine speed to the slower wheel speed, thus improving torque. Multiple gear ratios are available in transmission, with the option to move around them as there is a difference in speed. This can be accomplished either by hand or automatedly. Control in both directions (forward and backward) may be available. Most contemporary gearboxes are designed to improve torque by lowering the speed of a prime mover output shaft, resulting in mechanical gain and an improvement in torque. Uses of a gearbox: Gearboxes have been applied for altering the direction in which power is transferred, altering the level of force or torque that is delivered, and adjusting the relative speed of the input compared to the output, along with other functions.

1.1 Objectives

The main aim of this work is to design the multi speed gear box. To control the experimental set up cost, a numerical approach was planned. A structure analysis is considered as same as the real time experimental set up. For Design the individual gear model, Table 2 designing data is used. Using this constant profile shape, 3D model of the Gears are prepared with Catia software

2. Literature Review

Gopikrishna et al. (2019) presented a paper on Gearbox, which has a set of gears that are enclosed in a casing, the gears are mounted on shaft which rotate freely about their axis. The gears are fixed on a shaft by key, this reduces the capacity of power source required and hence less fuel consumption. Ujjayan et al. (2018) describes the study of shaft material, gear box components and types of gearing etc. Gear box is a mechanical device which is used to provide torque and its conversion from input to output shaft. Whenever there is a requirement of frequent change in speed and torque at output shaft, multispeed gear boxes are used. Gear boxes work on the principle of meshing of teeth, which result in the transmission of motion. Heel et al. (2018) presented that; gear is a machine part having a clogs which contact with other toothed part in order to transmit the torque. This paper describes about various type of gears and need of efficient and compact gear boxes in industrial applications to improve their power density. Low efficiency of the gear box is a serious problem, because it increases the cost of maintenance and affects the prestige of the enterprise. Whenever a frequent change of speed/torque at the output is required, we use a multispeed multistage gearbox.

Francesca (2017) This paper proposes a method in the ISO standard environment for calculating a single global dynamic factor, Kav, by replacing Ka and KV, in the case of gears subjected to shift and load conditions and this process based on the Miner damage rule and calculate the equivalent tangential Force values, including all dynamic effects. Neeraj et al. (2017) this paper has attempt to automate preliminary design of gear box by using the software like kiss. The objective function is constrained by the bending strength contact stress plane width and the number of pinions and gear teeth. The design optimizes the action of the two-stage gearbox by using KISS -soft achieved by easily supplying the requested design parameters. Muhammad (2017) A study on the mechanism modeled by the mechanical system was carried out. The full gear shifting process in stages, which gives the opportunity to capture the nature of the body, solve the complexities of the detailed kinematic description. Rahi et al (2016) It is shown that the spur gear is designed with software like Creo parametric and ANSYS. The finite element method (FEM)is an easy and accurate technique for pressure analysis, FEA is performed in the finite element software ANSYS14.0. Also, due to the efficiency of the gear depends on its deformation, the variants 15nic1mo15 and SCM415 are obtained.

3. Methodology

In this article we want to design nine speed gearbox for that initially we are drawing ray diagram and then we are finding dimensions of every gear and design in done on catia and analysis in done on ansys for that we are assuming the following data (Table 1):

Initial specifications for the gearbox
Power transmitted is 340KW;
Minimum output speed is 1100rpm;
Maximum speed is 3400rpm
Motor speed (input speed) is 3000rpm
Number of speed steps is nine
Gear geometric progression ratio can be calculate as

$$\phi = \left(\frac{N\max}{N\min}\right)^{\left(\frac{1}{Z-1}\right)}$$

$$= \left(\frac{3400}{1100}\right)^{\left(\frac{1}{9-1}\right)} = 1.15 \quad \text{Eq.No----(1)}$$

The individual speeds can be calculate

$$N_i = N_{i-1} x \phi \quad \text{Eq.No----(2)}$$

Table.1: Individual speeds at outlet shaft

S.No	Speed(rpm)
1	1100
2	1266.54
3	1458.294
4	1679.08
5	1933.293
6	2225.993
7	2563.008
8	2951.048
9	3397.837

According to final output speeds, the structure diagram is planned, which are presented below and should satisfy the below condition.

$$\frac{N_{min}}{N_{i/p}} \geq 0.25 \qquad \frac{N_{max}}{N_{i/p}} \leq 2$$

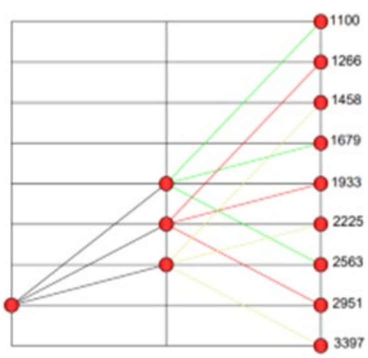

Figure 1 Structure diagram.

Kinematic arrangement of gears and stages are planned as (Figure 1 and 2).

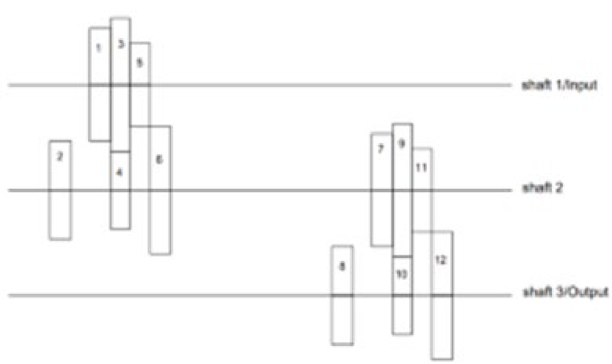

Figure 2. Kinematic arrangement

Gear design has done for individual gears and pitch circle radius, base circle radius, addendum circle radius and dedendum circle radius are calculated based on number of teeth and module of gear (Table 2).

Table.2: Gears and its Details

Gear No	No of teeth	Module	Radius in mm			
			Pitch circle	Base circle	Addendum Circle	Dedundum Circle
1	22	3.5	38.5	35.875	42	34.125
2	28	3.5	49	46.375	52.5	44.625
3	23	3.5	40.25	37.625	43.75	35.875
4	27	3.5	47.25	44.625	50.75	42.875
5	20	3.5	35	32.375	38.5	30.625
6	30	3.5	52.5	49.875	56	48.125
7	26	3.5	45.5	42.875	49	41.125
8	30	3.5	52.5	49.875	56	48.125
9	32	3.5	56	53.375	59.5	51.625
10	24	3.5	42	39.375	45.5	37.625
11	20	3.5	35	32.375	38.5	30.625
12	36	3.5	63	60.375	66.5	58.625

4. Data Collection

To design a gear is a complicated task. so to simply the design of spur we are taking experimental formulas from PSG data book pg.no.7.20.

Pitch circle diameter for Pinion, d1 = m*z1 mm
Pitch circle diameter for Gear, d2 = m*z2 mm
Base circle diameter for Pinion, db1 = d1*cosα mm
Base circle diameter for Gear, db2 = d2*cosα mm
Tip circle diameter for Pinion, da1 = d1+2m mm
Tip circle diameter for gear, da2 = d2+2m mm
Root circle diameter for Pinion, df1 = d1-2*1.25 mm
Root circle diameter for gear, df2 = d2-2*1.25 mm
Tooth thickness on pitch circle, S = πm/2 mm
Clearance, C = 0.25 mm
Centre distance, a = (d1+d2)/2 or m(z1+z2)/2 mm
Total Depth, h = 2.25*m mm
Circular pitch, p = πm mm
Face width, b =3* π * m mm
Ratio of gear width to center distance, Ψ = b/a
Gear ratio, i = z1/z2 = n1/n2 = w1/w2

5. Results and Discussion

Mesh formation

Structural analysis of character tools tiers has achieved using ANSYS workbench. To run the evaluation, 64-bit operating system,4GB ram and ANSYS 19. 0 is used. Without any trouble, to run analysis software this configuration may be very apt. The previously created IGS report is imported on ANSYS file geometry. In ANSYS, modal analysis and harmonic are accomplished (Figure 3).

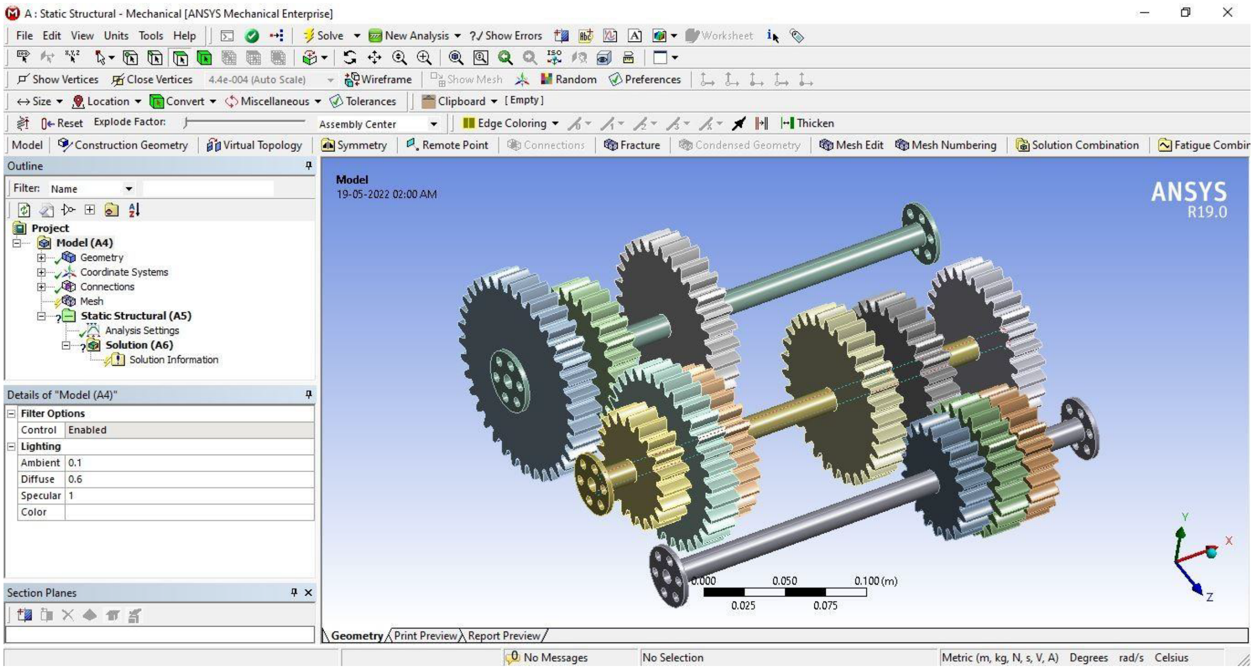

Figure.3 Geometry model of gear box

The I.G. E. S. Model what we created in Catia software program is imported into ANSYS and all dimensions are considered in millimeters. Imported version indicates as above. 1st stage tools set. Is divided as small length elements. Here tetra hadrons mesh method is carried out to divide the combined. If we elevated the number of factors for 1st level equipment set version we can the accurate consequences. Here after typically the meshing the model getting 12249 elements and 21594 nodes.

Deformation of Gearbox

An Ansys analysis was used to determine the structural behavior. After the geometry has been produced and imported, the structural solver in ANSYS is used to perform the analysis. To achieve optimal results, the gearbox unit has meshed properly. A structured mesh for the 3D model was planned based on this (Figure 4). The domain has hexahedron elements with 120978 nodes and 24775 elements after meshing. A fine mesh is intended at the blade's entry to prevent turbulence. The structural analysis takes into account input gear torque. After the meshing is completed, ANSYS software is used to impose bearing and displacement criteria on the shafts. Subsequent structural analysis was carried out using these Moment loadings

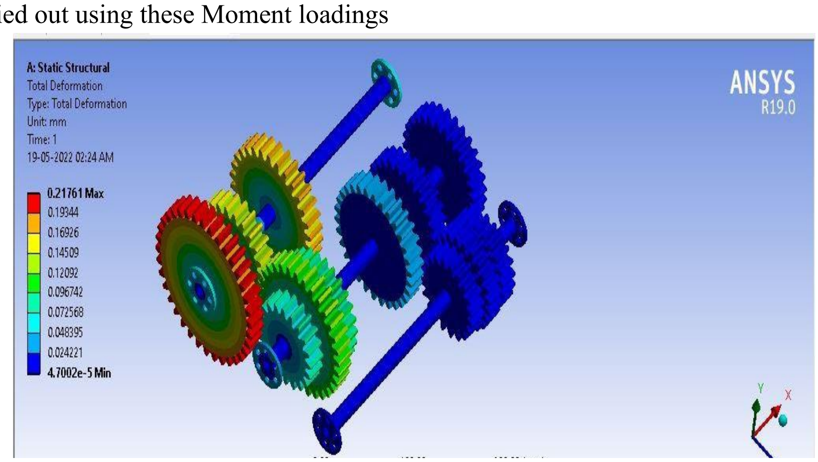

Figure.4 Deformation of Gear Box

The above Figure depicts the overall deformation of the Gear Box when a torque load is given to the face of the Input Gear; the red region represents the highest deformation, while the blue area represents the least deformation. As there is no support at the tip of Gears, maximum deformation takes place there. As a result, the Gear is more likely to bend at the tip first. The hub of the Gear shows minor deformation, as may be seen in the image above. The maximum deformation is 0.21 mm in total (Figure 5).

Stresses on gear box

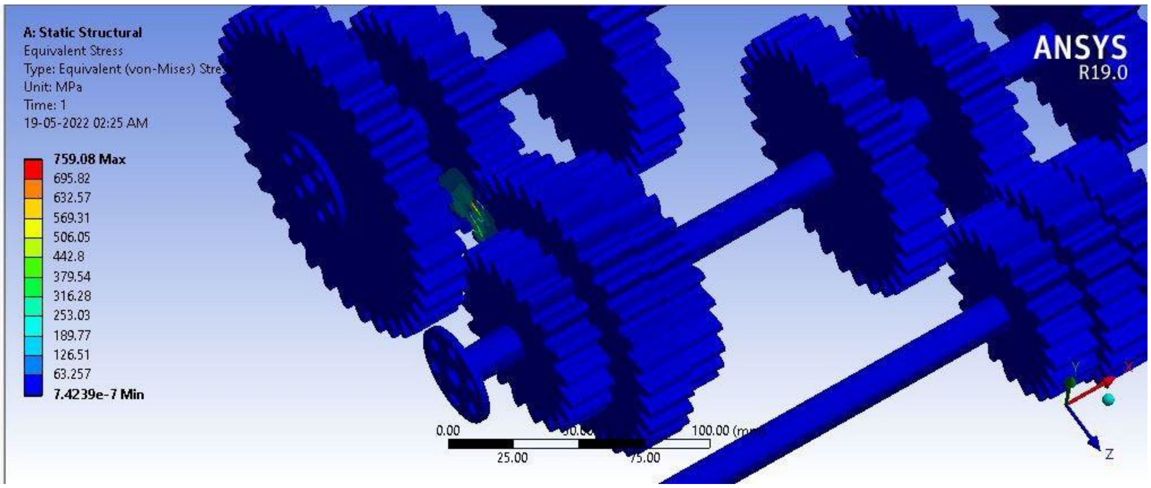

Figure 5. Stress on Gear Box

The graphic above depicts the stresses on the Gear Box when the maximum torque is applied. The colors blue and red represent minimal and maximum stresses, respectively. Minimum stresses occur throughout the Blade. At the interface between Gear 3 and Gear 4, there is larger stress. The complete portion is within the design parameters. However, the highest stress is concentrated in the Blade's sharp corners (Figure 6).

Elastic strain on gear box:

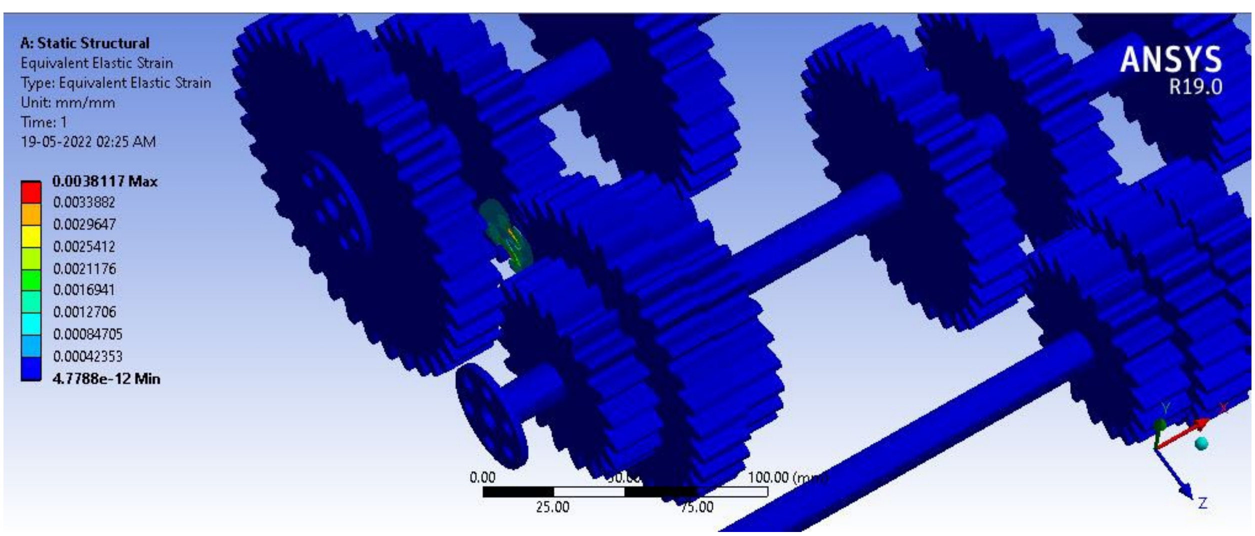

Figure 6. Elastic strain on Gear Box

The graphic above depicts the elastic strain on the Gear Box when the maximum torque is applied. The colors blue and red represent minimal and maximum strains, respectively (Table 3).

Table 3. Results of gearbox

Gear material	Von –mises Stress (MPa)	Deformation(mm)	Elastic strain
Carbon steel	759.08	0.21761	0.00381117

6. Conclusion

Lastly, it concluded that as per the design criteria, it has designed the gearbox and the design made by us is safe and satisfactory and can be proceeded with the production process. Also, the stepwise solution of the present work would be beneficial as per an aspect of time and reducing complexity for designing the gearbox. The ray diagrams are used to make the design more feasible concerning the number of teeth used in gearbox and transmission ratio. The analysis shows that the gearbox can carry maximum stresses and deformation under the safety zone. Based on the results, spur gear with a higher module is preferred if a large amount of power is required to transmit.

References

A.Y.V. Gopi Krishna, R.V. Kiran “Design and Analysis Of A Two Stage Reduction Gearbox” International Research Journal of Engineering and Technology (IRJET) Volume: 06 Issue: 12. 2019.

Ujjayan Majumdar, Sujit Maity, Gora Chand Chell, “Design and Analysis of Six Speed Gear Box”, International Journal of Research in Engineering, Science and Management Volume-1, Issue-9,. 2018.

Heel Patel, Dhruv Wadhwa, Harsh Patel, Parth Trivedi, Jay Mandalia, “Design & Manufacturing of Reduction ”,International Journal of Research in Science, Engineering and Technology,. ,2018.

Francesca Cura, “Method for calculating a global dynamic factor KAV in gears subjected to variable velocity and loading conditions”, 7th International Conference on Fatigue Design, Fatigue Design, 29-30. 2017.

Neeraj Patel ,Tarun Gupta ,Aniket Wankhede ,Vilas Warudkar Design and Optimization of 2-Stage Reduction Gearbox” International Journal of Engineering Development and research, Volume 5, Issue 2. 2017.

Muhammad Irfan “Modelling and optimization of gear shifting Mechanism” Application to heavy vehicles transmission systems -Thesis for Licentiate Of Engineering no 2017:01 ISSN 1652-8565. ,2017.

Rahi Jain and Pratik Goyal “Design and analysis of gear-box using spur gear and eliminating the differential unit” International Journal of Mechanical Engineering and Technology (IJMET)Volume 7, Issue 6, 2016.

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