Designing of a 5 Speed Sliding-mesh Gearbox Prototype

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Abstract — A gear box is very necessary to drive any vehicle and this is about the five speed manually operated sliding-mesh gearbox. The objective of this task is to prepare the assembly and working mechanism of a gearbox and to observe speed variations and actual working of gears by shifting gears. The transmission consists of gear train with different sizes of gears. The main aim was to study concept of working of manually operated Sliding-mesh gearbox consists of six gears including a reverse gear. For this, the design of spur gear was done as per design procedure and observed mechanical drive. The design procedure was followed as per machine design subject using design data book. All gears were designed and CAD modelling was done by using SOLIDWORKS software. The material selection is done on the basis of availability and cost of material and fabricated gearbox.

Keywords: Gears, Gear Design, Gear-Train, CAD Modelling

I. INTRODUCTION

The Gear Box is a mechanical device which is widely use in Automobile vehicles. The Gearbox is the device by which we get required torque and speed on required conditions. Gears box is assembly of different size of gears mounted on various shaft. It is used to transfer the energy from one rotating power source to another, mostly used in the automobile industry. As the speed of the shaft increases, the torque transmitted decreases and vice versa. Multi-speed gearboxes are used in applications which require frequent changes to the speed/torque at the output shaft. Gearboxes work on the principle of meshing of teeth, which result in the transmission of motion and power from the input source to the output.

Transmission of a gearbox: A transmission or gearbox provides speed and torque conversions from a rotating power source to another device using gear ratios. The transmission reduces the higher engine speed to the slower wheel speed, increasing torque in the process. A transmission will have a multiple gear ratios, with the ability to switch between them as speed varies. This switching may be done manually, or automatically. Directional (forward and reverse) control may also be provided. Most modern gear boxes are used to increase torque while reducing the speed of a prime mover output shaft, and this reduction in speed will produce a mechanical advantage, causing an increase in torque.

II. OBJECTIVE

The main aim was to study concept behind working of manually operated 5 speed Sliding-mesh gearbox. The aim was to design and fabricate a prototype and working model of gearbox to show its actual working. This project can help's us for better understanding of gearbox and shows how gears are meshes during the shifting of gears. It also shows changes in wheel rpm after shifting of gear. The project is made for the study purpose.

III. LITERATURE REVIEW

A.Y.V. Gopi Krishna, R.V. Kiran [1] (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 Magumdar, Sujitb Maity [2] (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 Patel, Harsh Patel [3] (2018) presented that, gear is a machine part having a clogs which contact with other toothed part in order to transmit the torque. These 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.

Francesca Cura [4] (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 Patel & Aniket Wankhede [5] (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 Irfan [6] (2017) A study on the mechanism model 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 Jain and Pratik Goyal [7] (2016) It is shown that the spur gear is designed with software like Creo parametric and ANSYS. S 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.

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IV. PROBLEM IDENTIFICATION

Without a transmission, vehicle would be limited to one gear ratio, and that ratio would have to be selected to allow the vehicle to travel at the desired top speed. If somebody wanted a top speed of 80 km/h, then the gear ratio would be similar to third gear in most manual transmission vehicle. For example, if a driving using the third gear at initially there are no acceleration and the engine will start screaming. So, the transmission uses gears to make more effective use of the engine's torque, and to keep the engine operating at an appropriate speed. The gear system was designed for the smooth running of vehicle.

There are two types of the gear system available at vehicle. The first is manual and other-one is automatic. Therefore, for study purpose we made this project on manually operated sliding-mesh gearbox.

V. METHODOLOGY

A. Research Instruments:

This research utilized in quantitative and qualitative research methodology. The required instruments are used for the measurement and observation. Instrument used – Vernier calliper, measuring tape and tachometer etc.

B. Research Procedure:

Following are the stepwise procedure which we have conducted during working on project.

- Read articles and research paper for understanding working of gearbox. All studied research paper and articles are mentioned in Literature Review.
- Analysis the processes required as per data
- Designing of gear and shaft
- CAD modelling
- Material selection
- Market survey for the required equipment's
- Fabrication of gears
- Assembly of all gears, shaft and other required components.

C. Designing of Gears

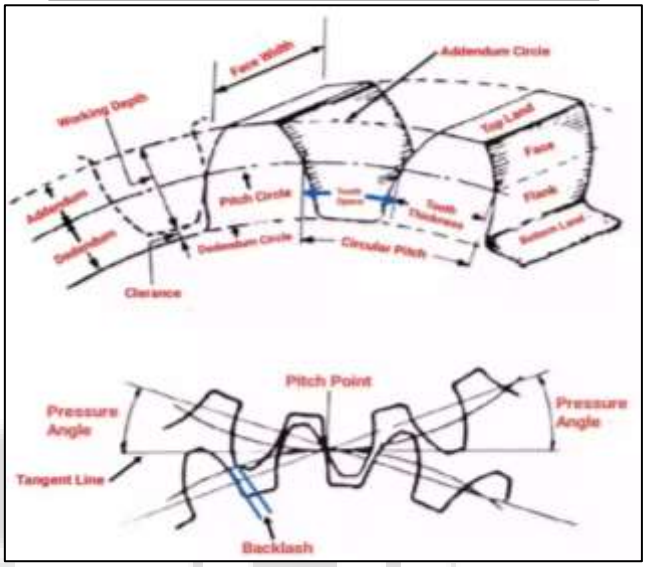
The designing of is done by the using design procedure observed from Machine design subject and use Design Data Book by B. D. Shiwalkar page no 164-171.

- The Spur Gear is use for the transmission in gearbox system.
- The design of gear is considered on gear train form during third gear. In this the rpm of motor shaft gear and wheel is same (60 rpm).
- The required assumptions are taken during designing of gear drive.

D. Spur Gear Terminology

Spur gears are gears which have vertical upright teeth perpendicular to the radial axis of the Gear wheel. The following figure illustrates the terms and notations associated with a spur gear.

Spur Gears are used to transmit power and motion between parallel axes or shafts.



- Some terms associated with spur gears:
  - Module is the ratio of pitch circle diameter in mm to the number of teeth in the same gear.
  - Pitch is a measure of the tooth spacing and is expressed in several ways.
  - Circular Pitch (pc): It is a direct measure of the distance from one tooth centre to the adjacent tooth centre. It is one of the most widely used terms in gearing.
  - Diameter Pitch pd: The ratio of number of teeth to the pitch circle diameter in inches is called the diameter pitch.
  - Pressure Angle: The angle between the line of force between meshing teeth and the tangent to the pitch circle at the point of mesh is known as pressure angle.

*Gears must have the same module and pressure angle to mesh without interference.

E. Design Procedure:

Assumptions taken-
Rpm of D.C Motor and Gear1 (N_1) – 60 rpm
Rpm of wheel shaft gear (N_2) – 60 rpm
Torque produced by motor shaft (T) – 38 kg.cm
$= 38*9.81*10^{-2} = 3.7278$ Nm.
$\Theta = 20°$ full depth teeth of spur gear
Gears consists of same no of teeth

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Procedure :-
Rated Power,

$$P_r = \frac{2\pi N1T}{60}$$

$$P_r = \frac{2\pi \times 60 \times 3.7278}{60}$$

P_r = 23.42 w
Velocity ratio $V_R = N_1/N_2 * t_1/t_2 * Dp_1/Dp_2$
$V_R = 60/60 = 1$

Design Power
$P_d = P_r * K_1$ …DB/164 T- XVI1
Where, K_1 = Load factor …DB/166 T- XVI2
Considering Medium shock 3 hr/ day
$K_1 = 1.25$

$P_d = 23.42*1.25$
$P_d = 29.275$ w

Static Condition
$F_t \leq F_B$

Tooth Load, F_t
$F_t = P_d / V_p$ …DB/164 T- XVI1
Where, V_p = Pitch line velocity, m/sec

$$V_p = \frac{\pi \times Dp_1 \times N_1}{60 \times 10^3}$$

$Dp_1 = m * t_1$ Assume teeth $t_1 = 30$
$Dp_1 = 30(m)$

$$V_p = \frac{\pi \times 30(m) \times 60}{60 \times 10^3}$$

$V_p = 0.0942(m)$ m/sec
$F_t = 29.275 / 0.0942(m)$

$$F_t = \frac{310.77\ N}{(m)} \quad (1)$$

Bending Strength by Lewis equation, F_B

$F_B = S_o * Y * b * m * C_V$ …DB/164 T- XVI1
Where, S_o = Basic strength, mpa
S_o = 45 Mpa (Polyacetal POM Material is used)
C_V = Velocity factor
= 0.3 (assumed)
b = Face width of gear, mm
= 10(m) (assumed)
Y = Modified Lewis form factor
m = Module, mm

Y = 0.485 – 2.87
t_1 …DB/167 T- XVI5
Y = 0.485 – 2.87
30
Y = 0.3893

$F_B = 45 * 0.3893 * 10(m) * (m) * 0.3$
$F_B = 52.55(m)^2$ ……(2)

From eq ① & ②
$F_t = F_B$

$$\frac{310.77}{(m)} = 52.55(m)^2$$

$$\frac{310.77}{52.55} = (m)^3$$

m = 1.808 ≈ 2 mm …DB/169 T- XVI7
preferred module size = 2 mm

* Standard Dimensions
Pitch Circle Diameter of both gears,
Dp_1 & Dp_2 = 30(m) = 30*2 = 60 mm
Pitch line velocity, V_p = 0.0942(m)
V_p = 0.0942*2 = 0.1884 m/sec
Face width of gear, b =10(m) = 10*2
= 20 mm
Velocity factor, $C_v = \frac{0.75+0.25}{1.0+V_p}$
C_v = 0.881
…DB/166 T- XVI3

$$F_t \frac{310.77}{(m)} = \frac{310.77}{2} = 155.385\ N$$

6. $F_B = S_o * Y * b * m * C_V$ = 45*0.3893*20*2*0.881
F_B = 617.35 N

$F_t < F_B$
(Design safe)

Check for Standard face width
8.5(m) < b < 12.5(m)
8.5*2 < b < 12.5*2
17 < 20 < 25
(Design safe)

Wearing condition
$F_d \leq F_w$

Dynamic Load, F_d, N

$$F_d = F_t + \frac{21 V_p (Ceb + F_t)}{21 V_p + \sqrt{Ceb + F_t}}$$ …DB/167 T- XVI5

Where, C = Deformation factor, XVI-4
e = Error in profile, mm figure below
e = 0.024 mm

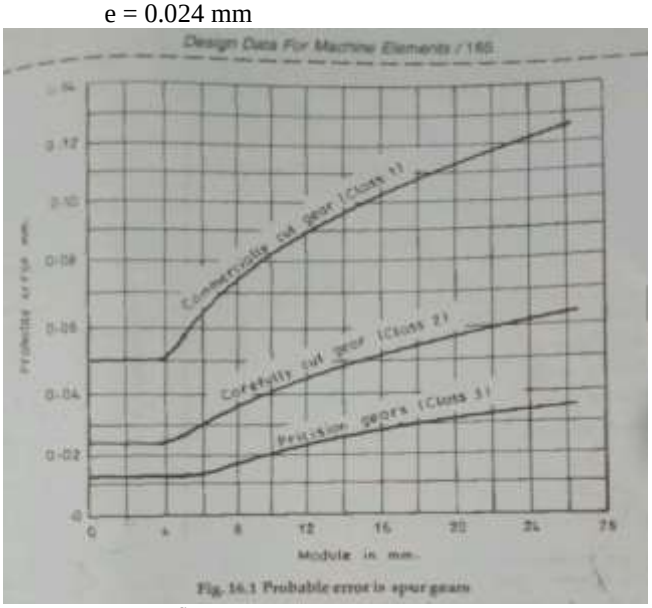

Fig. 16.1 Probable error in spur gears

$$C = \frac{a}{1/E1 + 1/E2}$$ ….DB/167 T-XVI4

Where, a = 0.111 for 20° full depth
E1 & E2 = Young's modulus for gear

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= 3150 mpa

$$C = \frac{0.111}{1/3150 + 1/3150}$$

C = 174.285 mpa

$$F_d = \frac{155.385 + 21 \times 0.1884(174.825 \times 0.024 \times 20 + 155.385)}{21 \times 0.1884 + (174.825 \times 0.024 \times 20 + 155.385)^{1/2}}$$

F_d = 183.91 N .....(3)

Limiting Wear strength F_w , N

$F_w = Dp_2 * b * K * Q$ ....DB/164 T- XVI1

Where, K = Load stress factor

Q = Size factor,

$Q = 2 * t_2 / t_2 + t_1$ ....DB/164 T- XVI1

$Q = 2 * 30 / 30 + 30 = 1$

$F_w = 60 * 20 * K * 1$

$F_w = 1200(K)$ N .....(4)

From eq③&④

$F_d \leq F_w$

$F_d = F_w$

$183.91 = 1200(K)$

$K = 0.153$

Back lash = 0.06 * module

= 0.06*2 = 0.12

Root Clearance = 4.5 * back lash

= 4.5 * 0.12 = 0.54

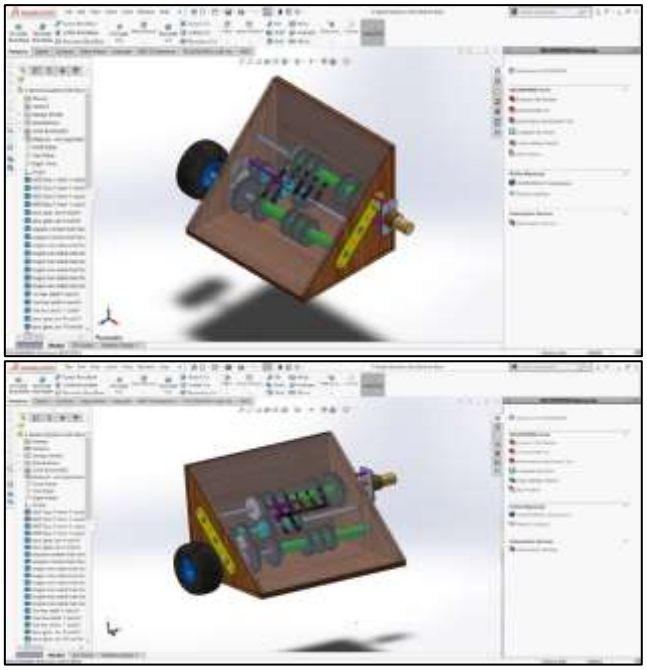
Specification Chart

Sr. No	Description	Gear 1 & 2
1	Material	Polyacetal
2	Strength, S_o	45 mpa
3	Young's Modulus, E	3150 mpa
4	Pitch Circle Dia.Dp_1 & Dp_2	60 mm
5	No. of teeth t_1 & t_2	30
6	Module, m	2 mm
7	Face width, b	20 mm
8	Pitch velocity, V_p	0.1884m/sec
9	Liew equation, Y	0.3893
10	Velocity factor, C_v	0.881
11	Back lash	0.12
12	Root Clearance	0.54

On the basis of this, gear we design other gears as per required RPM and gear ratio. Module and Pressure angle is same.

VI. CAD Modelling

The CAD Modelling is done by using SOLIDWORKS software. It is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) application published by Dassault System. SOLIDWORKS is used to develop mechanical systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modeling, feasibility assessment, prototyping, and project management.



VII. Advantages

- Due to the varying torque ratios provided by this gearbox, the automobile vehicle is made to go to the hill stations which was not possible earlier.
- Time taken to reach the destination was decreased as overall speed of the vehicle increased due to the high-speed ratios provided by it.
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VIII. Applications

- The main application of gearbox is in Automobile vehicle.
- Machine tools.
- Industrial equipment.
- Steel Industry.

IX. Conclusion

We have successfully studied the concept and Working of Sliding-mesh gear box. We have made an attempt to design a 5 Speed Gearbox for making a working prototype. In this process we have designed Spur Gears. We also done CAD modelling in SOLIDWORKS software and further made the prototype and successfully achieved the working result.

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