Design and Analysis of Two Stage Reduction Gearbox

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ABSTRACT: Gearbox designed is safe affordable of performance efficient with respective speed and torque required to clear the dynamic event satisfactorily. It is 2 stage reduction gearbox along with reversal transmission system induced with efficient output and comparatively lesser weight. All this achieved by studying the gear ratio and various resistance acting on vehicle calculation of gear, shaft, bearing etc. with respect to force, speed, density, and other parameters. It also required specification of vehicle, engine and CVT. The design and its simulation is covered by SOLIDWORKS and ANAYS.


1. INTRODUCTION

Vehicle transmission is to convert the energy provide by engine into traction of vehicle as efficiency to overcome the speed, thrust, bumps, climbing, etc. By simulation of adjustment of gear speed, acceleration of vehicle, CVT reduction ratio, weight and fuel consumption. The reverse gear system to ensure the vehicle to get rid during uneven situation where vehicle is restricted to move due to muddy terrain to achieve all the dynamic events and endurance race.

2. LITERATURE SURVEY

Design and analysis of two stage reduction of gearbox for all terrain vehicles(OCT-2010)¹ The parameters such as various road resistance, air resistance, gradient resistance etc can affect the reduction ratio of gearbox.

Design and development of trans system for an ATV(May-2017)² To increase the efficiency with respective materials and to achieve required reduction ratio with constant and continuous power transmission.

Design of reverse gear mechanism in two wheeler for physically challenged person(JULY-2016)³ We studied reversed mechanism which consists of 3 shaft with keyway cutting and four Spur gear mechanism shifted from R-L moves in forward direction and L-R reverse direction for physically challenged person.

Design and manufacturing of 2-stage speed reduce for BAJAATV(OCT.-2017)⁴ The parameters such as various road resistance, air resistance, gradient resistance etc can effect the reduction ratio of gearbox.

3. PROBLEM DEFINITION

1. Lack of reversal system in two stage reduction gearbox.
2. In order to tackle heavy weight of the existing reversal system in gearbox.
3. Reduction ratio of gearbox is high. The current reduction ratio is 12.89.
4. Costly
5. Space

4. OBJECTIVE

1. To design and optimize reversal gearbox for all-terrain vehicle.
2. To reduce the heavy weight of the gearbox comprising of reversal system in vehicles such as auto rickshaw, wheelchairs.
3. To reduce the reduction ratio of the gearbox in reverse system.
4. To reduce the cost of the the gearbox by using efficient materials.
5. To reduce the space required for the gearbox by designing an integrated design model with respect to the other components in the assembly of the vehicle.

5. REQUIRED SPECIFICATION

<table>
<thead>
<tr>
<th>INPUT POWER</th>
<th>7.5kw</th>
</tr>
</thead>
<tbody>
<tr>
<td>HORSE POWER</td>
<td>10hp</td>
</tr>
<tr>
<td>MAXIMUM TORQUE</td>
<td>20Joules=20Nm</td>
</tr>
<tr>
<td>ENGINE SPEED(RPM)</td>
<td>3600rpm</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
</tr>
<tr>
<td>WHEEL SPEED</td>
<td>ph</td>
</tr>
<tr>
<td>MAXIMUM OUTPUT TORQUE</td>
<td>560Nm</td>
</tr>
<tr>
<td>ENGINE IDLE SPEED</td>
<td>1750RPM</td>
</tr>
<tr>
<td>TYRE DIMENSION</td>
<td>22×8×12(INCHES)</td>
</tr>
<tr>
<td>MAXIMUM WEIGHT OF VEHICLE</td>
<td>220KG</td>
</tr>
<tr>
<td>OPERATING TEMPERATURE</td>
<td>108°</td>
</tr>
<tr>
<td>WEIGHT OF DRIVER</td>
<td>50KG</td>
</tr>
<tr>
<td>CVT REDUCTION RATIO</td>
<td>Min-3 OR Max -0.5</td>
</tr>
</tbody>
</table>

### 7.1 DESIGN OF GEAR

**MATERIAL SELECTION:- WHITE CAST IRON**

- Density = 7.77 × 10³ kg/cm³
- Young’s modulus = 175 × 10³ N/mm²
- Tensile Strength = 700 N/mm²
- BHN = 415, FOS = 4
- Poisson Ratio = 0.27-0.28
- Bulk Modulus = 58-107 * 10³ N/mm²
- 1. Bending Stress = 700/FOS = 1750 kgf/cm²
- 2. Crushing Stress = 2.8(BHN)-70 = 10920 kgf/cm²

### 6. GEAR RATIOS CALCULATION

1. Rolling Resistance = Weight × Rolling Resistance Coefficient
   \[ Fr = 270 \times 9.81 \times 0.16 = 423.92 \text{ N} \]
2. Gradient Resistance = Weight × Gradient Coff.
   \[ Fa = 270 \times 9.81 \times 0.60 = 1589.22 \text{ N} \]
3. Total Resistance (TR) = Fr + Fa = 2013.012 N
4. Reactive Torque On Wheels = TR × TYRE RADIUS
   \[ = 2013.012 \times 0.294 = 562.435 \text{ Nm} \]
5. Reduction Ratio Is Given By:
   Reactive Torque On Wheels = Engine torque × CVT Ratio × reduction ratio
   \[ 562.435 = 18.5 \times 3 \times R.R \]

### 7. GEAR

A gear is a rotating machine part having teeth which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque and direction of power source.

#### GEAR 2
- PCD = 90mm
- \( Z_2 = 36 \)

#### GEAR 3
- PCD = 250mm
- \( Z_3 = 100 \)

#### GEAR 4
- PCD = 50mm
- \( Z_4 = 20 \)

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### CALCULATION FOR FORWARD MOTION OF GEARBOX: FIRST STAGE

**A) Specification:**

**Gear 1 module(m) = 2.5 \( Z_1 = 12 \)**

1. Blank Diameter = \( m(Z+2) = 2.5(18+2) = 35 \text{ mm} \)
2. Pitch Circle Diameter \( D = mz_1 = 30 \text{ mm} \)
3. Addendum = 2.5mm
4. Dedendum = 1.25×m = 3.125mm
5. Tooth Depth = 2.25×m = 5.625mm
6. Clearance = 0.625mm
7. Radius Fillet \( R = 0.4 \times m = 1 \text{ mm} \)
8. Diometrical Pitch \( P_d = Z_1/D = 0.4 \text{ mm} \)
9. Circular Pitch = \( II/D/P_d = 234 \text{ mm} \)
10. Root Diameter = \( Z_2/P_d = 25 \text{ mm} \)
11. Base Diameter = \( D \times \cos 20 = 28.19 \text{ mm} \)
12. Circular Thickness = 1.57/Pd = 3.925mm

**B) GEAR INDEXING CALCULATION:-**

1. Index Crank 1 Moment = \( 40/Z_1 = 3.33 = 4 \)
2. No Of Rotation Required To Cut One Tooth = \[ 40/Z_2 = 1.11 = 1, 40/Z_3 = 0.4 = 0.5 \]
C] FORCE ANALYSIS:

D₁=30mm, D₂=90mm, D₃=250mm
N₁=1200rpm N₂=400rpm N₃=148rpm
Therefore V=πDN/60
V₁=2m/s V₂=2m/s V₃=2m/s

For Gear 1:
T₁₁=P/V₁=7457/2.83=3728.5Nm
V₁=V₂=V₃. Therefore T₁₂=T₁₃=3728.5Nm
Radial force
R₁₀=T₁₀×tan20=1357.09N
Resultant force (F)
F₁=T₁/ cosa=2634.98/ cosa=3967.7N
F₁=F₂=F₃=3967.7N

D] Design Procedure for spur gear based on gear life power=7.5kw=7457watts

N₁=1200rpm N₂=400rpm N₃=148rpm
P=2πNT/60
T₁=59.34 T₂=197.80 T₃=593.40

CHECKING STRESS:
1. Bending Stress =700/FOS=1750kgf/cm²
2. Crushing Stress=2.8(BHN)-70=1052.8 N/mm²
3. Design Torque[Mt]=KₓKₐM₁
Mₙ=97420N/mm² ..........KW=P×S.F=8.9kw
Therefore Mₙ=72646 Nmm

[M₁]=94439.8 Nmm
4. Centre Distance[a]=(m₁Z₁+ Z₂)/2=60mm
5. Selection of Teeth on Pinion Z₂=36
Therefore Z₂=ix Z₁
Z₁=36/3=12 teeth.
6. Calculation of Module (m)=2Mₙ/ (Z₁+Z₂)=2X60/12=5mm
7. Calculation of b, d, v, φp
Face width(b)= φp×a=0.3×60=18mm

Pitch Diameter of Pinion (d₁)=mZ₁=30mm
Pitch Velocity (v)=2m/s
φp=b/ d₁=0.65

1. Checking for Bending σ₁
σ₁=\[Mt\]/amby=136.01 N/mm²

2. Checking for Crushing
σ₂=0.74×1/3×√F × Mt =91.304 N/mm²

Hence design is safe

Similarly for: - SECOND STAGE.

CALCULATION FOR REVERSE MOTION OF GEARBOX

MATERIAL SELECTION FOR REVERSE GEAR:

Material=40Ni10CrMo6
Density=7.8-8 kg/cm³
Young’s Modulus=215×10⁶N/mm²
Tensile Strength=1350N/ mm²
BHN=401, FOS=5
Poisson Ratio=0.3
Bulk Modulus=140×10⁶N/mm²
1. Bending Stress =1350/FOS=270N/mm²
2. Crushing Stress=2.8(BHN)-70=1052.8 N/mm²

NOTE:-Calculate the parameters for reverse motion of gearbox, mentioned below.

A] GEAR INDEXING CALCULATION:

B] FORCE ANALYSIS:

C] Design Procedure for spur gear based on gear life power=7.5kw=7457watts

CHECKING STRESS:

7.2 DESIGN PROCEDURE BASED ON AGMA METHOD:

1ST STAGE AND 2ND STAGE.

A]Material Selection :- white cast iron

B]Calculation of Z₁ and Z₂
Z₂=36 teeth Z₁=Z₂/1, therefore Z₁=12 teeth

C]Tangential Load (Wt):-P×K₀/V₁, V₁=πDN/60
Therefore V₁=2m/s and Wt=7500N
Critical Dynamic load \( W_d \) = \( W_t \times C_v \)

\[ C_v = \frac{6 + V_m}{6} = 1.471 \]

Therefore \( W_d = 11032.5 \) N

**Beam Strength** \( W_{bs} \) = \( \sigma_y \pi b y \), where \( y = 0.4568 \)

by calculation from data book.

\( W_{bs1} = 286984.5 \) N, \( W_{bs2} = 308508.32 \) N

\( W_{bs3} = 313518.18 \) N

**Wear Resistance** \( W_w \) = \( Q b d K \)

\[ Q = \frac{2i}{(i+1)} = 1.5 \]

\( d_1 = 30 \) mm, \( b = 25 \) mm

\[ K = \frac{2 \sin \alpha}{(2/E)} / 1.4 = 3.32 \]

\( W_w1 = 3735 \) N, \( W_w2 = 11205 \) N, \( W_w3 = 31125 \) N

Similarly:- FOR REVERSE

**7.3 ANYSIS OF STAGE 1 AND 2**

8. SHAFT-

A shaft is a rotating member/machine element, which is used to transmit power from one place to another.

**8.1 DESIGN OF SHAFT**

**SHAFT 1:**

1. Radial load on tooth surface (pinion) \( W_r \)

\[ W_r = W_t \times \tan \phi = 7500 \times \tan 20 = 2729.7 \] N

2. Bending moment on shaft:

\[ M = W_r r = 163788 \] Nmm

3. Twisting moment on shaft: \( T = W_r d / 2 = 112500 \) N

4. Equivalent torque on shaft:

\[ T_e = \sqrt{m^2 + T^2} = 198702.68 \] Nmm

5. Shaft diameter \( d \) = \[ 3 \sqrt\frac{T_e \times 16}{\pi \times 4} = 19 \] mm

**FIG.8.1.1 SHAFT FIG.8.1.2 SLINDING GEAR SHAFT**

**8.2 ANALYSIS OF SHAFT:**

**FIG.8.2.1 SHAFT 1 SIMULATION**
9. BEARING –

Mechanical bearings are used between two automotive parts that allow for rotation or linear movements. These bearings will enhance the vehicles performance, bear heavy loads and reduce friction.

9.1 BEARING SELECTION:

1. Resistance force(R) = \sqrt{T^2 + R^2} = 5634.25N

2. \( L_{hr} = \frac{L_{0h} \times b \times N \times 60}{10^6} \) consider where \( L_{0h} = 92\% \) surivial, \( L_{hr} = 1000 \)

Therefore \( L_{0h} = 72\)mr

3. \( \frac{L_{08}}{L_{10}} = \left( \frac{1}{T_{10}} \right)^{\frac{1}{b}} \) therefore \( L'_{10} = 85.73\)mr

4. ‘c’ Required = \( C = \left( \frac{1.22}{T_{10}} \right)^{\frac{1}{3}} \times P \)

Therefore \( C = 11813.42N = 1181.342kgf \).

B.NO6304

(see page 5837 for rest of the calculations)

Bearing no. 3, 5 = 6405

10. CASING - The gear housing is the casing that surrounds the mechanical components of a gear box. It provides mechanical support for the moving components.
10.1 Casing Model

![Casing and Analysis of Casing](image)

**FIG 10.1.1 CASING AND ANALYSIS OF CASING**

11. Design Concept

In forward transmission the power is driven to input shaft, through which it drives \( G_1 \) in clockwise direction which drives \( G_2 \) in anticlockwise direction mesh with \( G_3 \), so \( G_2 \) drives \( G_3 \) in clockwise.

In Reverse transmission, \( G_5 \) power is driven to input shaft through which it drives \( G_1 \) with \( G_6 \). The lever connected to \( G_1 \) toward to mesh with \( G_4 \). Here \( G_4 \) rotates clockwise direction whereas it drives \( G_2 \) in anticlockwise direction.

![Forward Drive](image) ![Reverse Drive](image)

**FIG.11.1 FORWARD DRIVE**  **FIG.11.2 REVERSE DRIVE**

12. Solidwork Model

![Gear System Gearbox Assembly](image)

**FIG12.1**  **FIG.12.2 GEAR SYSTEM GEARBOX ASSEMBLY**

13. Conclusion

Our project "Design and Analysis of Two Stage Reduction Gearbox" gave us an opportunity to learn multiple knowledge of upgrading the problem solving and decision making concept in every steps of the project.

Such an mechanism of gearbox, its component and the parameters required for Designing as well as various boundary condition to be applied an simulation.

The project is mainly introduced to achieve the forward as well as reverse drive with an optimal requirement of speed and torque to enhance in the dynamic events.

These project will be very useful in setting a very efficient transmission drive

14. References


