Design, Analysis and safety norms of automatic power transmission in four wheeler

Project for the course - ME3090
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GROUP B

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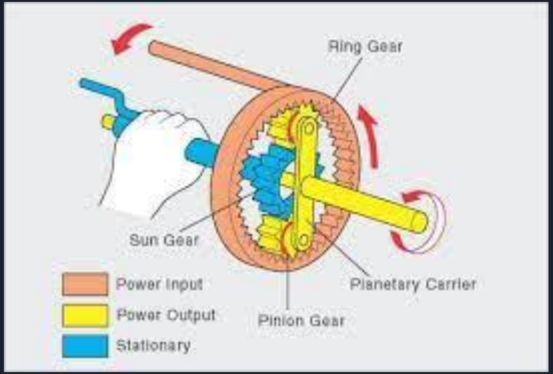
Abstract

- Our focus is to design a transmission system which will give optimum power output with minimum maintenance and less cost.
- This presentation will help you in selecting and differentiating between manual transmission and automatic transmission.
- We have included detailed information about the working, design consideration and mathematical analysis of transmission system of an all terrain vehicle
- It will also give you the information about different resistance available to an ATV and how to consider these resistance during design of transmission

Automatic Power Transmission

- An automatic transmission (commonly "AT" or "Auto") is an automobile gearbox that can change gear ratios automatically as the vehicle moves, freeing the driver from having to shift gears manually
- Automatic Transmissions have various modes depending on the model and make of the transmission. Some of the common modes are:
    - Park Mode(P)
    - Reverse Mode(R)
    - Neutral/No Gear Mode(N)
    - Drive Mode(D)



Other types of Transmission

- The other two transmission systems we can consider are manual and CVT
- The first transmission invented was the manual transmission system. The driver needs to disengage the clutch to disconnect the power from the engine first, select the target gear, and engage the clutch again to perform the gear change.
- The Continuously Variable Transmission (C.V.T.) is a transmission in which the ratio of the rotational speeds of two shafts, as the input shaft and output shaft of a vehicle or other machine, can be varied continuously within a given range, providing an infinite number of possible ratios

Disadvantages of MT and CVT

- One of many disadvantages in manual transmission is, if the clutch pedal is not properly pressed the vehicle can stall. The presence of a clutch makes the gearbox larger and a bit heavier.
- It takes time for a new driver to get used to the skill of engaging clutch, shifting gears and disengaging.
- Some of the disadvantages of CVT include overheating, slipping, sudden loss of acceleration and shuddering
- Since CVTs depend on the belts to operate, if these suffer from excessive stretching or too much wear, the transmission can completely fail.

Design Considerations

When a vehicle moves on a certain terrain then the vehicle undergo different dynamics consideration and hence collectively termed as vehicle dynamics. If the air drag is neglected at normal speed, then the load on the wheels is the main force acting on the vehicle.

Mass of the vehicle = 213 kg

Mass of the driver = 70 kg

Static coefficient of friction ($\mu 2$) = 0.9

The height of the center of gravity (h) = 50.8 cm

Wheelbase = 129.54 cm

Distance of the C.G from the front wheel center (a1) = 82.55cm

The distance of the C.G from the rear wheel center (a2) = 46.99cm

Tire dimensions (in inches) = 22*7*12 (front) & 23*7*12 (rear)

Design of Gears

- The material used for gears should have high tensile strength, high endurance strength, low coefficient of friction and high manufacturability.
- We choose 8620 Steel with the following properties :
  - S_{ut} = 800MPa S_{yt} = 600MPa
  - BHN = 300
  - Elongation = 17%
  - Poisson's ratio = 0.25
  - Bulk modulus = 110GPa
- We assume the module of gears 1 & 2 is 2.5 and that of gears 3 & 4 is 3

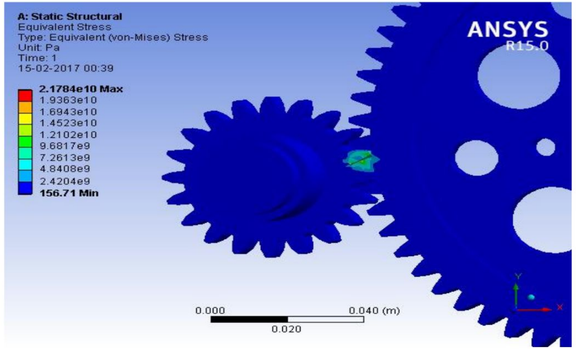


Fig- 5.5.1 Analysis of gear 1 and 2

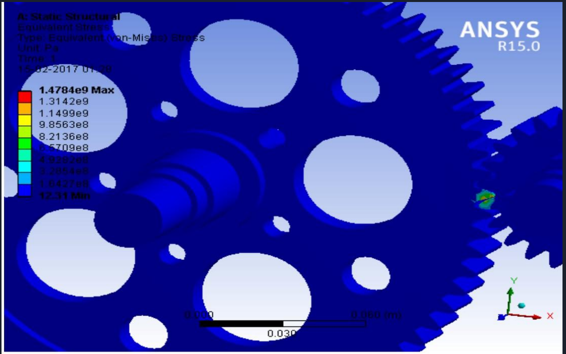


Fig-5.5.2 Analysis of gear 2 and 3

Fig 5.5.1&5.5.2, International Journal of Mechanical Engineering and Technology (IJMET) Volume 7, Issue 3, May–June 2016, pp.351–359.

Design of Gears

- Gear 1 rpm = 900 rpm
- Tangential velocity, v = πdN/60 =2356.2 m/s
- Tangential tooth load, WT=σ*CV*b*pc*Y
- Cv = Velocity Factor = 0.718
- b = Face Width = 25
- p = Circular Pitch = 7.3531
- Y = Lewis Form Factor = 0.1084
- WT = 4075.29N
- Power = 9.6Kw

- For Gear 3 rpm = 2700/ (3*3.15) =289.389 rpm
- v = πdn/60 = 1.0450 m/s
- Y = Lewis Form Factor = 0.114
- CV = velocity factor = 0.851
- B = face width = 30
- Pc = pitch circle diameter = 9.424
- WT = σ*cv*b*pc*y = 7314.17
- Power, p = 7.6 kW

Above value of power is larger than maximum power we are going to transmit which is 7.4kw. Hence the design is safe

Design of bearings

- Selection of bearing is based on the reliability. The criteria for selection is 90% reliability.
  - In our case the operation time is estimated to be 25000 hours(8hr/d).
- Since the axial load acting on the shaft are neglected and only radial forces are the primary concern for the gearbox gears functioning, Fa= 0. Therefore, the radial force acting on the gears is going to be divided into the two radial bearings and hence generating two reactions i.e. RA & RB.
  - At bearing A, R_A= 1050N. Now at bearing B, R_B= 2020N. Now axial thrust acting on the bearing F_a=0. For designing a bearing choosing greater load, therefore Rmax (F_R) = 2020N.
- Equivalent Dynamic Load, $F_{eff} = X_i*V*F_r + Y_i*F_a$. (F_r= Radial load. F_a= Axial load)

Design of bearings

- Let's choose the bearing to be Bearing No 6205.
- Dynamic load capacity, C = 14.3 KN
- Static load capacity, C_0= 7.8 KN
- For safety considerations 0.03*C< P < 0.1C
    - 0.03*14300< P <0.1*14300 = 429< P < 1430;
- F_{eff} = X* V* Fr = 0.56*1*2020 = 1131.20N
- Now the F_{eff} lies in the safe region hence the bearing chosen is justified.
- Life of bearing = $(C/F_{eff})^{a}$ * 10^6 / (60*900) = 41536 hours.

Shaft Design

- A shaft is a cylindrical object composed of either same material as that of gear or different materials depending upon the objective of usage.
- Design of shaft primarily involves in determining stresses at critical point in the shaft that is arising due to aforementioned loading
- Designing a shaft on the basis of strength following factors are considered: Torque, Bending moments, Axial loads.
- The shaft is subjected to a combination of torque and bending stress.
- Principal stresses are calculated.
- Different failure theories are used. Design of the shaft mostly uses maximum shear stress theory.

Shaft Design

$$\tau_{xy} = \frac{16T}{\pi d_0^3(1-k^4)}$$

$$\sigma_x = [\frac{32M}{\pi d_0^3(1-k^4)} \pm \frac{4\alpha F}{\pi d_0^2(1-k^2)}]$$

- τ_allowable=16/(πd_0^3 (1-k^4)) √((M+(αd_0^2 (1+k^2))/8)^2+T^2)
- Deflection in the shaft is proposed by eq.

  ϵI (d^2 y)/(dx^2)=Ra*x- 3061.6135*(x - 74.5)

Parameters	SHAFT 1	SHAFT 2	SHAFT 3
Diameter	17mm	25mm	45mm
Deflection	0.005mm	0.0021mm	0.0026mm
Angular deflection	0.008	0.0087	0.009695

FEM- Analysis

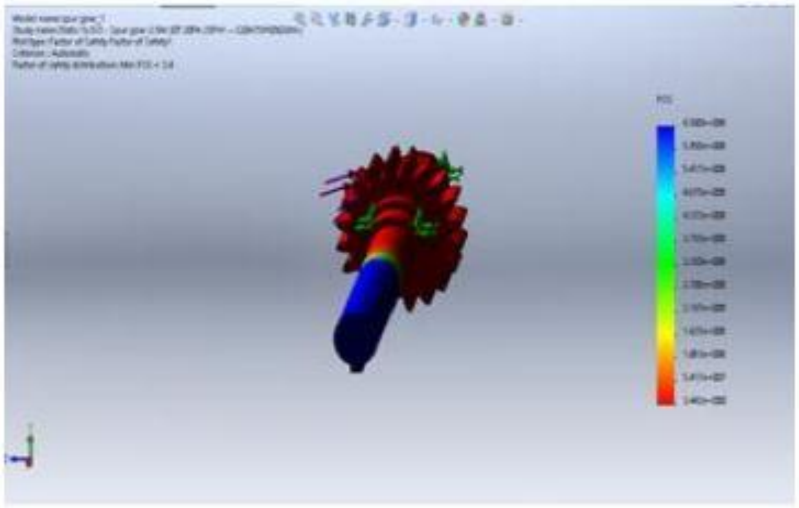


Fig-6.1 Analysis of shaft 1 on SolidWorks

Fig 6.1,International Journal of Mechanical Engineering and Technology (IJMET) Volume 7, Issue 3, May–June 2016, pp.351–359.

Fig-6.2 Analysis of shaft 4 on SolidWorks

Fig 6.2,International Journal of Mechanical Engineering and Technology (IJMET) Volume 7, Issue 3, May–June 2016, pp.351–359.

Safety

- Failure of any component or product or system before its time period is always unacceptable and hence in the engineering design the safety reliability of any system is invariably the principal technical objective
- The safety and reliability of the transmission system has been discussed based on failure criteria.
- The components most vulnerable to failure are :
    - Gear pairs
    - Shafts
    - Bearings

Safety(Contd.)

- Gear pairs
  - Failure is characterised by bending and surface wear
  - Suitable face width is calculated considering bending and surface wear.
  - From various data samples , we conclude that reliability of the gear train increases with increase in face with values

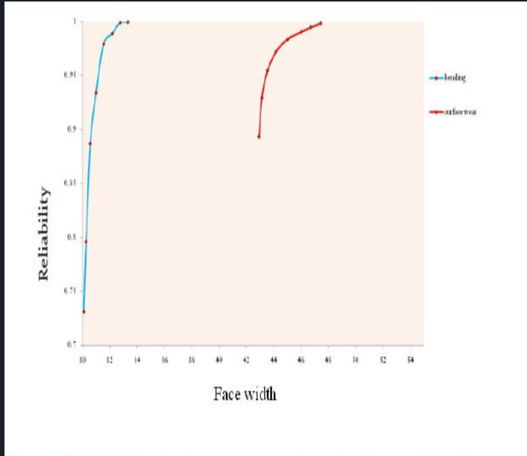


Fig.2: Reliability of Gear pair system Vs face width of gear

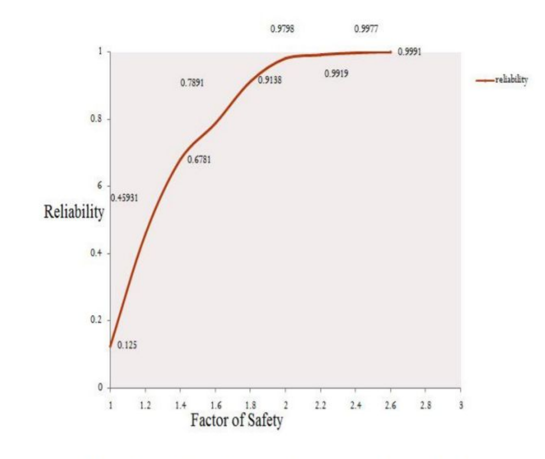


Fig.1: Reliability of Gear pair system Vs factor of safety

Figure 1&2,Journal of Reliability and Statistical Studies; ISSN (Print): 0974-8024, (Online):2229-5666 Vol. 5, Issue 2 (2012): 59-76

Safety(Contd.)

- Shafts
  - The transmission shafts are subject to bending and torsion
  - The diameter for shafts are calculated considering fatigue failure with maximum shear stress
- Bearings
  - For bearings the length of the roller of bearings is calculated considering contact stress developed between two cylinders.

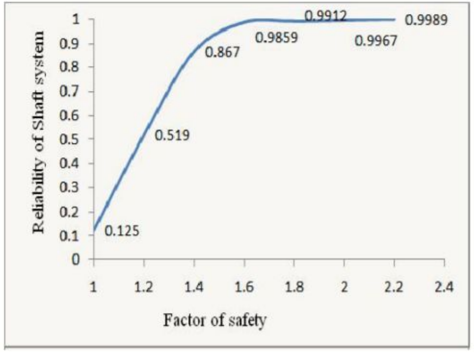


Fig.3: Reliability of shaft system Vs factor of safety

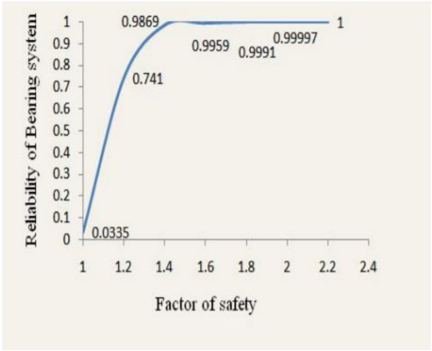


Fig.4: Reliability of bearing system Vs factor of safety

Figure 3&4,Journal of Reliability and Statistical Studies; ISSN (Print): 0974-8024, (Online):2229-5666 Vol. 5, Issue 2 (2012): 59-76

Safety(Conclusion)

- From data samples , we see that for a factor of safety of 1.0, the reliability of gear pair, shaft and bearing system is very less and hence the chance of failure is high.
- For gear pair systems, to have a reliability of 0.98 and above, the minimum factor of safety should be 2
  For shaft systems , factor of safety should be minimum of 1.6
  For Bearings, factor of safety should be minimum of 1.4
- As all these components are connected in series, to make a safe design for the entire system, the factor of safety should be kept above 2.5 for all three

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Thank You