Comparative Study of Hollow and Solid Shaft for the Application in Eight Speed Gear Box

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ABSTRACT *A gearbox is a mechanical device that is used to provide speed and torque conversions from a rotating power source to output shaft. Design of gearbox is to converts motor (1440) rpm into 8 different steps are 110,140,200,280,400,560,800 and 1120 rpm.*
For speed variation 12 gears and 4 shafts are used in which one input, output and two intermediate shafts. The input and output shaft we use hollow instead of solid for weight reduction purpose and also we have done analysis based on comparison of solid and hollow shafts. Further modification rim type gears are used instead of solid convention gear.

Keywords:

Analysis of Hollow shaft And Solid shaft

- Twisting moment or torque depends upon the distance from neutral axis to the outer most fibre in mm. So taking same weight f material the above dimension of a hollow shaft will be greater than a solid shaft. Now the torque produced in hollow shaft will be greater than the solid shaft. So hollow shaft is more preferable.
- We dont need mathematical proof for this just a simple common sense is enough.The hollow shafts can withstnad the same stress as that of solid shafts.In torsion the stress profile is a linear relationship with diameter.So the outermost surface or the outermost material of the shaft is the place where maximum stress is acting in torsion.To reduce the cost, the manufacturers prefer the hollow shaft rather than the solid shaft.so hollow shaft is better than solid shaft in terms of the cost.A solid shaft in bending or tensile or compressive forces will always be significantly stronger for the same material,dimensions and loading.
- In comparison to a solid shaft, a **hollow shaft is of less weight**, for a given length and diameter. This is pretty obvious and wont be requiring any further explanation. Moreover it's a good idea to go ahead with hollow shafts, if we our emphasis is on **weight reduction and cost-cutting.**
- **Hollow shafts are much better to take torsional loads compared to solid shafts**. As shown in the figure, shear stress in a "shaft subjected to torsion" varies linearly from zero at the center to the maximum at the boundary. Inside a solid shaft, most of the material experiences / carries a shear stress whose value is much below the maximum shear stress [Interior portion of the shaft]. But at the same they are adding to the weight, without contributing much to the capability of the shaft to carry torsional load.

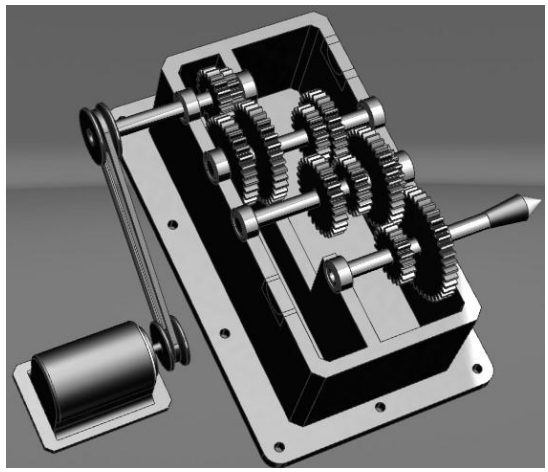

Figure 1 3D Model of 8 speed gearbox.

- The shaft used in gearbox is hollow shaft for input and output and solid shaft is intermediate for power transmission for gearbox. Designing of hollow and solid shaft as per below

  For solid shaft O.D=25.4 mm, gear pair Tp=20,
  Pinion width (b) =25.4 mm

- Normal load acting between tooth surface (Wn)

$$Wn = \frac{Wt}{cos\emptyset} = \frac{5730.44}{cos\ 20} = 6098.20\ N$$

- Weight of pinion

$$Wp = 0.00118 * Tp * b * m^2$$
$$= 0.00118 * 20 * 25.4 * 4^2$$
$$= 9.59104\ N$$

- Resultant load acting on pinion

$$Wr = \sqrt{Wn^2 + Wp^2 + 2Wn * Wp * cos\emptyset} = 6107N$$

- Bending moment on shaft

  Let take over hung of shaft is 100mm

$$M = Wr * 100 = 610700\ N$$

- Twisting moment on shaft

$$T = \frac{Wt * Dp}{2} = \frac{5730.44 * 80}{2} = 229127.6\ N * mm$$

- Equivalent twisting moment

$$Te = \sqrt{M^2 + T^2}$$
$$Te = \sqrt{610700^2 + 229217.6^2} = 652299.92\ N * mm$$

- Shear stress acting on shaft

$$Te = \frac{\pi}{16} * \tau * Dp^2 = 202.72\ Mpa$$

  For Hollow shaft O.D=25.4 mm, I.D=17.4 mm
  Gear pair Tg=32,
  Pinion width (b) =25.4 mm

- Normal load acting between Tooth surface (Wn)

$$Wn = \frac{Wt}{cos\emptyset} = \frac{5730.44}{cos\ 20} = 6098.20\ N$$

- Weight of pinion (Wp)

$$Wp = 0.00118 * Tp * b * m^2$$
$$= 0.00118 * 32 * 25.4 * 4^2$$
$$= 15.34\ N$$

- Resultant load acting on pinion (Wr)

$$Wr = \sqrt{Wn^2 + Wp^2 + 2Wn * Wp * cos\emptyset} = 6112.61N$$

- Bending moment on shaft (M)

  Let take over hung of shaft is 100mm

$$M = Wr * 100 = 611261.71\ N$$

- Twisting moment on shaft (T)

$$T = \frac{Wt * Dp}{2} = \frac{5730.44 * 128}{2} = 366745.60\ N * mm$$

- Equivalent twisting moment (Te)

$$Te = \sqrt{M^2 + T^2}$$

$$Te = \sqrt{611261.71^2 + 366745.60^2} = 712841.64\ N * mm$$

- Shear stress acting on shaft (τ)

$$Te = \frac{\pi}{16} * \tau * \frac{d_0^4 - d_i^4}{d_0} = 284.11\ Mpa$$

Comparison table

Solid shaft	Hollow shaft	Difference
O.D.=25.4 mm	O.D.=25.4 mm I.D.=17.4 mm	8 mm
Normal load=6098.20 N	Normal load=6098.20 N	-
Weight of Pinion=9.59 N	Weight of Gear=15.34 N	5.78 N
Resultant Load=6107 N	Resultant Load=6112.61 N	5.67 N
Twisting Moment=229217.6 N*mm	Twisting Moment=366745.6 N*mm	137528 N*mm
BendingMoment=610700 N*mm	BendingMoment=611261.71 N*mm	561.71 N*mm
Shear Stress=202.72 Mpa	Shear Stress=284.11 Mpa	81.39 Mpa

Table 1 Comparison table

Analysis of Shafts Subjected to Different Load

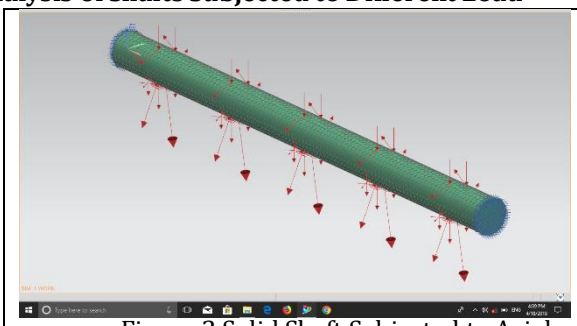

Figure 2 Solid Shaft Subjected to Axial load twisting moment and bending load

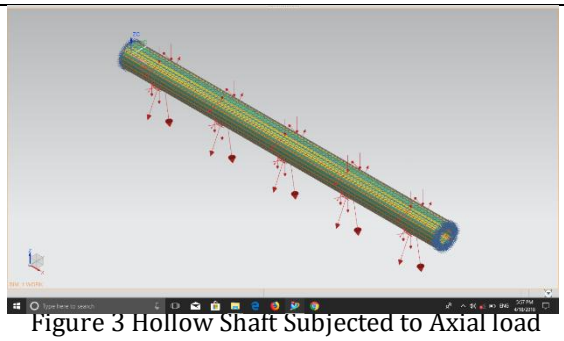

Figure 3 Hollow Shaft Subjected to Axial load twisting moment and bending load

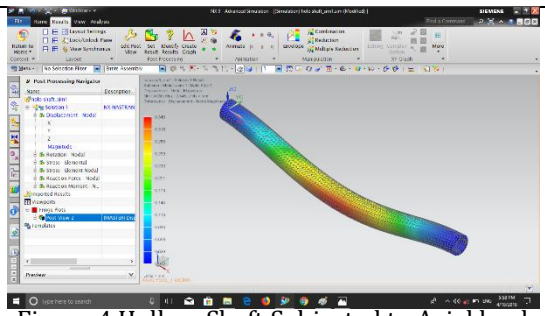

Figure 4 Hollow Shaft Subjected to Axial load

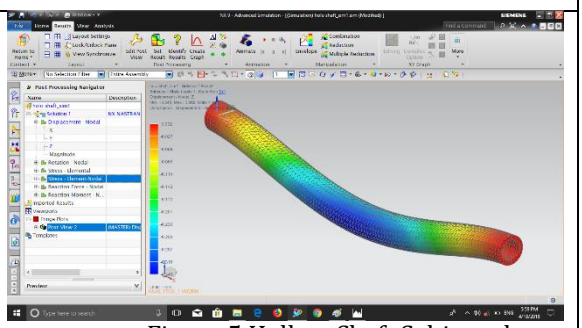

Figure 5 Hollow Shaft Subjected twisting moment

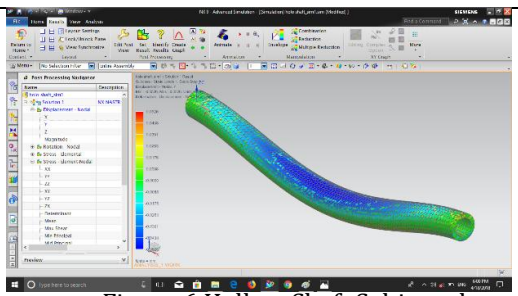

Figure 6 Hollow Shaft Subjected to bending load

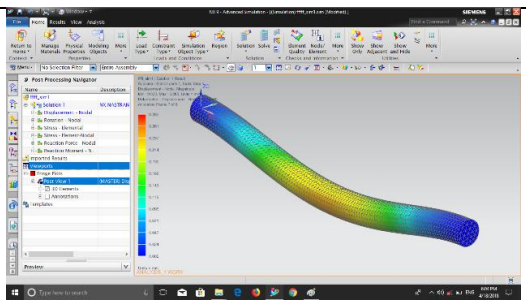

Figure 7 Solid Shaft Subjected to Axial load

Conclusion:

From the comparison table 1 we can conclude that hollow shaft can be successfully replace the solid shaft without compromising strength and safety. More over it will reduce the cost and weight which is beneficial in automobile industry.

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