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Design, Analysis and Fabrication of Shaft Driven Motorcycle

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Abstract: The normal motorcycle is one of the ways of travelling. The normal motorcycle uses chain, gear and power transmission system which includes engine, clutch which is main components of bike. But in case of shaft driven motorcycle uses shaft which contain two set of bevel gear and one long rod known as shaft which connects this set of gear and perform main function of power transmission. And the arrangement of bevel gear at an angle of 90^0 . And power is transmitted at a right angle. Which reduce noise as well as vibration [1]. The main function of the shaft to reduce unnecessary stress and vibration and to overcome lack of torque required to drive the vehicle [3]. In this type of arrangement 1st set of gear which is connected to near the engine and another set of gear which is connected to rear wheel through the shaft. This system avoids the usage of chain and sprocket system [5]. The spiral bevel gear use to avoid large noise and proper meshing of gear. The use of the spiral bevel gear allows the power transmission at an angle of 90^0 . The spiral bevel gear at the end of shaft that mesh with the rear wheel hub which transmit the power to the real wheel [6]. This paper aims towards review of research articles and perform calculation based analysis.
Keywords: spiral bevel gear, shaft drive, analysis, transmission system, power

I. INTRODUCTION

The shaft drives uses a shaft instead of chain to transmit power from engine to rear wheels. Our shaft drive, now in its third generation has been in production since 1991[2]. Shaft driven motorcycle uses bevel gear where conventional bike uses chain ring. The use of bevel gear to transmit the power through 90 degree, which acts as a differential. Bevel gear produces less noise and less vibration then chain driven bike. In case of chain driven needs regular lubrication and in case of breaking of chain and replacing chain increases cost of maintenance. But in shaft drive needs periodic lubrication using grease to keep gear running smoothly. In case of shaft driven motorcycle there is no need to replace the shaft until and unless it will broke hence reduce the cost of maintenance. Also the look of shaft driven motorcycle is attractive then chain driven bike [3].

Figure 1 - spiral bevel gear

Source: https://images.app.goo.gl/5eWh8
MhfJT4d5S

II. LITERATURE REVIEW

The first shaft drives of cycle have been introduced in 1890 in United States and England. The drive shaft carries the torque as well as stress which represent the difference between input force and load. In those days manufacturing of bevel gears was not so precise and cost effective; therefore, it was not possible to replace chain drive shaft driven gear system. Most familiar application of the spiral bevel gear is in automobile differential, in which the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels of the vehicle. The shaft drive bicycle has more efficiency than conventional chain drive bicycle. The drive shafts carry of torque. The steel drive shaft satisfies three design specifications such as torque transmission capability, buckling torque capability & natural frequency in bending mode. The shaft drive increases power transmission efficiency. Generally, for power transmission from the engine to the rear wheel various mechanical components and systems are required like clutch, gearbox, and finally transmitting drive. All these three combined together make a transmission system in a motorcycle [2].

The drive shaft carries torque and they are subjected to various stress and load. Hence they must be strong enough to bear the stress, without imposing the inertia effect by virtue of weight of the shaft. The transmitting drives are the mechanical connection from the output shaft of the gearbox to the rear wheel. In scooters, the engine is placed at the rear or back end so there is a direct connection between out shaft of the gearbox to the wheel but in motorcycles, the engine is placed in front, in between both wheels and so there are enough gaps between the output shaft of gearbox and wheel. To connect these two, transmitting drive is used. If we want to attain maximum efficiency, all components must have minimum losses and final drive is one the component which has a direct influence on efficiency and losses due to friction, as it is almost present in the open space and its maintenance and lubrication depends completely on the owner and mechanic completely. Loss of power or lower efficiency in these drives depends on various other factors like friction, air resistance, inertia, lubrication, wear, tear, and slag or tightness of the drives [5]. In shaft drive at both ends of shaft pair of spiral gears is used. Most familiar application of the spiral bevel gear is in automobile differential, in which the direction of drive from the drive shaft must be turned 90 degrees to drive the wheels of the vehicle. The shaft drive bicycle has more efficiency than conventional chain drive bicycle. Moreover, the application of chain drive leads to underutilization of human effort due to the fact the maximum transmission of the bicycle chain remains below 70 per cent due to polygon effect in chain sprocket drives. Thus, there is need to replace conventional chain drive using the spiral bevel gear arrangement. In a shaft driven bicycle, a drive shaft is used instead of a chain to transmit power from the pedals to the wheels. The drive shafts carry of torque. The steel drive shaft satisfies three design specifications such as torque transmission capability, buckling torque capability & natural frequency in bending mode. The shaft drive increases power transmission efficiency [6].

III. COMPONENTS

A. Bevel Gear

The bevel gears are used for transmitting power at a constant velocity ratio between two shafts whose axes intersects at a certain angle [1]. Also, it's a kind of gear in which the two wheels working together lie in different planes and have their teeth cut at right angles to the surfaces of two cones whose apices coincides with the point where the axes of the wheels would meet is shown in fig below [2].

Figure 2- Bevel gear

Source
https://images.app.goo.gl/FQnTSzLfqT4uL9Yb8

B. Drive Shaft

A shaft is a rotating member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation or oscillation, of elements such as gears, pulleys, flywheels, cranks, and the like and controls the geometry of their motion [1].

Figure 3 Drive shaft

Source
https://images.app.goo.gl/ESMo9CixBctmbDes9

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C. Bearing

For the smooth operation of shaft, bearing mechanism is used. To have very less friction loss the Two ends of shaft are pivoted into the same dimension bearing [1].

Figure 3 - Bearing

Source
https://images.app.goo.gl/RcnddM5T8o2DHMaZ8

IV. WORKING PRINCIPLE

The job involved is the design for suitable drive shaft and replacement of chain drive smoothly to transmit power from the pedal to the wheel without slip. It needs only a less maintenance. It is cost effective. Drive shaft strength is more and also drive shaft diameter is less. It absorbs the shock. The both end of the shaft are fitted with the bevel pinion, the bevel pinion engaged with the crown and power is transmitted to the rear wheel through the drive shaft and gear box. With our shaft drive motorcycle; there is no more grease on your hands or your clothes [1].

In this shaft driven motorcycle, the Bevel gear is mounted with the motorcycle. It is mainly used to the gear transmission for increasing the speed of the motorcycle. The shaft drive only needs periodic lubrication using a grease gun to keep the gears running quiet and smooth. It is attractive in look compare with chain driven bicycle. It replaces the traditional method [2].

V. DESIGN METHODOLOGY

The shaft drive system is a two stage bevel gear system and has various parts like two sets of bevel gear, a drive shaft which connect that two stages from engine input to end transmission, bearings for support and smooth actions of the parts and a cover. The basic approach behind design of all this parts is to keep the design less complex, easy to work on and economical.

A. Design Assumptions

1) The drive shaft is rotating at constant speed about its longitudinal axis.
2) The dive shaft has a uniform, circular cross section area.
3) All damping and nonlinear effects are neglected.
4) The stress-strain relationship for the composite material is linear & elastic

B. Design Calculations

Given: - P = 6.15KW
I = 1
N1 = N2 = 8000rpm
Material used: - EN08
[ ] = 850/3 =283.33Mpa
[ ] = 3×255 =765Mpa
Assumptions: - i) External meshing
ii) 20 FDI
iii) Z1 = Z2 = Z3 = 20
iv) Closed gear box
v) Assuming service

1) Design

STAGE 1

Design power = S.F×6.15×1000

P = 9.225KW

ii) Gear pair dynamics:-

w1 = 2×3.14×N1/60 = 837.75 rps = w2

T1 = P/w1

= 9.225×1000/837.75

= 11 N-m

N1 = N2 = 8000rpm & Z1=Z2= 20

iii) Gear Geometry,

θ = δ1 + δ2 where δ1 = driver angle

δ1 = tan-1 (1/1) δ2 = driven angle

= 45

Δ2 = 45

Zv1 = z1/cosδ1

= 28.28 = Zv2

iv) Pinion design:

Mav ≥ 0.163 cm

Mav = 1.63 mm

Mt = 1.63 + 1.63×10 sin 45/20

= 2.2 ≈ 2.5mm

v) Check for wear strength,

Fw ≥ Fbd

Fw = d1×Q×k×b

= 50×1.429×16.3

= 1164.63 N Where d1 = mt × z1

2.5×20 = 50 mm

Θ = 2i / i+1 = 1

K = sin20×2/2×100000×1.4

= 1.429

B = 16.3mm

$\therefore f_{bd} = f_t + [(0.164v_m\ (cb+f_t\ ) / (0.164v_m + 1.485\ (cb+f_t)^{1/2}\ )$

Where $f_t = T_1/\ \gamma_1 = 11*1000/25 = 440N$

$V_{m\,=}\ w_1 * r_1 = 837.75*25=20.9m/s = 1254m/min.$

C= 11860*0.0125= 148.25

$\therefore F_{BD} = 2501.063N.$

$\therefore F_W$ IS NOT GREATER THAN F_{BD} [HENCE DESIGN IS NOT SAFE FOR MODULE 2.5MM]

Assuming higher module (M_t =5mm)

$\therefore F_w$= dqkb where; d= m_t * 20=100mm, q=1, k= 1.429, b=36.9

$\therefore F_w$ = 100*1.429*36.9=5273.01N

$\therefore f_{bd} = f_t + [(0.164v_m\ (cb+f_t\ ) / (0.164v_m + 1.485\ (cb+f_t)^{1/2}\ )]$

Where $f_t = T_1/\ \gamma_{1\,=}$ 11*1000/50 = 220N.

$V_m = w_1 * r_1$= 837.5*50=41.8m/s=2512.8m/min.

$f_{bd=}$4694.2N.
∴$F_W \geq F_{BD}$
∴ DESIGN IS SAFE FOR 5 mm MODULE.

STAGE 2

1) Gear pair dynamics
Assuming velocity v=60kmph=16.67 m/s; where; d=dia. of tire =18 inch=0.4572m
∴r=0.2286 $\quad$ i=N_3 / N_4 =8000/3047=2.62
∴V=3.14*D*N/60 $\quad$ i= Z_4/Z_3 = Z4 /20
∴N_4 = 3047RPM. $\quad$ ∴Z_4=53
∴ W_4=2*3.14*N_4/60 = 319.08RPS
2) GEAR GEOMETRY:
$\Theta=\delta_1+\delta_2$
δ_1= Tan^{-1}(1/2.62) =20.89 $\quad$ ∴90=20.89+ δ_2 $\quad$ ∴ δ_2=69.109^0
∴Z_{V3}=Z_3/COS δ_1 = 21.4 $\quad$ ∴Z_{V4} = Z_4/COS δ_2=148.62
iii) PINION DESIGN;

$$m_{av} \geq 1.28\sqrt[3]{\frac{[mt]}{yv3*[\sigma b]*\psi m*z3}}$$

$$m_{av} \geq 1.28\sqrt[3]{\frac{143}{0.11138*2833.33*10*20}}$$

$m_{av} \geq$ 0.168 cm
m_{av} = 1.68 cm

$$m_t = 1.68 + \frac{16.8}{20}\sin(20.89)$$

m_t = 2 mm

2) Check For The Wear Strength

$F_w = d_3*Q*k*b$ $\quad$ Where; d_3 = 40 mm
F_w = 1390.01 N $\quad$ $Q = \frac{2*i}{i+1} = 1.4475$
V_m = w_3*r_3 = 837.75*20 $\quad$ b = 16.8 mm
V_m = 16.75 m/s $\quad$ k = 1.429
V_m = 1005 m/min
C = 11860*0.025 = 296.5
F_t = 550 N

$$F_{BD} = F_t + \left[\frac{0.164*Vm*(cb+Ft)}{0.164*Vm+1.485\sqrt{(cb+Ft)}}\right]$$

F_{BD} = 3861.938 N
F_w is not greater than or equal to F_{BD} $\quad$ (Design is not safe for 2 mm module)
Assuming module to be m_t =4mm;
∴$F_w = d_3*Q*k*b$ $\quad$ Where; d_3 = 80 mm
∴F_w = 5609.7 N $\quad$ $Q = \frac{2*i}{i+1} = 1.4475$
b = 33.9 mm
k = 1.429

$$F_t = \frac{T3}{r3} = \frac{11*1000}{40} = 275N$$

V_m = 837.75*40 = 33.5m\s = 2010 m/min
C = 11860 * 0.0125 = 148.25
∴ F_{BD} = 4266.5 N
∴ $F_w >= F_{BD}$
∴ Design is safe for module 4mm.

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Dimensions of gear

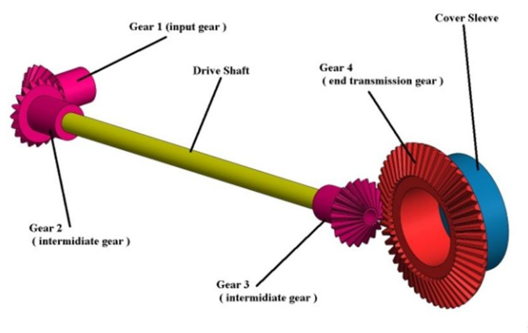
members	Stage 1		Stage 2	
	Pinion	gear	pinion	gear
Module (m_t)	5mm	5mm	4mm	4mm
Teeth(z)	20	20	20	55
PCD (D=zm)	100	100	80	212
Face width(b=10*m)	50	50	40	4
a=m	5	5	4	4
bl=1.2*m	6	6	4.8	4.8
ACD(D+2a)	110	110	88	220
DCD(D-2a)	90	90	72	204

C. Analysis Of Spiral Bevel Gear And Drive Shaft

The CAD geometry of all components is created by using SOLIDWORKS software. The analysis is done on all necessary components using the same software. Maximum stress using von mises theory and deformation is calculated for the components and results are shown below.

From the data available it is found that the maximum input torque obtained is 12 Nm, which also includes a small safety factor. Every individual component is analyzed for maximum torque accordingly by fixing one of the position and Appling torque.

The mechanism is a two stage gear mechanism which includes total of 4 bevel gears. Each gear has individual position in mechanism. The force is applied on the gears according to their position in the system. For simplification gears are numbered as follows.



1) *Analysis on bevel Gear:* In case of gear 4 the part which meets to the wheel components is fixed, where the teeth meshed with gear 3 are under application of torque. Fixed positions are shown with green arrows where applied forces are shown in purple arrows.

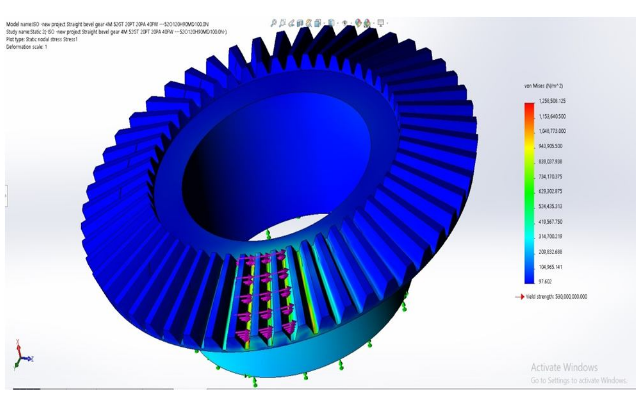


Figure 4 - Max stress (von mises)

Maximum stress = $12.58*10^5$ N/m^2.

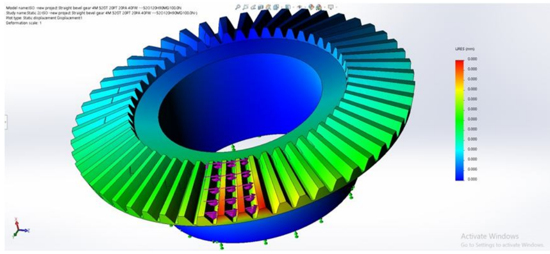


Figure 5 - Deformation (in mm)

There is no deformation in the component for given stress.
Rest of the three gears are nearly identical, therefore there is no need for separate analysis. The analysis is the same way as above for other gears too.

2) *Analysis on drive Shaft:* This component of the system is symmetric in both directions. Therefore either of the spines is fixed where another is under application of torque.

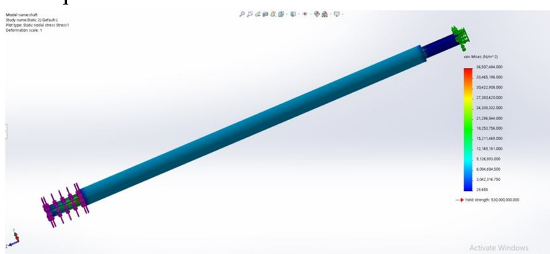


Figure 6 - Max stress (von mises)

Maximum stress = $36.50*10^5$ N/m^2.

Figure 7 - Deformation (in mm)

Maximum deformation is $2.7*10^{-2}$ mm.

VI. RESULT AND CONCLUSION

The presented work was aimed to reduce the power loss in chain sprocket transmission. The presented work also deals with optimization. Instead of chain drive one piece drive shaft for rear wheel drive have been designed. Maintenance cost and duration is reduced because of shaft drive transmission system.

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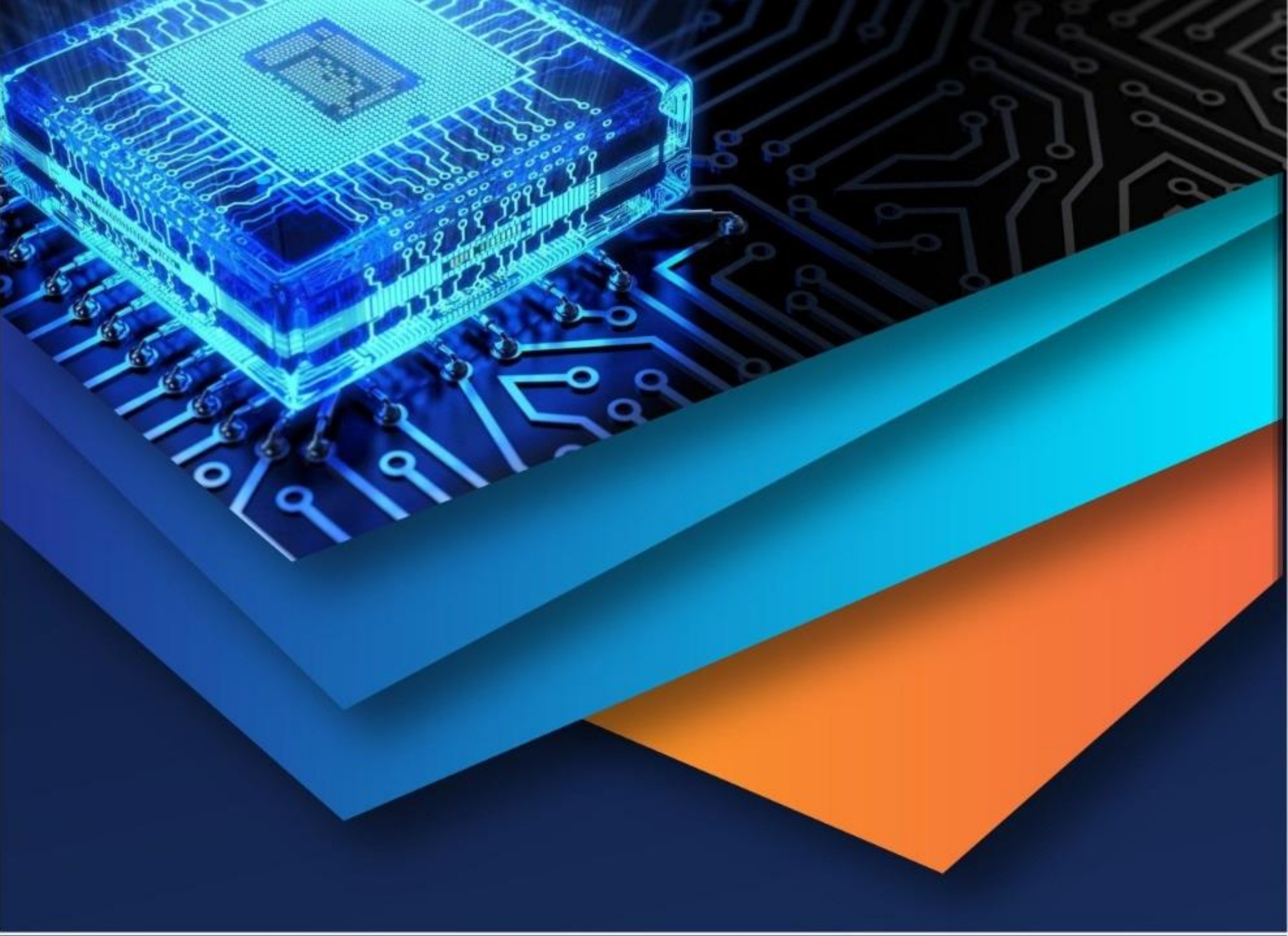

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