Planetary Ball Continuously Variable Transmission System

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Abstract - *In this paper, we present a new continuously variable power transmission concept; the Planetary Ball Continuously Variable Transmission System. Continuously Variable Transmission offers variable gear ratios that can achieve, whereas traditional transmission system has limitations on gear ratios. An attempt has been made to understand, behavior of system under load condition. First, analytical calculation of power transmitting planet ball shaft, spherical planetary balls has been done. Second, CAD model of load carrying shaft, power transmitting rings, variator, spherical balls which transmit torque from one end to another end, casing for whole assembly is prepared. Third, analysis of torque transmitting shaft, Planetary ball at different working condition such at low speed high torque to be transmitted and at high speed low torque is done in ANSYS. Main attempt of this paper is focus on highly stressed components design, analysis and study of those parts under working condition. Through this system we try to achieve various gear ratio and extensive range of torque transmission as well as various speed output during running of system.*

Key Words: Planetary ball, Power and torque transmission, analysis of various working conditions.

1. INTRODUCTION

A planetary ball continuously variable transmission system is a system which can change gear ratio by various times between maximum and minimum values. In other power transmitting systems they achieve certain gear ratios only. In those system there will be a certain input and with respect to that certain output will be present. The flexibility of a planetary ball continuously variable transmission system allows the driving shaft to maintain a constant angular velocity over a range of output velocities. Due to this better fuel efficiency is can be achieved than other power transmitting systems. In order to endorse new guidelines for automotive fuel economy and emissions, the planetary ball continuously variable transmission system, carry on to develop as a key technology for improving fuel efficiency of automobiles. planetary ball continuously variable transmission system uses infinitely adjustable gear ratios instead of specific gear ratio, which gives specific power output as an a engine performance. Since the engine always runs at the most efficient number of revolutions per minute for a given vehicle speed, planetary ball continuously variable transmission system attain better fuel efficiency and acceleration than conventional transmission systems. Planetary ball continuously variable transmission system is a type of variable power transmitting system. As power transmission systems are not new to the automotive world, but their torque transmitting capacity are quite low. New developments in this area i.e. gear ratio reduction to achieve variable power output. Development in research of new variable transmitting system leads to develop new models. As development in variable power transmission systems continue, it leads to reduce total cost of system, increase in efficiency of system, which in turn makes further development and application of variable power transmitting systems. Figure 1 show, working of planetary ball continuously variable transmission system.

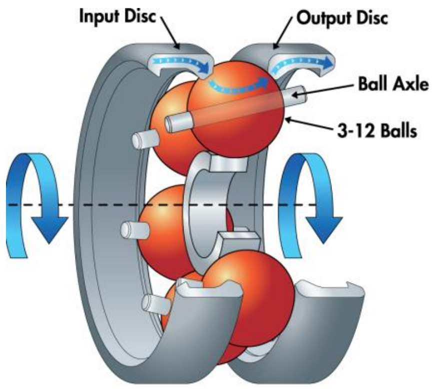

Fig. 1: working of planetary ball continuously variable transmission system

There are the various types of variable power transmitting systems are available in the market, but they have some limitation that they didn't give a constant power on certain transmission power. To reduce this problem we are comes with the CVT having constant power output having wide variety of transmission ratio. So we are planning to design the system for two wheeler for increasing its efficiency using this new planetary ball continuously variable transmission system.

2. CALCULATIONS

2.1 Drive Motor

TYPE: - SINGLE PHASE AC MOTOR.
Power: -0.25HP (185WATT)
Voltage: - 230 V, 50 Hz

Current: - 0.5 Amp
Speed: - 1440
Operating Speed = 1440 rpm

Motor Torque

$$P = \frac{2\pi NT}{60}$$

$$T = \frac{60 * 185}{2\pi * 1440}$$

T = 1.23 N-m

Power is transmitted from the motor shaft to the input shaft of drive by means of an open belt drive,
Motor pulley diameter = 38 mm
Input shaft pulley diameter = 76 mm
Reduction ratio = 2
Input shaft speed = 1440/2 = 720 rpm
Torque at Input shaft = 2 x 1.23 = 2.46 Nm

2.2 Design of Spherical Ball:

Size of the planetary ball is based upon the size of the rotor. We can validate the friction on the ball by analysis and theoretically.

In theoretically we can find out the friction on the ball surface by simply assuming tangential force on ball surface and find out friction on it.

In ANSYS we find out the stress analysis and factor of safety. That images shows in figure as follows.

2.3 Design of Planet Ball Shaft:

ASME code for design of shaft

Since the loads on most shafts in connected machinery are not constant, it is necessary to make proper allowance for the harmful effects of load fluctuations According to ASME code permissible values of shear stress may be calculated form various relation.

$fs_{max} = 0.18\ f_{ult}$ OR $fs_{max} = 0.3\ f_{yt}$
$fs_{max} = 0.18 \times 800$ OR $fs_{max} = 0.3 \times 680$
$fs_{max} = 144\ N/mm^2$ OR $fs_{max} = 204\ N/mm^2$

Considering minimum of the above values;
$fs_{max} = 144\ N/mm^2$

Shaft is provided with key way; this will reduce its strength. Hence reducing above value of allowable stress by 25%

$fs_{max} = 108\ N/mm^2$

This is the allowable valve of shear stress that can be induced in the shaft material for safe operation.

To calculate input torque
T = 2.46 Nm Assuming 100% overload.
$T_{design} = 2 \times T$
$T_{design} = 4.92 \times 103$ N-mm.

Input disk is in contact with ball at an radius of 93 mm whereas radius of ball is 24mm hence speed ratio is 24/93 =3.875 hence torque transferred to ball is given by

$T_{design} = 4.92 / 3.875 = 1.26$ N-m.

Check for Torsional shear failure of shaft:

Assuming minimum section diameter on planet ball shaft to be 6mm as ball is fitted in ball bearing 606zz with 6mm internal diameter.

Assuming minimum section diameter on shaft = 6mm
d = 6 mm

$$Td = \frac{\pi}{16} * fs_{act} * d^3$$

$$fs_{act} = \frac{16 * Td}{\pi * d^3}$$

$$fs_{act} = \frac{16 * 1.26 * 10^3}{\pi * 6^3}$$

$Fs_{act} = 29.7$ N/mm
As $fs_{act} < fs_{all}$

Planet ball shaft is safe under torsional load

Check for direct shear failure of planet ball shaft:

Planet ball shafts are located in holders at a PCD of 142 mm. These shafts engage in the ball bearings placed in the bearing holders and act as transmission elements.

They can be designed similar to the bush pins in the bush pin type flexible flange coupling.

'Three pins' transmit the entire torque.
These pins are located at PCD (D_p) = 142mm

$$\text{Tangential force on each bolt (Fb)} = \frac{T}{Dp * N}$$

Now,

$$fs_{act} = \frac{Fb}{\frac{\pi}{4} * d^2}$$

$$Fb = fs_{act} * x * \frac{\pi}{4} d^2$$

$$T = n * fs_{act} * \frac{\pi}{4} d^2 * \frac{Dp}{2}$$

Assuming shaft diameter = 6 mm
No. of balls = n=2

$$4.92 * 10^3 = 2 * fs_{act} * \frac{\pi}{4} 6^2 * 142 \frac{1}{2}$$

$Fs_{act} = 3.84\ N/mm^2$
As $Fs_{act} = fs_{all}$
Planet ball shaft are safe under shear load.

3. MODELING:

It is the representation of drawing in 3D modeling is done in cad software i.e. CATIA V5 R20. Cad software is used to improve quality of drawing to have better communication.

3.1 3D Model of Shaft.

It is the 3 D model of power transmitting shaft of diameter 15 mm.

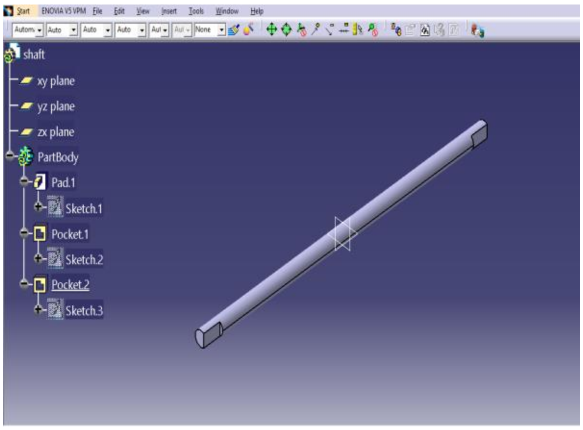

Fig. 2: 3D model of power transmitting shaft

3.2 3D Model of Input and Output Ring

Input ring transfer power through planetary ball to output ring. Balls are connected to these rings. Axis of planetary ball is rest in groove of input and out ring.

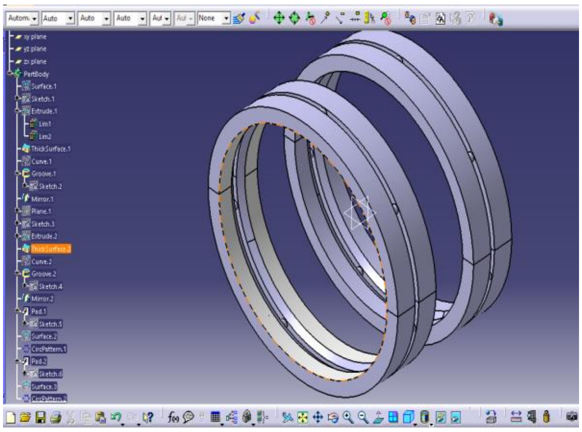

Fig. 3: 3D model of input and output ring

3.3 3D Model of Variator

Variator reciprocate with in contraints and with the help of variators movement axis of planetary ball creates an angle to its mean position.

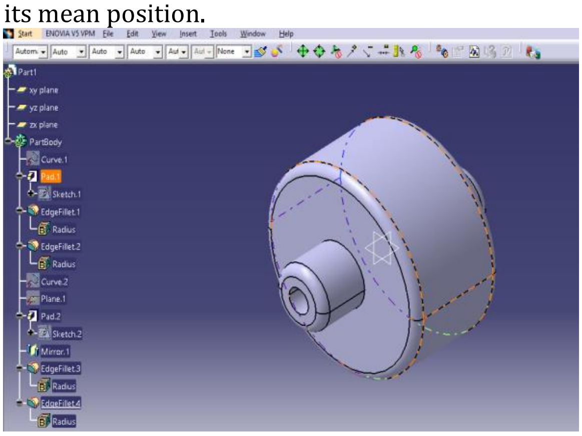

Fig. 4: 3D model of variator.

3.4 3D Model of Spherical Balls

Planetary ball transmit power which is received from input ring to output ring.

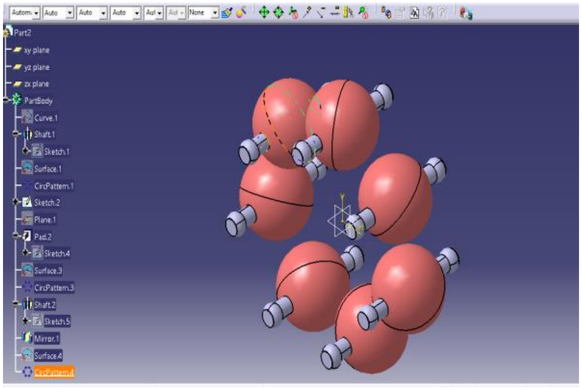

Fig. 5: 3D model of spherical balls

3.5 Exploded view

Following figure shows exploded view of planetary ball power transmitting system.

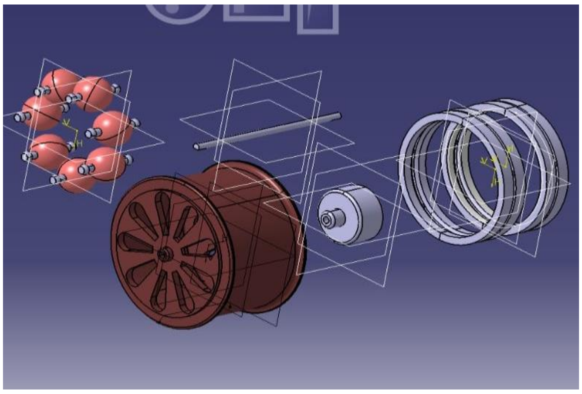

Fig. 6: Exploded view of planetary ball power transmitting system

4. ANALYSIS

Analysis of spherical ball.

4.1 Initial Condition

4.1.1 Total Deformation

Here total deformation of planetary ball at initial stage where torque is high.

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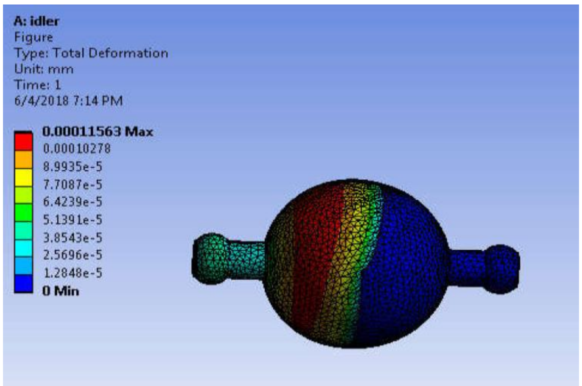

Fig. 7: total deformation of planetary ball when torque is high

4.1.2 Equivalent Stress

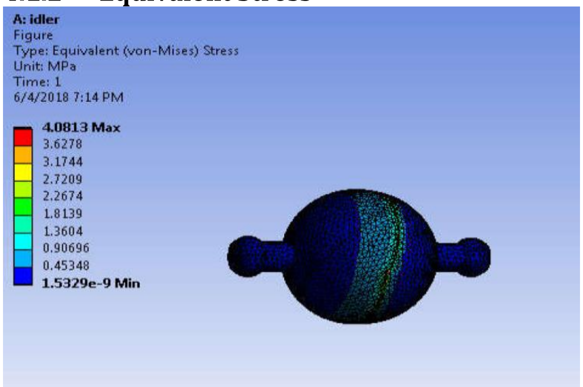

Fig. 8: Equivalent stress

4.2 Ideal Condition: Input = Output

4.2.1 Total Deformation

Total deformation when planetary ball is in ideal running condition

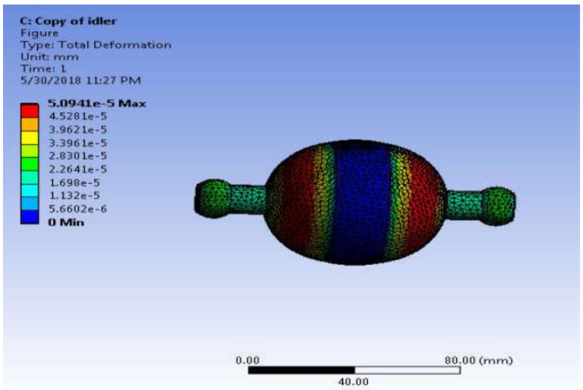

Fig. 9: total deformation under ideal running condition

4.2.2 Fixed equivalent stress

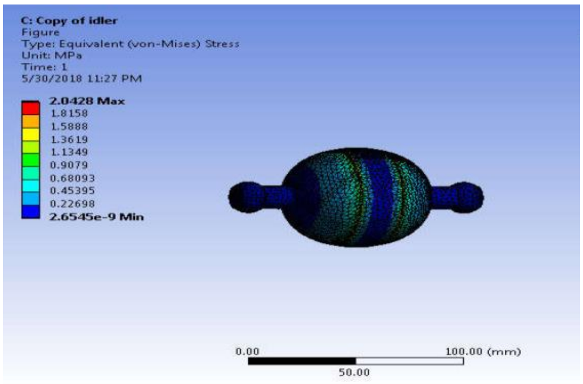

Fig. 10: Fixed equivalent stress.

4.3 Incined at 45 deg.

4.3.1 Equivalent Stress

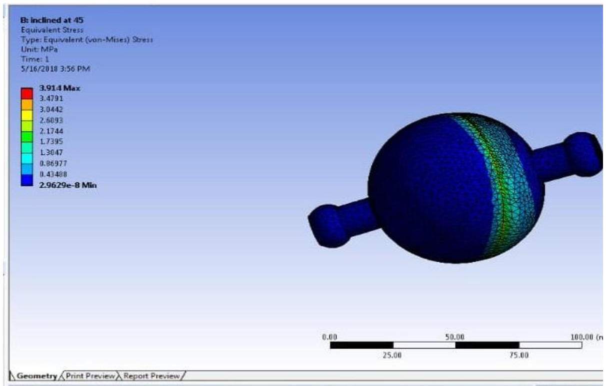

Fig. 11: Equivalent stress inclined spherical ball

Above figure is for stress analysis at the point where ball is tilted at one side the major stress developed at the one end of the ball means maximum friction occur that point.

4.3.2 Total Deformation

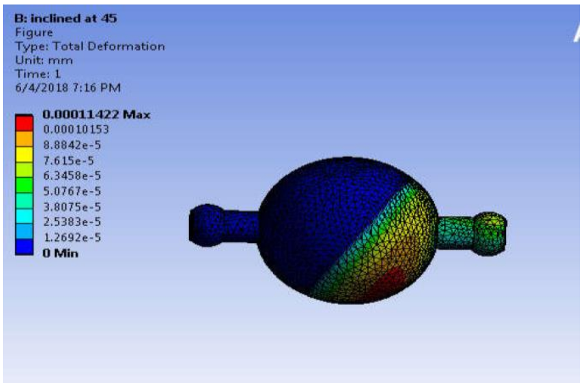

Fig. 12: Total deformation

Above figure shows that the condition at normal position where both rotor i.e. input rotor and output rotor is connected to the ball. In fig shows the stress generated at the both side of the ball.

4. CONCLUSION

In the above work we have design a planetary ball continuously variable transmission system. Firstly we designed analytically input / output shaft, planet ball shaft, spherical ball. A 3D model is prepared in CATIA V5, 3D model of input shaft, input/ output ring, variator, planetary ball and casing is prepared. Static structural analysis of shaft, and various conditions of planetary ball i.e. initial condition, ideal condition and inclined condition is examined. Based on the results in ANSYS, we found that deformation in components is less. After applying total system torque 35717 N-mm, we found that stress generated and deformation occurs in components is minimum. We design components analytically with in safe limit. As very less deformation is seen in all four cases under action of system forces and analytically designed parts are also in safe limit, thereby design is suitable for practical performance.

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REFRENCES

[1] Luca Piancastelli and Leonardo Frizziero , "Study and Optimization of an Innovative CVT Concept for bikes ", Vol. 9 No.8, (2014)

[2] Chad Phillip Glinsky, "Control Methods for a Continuously Variable Transmission Wind Turbine

[3] T John Babu, M. Khaja Gulam Hussain, "Design and Fabrication of CVT", Vol.3 Issue 07, (2016)

[4] Russ Whisler, Chris Schneider, "An Analytical Approach for Assessing CVT Alternatives"

[5] Vishnu Seelan,"Analysis, Design and Application of Continuously Variable Transmission (CVT)", Vol. 5, Issue 3, (2015)

[6] Kevin R. Lang , 2000 , "Continuously Variable Transmissions, An Overview of CVT Research Past, Present, and Future".

[7] Norman H. Beachley and Andrew A. Frank , 1979 ," CONTINUOUSLY VARIABLE TRANSMISSIONS:THEORY AND PRACTICE" , College of Engineering,University of Wisconsin, Madison.

[8] Kluger, M. and Fussner, D., 1997, "An Overview of Current CVT Mechanisms, Forces, and Efficiencies," SAE Technical Paper No. 970688.

[9] Kluger, M. and Long, D., 1999, "An Overview of Current Automatic, Manual and Continuously Variable Transmission Efficiencies and Their Projected Future Improvements," SAE Technical Paper No. 1999-01-1259.

[10] Hewko, L., 1986, "Automotive Traction Drive CVTs – An Overview," SAE Technical Paper No. 861355.

[6] Fenton, J., 1996, "Handbook of Vehicle Design Analysis," Society of Automotive Engineers, Inc., Warrendale, PA, Ch. 19.

[11] Hyunsuk Kim Hyundai Motor Company, 772-1, Changduk-dong, Whasung- shi; Kyunggi-tio, 445-706, Korea.

[12] Allen, Mark and LeMaster, Robert. "A Hybrid Transmission for SAE Mini Baja Vehicles", SAE Publication 2003-32-0045