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Design, development & testing of half toroidal continuous variable transmission system

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***Abstract* —A continuously variable transmission, however, is a type of transmission that allows an infinitely variable ratio change within a finite range, thereby allowing the engine to continuously operate in its most efficient or highest performance range. The Half Toroidal CVT is an innovative transmission that executes smooth, continuous gear ratio changes by changing the angle of the power rollers between the input disk and output disk. This paper describes the working principle of Half Toroidal CVT and measurement of power transmitting capacity along with efficiency of the drive. This work documents a successfully developed experimental model of a 'Toroidal' continuously variable transmission (CVT) by adjusting its geometrical configuration of CVT and plotted the experimental results of speed, torque and power delivered at the output disc.**

***Index Terms*—Half Toroidal, CVT, Infinite Speed Stages, Elliptical Contact, Traction**

I. INTRODUCTION

As we know there are various problems with conventional transmission system in automobile industry. Also the efficiency of the system is max 70% and operation is not smooth due to engagement and disengagement of clutch while shifting the gears[1]. Hence there is a need of automotive transmission system with better efficiency, smooth and simple changing of gear ratio, we are going to use a Continuous Variable Transmission System. From environment saving point of view the analysis performed seems to indicate that CVT adoption could produce a certain reduction of polluted emissions and a lower level of noise. All this features can be got because of the possibility offered by the CVT of changing the speed ratio in a continuous way under load conditions [7].

The Half Toroidal is one of the major types of Continuous Variable Transmission System. The first toroidal drive is patented in 1877 by C. W. Hunt[2]. In last 30 years there is a significant improvement in the fields of material, lubrication fluids, tribology and control.

II. THEORY

A continuously variable transmission (CVT) is a transmission which may change step less by way of an infinite variety of effective gear ratios between maximum and minimum values. This contrasts with different mechanical transmissions that solely permit just a few different distinct gear ratios to be selected. Continuously variable transmissions (CVTs) are mechanical devices that allow a continuous variation of the output velocity by adjusting its geometrical configuration. This offers several advantages over traditional transmissions such as better fuel efficiency [2], quieter operation, and a lower mass. Current efforts to reduce the vehicle fuel consumption in order to protect the environment and save fuel have seen a recent resurgence in CVT research, especially in the automotive industry. The torque of the continuously variable transmission system with friction drive mechanism is transmitted by contacting roller with input and output disks. For the higher transmitted torque, it is necessary to apply large load in order to get higher friction force, which in turn generates severe high stress on the contact surfaces of roller and disks. The 'Toroidal' type CVT system has simple component arrays that have three contact points between roller and each input or output disk to get the torque transmitted.

III. PROPOSED WORK

The Half Toroidal CVT is an innovative transmission that executes smooth, continuous gear ratio changes by changing the angle of the power rollers between the input disk and output disk. One disc connects to the engine. This is equivalent to the driving pulley. Another disc connects to the drive shaft. This is equivalent to the driven pulley. Rollers, or wheels, located between the discs act like the belt, transmitting power from one disc to the other

The wheels can rotate along two axes. They spin around the horizontal axis and tilt in or out around the vertical axis, which allows the wheels to touch the discs in different areas. When the wheels are in contact with the driving disc near the center, they must contact the driven disc near the rim, resulting in a reduction in speed and an increase in torque (i.e., low gear). When the wheels touch the driving disc near the rim, they must contact the driven disc near the center, resulting in an increase in speed and a decrease in torque (i.e., overdrive gear). A simple tilt of the wheels, then, incrementally changes the gear ratio, providing for smooth, nearly instantaneous ratio changes.

IV. LAYOUT OF HALF TOROIDAL CVT

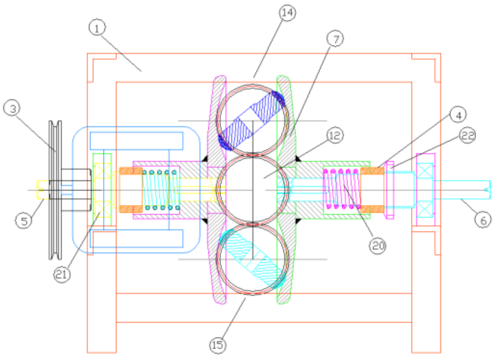

Fig.1. CAD Model of Half Toroidal CVT

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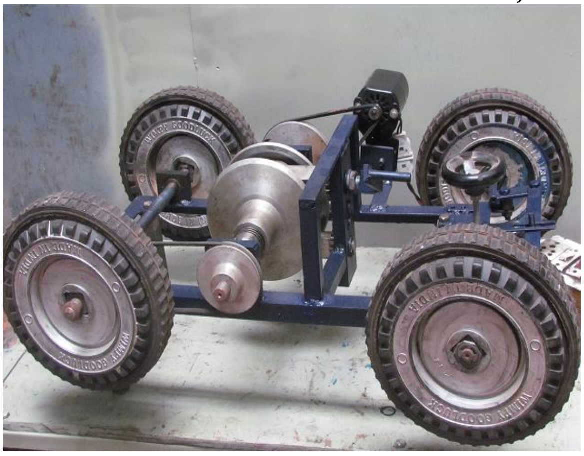

Fig. 2. Actual Setup Photograph

22.	LOCK NUT	STD	01
21.	BALL BRGS	STD	02
20.	SPRINGS	STD	02
19.	BELT	STD	01
18.	EXT FORK PIN	EN9	02
17.	ROLLER PINS	EN24	02
16.	CEN_GEAR_PIN	EN24	01
15.	FORK GEAR_1	EN9	01
14.	FORK GEAR_1	EN9	01
13.	BACK PLATE	EN9	01
12.	CENTRAL GEAR	EN9	01
11.	EXT FORK	EN9	02
10.	ROLLER FORK	9.	02
9.	ROLLER	8.	02
8.	BRG HSG	EN9	02
7.	FRICTION BOWL	EN24	02
6.	OP_SHAFT	EN24	01
5.	IP_SHAFT	EN24	01
4.	SPACER	EN9	02
3.	IP_SHAFTPULLEY	EN24	01
2.	MOTOR	STD	01
1.	FRAME	MS	01
SR	PART NAME	MTRL	QTY

Table 1: Part list

V. SPECIFICATION OF THE 2 POWER-ROLLER VARIATOR

Toroidal Diameter ***D*** [mm]	25
Cavity Radius r_0 [mm]	36.5
Contact cone angle θ_0 [deg.]	62.5
Number of power rollers ***n***	2
Swing angle of power roller φ [deg.]	27.5^0 to 97.5^0
Speed ratio	0.427 to 2.344
Ratio range	5.49
Maximum input torque T_{1max} [Nm]	140
Maximum input speed N_{1max} [rpm]	6000

Table 2 : Specification of Half Toroidal CVT

VI. RANGE OF HALF TOROIDAL CVT

A) Input speed = 1000 rpm
B) Min output speed = 1000 x 0.427 = 427 rpm
C) Max output speed = 1000 x 2.344 = 2344 rpm
D) Range = 430 to 2300 rpm (approximately)
E) Gear ratios possible = 200
D) Theoretical efficiency = 90 to 92 %

VII. TESTING ON TOROIDAL CVT

A] AIM: - To conduct trial to determine

1. TORQUE Vs SPEED CHARACTERISTICS

2. POWER Vs SPEED CHARACTERISTICS

In order to conduct trial on dynobrake pulley cord, weight pan are provided on the output shaft.

B] INPUT DATA:-

Drive Motor AC230 Volt

0.5 Amp, 50 watt

50 Hz, 200 to 4500 rpm

TEFC Commutator Motor

Effective Diameter of Dynobrake pulley = 25 mm.

C] PROCEDURE:-

a) Start motor by turning electronic speed variator knob.

b) Let mechanism run & stabilize at certain speed (say 1300 rpm)

c) Place the pulley cord on dynobrake pulley and add 100 gm weight into the pan, note down the output speed for this load by means of tachometer.

d) Add another 100 gm cut & take reading.

e) Tabulate the readings in the observation table

f) Plot Torque Vs speed characteristic

Power Vs speed characteristic

D] Specimen method:- (AT 0.6 kg Load)

1. Average Speed:-

$$N = \frac{N_1 + N_2}{2} = \frac{850 + 850}{2} = 850 \text{ rpm}$$

2. Output Torque:-

T_{dp} = Weight in pan x Rad. of Pulley
= (0.6 x 9.81) x 12.5
=73.575 N.mm
T_{dp} =0.0737575 N.m

3. Input Power :- ($P_{i/p}$)

$$P_{i/p} = \frac{2\,\Pi\,N\,T_{i/p}}{60}$$

$$= \frac{2 \times \Pi \times 850 \times 0.10}{60}$$

$P_{i/p}$ =8.90 watt

4. Output Power :- ($P_{o/p}$)

$$P_{o/p} = \frac{2\,\Pi\,N\,T_{o/p}}{60}$$

$$= \frac{2 \times \Pi \times 850 \times 0.0737575}{60}$$

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$P_{o/p}$ = 6.565 watt

5. Efficiency:-

$$\eta = \frac{\text{Output power}}{\text{Input power}}$$

$$= \frac{6.565}{8.90} \times 100$$

$$\eta = 73.76\%$$

VII. RESULT PLOT

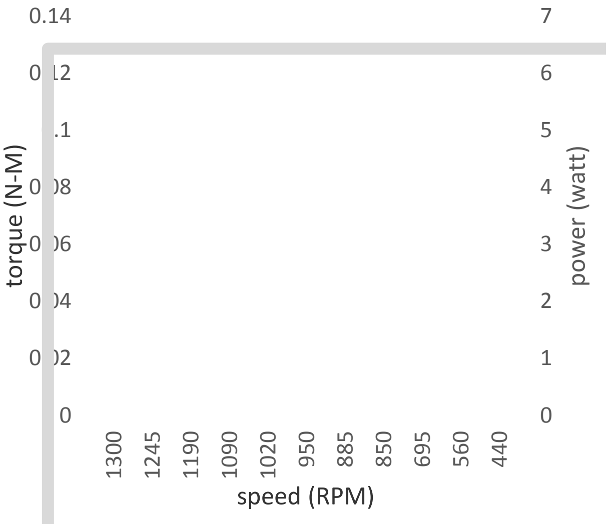

Fig. 3. Graph of Speed v/s Torque, Speed v/s Power

VIII. ADVANTAGES

1. Dual friction drive; i.e. two friction surfaces in contact which increases the torque transmitting capacity.
2. Even wear of rollers; thereby properly balanced power transmission.
3. Easy to maintain proper pressure between the contact surfaces thereby resulting in trouble free operation.
4. Multiple speeds can be obtained; whereas regular clutches are of ON-OFF type where only one speed is available.
5. Infinitely variable speed available over a given range.
6. Ease of operation; the speed changes are gradual, without any shock.
7. Singular control:-

Entire range of speeds is covered by a single hand wheel control.

IX. APPLICATIONS

1. Speed drives for machine tools spindles Machine tool spindles are required to be driven at various speeds depending upon the size of work and material to be cut in such cases the gear less variable speed reducer can be used along with all geared head stock to give an infinitely variable speed condition.

2. By combination the duplex friction drive and a three stage all gear head stock a still wide range of speeds can be obtained for the main spindle of lathe.

3. Feed drives for machine tool slides. Machine tool slides can be moved at different speeds to impart feeding motion to the cutting tool.

4. Variable speed drives for conveyors in assembly line and automatic assembly plants.

5. Variable speed drives in automatic transfer lines and pick and place robotic devices.

6. Mr. Cheris Brocbank, and Mr. Cheris Greenwood[4] already explained the applications of full toroidal continuous variable transmission in the formula 1 racing cars along with kinetic energy Recovery System. Torotrack is participating in the development of a mechanical Kinetic Energy Recovery System (KERS) which utilize full- torodial fraction drive variatior connected to a high speed flywheel.

X. LIMITATIONS

1. Duplex friction drive is actually a friction type drives which automatically limits the torque that can be transmitted by the drive hence it can be used satisfactorily for light to medium duty application.

2. The amount of slip becomes significant of high torque conditions, which reduces the velocity ratio making in-accuracies in power and motion. The minimum contact life appears at the maximum speed ratio[5].

3. Friction surfaces generate a lot of heat, being a dry friction drive; proper ventilation preferably forced ventilation must be provided for satisfaction application at any loads.

4. In case of full toroidal and half toroidal system; due to limitation of spin and slip effect, there is restriction on maximum speed ratio range [6].

XI. CONCLUSION

This paper shows test results of efficiency and power output capacity of 2 power-roller half-toroidal CVT for transmitting 0.073 Nm torque by r0 = 36.5 mm cavity-radius discs. The measured power-transmission efficiency is nearly about 73% which shows this kind of drive is applicable in automobile by avoiding the slip rate in the belt drive.

XII. FUTURE SCOPE

1) The speed changing mechanism presently is manually operated which can be further modified by connecting it to be servo motor to make it microprocessor baud control. This will enable to have a truly infinite variable speed and speed can be minutely changed i.e. ± 0.5 rpm etc.

2) This could also be convert into a wet friction type clutch by modifying the liner material and an oil tight casing with proper heat dissipation facility.

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