An Experimental Study on Full 'Toroidal' Continuously Variable Transmission System

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Abstract: 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, quieter operation, and a lower mass. Current efforts to reduce the vehicles, 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. This work documents a successfully developed experimental model of a 'Toroidal' continuously variable transmission (CVT) by adjusting its geometrical configuration of CVT design and compared the experimental results of speed, torque and power delivered at the output disc with those obtained by a theoretical.

Keywords: CVT, Full 'Toroidal', Geometrical Configuration of CVT Design

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1 INTRODUCTION

Continuously variable transmission (CVT) has been used for many years in diverse industries. The continuous adjustment of the output speed at constant driving speed is required in many applications. Usage of CVT is especially in the automotive industry as they offer the potential for an improvement in fuel economy relative to discrete ratio transmissions. This arises from the ability to match the engine operating point more beneficially to vehicle requirements as a result of the continuous ratio range. The traction continuously variable transmission (CVT) drives has continued to be an object of considerable research interest within the mechanical design community, driven primarily by automotive industry's demands for more energy efficient and environmentally friendlier vehicles. An overview of the historical background of the continuously variable transmission (CVT) has been introduced [1-2], among them, primarily two types that are of interest in the automotive area, viz, half 'Toroidal' traction drives and full-'Toroidal' traction drives which are illustrated in Fig.1. The different characteristic in these systems is the shape of cavities in the power transmission elements [3-5]. Such traction drives rely on thin film of the traction fluid to transmit power. The thin oil film solidifies under high contact pressure [6]. The performance of the drive depends, to a large extent, on the maximum value of the Hertz stress in the contact areas, where the aspect, material properties, operating conditions, geometrical factors must be considered. The stress calculations for the contacts of the 'Toroidal' CVT for fatigue life analysis were performed by using Hamrock's method [7]. The present work attempts to study geometrical configuration of 'Toroidal' CVT design in order to determine the theoretical & experimental results of speed, torque and power delivered at the output disc.

2 CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

The continuously variable transmission (CVT) although a pretty new innovation to the automobile industries, the idea has been around since the 15th century when Leonardo Da Vinci sketches his version of a stepless continuously variable transmission. The main advantage and appeal of the CVT is the fact that there are infinite amounts of gear ratios between a maximum and a minimum (there are no gears in the CVT; however the term gear ratio is still used for what it represents). It provides better fuel economy, a smoother drive and more useable power than offered by an automatic transmission. With a CVT you never feel the transmission shift when driving and it changes adapting to the driving condition. The CVT operates on many different systems of which common types are variable-diameter system, 'Toroidal' system, and hydrostatic system.

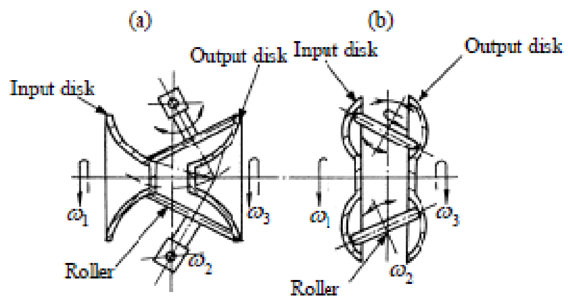

Fig. 1 Configurations of 'Toroidal' traction drive CVT: (a) Half 'Toroidal' (b) Full 'Toroidal'

2.1. 'Toroidal' type of CVT

'Toroidal' continuously variable transmission includes an input disk, an output disk facing the input disk, a power roller gripped between the input disk and output disk, Power is transferred from one side to the other by power rollers. When the roller's axis is perpendicular to the axis of the near-conical parts, it contacts the near-conical parts at same-diameter locations and thus gives a 1:1 gear ratio. The roller can be moved along the axis of the near-conical parts, changing angle as needed to maintain contact. This will cause the roller to contact the near-conical parts at varying and distinct diameters, giving a gear ratio other than 1:1. The variation in speed of both the discs due to change in position of power roller is shown in Fig. 2.

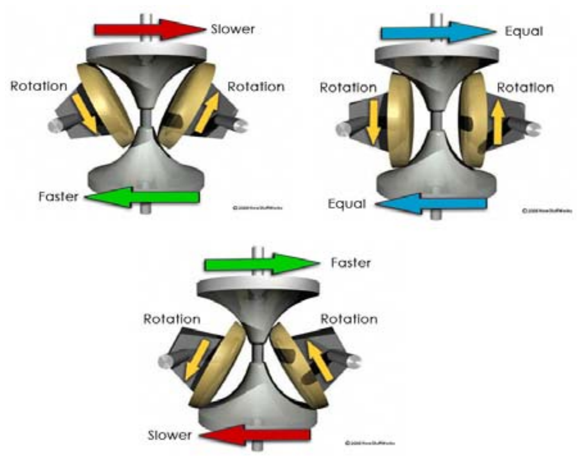

Fig. 2 Variation in speed of 'Toridal' disc due variable position of power roller

Table 1 Co-ordinates of parabolic curve

X(mm)	15	30	45	60	75	90	105	120	135	150
Y(mm)	15.35	16.4	18.15	20.6	23.75	27.60	32.15	37.40	43.35	50

2.2. Design of parabolic shaped disc

The shape of parabola can be obtained by using Parabolic equation $Y = AX^2$ Assuming Y=35mm and X=150mm so A= 0.001555.
Parabolic equation is $Y=C+AX^2$ where C=15.
The length of disc is divided into 10 equal divisions. The parabolic profile based on Table 1 is shown in Fig. 3.

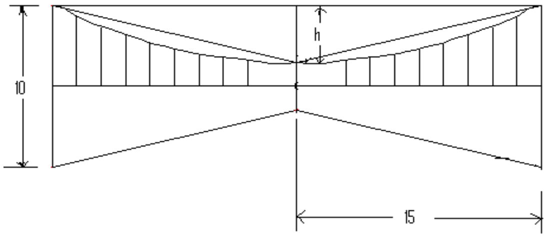

Fig. 3 Design of parabolic discs

The force acting on disc due to power transmission is represented by Fig. 4.

$P = T_s / r$
$= 3280/26$
$= 126.15$ N

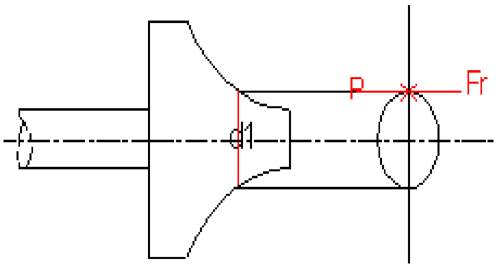

Fig. 4 Force analysis of disc

Fig. 5 represents normal force on disc due to power roller & spring:

Weight of roller, $W_r = 14.15$ N.
Spring force, $F_s = 49$ N.
Angle, $ø = \tan^{-1}(x/y)$
$= 22.71^0$

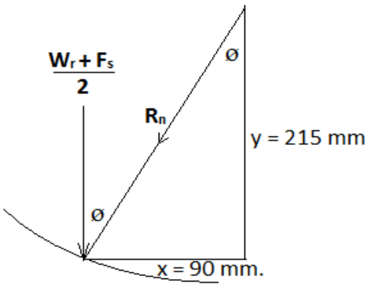

Fig. 5 Normal force analysis of disc

Normal force, $R_n = (W_r + F_s)/2 \times \cos ø$
$= 29.13$ N.
Coefficient of friction, $\mu = 0.8$
Frictional force, $F_r = \mu \times R_n$
$= 23.30$ N.

2.3. Design dimension of CVT

The input & output disc are made from M.S. material having length of 150mm, larger diameter of 100mm, & smaller diameter of 30mm. The power roller is made up of cast iron with mean diameter of 180mm (Fig. 6).

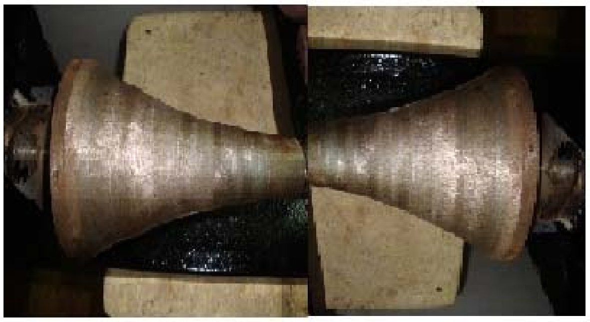

Fig. 6 'Toridal' C.V.T.

3 EXPERIMENTAL SETUP OF C.V.T.

The experimental setup of a 'Toroidal' continuously variable transmission (CVT) is shown in Fig. 7. A 'Toroidal' CVT is made up of two disks on a central axle and a 'Toroidal' roller that transmits motion between them. Two discs are connected to each other through thrust bearing. The input disc is connected to the induction motor (3¢, 1hp, 1440rpm) through belt drive and the one opposite to it is the output disc. One power roller is kept over both disks. This roller revolves around the vertical axis. When the axis of rotation of roller is perpendicular to the axis of rotation of discs, it contacts them at same-diameter locations and thus gives a 1:1 speed ratio. By tilting the handle of roller we can vary the speed as well as torque on the output disc for same input speed. If the diameter in contact to output disc is larger, high torque and low speed is obtained at output. Reversely, if the diameter in contact to the output disc is smaller, low torque and high speed is obtained at output.

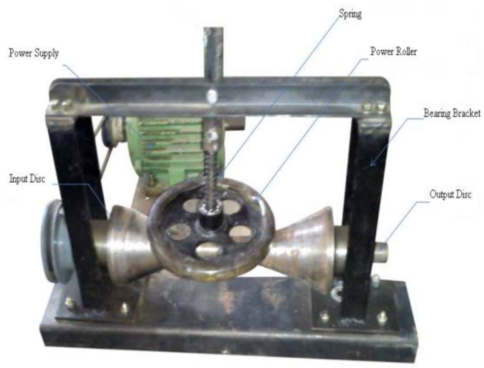

Fig. 7 Experimental setup of ‘Toridal’ CVT

4 RESULTS AND DISCUSSION OF CVT

Because of the existing literature it is swift to confess that the automotive industry lacks a wide knowledge base regarding CVT whereas conventional transmissions have been continuously refined and improved since the very start of the 20th century, CVT development is just beginning. Theoretically it is found that on input disc the speed, torque & power are constant with respect to angular deflection of input disc as shown in Fig. 8. The geometry like deflection & disc diameters are kept fixed on input and output disc as claimed in table 2.

Table 2 Geometry of output disc

Deflection θ^0	-10	-5	0	5	10
Diameter D_1(mm)	92	68	52.5	40	34

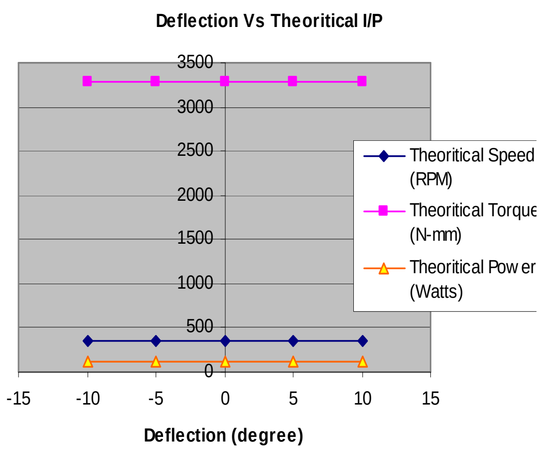

Fig. 8 Theoretical results of input disc

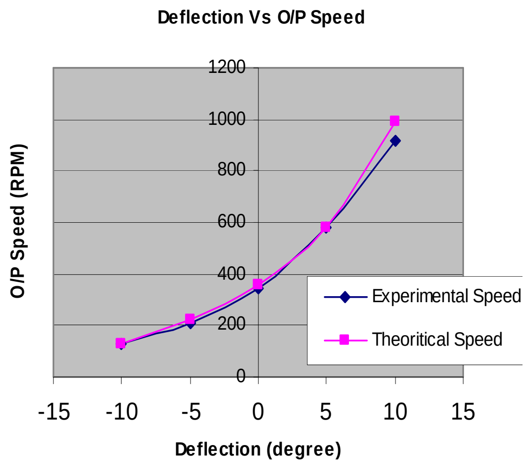

Fig. 9 Deflection Vs O/P speed

Theoretically & experimentally it is observed that on output disc, the geometrical configuration of disc may affect the results of output speed, torque & power as shown in Fig. 9 through 11.

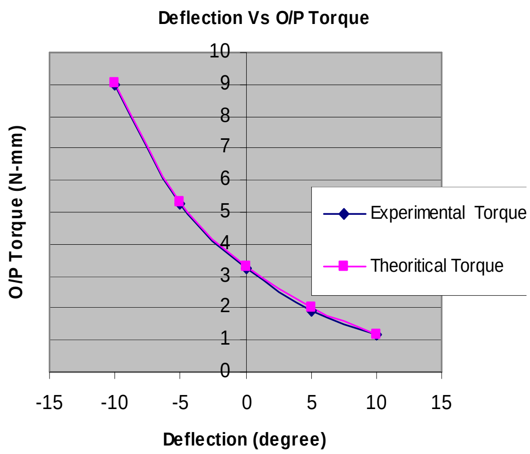

Fig. 10 Deflection Vs O/P torque

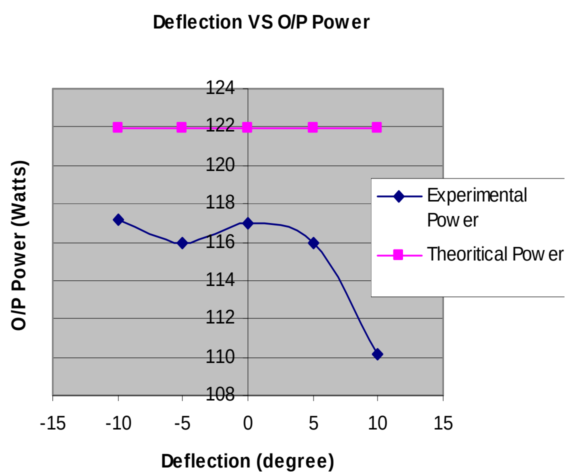

Fig. 11 Deflection VS O/P power

As communications is built up along with said knowledge base, CVTs will become even more prominent in the automotive industry. Even today's CVTs, which represent first generation designs at best, outperform conventional transmissions. Automakers who fail to develop CVTs now, while the field is still in its early years, risk being left behind as CVT development and implementation continues its exponential growth. Moreover, CVTs do not fall exclusively in the realm of I.C. engines. Currently it is used in numerous vehicles.

Continual technology and material developments enhance feasibility. Environmental concerns and emission regulations of fuels are CVT advancements. Because of these benefits CVTs are beneficial to use in future. In this it is targeted various geometrical configuration of 'Toroidal' CVT for development and demonstrated how well the new developments performed in a next-generation 'Toroidal' CVT mounted to a vehicle. We thus verified that real-world application of the next-generation 'Toroidal' CVT is highly possible.

NOMENCLATURE

CVT	- Continuously variable transmission
P	- Force acting due to power transmission
T_s	- Shaft torque
R	- Radius at smaller end of disc
Y	- Height of the disc
X	- Length of the disc
A	- Constant
C	- Small end height of disc
W_r	- Weight of roller
F_s	- Spring force
ø	- Angle
R_n	- Normal force,
μ	- Coefficient of friction
F_r	- Frictional force,

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