International Journal of Research in Advent Technology, Vol.3, No.12, December 2015
E-ISSN: 2321-9637
Available online at www.ijrat.org

Review of Free Ball traction Drive for CVT

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Abstract: There are many machines and mechanical units that under varying circumstances make it desirable to be able to drive at an barely perceptible speed, an intermediate speed or a high speed. The primary motions of machine tools are power driven. Thus an infinitely variable (stepless) speed variation in which it is possible to get any desirable speed. Some mechanical, hydraulic, drives serve as such stepless drives. Traction drive system has been used for various purposes and in various environments. Mainly Traction drive is used for CVT (continuously variable transmission) applications. Traction drive systems can be alternative to the gearing system. The advantage of Traction drive is the smooth traction surfaces that provide more variability ratio and capability for higher and lower speeds than gears. The current paper reviews the state-of-the-art research review on control of friction-limited continuously variable transmissions by using free ball traction drive.

Key words: continuously variable transmission, Traction Drive

1. INTRODUCTION

Traction drives were one of the earliest forms of CVT concepts ever developed.
A traction drive is a transmission that transmits power through rolling contact. The 1906 Cartercar, powered with a 12-hp engine, was developed with just such a transmission. Many current applications employ traction drives. These include applications such as machine tools, low-power yard equipment, and recently some automotive applications.

Transmission systems provide speed and torque conversions from a rotating power source to another device. Mechanically a transmission system in an automotive application is complex and is required to disconnect and connect the engine drive train from the wheels as required; reduce the rotational speed of the engine; and vary the transmission gear ratio as required by the driver to match the torque demanded at the wheels. Hence the efficient transmission of power from the engine to the wheels of an automotive vehicle is one of the greatest challenges facing automotive engineers. Transmission systems can be broadly divided into two categories: step-gear, in which the transmission has a discrete number of individual ratios; or continuously variable (CVT).
. There are many kinds of cvts, each having their own characteristics, e.g. Spherical CVT, Hydrostatic CVT,E-CVT, Toroidal CVT, Power-split CVT, Belt CVT, Chain CVT, Ball-type toroidal CVT, Milner CVT, etc. However, belt and chain types are the most commonly used CVTs, among all, in automotive applications. This paper reviews the state-of-the-art research, review on control of friction-limited continuously variable transmissions by using Free Ball traction drive to enhanced machine tool performance. [1]

Table 1: Summary of features and benefits of using a CVT in a automotive vehicle

Feature	*Benefit*
Step-less gear-change from rest to cruising speed	Eliminates "shift-shock" making the ride smoother
Keeps the engine in its optimum power range regardless of how fast the car is travelling	Improved fuel efficiency
Responds better to changing conditions, such as changes in throttle and speed	Eliminates gear hunting as a car decelerates, especially going up a hill
Less power loss in a CVT than a typical automatic transmission	Better acceleration
Can incorporate automated versions of mechanical clutches	Replaces inefficient torque converters

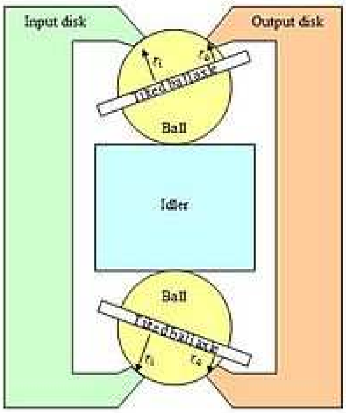

Fig:1 Tilting ball variator schematic [2]

The B-CVT is intended to overcome some of the limitations of existing CVT designs. Its compact and simple design and relatively its easier control make a good potential that B-CVT to be used in wide variety of mechanical and vehicle transmission systems. Working principle of this system is like a toroidal CVT. Basically, main components of B-CVTs consist of input disk, output disk and balls. B-CVT is traction type and balls work instead of rollers in toroidal CVTs, which connect these two disks to each other. Pohl et al. presented the analogy between the B-CVT and a controversial planetary gear set. [7]. Carter et al. has analyzed the effect of B-CVT usage on performance and efficiency of a two-Wheeled light electric vehicle. They showed that the B-CVT not only raised the top speed and time driving, but improved the controllability of the vehicle [8]. Park et.al. developed a prototype of a ball CVT for a motorcycle. They determined the design parameters, and measured the efficiency performances of the CVT experimentally [9]. Kim, et al., employed a ball CVT to drive a nonholonomic wheeled mobile robot. Their design had a low power to weight ratio, that makes it unsuitable for automotive or similar heavy duty applications [10].

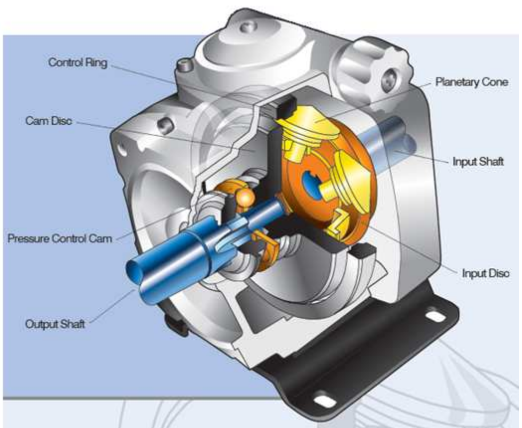

Fig2. Picture of CVT

Although in the recent years the researchers have investigated and designed different kinds of B- CVTs, there is not detailed and analytical description on their traction performance, power efficiency and corresponding power losses. In this paper, we analyze the performance of a B-CVT. Here, the Hertz theory is used to model the pressure distribution over the contact area to compute the power rate and friction losses. The relative velocities at contact areas and related spin loss as main sources of power loss in CVT systems are computed. After describing geometrical and traction parameters we derive power transmission efficiency of the B-CVTs. Finally, the effect of different geometric and power transmission conditions in efficiency of a B-CVT is presented, and compared with a toroidal CVT.

The operation of a B-CVT has been depicted in Figure . Speed ratio is controlled by tilting the balls rotation axis angle which leads to 3 different conditions. In Figure 1-a, the system is in under drive condition, means the output shaft rotates slower than input shaft. In Figure 1-b, the system is in neutral position, so the speed of the input and output shafts are the same, and in Figure the system speed ratio is upper than 1.

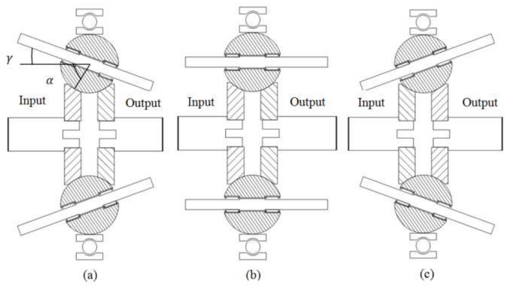

Fig3. Different situations of ball CVT [4]

B-CVTs usually includes 4 balls to transmit power between input and output disks, but CVTs with 6 and 8 balls are used for specific applications.

2. LITERATURE REVIEW

A number of different CVT designs exist and have existed for over a century. CVTs have traditionally been dismissed due to their limited torque and durability, however these problems have been solved in recent years, and the race is currently on to produce the CVT design that will be widely adopted, in particular by the automotive industry. The design with the most promise is the toroidal traction-type CVT, which utilises a special traction fluid in order to transmit shear force from one part to the next. A number of different traction designs have been developed, but have not been particularly successful due to the complex control mechanism required for synchronisation and ratio selection. Any design that hopes to be successful must hence address these issues as a priority. One such design, the CP-CVT, appears to meet these criteria, and furthermore, has been approved for patenting through an external company report (Nerac) which specialises in assessing the intellectual property potential in novel designs

The concept of Continuously Variable Transmission has existed for over a century, with the first European patent being taken out in 1886. Even before this, Leonardo Da Vinci had his own idea about the concept as early 1490 (Harris, 2008), shown in Figure

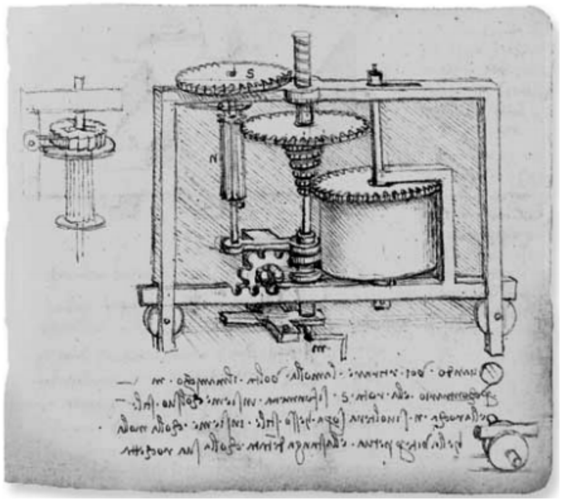

Fig4 One of the earlier designs for a Continuously Variable Transmission

A good history of the development of traction drives is presented by Heilich and Shube (1983). It is claimed here that CVTs have enjoyed moderately wide-spread industrial use since the 1930s, whilst the automotive industry, notorious for being slower to react to new technologies, never really adopted their use, despite the obvious advantages discussed previously. The reluctance of the automotive industry to react to new technologies is highlighted in Figure (from Hellman and Heavenrich, 2001).

Cretu and Glovnea, 2005-

Recently a novel type of toroidal CVT has been developed that is capable of automatically adjusting the transmission ratio as a function of the resistive torque.The device consists of two input discs, one conical, fixed to the shaft and the other toroidal, which has axial but not rotational mobility relative to the shaft. An inverted conical output disc is connected to the output shaft through a mechanism which is able to convert torque to axial force, such as a ball-screw. Between the input and output discs there are placed a convenient number (typically three-five) of spherical elements, which do not have a materialised axis of rotation. The arrangement of these parts is shown in Figure

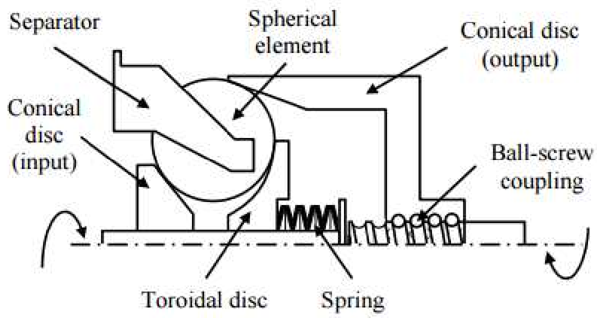

Fig5: Design solution for a constant-power CVT

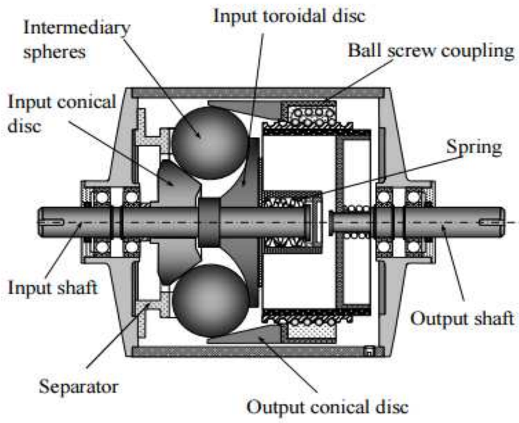

Fig6: Intended CP-CVT layout

The validity of the optimised design is demonstrated through the use of a "ground-up" simulation that attempts to model the behaviour of the CVT in a real automotive application using multiple fundamental theories and models including tire friction and traction behaviour.

Additional complementary research looks at the accuracy of the tire friction models through the use of a specially design tire friction test rig. Furthermore, a monitoring system is proposed for this particular CVT design (and similar) that is capable of continuously checking the contact film thickness between adjacent elements to ensure that there is sufficient lubrication to avoid metal-on-metal contact. The system, which is based around electrical capacitance, requires the knowledge of the behaviour of the electrical permittivity at increased pressure. This behaviour is studied through the use of an experimental test rig.[5]

Brad Pohl- Fallbrook Technologies

In this paper, we present the analogy between the spherical variator and a conventional planetary gearset. Infinitely variable transmission (IVT) characteristics are typically obtained by utilizing a planetary gear set in a split-power transmission configuration. The spherical traction CVT developed by Fallbrook Technologies is kinematically analogous to a variable planetary gear set. The geometry of the spherical traction CVT patented and under development by Fallbrook Technologies Inc (formerly Motion Technologies LLC)

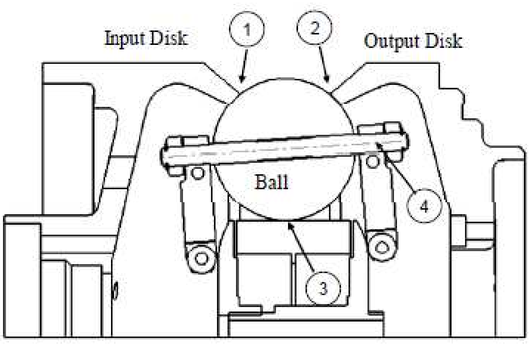

Fig7: Spherical CVT

The power density of the spherical CVT makes it uniquely scalable to a broad range of applications. Dual- or triple-power input (or output) is also possible, with obvious advantages for hybrid vehicles. Combinations of the CVT with a fixed ratio planetary generate numerous power paths that can be combined to further increase the ratio range of the device. The transmission components must be capable of handling the recirculating power, which is often far greater than system input power, though IVTs using other types of variators also face this situation.[7]

H. Ghariblu - Traction and Efficiency Performance of Ball Type CVTs

This paper concerns the design and analysis, of a ball type continuously variable transmission, (B-CVT). This B-CVT has a simple kinematic structure, and same as a toroidal CVT, transmits power by friction on the contact points between input and output discs, that are connected to each other by balls. This paper, introduced a new type of a ball CVT and developed a basic methodology to analyze the performance and efficiency of the ball CVT. Our analysis shows that relative geometrical dimension and arrangement between input and output disks with balls has significant effect on the overall efficiency of the ball CVT. Also, comparing a ball CVT with a full toroidal CVT under equal conditions shows that efficiency of both systems are similar. Since the geometry of different kinds of ball CVTs are such that they are easily controllable, the B-CVT has a good potential to be used instead of belt and toroidal CVTs.[4]

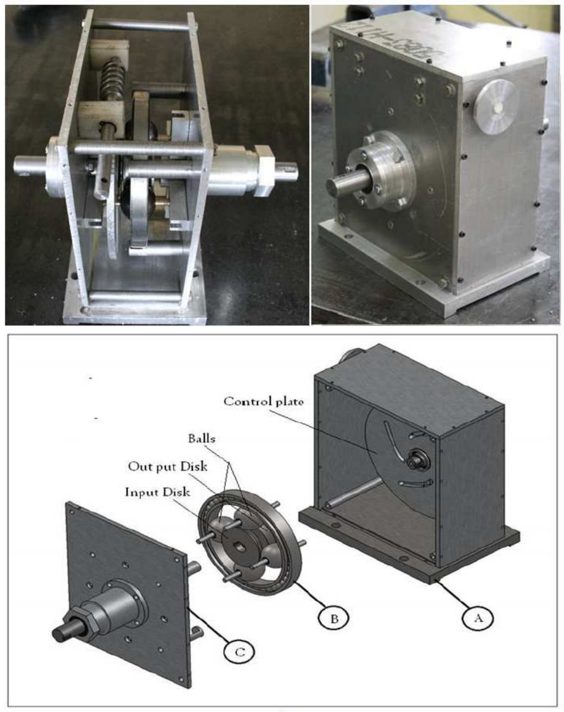

Fig8 . a)Two views of B- CVT prototype, and b) Exploded view [4]

Nerac Report

A Nerac1 report conducted for the purposes of exploring the intellectual property potential of the CP-CVT revealed the closest perceived rivals in terms of design and patent. Aside from certain belt-driven infinitely variable transmissions that employ a ball screw for automated control, the greatest threat to the CP-CVT was considered to be spherical element traction drives, such as the Milner-CVT described earlier. Additional patent threats were considered to be the Nissan/NSK CVT shown in Figure (Tenberge and Mockel, 2002), and the Torotrak CVT, discussed previously, both of which are considered fundamentally different enough in design and operation that patenting is still a distinct possibility.[11]

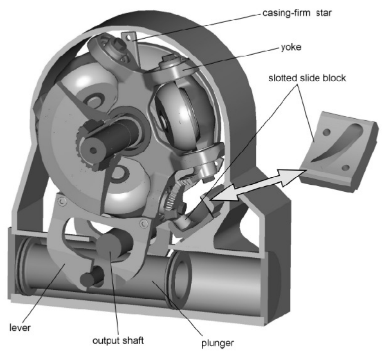

Fig9:Nissan/NSK developed Toroidal CVT with compact roller suspension [11]

Infinitrak for the Outdoor Power Equipment (OPE) market-

Infinitrak, the US based joint venture company owned by transmission innovation specialist Torotrak and OPE market leader MTD, has developed a new type of epicyclic drive that replaces gears with traction spheres, combining the functionality of a thrust bearing and an epicyclic drive stage. The first application of the traction drive epicyclic will be in a compact and affordable Infinitely Variable Transmission, developed by Infinitrak for the outdoor power equipment (OPE) market.

"One of the most challenging issues in any transmission is minimising noise levels, and this is particularly the case in low-cost OPE drive units since the precision and geometries required for refined operation with conventional gear sets can add significantly to product complexity and cost," explains Infintrak's Chief Operating Officer, Rob Oliver.

To address this issue, the new epicyclic replaces conventional gears with spherical traction drive elements that transfer torque through traction fluid using the same mechanism proven by Torotrak for its full-toroidal variator technologies. Eliminating meshing teeth ensures very low noise, while the use of fewer moving parts combined with materials and manufacturing technologies already proven in established ball bearing applications reduces cost and weight as well as providing increased durability compared with conventional epicyclic systems.

Epicyclic drives play a fundamental role in Infinitely Variable Transmissions (IVTs). Without an epicyclic drive, a full-toroidal variator based on Torotrak's traction drive technology works as a continuously variable transmission (CVT) that can change speed steplessly over a wide range of ratios. To allow the direction of drive to be changed within the transmission, giving it an in-built 'forwards-through-neutral-to-reverse' capability, an epicyclic arrangement is added to manage the input to and output from the variator, transforming the CVT into an IVT.

A conventional epicyclic gear train consists of a central gear (the sun gear) around which several planet gears are mounted on a rotating carrier. These gears also mesh with an outer, internally toothed ring (the annulus). By connecting the variator input to the sun and the variator output to the annulus, the planet carrier rotates at the speed difference between the two which can be positive, negative or zero. The planet carrier, effectively the output from the transmission, is connected to the vehicle's axle allowing the machine to move seamlessly from forward, through geared neutral (a condition where the engine and elements of the transmission are turning but the wheels are not), to reverse.

In the new traction drive epicyclic, the planet gears are replaced with steel spheres running in prescribed tracks in the rear face of the variator output disc and the end plate, which replaces the conventional annulus.

Engineers at OPE transmission specialist Infinitrak have also been successful in integrating the thrust bearing function (which is required to provide a reaction for the clamping forces within a single cavity variator transmission) within the epicyclic arrangement. This significantly reduces the number of moving parts, cutting weight, reducing packaging requirements and providing increased power density.

The first production application of Infinitrak's new traction epicyclic technology will be in a new transmission being finalised for launch in the outdoor power equipment (OPE) market "There is nothing on the market like this," concludes Rob Oliver. "We expect that the ease of control, refined operation, low noise and enhanced durability offered by the new transmission will make it highly competitive in this significant market sector."[3]

3. CONCLUSION

Research in this area has shown ball to have advantages in accuracy of rotation and stiffness, even at high speeds. A related area of interest is the use of free ball in pure rolling contact self actuating traction drive.

Since this new traction drive design consists of spherical -shaped ball rather than complex shaped gear teeth, it will be simpler to manufacture, easier to assemble, and will run quieter. CVTs operate smoothly since there are no gear changes which cause sudden jerks. They can deliver a lot of power and can reach barely perceptible speeds and Torque, all without need for a clutch or shift gears. Free ball traction drives are provided as a CVT in place of commonly used transmission drive such as belt drive, gear drive etc.

REFERENCES

[1] A Review On Continuously Variable Transmissions Control Da Wen Ge, Sugeng Ariyono and Daw Thet Thet Mon National Conference in Mechanical Engineering Research and Postgraduate Students
[2] https://en.wikipedia.org/wiki/File:Tilting_ball_variator.jpg
[3] http://www.torotrak.com/new-epicyclic-drive-technology-from-infinitrak-joint-venture-eliminates-gears-to-enhance-refinement-durability-cost-weight-and-packaging/
[4] Traction and Efficiency Performance of Ball Type CVTs H. Ghariblu *,1 ,A. Behroozirad2, A. Madandar3 International Journal of Automotive Engineering Vol. 4, Number 2, June 2014
[5] Concept Design for Transmission Systems Colin A. BELL, Cristinel MARES and Romeo P. GLOVNEA School of Engineering and Design, Brunel University Kingston lane, Uxbridge, UB8 3PH United Kingdom
[6] 04CVT-9,Configuration Analysis of a Spherical Traction Drive CVT/IVT Brad Pohl, Matthew Simister, Robert Smithson, Don Miller Fallbrook Technologies
[7] Pohl, B., Simister, M., Smithson, R., Miller, D.; "Configuration Analysis of a Spherical Traction Drive CVT/IVT", Fallbrook Technologies Inc.

[8] Carter, J., McDaniel, L., Vasiliotis, C., 2007, Use of a Continuously Variable Transmission to Optimize Performance and Efficiency of Two-Wheeled Light Electric Vehicles (LEV) ; European Ele-Drive Conference, Brussels, Belgium.
[9] Park, N. G., et.al. 2009, Development of the inner spherical CVT for a motocycle, Int. J. of Auto. Technol., 10(3), pp. 341-346
[10] Kim, J., Park F. C. and Park Y., 2002, Design, Analysis and Control of a Wheeled Mobile Robot with a Nonholonomic Spherical CVT, the Int. J. of Rob. Res., 21, pp. 409-426.