# Performance of Infinitely Variable Transmission System Based on Constantinesco Torque Convertor

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***Abstract*— The Infinitely Variable Transmission (IVT) system is a automatic gearbox designed to save fuel, give a smoother drive and improve performance of the vehicle. The purpose of the IVT is to allow the engine to maintain an almost constant speed. The Infinitely Variable Transmission system (IVT) is a transmission design that transmits mechanical power via oscillating torque. It is different from the traditional speed ratio methods. This infinitely variable transmission (IVT) controls the output torque its opposite from the output speed ratio. From zero torque to the full capacity of torque output it is the infinitely variable torque. it can be produced with no clutching or torque conversion required at the input in the IVT. The centrifugal forces of rotating eccentric masses is mounted on shaft to create an oscillating torque which harness the power. The function of One-way clutches is to convert the oscillating torque to a unidirectional torque. In the infinitely variable transmission (IVT) system a series of offset masses used to transmit torque to the output shaft which comes after the clutches. The three diamensional design made for all components of IVT in the 3D software CATIA V5 and made 2D drawings for the production of parts and assembly of the test rig.**

***Key words* — Infinitely Variable Transmission (IVT), Continuously Variable Transmission (CVT), Automatic gearbox.**

## I. INTRODUCTION

The manual gearbox in the cars could be very difficult for the driver while driving in the traffic. To optimize the fuel consumption it needs to change gears frequently. In the automatic infinitely variable transmission eliminates the speed gear change operations for driver and it ensures the optimal transmission ratio. In IVT the zero transmission ratios can be achieved, as an IVT is a continuously variable transmission with an infinite ratio range.

The main motto is to design the infinitely variable transmission for the use of vehicle and improvements in the existing design. The Infinitely Variable Transmission system must be able to withstand a series of tests including that of endurance.

The moments produced by rotating offset masses to transfer torque is utilized in the transmission in the IVT at variable output speed, from the engine to the output shaft. All parts from the old IVT design and existing research are analyzed in detail to modify the same for reliable and efficient IVT system.

### A. PROBLEM STATEMENT

Manual transmissions (MT) are the most common in today's cars. This transmission only allows a limited set of fixed gear ratios. The gear box is manual transmission gear box with 4 or 5 speeds. i.e., Gears 0-1-2-3-4-5, in order to shift from one gear to another one has to perform three operations i.e., De-clutching, change gear gradual engagement thus in order to reach top speed i.e., $5^{th}$ gear we will have to perform 15 operations. This becomes a problem while running vehicle in dense traffic conditions.

The infinitely variable transmission (IVT) system is a sophisticated automatic gearbox designed to save on fuel, cut emissions, give a smoother drive and improve performance. Because most motors, whether powered by liquid fuel or electricity, have a narrow RPM range at which they operate at top efficiency, they generally need a transmission to allow for variances in output speed. Most transmissions have a certain number of gears available, meaning there is still significant variation in engine speed before the transmission shifts to the next gear .The purpose of the IVT is to allow the engine to maintain an almost constant speed while the output speed changes to meet the needs of the equipment or process involved.

### B. METHODOLOGY

The data collection phase involves the collection of reference material for project concept. The idea for IVT is taken from the book ingenious mechanisms for designers and inventors. In the phase System Design comprises of development of the mechanism so that the given concept can perform the desired operation. The system design also determines the system components and their shape and overall dimensions. In the phase Mechanical Design, the parts mentioned in the bill of material is designed for stress and strain under the given system of forces and appropriate dimensions are derived. The standard parts are selected from the PSG design data handbook.

For the next phase Production Drawing Preparation, Production drawings of the parts are prepared using the 3D modeling software CATIA V5. The 3D design and 2D drawings are made with the same software with appropriate dimensional and geometric tolerances. Raw material sizes for parts are also determined. In the phase Material Procurement & Process Planning, material is procured as per raw material specification and part quantity. Part process planning is done to decide the process of manufacture and appropriate machine for the same. The next phase is manufacturing, parts are produced as per the part drawings. In the phase Assembly of the IVT test rig, assembly of the device is done as per assembly drawings. Test and trial is conducted on the IVT test rig for evaluating the performance.

## II. LITERATURE REVIEW ON IVT

A) Giacomo Mantriota, Presented paper on Performances of a series infinitely variable transmission with type I power flow [1], In this paper it is shown the possible power flow directions of a power split CVT system. In this work the experimental results related to the measure of power flows and the efficiency of the series-IVT with type I power flow are obtained. The experimental tests were performed using a special test rig to measure the power flows in different operating conditions.

B) Giacom Mantriota, Presented paper on Performances of parallel infinitely variable transmissions with a type II power flow [2], He reported the work on experimental results obtained for a parallel-IVT prototype with type II power flow. The main goal of this work is to appraise the IVT performances in terms of torque, power flows and efficiency.

C) F.Bottiglione, S. De Pinto, and G. Mantriota, Presented paper on infinitely variable transmissions in neutral gear: Torque ratio and power re-circulation [3]. In this paper, the power recirculation and the torque ratio of infinitely variable transmissions (IVT) are investigated. The focus is on the gear neutral condition, which very useful in many applications but actually critical in terms of efficiency, reliability and control.

D) Ion ION, Presented paper on George Constantinescu' Torque Converter Analysis by Simulink [5]. He analyzed Constantinescu Torque converter by Simulink. Modeling of the dynamics for an automotive application is demonstrates its high performance characteristics. In the modeling of this power transmission system, the stiffness of the shaft and various control logics are included.

E) Amarsinh Shinde, Subim Khan, Presented paper on Modeling, Design and Development of Infinitely Variable transmission System [9]. Studied that the design considerations for the parts in IVT and the methodology to select the good option from various solutions. This study is based on the modeling, design and development of the infinitely variable transmission system. This study shows the methodology of part selection and analysis of critical parts made to ensure the reliability and performance of Infinitely Variable Transmission system.

## III. OBJECTIVES OF THE STUDY

1) The Infinitely Variable Transmission (IVT) system is designed to study the various characteristics like Torque, Power and Efficiency across the Speed.
2) Modeling, Design and Development of infinitely variable transmission system based on constantinescu torque converter using the 3D software CATIA V5 and analysis software ANSYS.
3) The dynamometer testing is to ensure the safe operation of the Infinitely Variable Transmission system.
4) The objective is to understand the construction and operation of IVT and determine where improvements can be made.
5) The objective is to prove the infinitely variable transmission system is reliable at higher speed for the testing.
6) The elimination of gear box and friction clutches from the transmission system results the low weight and compact transmission system, this increases the transmission efficiency. IVT makes the automatic transmission as it not required changing the gears frequently.

## IV. INFINITELY VARIABLE TRANSMISSION (IVT) SYSTEM

The infinitely variable transmission (IVT) made for the vehicle is based on a patented design owned and developed by Terry Lester, of Fort Worth, Texas. Modifications have been made in to the design to match the requirements of the vehicle. The final result is a somewhat simplified version of Infinitely Variable Transmission system of Mr. Lester's original design. The basic design and performance characteristics remain the same.

A British-French engineer, George Constantinescu made the constantinescu torque converter. Constantinescu's invention of the "oscillating masses" mechanical torque converter is the main inspiration behind the car. This mechanical torque converter is a replacement for clumsy gear shifting system to get a smooth and highly efficient transmission. The transmission ratio was determined by the oscillation of pendulum. The extent of the oscillations being determined by the pendulum's mass. An oscillating masses torque converter eliminates entire complex geared automotive transmissions. A complex geared automotive transmission has their jerky shifting, added weight and low efficiency. Constantinescu's needed a substantially smaller engine as compared to a similar car with a gear based transmission. It is lighter overall and was much more fuel efficient [6].

The infinitely variable transmissions (IVT) maintained the variable transmission ratio with continuity. It is offering the possibility of also reaching zero transmission ratio and motion inversion. The infinitely variable transmission system is one type of power split CVT system. This ensures infinite ratio range coverage by providing even zero transmission ratios with an unmoving both shafts output shaft and an input shaft without zero velocity. A compact transmission is obtained which includes a clutch function. It allows the running of the vehicle at very low speed due to absence of friction clutch. It will not allow to arise any problem from clutch's engage and disengages control [1].

### A. IVT CONCEPT

The input provided to the infinitely variable transmission by the engine. Which produces a power and torque output. For the given speed the power and output torque is constant with respect to time. This constant power and torque is transmitted to the arm assembly via the input assembly and it is shown in figure 1.

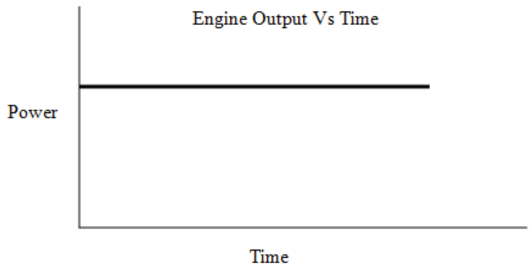



Figure 1 - Engine output

The IVT in turn converts the constant input into oscillating torque via its specific mechanism. Figure 2 shows arm assembly output and the behavior of the oscillating torque developed.

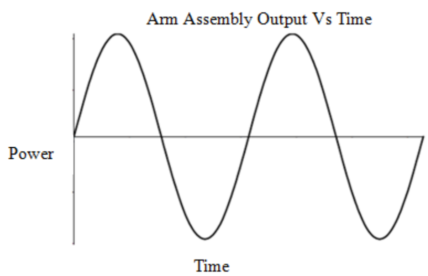



Figure 2 - Arm Assembly Output

The input power for the clutch assembly is the output power of arm assembly. The clutch assembly of the IVT converts the oscillating power into unidirectional power pulses as shown in Figure 3. The amplitude and frequency of these pulses decides the average power. To get higher power output, amplitude and frequency must be higher. The magnitude of the input received from the engine generates amplitude of the power pulses. The speed of the arm assembly shaft decides the frequency of the pulses.

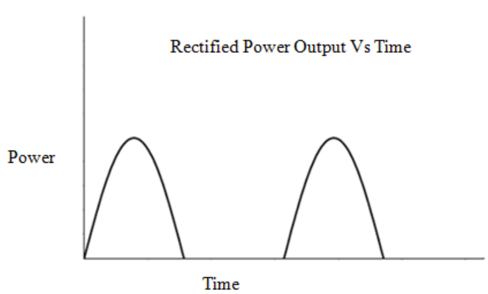



Figure 3 - Rectified Power Output

The engine will operate at its optimum speed for either power, torque or fuel economy. The output pulses and oscillations will be of sufficiently high frequency to produce an output. That output will observe essentially consistent rotational motion, these behavioral characteristics shown in figure 4.

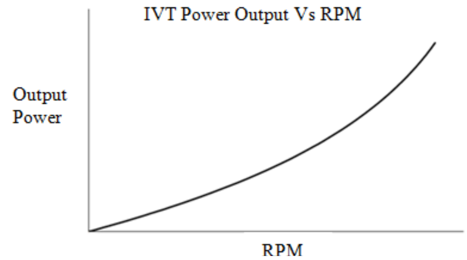



Figure 4 - IVT Power Output

B. IVT OPERATION

The IVT consist of four main parts and these are the input assembly, arm assembly, clutch assembly and the output shaft. All of these areas have a specific role in the operation of the IVT. The input assembly takes the input from the engine and delivers it to the arm assembly. The arm assembly generates oscillating torque. The clutch assembly rectifies that oscillating torque to a single direction, and the output shaft delivers the output to the further transmission. These main parts and their associated functions can be seen in Figure 5.

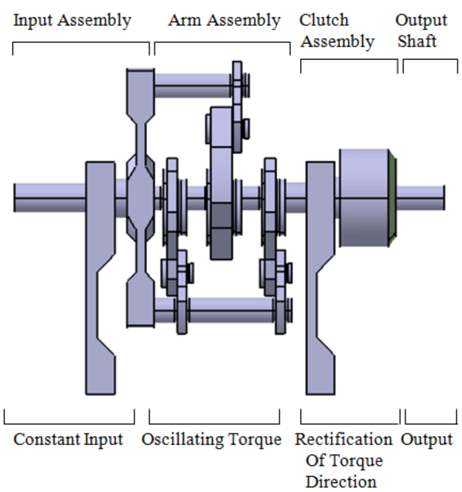



Figure 5 - IVT Overview

Using the V belt drive between the engine output shaft and the input shaft of the IVT, the IVT will receive input from the engine through the use of that. The input shaft will transmit the torque to a yoke. The yoke has two pins projecting from it as shown in figure 6. The yoke pins are connected to the links.

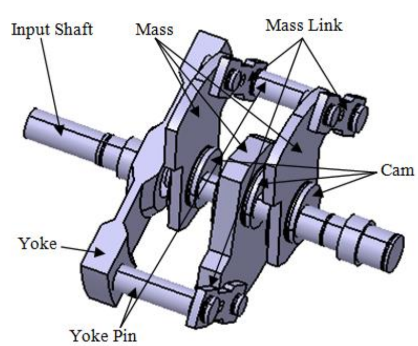



Figure 6 - Input and Arm Assemblies

The links are in turn pin connected to three masses. These masses are attached to the arm assembly. The core part of the IVT is the method in which the masses interact with the arm assembly. This arm assembly by the rotation of masses allows generating torque. This generated torque transmitted to the output shaft.

The intermediate shaft of the arm assembly has three cams mounted on it. These cams are circular pieces of steel like hollow shaft, which having an offset bore for the arm assembly shaft as shown in the figure 7. Any force acting radically on the cam is translated into a moment which acts on the shaft due to the offset shaft construction. This is because the center of the cam is offset from the center of the shaft, creating a moment arm.

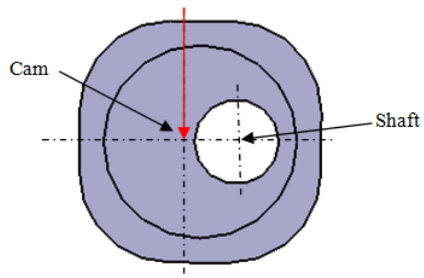



Figure 7 – Cam

The three cams are mounted on arm assembly shaft. These are offset and exactly 180° opposite of the other two cams and each with a bearing press-fit onto it. The center cam is longer in dimension than the other two cams. The length of cam decided according to the dimensions of masses. The weight of central mass is equal to the weight of addition of other two masses. This configuration is made to ensure the balancing of the shaft. The centrifugal forces generate create a moment about the arm assembly shaft as the masses rotates around the cams.

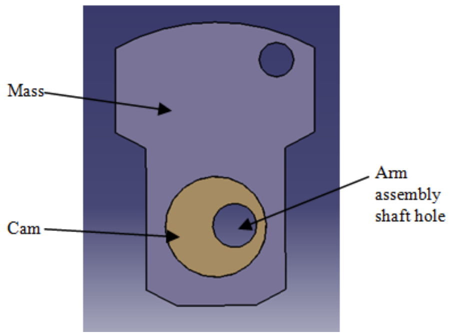



Figure 8 – Offset Cam and Mass

The following four steps explain the oscillatory nature of the torque generated by the IVT.

In step 1, the rotating masses generate the centrifugal forces pass through the point of rotation. Therefore it do not generate any moment. At step 2 the centrifugal forces generate a clockwise torque, as the masses have continued to rotate.

In step 3 the masses having continued to rotate to the point where their centrifugal forces once again pass through the point of rotation, thus it will cause no moment. In the last step 4 the masses have rotated so that their forces will produce a counter-clockwise torque. For this the maximum torque is calculated by the formula:

$$T = m.\omega^2.R_{CG}.D_{Cam\ Offset} \qquad (1)$$

The centrifugal force is proportional to the square of rotational speed. Once the rotational speed of the masses increases good enough, then the resistances on the assembly shaft will be overcome by the moment developed and the assembly shaft will begin to rotate. From this stage on, the mechanics of the arm assembly and masses will be dynamic. The arm assembly shaft rotating itself and with respect to this one of the four steps above will be occur. The rotation of the masses about the cam will be decreasing as the rotation of the arm assembly shaft increases. With respect to the arm assembly shaft the period of the oscillation will increase. The period of the torque oscillations will approach infinity due to the rotational speed of the arm assembly shaft. At this stage the IVT will act like a direct connection between input and output.

To convert the oscillating torque into unidirectional motion, in IVT uses two sets of one-way clutches. The first set of clutch is between the arm assembly shaft and the support case to the arm assembly. The oscillating torque gets converted into torque pulses in this set of clutches. The clutches operates between the output shaft and the arm assembly shaft is from the second set of the clutches. The purpose of this clutch set is to allow the output shaft to make free to rotate between torque pulses. The vehicle's wheels would stop and start with every torque pulse without these clutches.

## V. MODELING, DEIGN AND DEVELOPMENT

The Infinitely Variable Transmission (IVT) system is designed to study the various characteristics like torque, power and efficiency across the speed. The components from IVT are designed with the considerations of various factors like material, cost, ease of manufacturing and the reliability of the system. The basic design of the IVT system and its components are done with the 3D modeling software CATIA V5 R20 version. Further made the drawings for the manufacturing to assemble the IVT experimental setup. The design for the Infinitely Variable Transmission system is to be specially designed to get the match with vehicle requirements. Therefore all the design modifications and optimizations are made to achieve top speed, pulling capability and weight/space savings in the IVT. The study is made on the design considerations for all parts and analysis of the critical parts from the IVT system. The basic inputs considered as per the requirement and design calculations done with the reference of theoretical base for all the IVT components. As per the theoretical calculations, the dimensions and the failure mode conditions are safe for the input torque conditions [9].

## VI. TEST RIG

The experimental results related to the torque, power and efficiency of infinitely variable transmission (IVT) are getting in this work. To get the above results we built a special test rig.


Figure 9 – Test Rig of IVT

The suitable manufacturing methods are used to manufacture the parts and then assemble the test set-up. Several key alterations have been incorporated into the IVT design in order to improve and optimize reliability, quality, and efficiency. These changes will differentiate this IVT from the mini car IVT. The areas in which these changes have occurred are the masses, the bearings, the arm assembly, and the yoke assembly.

For the Infinitely Variable Transmission system, this is the main stage as its reliability and performance are directly proportional to the vehicle's reliability and performance. Hence from the testing session it must be shown that the infinitely variable transmission system can withstand all performance and criteria demanded by the vehicle. To check this, a various tests were conducted to determine various characteristics for the IVT system.

For the testing performance of any engine, the engine dynamometer is the logical step in this process. For the ease of testing we installed rope pulley dynamometer on the test rig itself. The effective diameter of the dynamometer pulley is 65 mm. The pulley is mounted on the output shaft of the infinitely variable transmission system on the test rig as shown in figure 9. The engine is replaced by AC motor to mount on the test rig. 50 watt variable speed motor having speed range is 0 to 6000 rpm.

## VII. TEST AND TRIAL

The aim for this experimental setup is to conduct trial on lestran infinitely variable transmission system to determine the various characteristics like torque, power and efficiency across the speed. In order to conduct trial, a rope pulley dynamometer, weight pan are provided on the output shaft.

In this experimental setup instead of engine drive we use motor drive to obtain the results. The motor is of AC 230 volt, 0.5 ampere, 50 watt, 50 Hz, 200 to 6000 rpm TEFC Commutator motor. The effective diameter of dynamometer pulley is 75 mm.

The suitable procedure has been followed to obtain the observations and to plot the graphical results. First start motor by turning electronic speed variation knob. Let mechanism run & stabilize at certain speed (say 800 rpm). Then place the pulley cord on dynamometer pulley and add 100 gm weight into the pan. Measure and note down the output speed for this load by using tachometer. For the next reading add another 100 gm weight & take reading. Number of readings taken for various weights as it is increasing by 100 gm in the pan. Tabulate the readings in the observation table and plotted the various characteristics like torque, power and efficiency across the speed.

Calculations have to be made for torque, power and efficiency with the readings taken by above procedure. The factors like average speed, output torque, input power, output power and efficiency are calculated for the final results.

## VIII. OBSERVATIONS AND CALCULATIONS

TABLE 1
DYNAMOMETER TESTING OBSERVATIONS

| Sr. No. | Loading | | Unloading | | Mean Speed (RPM) |
|---|---|---|---|---|---|
| | Weight (gm) | Speed (RPM) | Weight (gm) | Speed (RPM) | |
| 1 | 100 | 760 | 100 | 760 | 760 |
| 2 | 200 | 742 | 200 | 742 | 742 |
| 3 | 300 | 734 | 300 | 734 | 734 |
| 4 | 400 | 721 | 400 | 721 | 721 |
| 5 | 500 | 715 | 500 | 715 | 715 |
| 6 | 600 | 660 | 600 | 660 | 660 |
| 7 | 700 | 510 | 700 | 510 | 510 |

Sample Calculations -

For 500 gm (0.5 kg) Load –

1) Average Speed –

$$N = \frac{N_1 + N_2}{2} = \frac{715 + 715}{2} = 715\, rpm$$

2) Output torque –

$T_{o/p}$ = (weight in pan) x (radius of dynamometer pulley)
= (0.5 x 9.81) x 32.5
= 159.413 N.mm = 0.159413 N.m

3) Input Power –

$$P_{i/p} = \frac{2.\pi.N.T_{i/p}}{60}$$

$$= \frac{2 \times \pi \times 715 \times 0.20033}{60} = 14.999\, watt$$

4) Output Power –

$$P_{o/p} = \frac{2.\pi.N.T_{o/p}}{60}$$

$$= \frac{2 \times \pi \times 715 \times 0.159413}{60} = 11.9375\, watt$$

5) Efficiency –

Efficiency = (Output Power) / (Input Power)

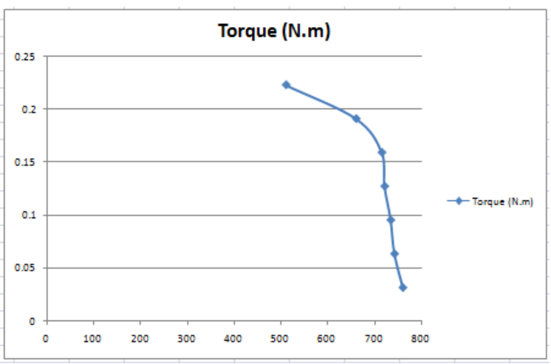
$$= \frac{11.9375}{15} \times 100 = 79.58\ \%$$

TABLE 2
CALCULATION RESULTS

| Sr. No. | Load (gm) | Speed (RPM) | Torque$_{o/p}$ (N.m) | Power$_{o/p}$ (watt) | Efficiency (%) |
|---|---|---|---|---|---|
| 1 | 100 | 760 | 0.031883 | 2.537762 | 16.918 |
| 2 | 200 | 742 | 0.063765 | 4.955314 | 33.033 |
| 3 | 300 | 734 | 0.095648 | 7.352831 | 49.018 |
| 4 | 400 | 721 | 0.12753 | 9.630139 | 64.20 |
| 5 | 500 | 715 | 0.159413 | 11.9375 | 79.58 |
| 6 | 600 | 660 | 0.191295 | 13.22308 | 88.15 |
| 7 | 700 | 510 | 0.223178 | 11.9208 | 79.47 |

## IX. GRAPHICAL REPRESENTATION OF THE RESULTS

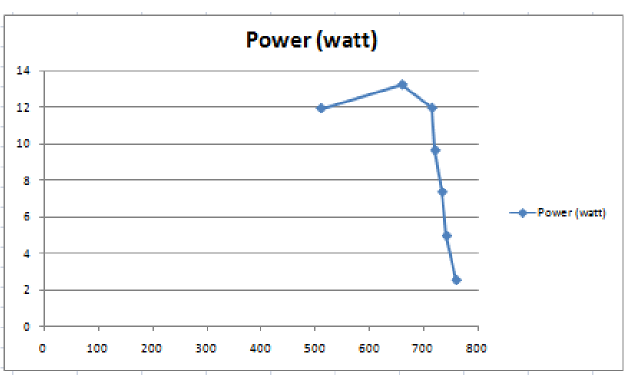
1) Torque Vs Speed Characteristics




Graph No. 1 - Torque Vs Speed Characteristics

The number of readings taken for the different load conditions and calculations for torque made for each observation. The following graph no. 1 represents the results of Torque on vertical axis Vs Speed on the horizontal axis. This graph represents the IVT system gives maximum torque when speed is low and the torque lowers with the increasing speed.

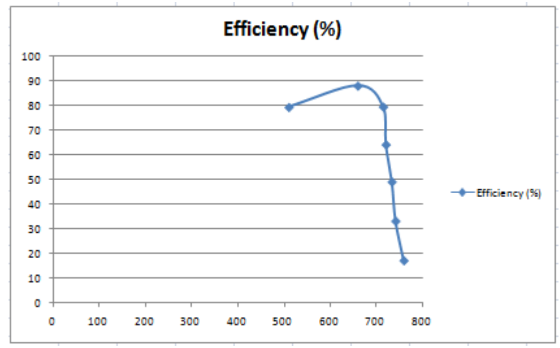
2) Power Vs Speed Characteristics




Graph No. 2 - Power Vs Speed Characteristics

With the different load conditions various readings taken on the test rig. The calculation made for the power from the input available and calculates torque above. The following graph no. 2 represents the results of Power on vertical axis Vs Speed on the horizontal axis.

3) Efficiency Vs Speed Characteristics




Graph No. 3 - Efficiency Vs Speed Characteristics

The Efficiency of the system is calculated from the torque and power of the IVT system. The efficiency for different load conditions is represented against the speed of the system. The following graph no. 3 represents the results of Efficiency on vertical axis Vs Speed on horizontal axis.

## X. CONCLUSION

A simple methodology for measuring IVT transmission efficiency using a rope pulley dynamometer was constructed in the test rig and validated. The results and graphs obtained from the above experimental trials are close to the values given in the literature. This modified infinitely variable transmission design easily meets the design requirements for construction and testing of the transmission. As per the material and cost considerations the design if this IVT is under allowable budget.

The current design for the IVT is modeled with the help of previous parameters determined and validated in the literature. The desktop model is built to demonstrate that the design is constructible and actually functions very well.

Comparing the final results with the objectives set for this work, it can be seen that the results and objectives met the requirements. The Infinitely Variable Transmission system run exceptionally smooth while the testing. This modeling of the IVT for an automotive application is demonstrating its high performance characteristics.

## XI. ACKNOWLEDGMENT

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## XII. REFERENCES

[1] Giacomo Mantrioa, "Performances of a series infinitely variable transmission with type I power flow". Dipartimento di ingegneria meccanica e gestionale, Politecnico di bari, Viale japigia, 182-70126 Bari, Italy, January 18, 2002.
[2] Giacomo Mantrioa, "Performances of parallel infinitely variable transmissions with a type II power flow". Dipartimento di ingegneria meccanica e gestionale, Politecnico di bari, Viale japigia, 182-70126 Bari, Italy, January 18, 2002.
[3] F.Bottiglione, S. De Pinto, G. Mantriota, "Infinitely variable transmissions in neutral gear: Torque ratio and power re-circulation". Departimento di meccanica e management, Politecnico di bari, Viale japigia 182, 70126 Bari, Italy, 2014.
[4] Fenwick Jeffrey, Ryan Grimm, Sami Sakalla, Mike Morine, Tom Hopkin, "Design selection for the infinitely variable transmission", Unpublished, Dalhousie University, Mechanical engineering department, Canada, 2005-2006.
[5] Ion ION, "George Constantinescu' Torque Converter Analysis by Simulink", SISOM 2007 and Homagial Session of the Commission of Acoustics, Bucharest, 29-31May.
[6] Haycraft, W.C. (1928). Lord Montagu of Beaulieu, "Constantinesco torque converter. Cars and Motor-Cycles", Vol. III, London & Bath: Pitman. pp. 1171-1178.
[7] Ullrich, K.T. and Eppinger, S.D., "Product design and development". 3rd Ed., the McGraw-Hill Companies, Inc., New York, 2004.
[8] Norton, R.L., "Machine Design: An Integrated Approach", 2nd Ed., Prentice-Hall Inc., Upper Saddle River, N.J., 2000.
[9] Amarsinh Shinde, Subim Khan, "Modeling, Design and Development of Infinitely Variable transmission System", International Journal of Scientific Research and Development, Vol. 4, Issue 03, 2016.
[10] Andersen, B.S., "An Investigation of a Positive Engagement, Continuously Variable Transmission", MS Thesis, Brigham Young University, Provo, UT, 2007.
[11] Dieter, G.E., "Engineering Design: A Materials and Processing Approach", 3rd Ed., The McGraw-Hill Companies, Inc., New York, 2000.
[12] Benitez, F.G., del Castillo, J.M., "Infinitely Variable Transmission of Ratcheting Drive Type Based on One-Way Clutches", ASME Journal of Mechanical Design, 2004, Vol. 126, pp. 673-682.