Design & Modeling of Infinite variable Transmission System Based on Constantaniesco Torque Convertor

Swapnil J. Patil, V. R. Gambhire

Abstract— Infinitely variable transmission eliminates clutch and gear box for automobile and gives the required torque conversions automatically. In this paper infinitely variable transmission systems have designed and modelled based on Constantaniesco torque convertor for light to medium duty vehicles. IVT includes various parts as input and output shafts, yoke, connecting link and masses. It is necessary while designing IVT to calculate the governing parameters of the model. The study also includes the comparisons of theoretical parameters with experimental parameters as speed, torque, efficiency, power etc. on performance curves. So first of all theoretical design and calculations are carried out. Then after development of experimental set up readings are taken and calculations are carried out, from which performance parameters are plotted.

Keywords— Infinite variable transmission system, torque conversion, experimental set up, performance parameters.

I. INTRODUCTION

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. Unlike conventional transmissions, this infinitely variable transmission (IVT) controls the output torque as opposed to the output speed ratio. Infinitely variable torque, from zero torque to the full capability of torque output, can be produced with no clutching or torque conversion required at the input.

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II. CONCEPT OF THE CONSTANTANIESCO TORQUE CONVERTOR

2.1 Principle of Operation

To illustrate the basic principle of the Constantaniesco Torque Converter, consider figures a and b,

The impulses are produced by a crank connected to a point distant from the apex of a pendulum, or lever with a weight on the end. This apex is connected by a short link to a fixed point; the apex of the pendulum is connected with links to unidirectional "mechanical valves" on the secondary shaft, which operate like ratchets, but much more smoothly. When the primary crank rotates slowly, figure 1.a, the pendulum swings to and fro about the apex, or fulcrum of the lever, as in a clock and no energy is imparted to the secondary shaft. This corresponds to the "neutral" position in a conventional gear box with the prime mover ticking over.

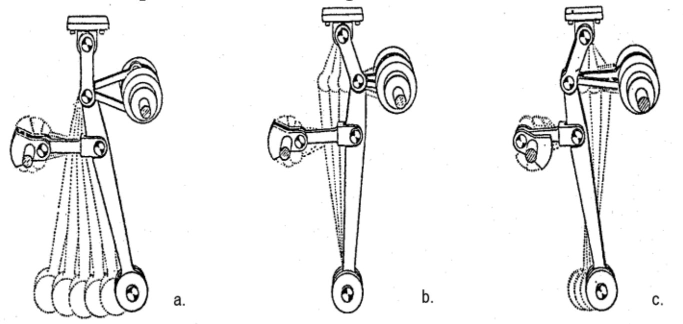

Figure.1 Principle Mechanism

When the revolutions of the prime mover are increased considerably, the frequency of the crank oscillations increases and thus tries to increase the frequency of the pendulum oscillations. At this point a new set of circumstances arises. Due to its inertia the pendulum weight tends to remain stationary fig. 1.b. Under these conditions and when the load on the secondary is moderate, the fulcrum of the pendulum, which was at the apex, has been transferred to the position of the pendulum weight. The result is that the apex of the pendulum oscillates instead, to the maximum to and fro motion, and permitted by the design. This causes the links to oscillate the valves, which in turn rotate the output shaft to the maximum angular speed permitted by the design. Under these conditions the system is operating in "top gear" with a 1 to 1 ratio. (The remarkable similarity to the operation of the hydrosonic system for the aircraft firing gear is apparent.

As soon as the aircraft engine reached a predetermined number of revolutions, the inertia of the liquid column diverted the high frequency pulses down the pipes connected to the trigger motors.) At intermediate angular speeds of the input crank the effective fulcrum will take up intermediate positions on the pendulum rod. Consequently there will be more or less swing (or amplitude) of the pendulum weight and more or less travel (or amplitude) of the valve links according to the speed of the input crank and the torque on the secondary shaft.

2.2 Construction and Working of IVT

The input to the mechanical torque convertor, the motor, produces a power and torque output that is constant with respect to time, at a given speed. This constant power and torque, is transmitted to the arm assembly via the input assembly. The IVT in turn converts the constant input into a sinusoidal, oscillating torque via its specific mechanism; the clutch assembly of the mass-inertia drive converts the oscillating power output from the arm assembly into unidirectional power pulses. The average power is dependant on the amplitude and frequency of these pulses. Higher amplitude and frequency will result in a higher average power output. The amplitude of the power pulses depends on the magnitude of the input received from the engine, while the frequency of the pulses is dependant on the speed of the arm assembly shaft.

The mechanical torque convertor can be considered to consist of four main parts. These are the input assembly, arm assembly, clutch assembly and the output shaft. All of these areas serve a specific purpose in the operation of the mass-inertia drive. The input assembly delivers the input from the engine, the arm assembly generates oscillating torque, the clutch assembly rectifies that oscillating torque to a consistent direction, and the output shaft delivers the output to the rest of the drive train. These sections and their associated functions can be seen in Figure.

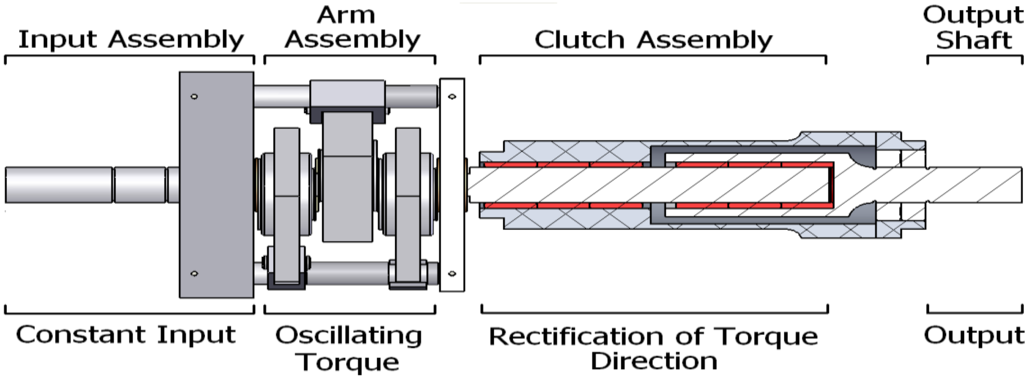

Figure.2 IVT transmission device.

The mechanical torque convertor will receive input from the motor through the use of a spur gear pair between the motor shaft and the input shaft of the mass-inertia drive.This input shaft will transmit the torque to a yoke, which has two pins projecting from it (see Figure).The yoke pins connect to links, which are in turn pin-connected to three masses. These masses are attached as well to the arm assembly.

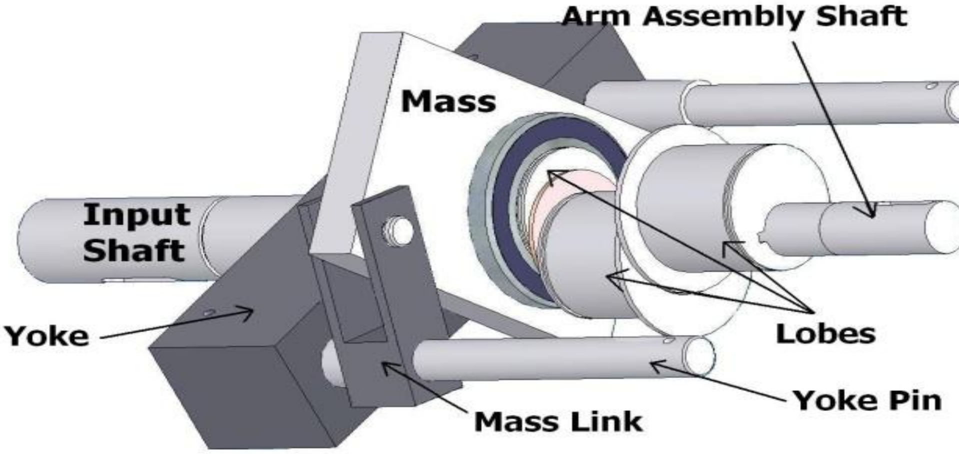

Figure. 3 Assembly of IVT

The heart of the mass-inertia drive is the method in which the masses interact with the arm assembly. This arm assembly allows for the masses to generate torque through their rotation and transmits it to the output shaft. The central shaft of the arm assembly has three lobes attached to it. These lobes are circular pieces of steel with an offset bore for the arm assembly shaft the offset shaft means that any force acting radially on the lobe is translated into a moment which acts on the shaft.

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This is because the center of the shaft is offset from the centre of the lobe, creating a moment arm.The arm assembly shaft is fitted with three lobes; one is offset 180° opposite of the other two lobes and each with a bearing press-fit onto it. The center lobe is fitted with the largest of the three masses, while the outer two lobes are each fitted with a mass half the size of the largest mass. This configuration ensures that the shaft is balanced; the two masses on one side of the shaft equal the mass of the largest mass on the opposite side of the shaft. When the masses rotate around the lobe, the centrifugal forces that they generate create a moment about the arm assembly shaft. We will initially consider the mechanics of the case where the arm assembly shaft is not rotating; that is, the moment developed by the masses is insufficient to overcome the resistances on the arm assembly shaft. In this case, the yoke will cause the masses to rotate about the lobes, and the masses in turn will generate moments, the direction of which will depend on what stage of rotation the mass is in.

III. COMPONENT DESIGN OF IVT

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well as post production servicing work

Table N0.1. Following are the design calculations of main parts of IVT assembly.

Sr. No.	Description	Material
1.	Input Shaft	EN24 (Alloy Steel)
2.	Mass-01	MS(Mild Steel)
3.	Mass-02	MS
4.	Output Shaft	EN24
5.	Yoke	EN9
6.	Connecting link	EN9
7.	Yoke Pin-1	EN24
8.	Yoke Pin-2	EN24
9.	Connecting Pin-1	EN24
10.	Connecting Pin-2	EN24
11.	Bearing 6005 ZZ	STD
12.	Bearing 6004 ZZ	STD
13.	Bearing 6008 ZZ	STD
14.	Bearing 6201 ZZ	STD
15.	Bearing 6006 ZZ	STD

3.1. Design of Input and Output Shaft

For Input Shaft, We have Prime mover motor,

P = 50 watt, Speed = 900 rpm, Therefore, considering factor of safety and belt drive ratio the torque we get is as,

T_{design} = 1.193 Nm.

= 1.19×10^3 Nmm

Using ASME code of design;

Allowable shear stress;

σs_{all} is given stress;

$\sigma s_{all} = 0.30\ S_{yt} = 0.30 \times 60$

$= 180\ N/mm^2$

$\sigma s_{all} = 0.18\ x\ S_{ult} = 0.18 \times 720$

$= 130\ N/mm^2$

Considering minimum of the above values;

$\sigma s_{all} = 130\ N/mm^2$

As we are providing dimples for locking on shaft,

So reducing above value by 25%.

$\sigma s_{all} = 0.75 \times 130$

$= 97.5\ N/mm^2$

a) Considering pure torsional load;

$$T_{design} = \frac{\pi}{16} \times \sigma s_{all} \times d^3$$

$$d^3 = \frac{16 \times 1.19 \times 10^3}{\pi \times \sigma s_{all}}$$

d = 4.0 mm

Selecting minimum diameter of spindle = 16 mm from ease of construction because the standard pulley has a pilot bore of 12.5 mm in as cast condition, and a bore of minimum 16 mm for keyway slotting operation. Similarly, the design of output shaft is done.

3.2. Design of Yoke-

According to the maximum shear stress theory

$S_{sy} = 0.5\ S_{yt} = 0.5 \times 600 = 300\ N/mm^2$

The permissible shear stress is given by,

$\tau_{sall} = S_{yt} / f_s$

$= 300/2 = 150\ N/mm^2$

Section of the crank pin at xx is subjected to combined bending and tensional

Moments

Mt = 60 x 52 =3120 N-mm

Mb = 60 x (10.5+12+50)

=4350N-mm

$\sigma_b = (M_b \times y)/I$

$= 4350 \times 32 / \pi d^3$

$\tau = (M_t \times r) / J$

$= [(3120 \times (d/2)] / (\pi d^4 / 32)$

$$\tau_{max} = \sqrt{(\sigma_b / 2)^2 + \tau^2}$$

d = 6.65 mm

But as per manufacturing considerations we have to consider the minimum section of the shaft to be 16 mm

3.3. Design of Connecting Pin-1and Connecting Pin-2

We know that,

T= force x radius

The eccentricity of the cam or eccentric = 25 mm as per the mechanism design.

1193.6 = force x 25

$$\text{Force} = \frac{1193.6}{25}$$

Force = 47.74 = 48 N

This force is transmitted by the cam to the mass is same as they both are rigid links

Check for direct shear of connecting pin -1

$$\text{Shear stress} = \frac{\text{shear force}}{\text{Shear area}}$$

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The connecting pin-1 supports the connecting link end and is supported in the mass-1 at other end hence will be subjected to a single shear failure

$$= \frac{48}{\pi / 4 \times (d^2)}$$

The connecting link is a standard part with the small end pin of diameter 8 mm

$$= \frac{60 \times 4}{\pi \times (8)^2}$$

Shear stress = 1.193 N/mm^2

Pin is safe in shear.

Similarly, the design of connecting pin-2 is done.

3.4. Design of Connecting Link

The connecting link is a link that is subjected to direct tensile load in the form of pull = 48 N. The connecting link being a standard part the weakest section of the connecting rod can be considered to be near the small end of the connecting rod.

The cross-sectional area of the link at this point is 146 mm^2.

Check for failure of connecting link under direct tensile load now, the allowable stress can find out as,

σ_{sall} = Yield strength / Factor of Safety

= 380 / 2 = 190 N/mm^2

Therefore, the actual stress can be calculated as,

σ_{act} = Load /Area

σ_{act} = 48/146

=0.328 N/mm^2

As $\sigma_{act} < \sigma_s$ all

The link is safe under tensile load.

3.5. Design of Mass-01 and Mass-02.

The mass -01 is a link that is subjected to direct tensile load in the form of pull = 48N

Check for failure of mass under direct tensile load at the eye end. This is the portion where the lever pin fits, the cross sectional area at this point is 288 mm^2.

Now, the allowable stress can find out as,

σ_{sall} = Yield strength / Factor of Safety

= 380 / 2 = 190 N/mm^2

Therefore,

σ_{act} = Load /Area

σ_{act} = 48/288

= 0.166 N/mm^2

As $\sigma_{act} < \sigma_{sall}$

The link is safe under tensile load.

Similarly, the design of mass-02 is done.

IV. RESULT AND DISCUSSION

The results of the IVT after testing are as follows:

Table No. 2 Result Table

Sr. No.	Speed (rpm)	Torque		Power		Efficiency (%)
		Theoretical (Nmm)	Experimental (Nmm)	Theoretical (Watt)	Experimental (Watt)	
01	981	298.43	269.775	30.20	27.66	91.58
02	970	364.03	323.73	36.96	32.89	88.98
03	946	434.83	377.68	43.01	37.35	86.83
04	937	504.32	431.64	49.15	42.32	84.77

The results of the IVT system are satisfactory and it shows it can be used for the light to medium duty vehicles. Also the torque available can take load very efficiently, So that we can use it for different loading applications as per requirement. The mechanism can be modified with advanced technology. The results can be more efficient than this. The performance characteristics of IVT can study by performance curves as follows:

4.1Torque Vs Speed

The performance characteristic of IVT for torque Vs speed shows that torque converts efficiently as load increase without any shifting mechanism as required in manual gear boxes. Also the available torque form the theoretical results vary in steady state with experimental results.

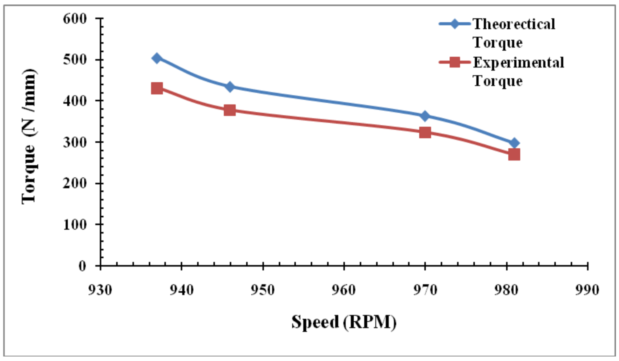

Figure. 4 Torque Vs Speed

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4.2Power Vs Speed

The power Vs speed performance curves shows that the power required for the IVT model increases torque increases. The power available gives the required speed for IVT. Also form the performance curve we can say that the required IVT model is able to take the load and to transmit the required torque.

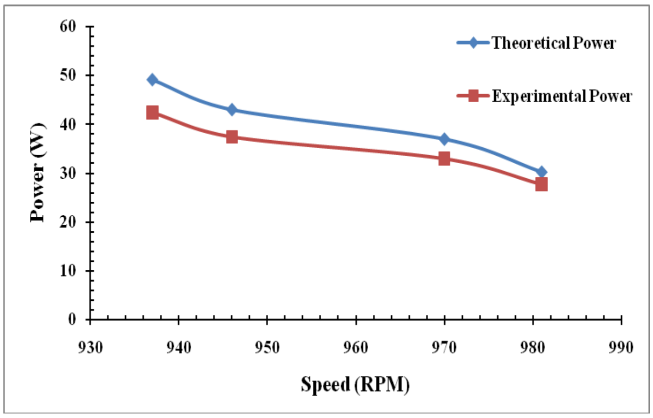

Figure. 5 Power Vs Speed

4.3Speed Vs Efficiency

The speed Vs efficiency performance curves shows that the efficiency of the model remains the in limits for various loading conditions, it varies within certain limits. The efficiency of manual transmission compared with This IVT model is satisfactory as compared to manual gear boxes with IVT for light to medium duty vehicles.

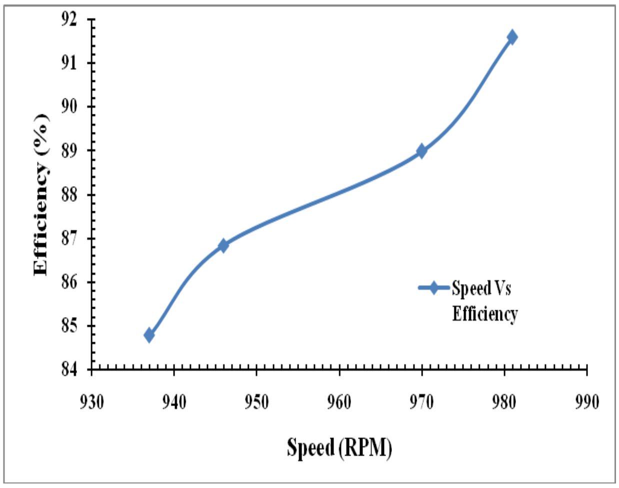

Figure. 6 Efficiency Vs Speed

V. CONCLUSION

Present study of IVT has helped in developing an automatic torque convertor for light to medium duty vehicles with eliminating the gear box.

- The IVT system is varying the required torque with balanced output as it is been varied in manual transmission gear boxes.
- Several readings of the system give idea that IVT system is safer for loading and unloading conditions.
- The cost of IVT system is same as compared to manual transmission gear boxes.

REFERENCES

1. Timothy Cyders, Robert L. Williams II, "Analysis of a new form intrinsically automatic continuously variable transmission", Proceedings of the ASME 2010 international design engineering technical conferences and computers and information in engineering conference IDTEC/CIE ,August 15-18,(2010).
2. Ryan R.Daling "An investigation of positive engagement, continuously variable transmissions", Thesis submitted to Brigham Young University, (2008).
3. Ion ION, "George Constantinescu torque convertor analysis by simulink", SIMON 2007 and homogial session of the commissions of acoustics, Bucharest, 29-31 may, (2007).
4. G. Carbone, M. Napolitano, E. Sedoni, "Design optimization of input and output coupled power split infinitely variable transmissions", ASME journal of mechanical design, vol. 131,(2009) .
5. A text book "Ian Constantinesco: Geroge Constantinesco his Torque Convertor and other Inventions" (chapter 5) (1925).
6. William T. Beale: US Patent # 7,011,322 B2: "Automatic Transmission with Steeples, Continuously Variable Speed and Torque Ratio" (2006).
7. John G. Bolger: US Patent # 4,907,474: "Mechanical Torque Convertor" (1990).
8. George Constantinesco: US Patent # 1,613,344: "Power Transmission" (1927).

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