Design and Analysis of Alternative Fixed Pitch CVT for Singular Stepless Control

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Abstract: **Continuously Variable Transmission (CVT) is a type of transmission, which allows an endless variable ratio change within a limited range. Anderson CVT is one of its types. In Anderson CVT, two cones having variable diameter kept parallel having 'floating sprocket bars' mounted in linear grooves around the perimeter of every cone. A non-standard belt engaged with the floating sprocket bars, and it can move with length of cones, with in change in gear ratio. The bars make the system positive drive, non-friction dependent. The sprocket bars made of rubber and mounted with help of conventional spring, which gets wear and tear, have to change frequently, so manufacturing cost of full system increases and the weight of system are also high due its solid cover over cone. The following study is dedicated to the suggest the change in existing design in order to use the Unconventional materials for cone, floating sprocket bars changing to steel bars and non-standard belt to standard timing belt. So in this report we designed and developed a Unconventional Fixed Pitch CVT by using empirical formulae.**

Keywords: **Anderson's CVT, Fixed Pitch, Standard Belt, Sprocket Bars, Singular Stepless Control**

1. Introduction

The primary function of a transmission is to transmit mechanical power from a power source to some form of useful output device. Since the invention of the internal combustion engine, it has been the goal of transmission designers to develop more efficient methods of coupling the output of an engine to a load while allowing the engine to operate in its most efficient or highest power range. Conventional transmissions allow for the selection of discrete gear ratios, thus limiting the engine to providing maximum power or efficiency for limited ranges of output speed. Because the engine is forced to modulate its speed to provide continuously variable output from the transmission to the load, it operates much of the time in low power and low efficiency regimes. A continuously variable transmission (CVT) is a type of transmission, however, 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, while the transmission provides a continuously variable output to the load. The development of modern CVTs has generally focused on friction driven devices, such as those commonly used in off-road recreational vehicles, and recently in some automobiles. While these devices allow for the selection of a continuous range of transmission ratios, they are inherently inefficient. The reliance on friction to transmit power from the power source to the load is a source of power loss because some slipping is possible. This slipping is also a major contributor to wear, which occurs in these devices. To overcome the limitations inherent in the current CVT embodiments employing friction, a conceptual, continuously variable, positive engagement embodiment has been proposed for investigation at Brigham Young University. This concept proposes utilizing constantly engaged gears which transmit power without relying on friction. Because the proposed embodiment is new, no engineering analysis has yet been performed to determine its kinematic and meshing characteristics, an understanding of which are necessary to validate the proposed concept as a viable embodiment. This research will investigate both the kinematic and meshing characteristics of this and related concepts.

The objective of this research is also to analyze the family of positive engagement CVTs. Although the CVT embodiment that has been proposed for investigation is new, other embodiments belonging to this family have been developed and published. The embodiments in this family do not rely on friction based power transmission. All embodiments in this family, however, have been based on overcoming a distinct problem which manifests itself seemingly regardless of the embodiment and will hereafter be referred to as the non integer tooth problem.

This research describes the nature of the non-integer tooth problem and details the occurrence of the problem in the proposed concept, as well as three published embodiments, and details solutions to the non-integer tooth problem as embodied in the three published embodiments. The presentation of some published solutions to the non-integer tooth problem clarifies the nature of the non-integer tooth problem, as well as aids in the development of characteristics of a general solution to the non-integer tooth problem applying to all members of the positive engagement CVT family.

It is a technology invented by Larry Anderson, under US patents. Two parallel cones have "floating sprocket bars" mounted in longitudinal grooves around the circumference of each cone. A specially-designed chain meshes with the floating sprocket bars, and is free to slide along the length of cones, changing the gear ratio at each point. The floating sprocket bars(Fig.) make the A+CVT positive-drive, non-friction-dependent. Another advantage of the A+CVT is the simplicity of its design, as it consists of far fewer components than other transmissions. The technology is also adaptable to a variable diameter pulley-type CVT, by mounting the floating sprocket bars on the inner face of the pulley sheaves.

Fig. 1.1 - Original Anderson CVT

The above design(Fig.1.1) uses conventional spring loaded rubber sprocket bars, which are subjected to heavy wear and tear, hence may have to be replaced frequently, so also the manufacturing cost of the above device is slightly on the higher side hence a alternative fixed pitch CVT is proposed in the following literature.

2. Literature Review

(1) **Lawrence A. Anderson et.al** has studied the variable ratio of transmission having a part of oppositely oriented conical torque input and output member. Where in the conical member include multi angle conical surface. Therefore it affects of an inextensible belt drive, as the belt drive is axially moved along the longitudinal length of the torque input and output member. T sprocket bar generally parallel to the surface of the conical member. Therefore, convenient shape, such as convex configuration is given. The sprocket bar freely moves diametrically and circumferentially. Hence, they fully engage a beaded or other suitably configured inelastic, inextensible drive chain.

(2) **Nikhil Patil et.al** has developed a conical roller with belt CVT system by employing the system driven product development approach and topology optimization of it is traditional design. The CVT design suffers from number of disadvantages including the considerable weight of the conical roller and a limited range of torque in the cone type CVT system and complex mechanism and high production cost in other CVT types. The design made by the CVT will decrease the weight of traditional cone type CVT by 44.69%. It shows non topology optimized cone CVT and can improve the efficiency by 25% fuel efficiency by 30% and cost of production by 30%.

(3) **Kenneth B. Hawthorn et.al** has studied using a fixed pitch continuously variable transmission is designed. It is an object of the present invention to provide a CVT capable staying positively engaged to transmit power while allowing for continuous changes in ratio. Thus, this type of CVT allows automatic selection of various gear ratios without disconnecting the transmission from the vehicle engine based on the power and mechanical load specifications of the vehicle, requiring no outside control input This CVT can be used in applications with heavy load as compared to Anderson’s CVT as friction losses are minimized in the designed CVT.

(4) **K. Vinod Kumar et.al** has studied different types of CVT’s and design pulley type CVT. He had studied the actual working, principle of WARKO system and Pros and cones of CVT. He has also design the part model of CVT’s and also the cad model of CVT’s. He manage to explore vast pool of knowledge in the field of automobiles and its component parts. It also provided valuable experience on power transmission. He has studied mostly component parts and design criteria and its performance parameters. The sense of development will lead to increase sales which in turn will prompt further R&D and the cycle will keep repeating. This will decrease manufacturing cost.

3. Problem Statement

- The technology Anderson CVT is developed for the transmission of power, with help of pair of oppositely cones and floating sprocket bars.
- But above design uses conventional spring loaded rubber sprocket bars, which are subjected to heavy wear, may have to replace frequently.
- The cones are solid in the system which increases net weight of the system, also leads to increase material cost.
- Use of Non-Standard Belt for Power Transmission.

- The manufacturing cost of full system is slightly on higher side.

4. Objectives

- Design and Analysis of model of Alternative CVT having drive and driven cones.
- To calculate and analyse the developed Alternative CVT to determine maximum and Minimum transmission efficiency.
- To study and compare performance characteristic curves speed Vs (Torque / Power / Efficiency).
- To find and analyse the various stresses acting on the input & output Shaft , Cone ring and Sprocket bar using Ansys Workbench.

5. Design Methodology

5.1 Design of Alternative CVT

Design consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy & efficiency.
Hence a careful design approach has to be adopted. The total design work has been split up into two parts:

5.1.1 System Design

5.1.2 Mechanical Design.

5.1.1 System Design

In system design we mainly concentrated on the following parameters:

a) System Selection Based on Physical Constraints

While selecting any machine it must be checked whether it is going to be used in a large scale industry or a small-scale industry. In our case it is to be used by a small-scale industry. So space is a major constrain. The system is to be very compact so that it can be adjusted to corner of a room. The mechanical design has direct norms with the system design. Hence the foremost job is to control the physical parameters, so that the distinctions obtained after mechanical design can be well fitted into that.

b) Arrangement of Various Components

Keeping into view the space restrictions the components should be laid such that their easy removal or servicing is possible. More over every component should be easily seen none should be hidden. Every possible space is utilized in component arrangements.

c) Components of System

As already stated the system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired.

d) Man Machine Interaction

The friendliness of a machine with the operator that is operating is an important criterion of design. It is the application of anatomical & psychological principles to solve problems arising from Man-Machine relationship.

Following are some of the topics included in this section:

- Design of foot lever
- Energy expenditure in foot & hand operation
- Lighting condition of machine.
- Chances of Failure

The losses incurred by owner in case of any failure are important criteria of design. Factor safety while doing mechanical design is kept high so that there are less chances of failure. Moreover periodic maintenance is required to keep unit healthy.

e) Servicing Facility

The layout of components should be such that easy servicing is possible. Especially those components which require frequents servicing can be easily disassembled.

f) Scope of Future Improvement

Arrangement should be provided to expand the scope of work in future. Such as to convert the machine motor operated; the system can be easily configured to required one. The die & punch can be changed if required for other shapes of notches etc.

g) Height of Machine from Ground

For ease and comfort of operator the height of machine should be properly decided so that he may not get tired during operation. The machine should be slightly higher than the waist level, also enough clearance should be provided from the ground for cleaning purpose.

h) Weight of Machine

The total weight depends upon the selection of material components as well as the dimension of components. A higher weighted machine is difficult in transportation & in case of major breakdown; it is difficult to take it to workshop because of more weight.

5.1.2 Mechanical Design

Mechanical design phase is very important from the view of designer .as whole success of the project depends on the correct deign analysis of the problem. Many preliminary alternatives are eliminated during this phase. Designer should have adequate knowledge above physical properties of material, loads stresses, deformation, and failure. Theories and wear analysis, He should identify the external and internal forces acting on the machine parts. These forces may be classified as:

a) Dead weight forces
b) Friction forces
c) Inertia forces
d) Centrifugal forces
e) Forces generated during power transmission etc

Designer should estimate these forces very accurately by using design equations .If he does not have sufficient information to estimate them he should make certain practical assumptions based on similar conditions which will almost satisfy the functional needs. Assumptions must always be on the safer side.

Selection of factors of safety to find working or design stress is another important step in design of working dimensions of machine elements. The correction in the theoretical stress values are to be made according in the kind of loads, shape of parts & service requirements. Selection of material should be made according to the condition of loading shapes of products environment conditions & desirable properties of material. Provision should be made to minimize nearly adopting proper lubrications methods.

In, mechanical design the components are listed down & stored on the basis of their procurement in two categories:

- Design parts
- Parts to be purchased

For design parts a detailed design is done & designation thus obtain are compared to the next highest dimension which is ready available in market. This simplification the assembly as well as post production service work. The various tolerances on the work are specified. The processes charts are prepared & passed on to the work are specified. The parts to be purchased directly are selected from various catalogues & specification so that anybody can purchase the same from the retail shop with the given specifications.

The technology Anderson CVT is developed for the transmission of power, with help of pair of oppositely cones and floating sprocket bars. But above design uses conventional spring loaded rubber sprocket bars, which are subjected to heavy wear, may have to replace frequently.

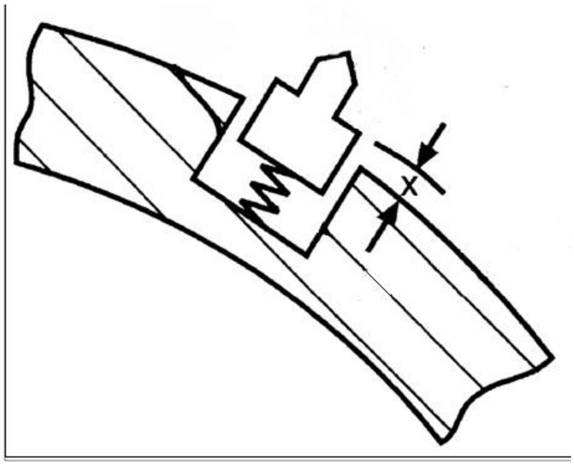

Fig. 5.1 - Spring Loaded Rubber Sprocket

5.2 Preliminary Design

A simplified version of the transmission is illustrated in Figure 3.1. It is a technology invented by Lawrence L. Anderson, under US patents. Two parallel cones i.e. oppositely oriented conical torque input and output pulleys, has „floating sprocket bars" mounted in longitudinal grooves around the circumference of each cone, as shown in fig.1.4. A specially- designed chain or belt meshes with the floating sprocket bars, and is free to slide along the length of cones, changing the gear ratio at each point. Anderson made an improvement in the previous transmission.

The power input to the system will be through driving cone to a driven cone with the help of drive belt, as in fig.1.3. The conical shape of pulley or cone has grooves on its perimeter of cone. The grooves are like channels, with Sprocket bars located in it. The Channels are circumferentially larger than the sprocket bars because to allow the movement of the sprocket bars. The bars have one or more compression springs or any other elastic material, attached between sprocket bar and channel groove.

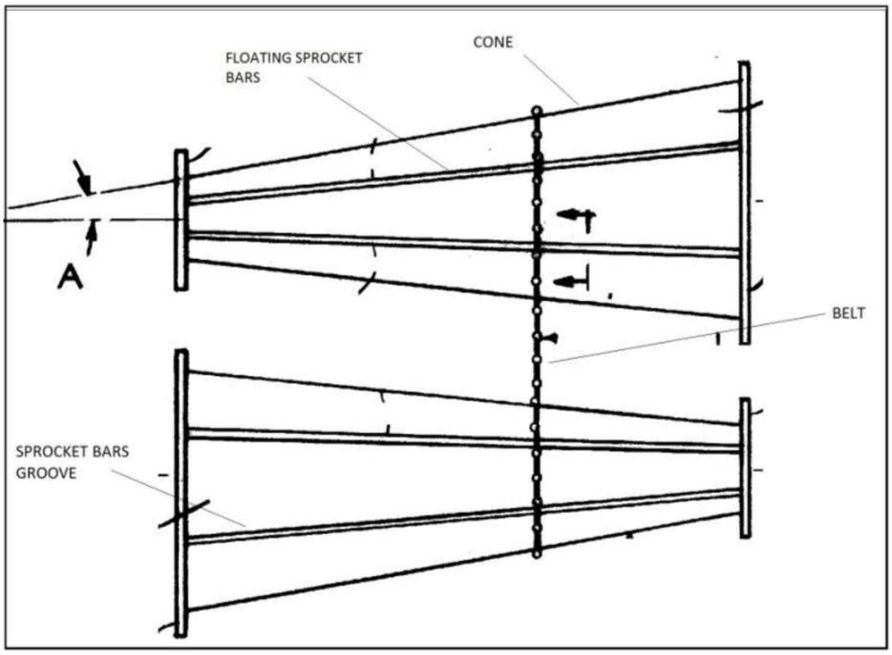

Fig. 5.2 - Schematic View of the Primary Elements of Improved Transmission

The floating sprocket bars make the CVT positive-drive, non-friction-dependent. Another advantage of the CVT is the simplicity of its design, as it consists of far fewer components than other transmissions. The technology is also adaptable to a variable diameter pulley-type CVT, by mounting the floating sprocket bars on the inner face of the pulley sheaves.

5.3 The Alternative CVT comprises of the following parts:

5.3.1 Motor Selection

Motor is a single phase AC motor, capacitor run three lead motor with the following specifications:

Power = 50 watt

Speed = 0 to 9000 rpm (variable)

5.3.2 Open Belt Drive

The open belt drive is used to transmit power from the input source that is the motor to the input cone shaft. Motor pulley is 20mm diameter where as the input cone shaft pulley is 110 diameters. The reduction ratio is thus 5.5 between the motor and input cone shaft. The power is transmitted by an FZ- section belt between the motor pulley and input cone shaft pulley.

5.3.3 Input Cone Shaft

The input cone shaft is basically an sub assembly of the base shaft, two sprocket bar holder rings on either side and the sprocket bars. The sprocket bars are solid round bars 4mm diameter held in radial holes in the holder rings. Holder rings are keyed to the base shaft and the sprocket bars are located on an radial pitch along the generators of the cone. The base shaft is held in heavy duty ball bearings at either ends, and carries the input pulley at one end.

5.3.4 Output Cone Shaft

The output cone shaft is basically an sub assembly of the base shaft, two sprocket bar holder rings on either side and the sprocket bars. The sprocket bars are solid round bars 6mm diameter held in radial holes in the holder rings. Holder rings are keyed to the base shaft and the sprocket bars are located on an radial pitch along the generators of the cone. The base shaft is held in heavy duty ball bearings at either ends, and carries the dyno-brake pulley at one end.

5.3.5 Input/output Bearing Housings

The input and output bearing housings hold the ball bearings for respective base shafts and they are bolted to the base frame.

5.3.6 Transmission Belt

The transmission element of the A+ CVT is PIX Xtreme Classical Synchronous belt with the following features:

- Trapezoidal tooth profile
- High efficiency due to positive engagement between belt teeth and sprocket bars
- No re-tensioning required
- Free from maintenance

- No high tension required

5.3.7 Speed Adjuster Mechanism
The speed adjuster mechanism is in the form of a screw and nut arrangement, where in the screw is held in ball bearings at either ends and carries a nut which holds the belt guide mechanism in the form of free rotating rollers. The screw carries the hand wheel at one end for speed change.

5.3.8 Base Frame
Base frame is the structural element that supports the entire assembly of drive and the motor.

5.4 Automation of Floating Sprocket Bar Drive
The floating sprocket drive is an innovative solution to above problem where in power is transmitted between two hollow cones fabricated from floating sprocket bars and the Stepless power transmission is achieved by movement of the belt via an automated speed change mechanism over these cones . The automation of the floating sprocket drive is done using a gear pair where in the pinion is integral with the motor and the gear is mounted on the speed changing mechanism screw. The specifications of the device are as follows:

On the exterior the power window motor is structured, it comprises of three main parts: The drive motor , 12 volt DC . The gear box that provides the necessary amplification of motor torque and reduction in speed in order to operate the power window mechanism. The driver gear or the output gear from the power window motor that drives the power window mechanism. The worm is made of case hardened steel 14C6 whereas the worm wheel is made of Nylon-66. Motor is 12 V DC motor gear box ratio to be 1:55 reduction output of the gear box will be a direct shaft with dynamometer pulley arrangement to carry out the testing of the gear box under various load conditions.

6. Design and Development
Based on design requirements the layout of the Alternative Fixed Pitch CVT is drawn in fig 1.3 and various components of it are also listed in the table. The standard parts like Electric motor, belt drive, bearings and pulleys are selected based on design requirements and the parts like shaft , bearing housing, base plate , speed adjuster mechanism, base frame are design and final dimensions are achieved.

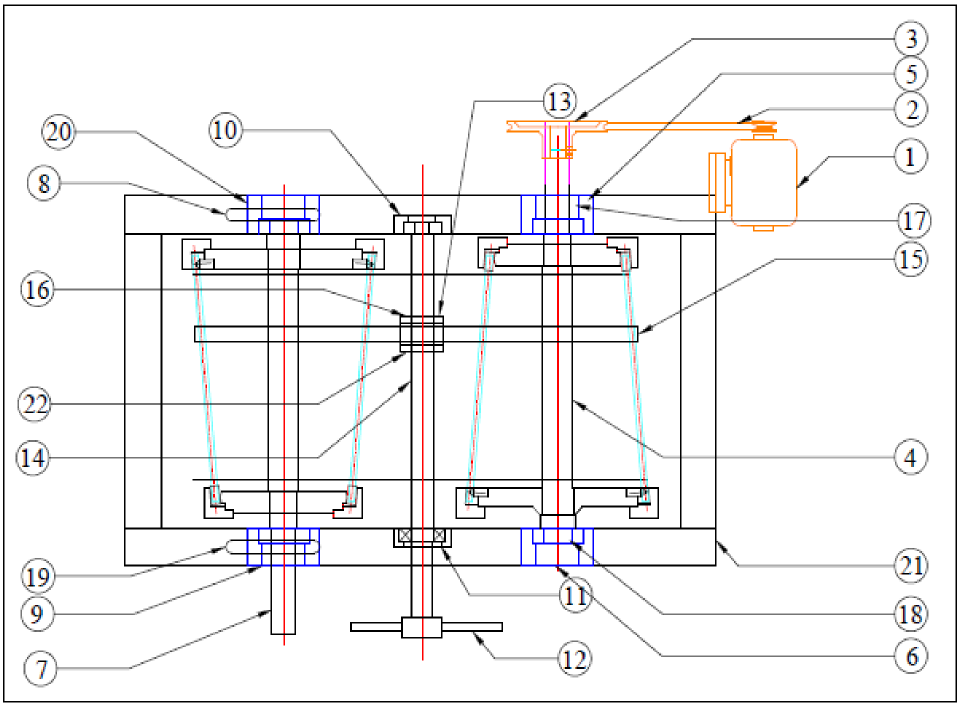

Fig. 6.1 - Detail Assembly of Alternative Fixed Pitch CVT

Table 6.1 shows details of all parts according to the part code, quantity and material selected and serially numbering to the detail assembly figure which notify parts of CVT.

Table 6.1 - Details of Parts

Sr. No.	Part Code	Description	Quantity	Material

1	ACVT-1	Motor	1	STD
2	ACVT-2	Belt	1	STD
3	ACVT-3	Reduction Pulley	1	MS
4	ACVT-4	Input Shaft	1	EN24

Table 6.2 - Parts List

Part No.	Part Name	Quantity
1	Base Frame	1
2	Housing Outer Side	1
3	Drum Brake Pulley	1
4	Housing Inner Side	1
5	Housing Inner Side	1
6	Supporting Roller	1
7	V- Belt	1
8	Slide Screw	1
9	Adjusting Screw	1
10	Slide Screw Knob	1
11	Bearing (Slide screw)	1
12	Bearing Housing (Slide Screw)	1
13	Bearing (Output Drive)	1
14	Drum Brake Pulley	1
15	Output Drive Shaft	1
16	Bearing (Input Drive)	1
17	Bearing Housing (Input Drive)	1
18	Input Drive Shaft	1
19	Reduction Pulley	1
20	V-Belt	1
21	Motor	1

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. General material used as, EN24 - alloy steel, EN9 - plain carbon steel, MS - mild steel, STD - standard parts selected from PSG design data/manufacturer catalogue.

6.1 Selection of Manufacturing Parts and Standard Parts

The manufacturing parts and standard parts are selected on the basis of requirement of CVT and also design procedure of parts.

6.1.1 Motor Selection

Motor is a Single phase AC motor, Power 50 watt; Speed is continuously variable from 0 to 8000 rpm. The speed of motor is varied by means of an electronic speed variator. Motor is a commutator motor i.e., the current to motor is supplied by means of carbon brushes. The power input to motor is varied by changing the current supply to these brushes by the electronic speed variator, thereby the speed is also is changes. Motor is foot mounted and is bolted to the motor base plate welded to the base frame of the indexer table.

6.1.2 Design and Analysis of Input Shaft and Output Shaft

The Input Shaft and Output Shaft are critical components of CVT, hence to find out the stress concentration by theoretical and analytical methods with help of design data and Ansys tool.

Table 6.3 - Manufacturers Catalogue of Shaft

Designation	Ultimate Tensile Strength N/mm2	Yield Strength N/mm2
EN 24	900	700

ASME code for design of shaft. Since the loads on most shafts in connected machinery are not constant, it is necessary to make proper allowance for the harmful effects of load fluctuations.
According to ASME code permissible values of shear stress may be calculated from various relation.

fs_{max} = 0.18 x Ultimate Tensile Strength (1)

= 0.18 x 900 = 162 N/mm^2

Shaft is provided with key way; this will reduce its strength. Hence reducing above value of allowable stress by 25%

Fs_{max} = 121.5 N/mm^2

This is the allowable valve of shear stress that can be induced in the shaft material for safe operation.

To calculate input torque
Power = $\frac{2\pi NT}{60}$ (2)

Assuming operation speed = 800 rpm

= $\frac{60\times 50}{2\times\pi\times 800}$

T = 0.5968 N.mm.

Assuming 100% overload

T design = 2 x T (3)

= 2 x 0.5968 x 103
= 1.19 x 103 N.m.

Check for torsional shear failure of Shaft,

Assuming minimum section diameter on input shaft and output shaft = 16 mm.

Now, d = 16 mm

$T_d = \frac{\pi}{16}$ x d^3 x Fs_{act}

$Fs_{act} = \frac{16\times T_d}{\pi\times 16^3}$

$Fs_{act} = \frac{16\times 1.19\times 10^3}{\pi\times 16^3}$

$fsact = 1.47\ N/mm\ 2$

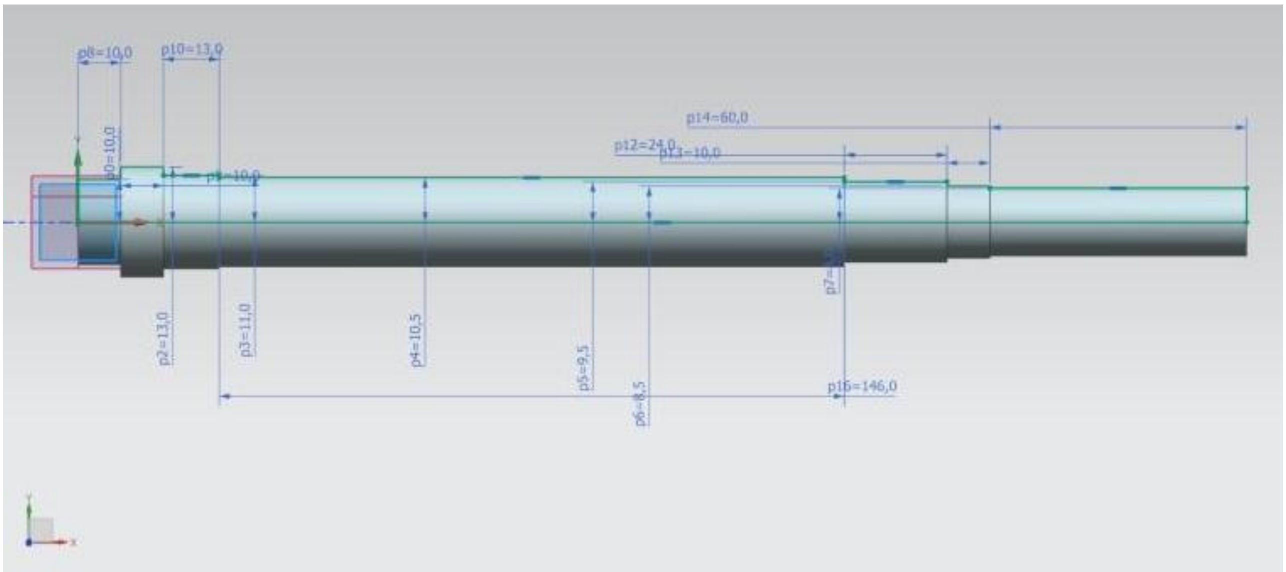

Fig. 6.2 - Design of Input Shaft

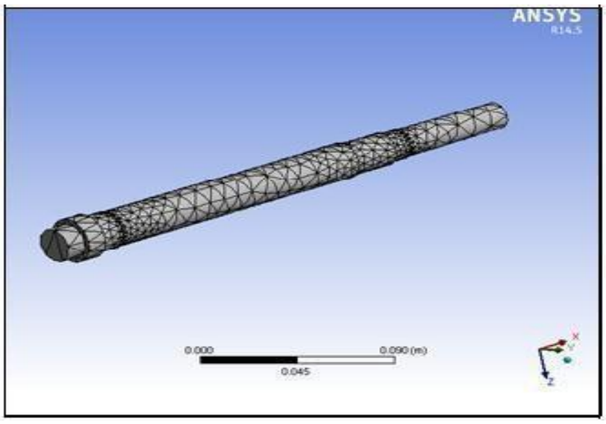

Fig. 6.3 - Meshing of Input Shaft/Output Shaft

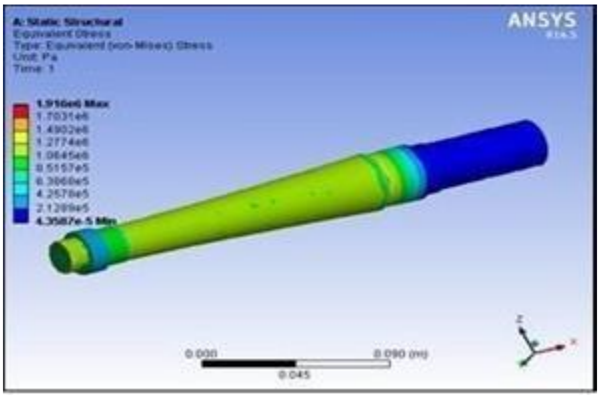

Fig. 6.4 - Stress Concentration of Input Shaft / Output Shaft

As,

$Fs_{act} < Fs_{all}$

We can say that, the actual torsional stress is well below the allowable tensile stress hence shafts are safe under torsional load.

6.1.3 Selection of RH-Bearing of Input Shaft, Selection of LH-Bearing of Output Shaft

Shaft bearing will be subjected to purely medium radial loads; hence we shall use ball bearings for our application. Selecting Single Row deep groove ball bearing as follows:

Table 6.4 - Manufacturers Catalogue of Bearing

ISI No.	Bearing of Basic Design No (SKF)	d	D1	D	D2	B	Basic Capacity	
17AC03	6003	17	19	35	33	10	2850	4650

Calculation of maximum force applied on ball bearing (P)

$P = X\ Fr + Y\ Fa$ (1)

For our application
$Fa = 0$
$P = X\ Fr$
As, $Fr < e \Rightarrow X = 1$

P = Fr = Belt Tension = 140.4 N
Max Radial Load = Fr = 140.4 N
P = 140.4 N

Calculation dynamic load capacity of bearing

$$L = \left(\frac{C}{P}\right)^{P} \quad (2)$$

Where, p = 3 for ball bearings
P = Maximum load on ball bearing
L = Life of ball bearing

For m/c used for eight hours of service per day

But, $L = 60\ n\ LH / 10^6$ (3)

Where, LH = Rated Bearing Life = 8000 hours
n = Speed of Rotation = 1000 rpm
L = 480 million rev.

Now C = 1918 N

For the calculation of capacity of bearing for 1000 days is less than the basic capacity as per the catalogue.

6.1.4 Design of Belt Drive

Selection of an open belt drive using V-Belt; Reduction ratio = 5.5, Planning at 1 stage reduction; Motor Pulley (D1) = 25 mm, IP - Shaft Pulley (D2) = 100 mm Section of belt section.

Table 6.5 - Manufacturers Catalogue of Belt Drive

C/S Symbol	Usual Load of Drive (KW)	Nominal Top Width (Wmm)	Nominal Thickness T mm	Weight per Meter Kgf
FZ	0.03 - 0.15	6	4	0.05

Now, M = 0.05 kgf

Tc = M x v2 (1)
Where, Tc = Centrifugal Tension

M = Mass of Belt per Meter Length v = Belt Speed (m/s)
Tc = 0.05 (26.67) 2 = 35.56 N

T = fall x Area (2)
Where, T = Maximum Tension in Belt

Fall = Allowable Tensile Stress between Belt and Pulley T = 8 x 20

= 160 N/mm^2

T1 = T - Tc (3)
Where, T1 = Tension in tight side of belt T1 = 124.4 N

Calculation of tension in slack side of belt:

$$\frac{2.3 log T1}{T2} = \theta \times \mu \times cosec\beta \quad (4)$$

Where, T2 = Tension in slack Side of Belt
θ = Angle of Lap on Smaller Pulley = 2.8 rad.
μ = Coefficient of Friction
β = Groove Angle

$\frac{T1}{T2}$ = 70.75

Power transmitting capacity of belt;
P = (T1 - T2) v (5)

= (124.24 -16) 26.67
P = 2.88 kw

The power transmitting capacity of belt 2.88 kw is higher than the power of electric motor 0.05 kw, hence we can say that the belt drive safely transmit power.

Selection of belt on the basis of design calculation, selection of belt FZ 6 x 600 from standard manufacturer's catalogue

Table 4.5 - Selection of Belt FZ 6 x 550

1	Belt Selected	FZ 6 x 550
2	Tight side Tension	T1 =124 N
3	Slack side Tension	T2 = 16 N
4	Motor pulley dia.(ϕ D1)	D1 =25 MM
5	Pulley (a) diameter (ϕD2)	D2 = 100 MM

6.1.5 Design and Analysis of Sprocket Bars

Sprocket Bars are located in holder ring on driver disk at an PCD of 122 mm. These bars engage in the belt placed as the transmission link and act as transmission elements. "40 bars" transmit the entire torque. They can be designed similar to the bush pins in the bush pin type flexible flange coupling.

Table 6.7 - Manufacturers Catalogue of Round Bars

Designation	Ultimate Tensile Strength N/mm^2	Yield Strength N/mm^2
EN 9	600	480

Now,

These pins are located at PCD (Dp) = 122 mm

fs_{max} = 0.18 x Ultimate Tensile Strength (1)

= 0.18 x 600 = 108 N/mm^2

Tangential force on each bolt (Fb),

$$F_b = \frac{T}{\frac{D_p}{2} \times n}$$

Shear Stress = Shear Force / Shear Area

$Fs_{act} = \frac{F_b}{\frac{\pi}{4} \times d^2}$

$F_b = \frac{Fs_{act} \times \pi \times d^2}{4}$

$T = n \times F$

Fs_{act} = 0.04 N/mm^2

As; $fs_{act} < fs_{all}$,
We can say that, the actual torsional stress is well below the allowable tensile stress, hence, pins are safe under Shear load.

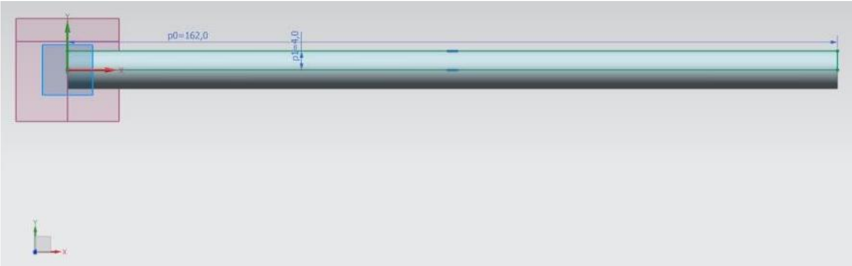

Fig. 6.5 - Design of Sprocket Bar

6.1.6 Design and Analysis of Cone Ring

Cone Rings are critical component of transmission. Cone rings are of two types i.e. one is higher diameter located on LH side of input shaft and RH side of output shaft, second is smaller diameter located on RH side of input shaft and LH side of output shaft, on this cone ring floating sprocket bars are mounted to transmit power. Design and analysis of higher diameter cone ring to find out the stress concentration by theoretical and analytical methods with the help of design catalogue and Ansys tool.

Table 6.8 - Manufacturers Catalogue of Cone

Designation	Ultimate Tensile Strength N/mm^2	Yield strength N/mm^2
EN 24	900	700

Inner Diameter of Ring, Di = 127.8 mm, Outer Diameter of Ring, Do = 140 mm,
ASME code for design of Cone.

Since the loads on most Cones in connected machinery are not constant, it is necessary to make proper allowance for the harmful effects of load fluctuations. According to ASME code permissible values of shear stress may be calculated from various relation.

Fs_{max} = 0.18 x Ultimate Tensile Strength (1)
= 0.18 x 900 = 162 N/mm^2

This is the allowable valve of shear stress that can be induced in the ring material for safe operation.

To calculate input torque

Power = $\frac{2\pi NT}{60}$

Assuming operation speed = 800 rpm

$= \frac{60 \times 50}{2 \times \pi \times 800}$

T = 0.5968 N.mm.

Assuming 100% overload.

T design = 2 x T (3)

= 2 x 0.5968 x 103
= 1.19 x 103 N.m.

Check for torsional shear failure of Shaft,

$$T = \left(\frac{\pi \times Fs_{act}}{16}\right) \times \left(\frac{Do^4 - Di^4}{Do}\right)$$

$$1.19 \times 103 = \left(\frac{\pi \times Fs_{act}}{16}\right) \times \left(\frac{140^4 - 127.8^4}{140}\right)$$

$Fs_{act} = 7.23$ N/mm^2

As, $fs_{act} < fs_{all}$,
We can say that, the actual torsional stress is well below the allowable tensile stress hence cone rings are safe under torsional load.

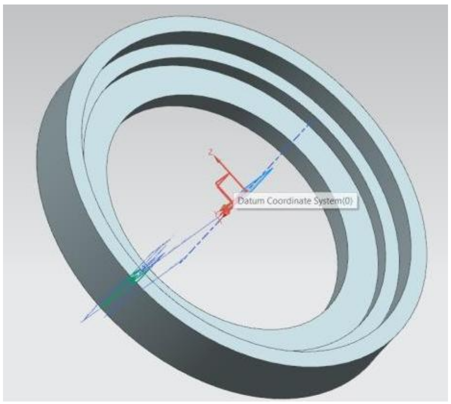

Fig. 6.6 - Design of Cone Ring

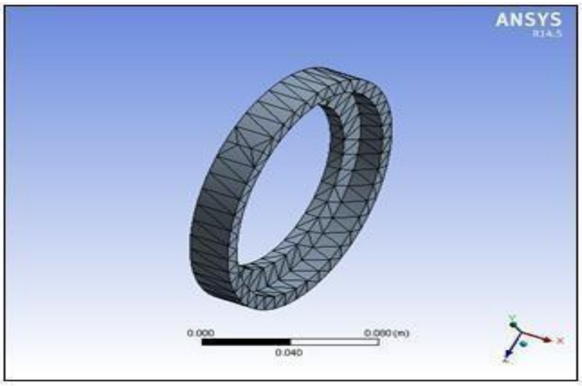

Fig. 6.7 - Meshing of Cone Ring

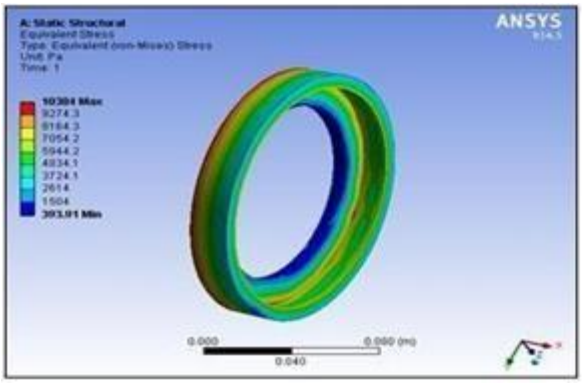

Fig. 6.8 - Stress Concentration of Cone Ring

6.1.7 Frame

The frame supports the all parts of transmission; the bearing housing is located on the table and location of motor at right hand side parts as shown in figure. The frame is made up of mild steel (MS).

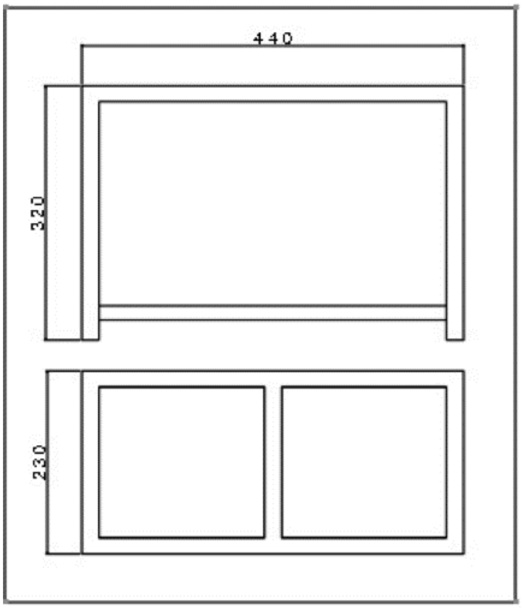

Fig. 6.9 - Frame of Alternative CVT

6.1.8 Bearing Housing

Bearing housing used for locating the bearing and support to other parts of transmission as shown in figure. The material is used for bearing housing is plain carbon steel (EN9).

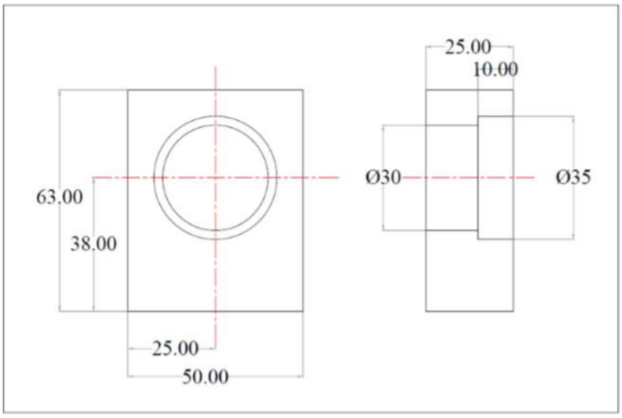

Fig. 6.10 - Bearing Housing

6.1.9 Selection of Pulley

Pulleys consist of a wheel that rotates on an axle which is a rod through the center of the wheel and a rope, cable, or chain. There are three main types of pulleys: fixed, movable, and compound.

Fixed Pulley Design using Data Sheet BS 4500A The Pulley Hole Basic Size 16H7 will have:
Max = 16 + 0.027 = 16.027 mm
Min = 16 + 0 = 16 mm

Shaft Basic Size 16F6 will have:
Max = 16 - 0.016 = 15.984 mm
Min = 16 - 0.03 = 15.966 mm

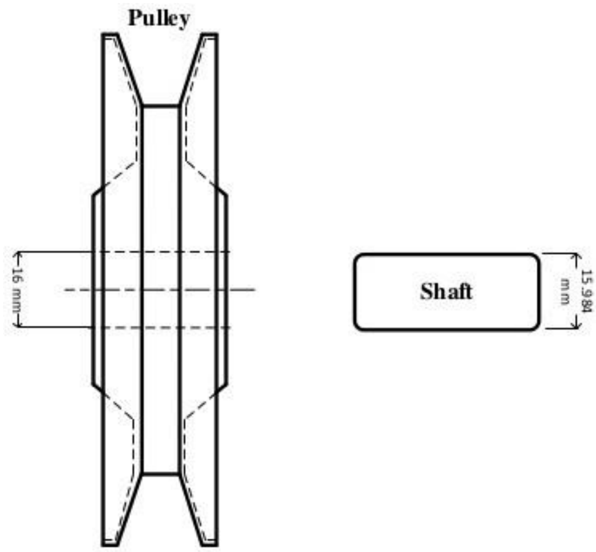

Fig. 6.11 - Pulley

Clearance	Fit	Max C	Min C
H8	F7	16.027	16
+27	-16	-15.966	-15.984
0	-34	0.067 mm	0.016mm

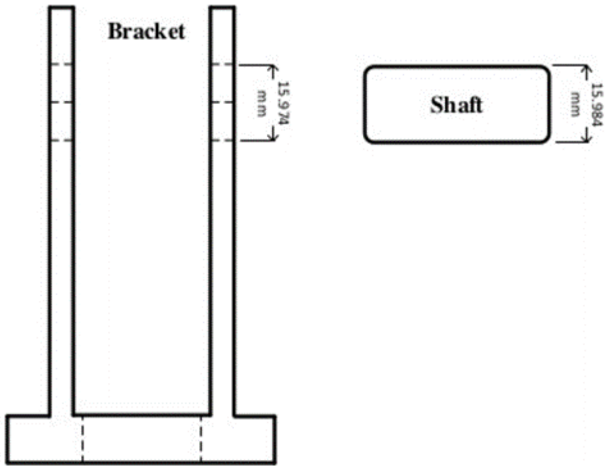

Fig. 6.12 - Pulley Bracket

Interference	Fit
-25	-10

Bracket Basic size 15.984 will have:
Max = 15.984 - 0.010 = 15.974 mm
Min = 15.984 - 0.025 = 15.959 mm

Bracket will be 15.974 mm Shaft stays 15.984 mm
It will be Heated and Braze

7. Future Scope

Speaking of CVTs, there isn't much of knowledge base around due to the existing research work and literature whereas conventional/standard transmission systems have been continuously improving since the very beginning of the 20th century. CVTs are going to be even more prominent in a few years of time as per automotive landscape because of the continuous improvement in the infrastructure along with the said knowledge base. Even today, CVTs which predominantly represent 1st generation designs or models at best, outrun Standard transmission systems. Automobile manufacturers and developers who fail to enhance CVT technology now (this field is still in its early improvement stages), much risk being perceived as CVTs R&D and applications continues to grow exponentially and will continue to do so. CVTs, however, do not fall that exclusively into the domain of IC engines.

8. Conclusion

(1) From the design analysis it was found that the speed ratio of Alternative CVT is mainly function between two cones.

(2) The speed ratio obtained at constant input speed and varing output loads for fabricated model of Alternative Fixed Pitch CVT.

(3) Transmission belt slip is reduced to some percent approximately to zero percent.

(4) Speed range can be from minima to maxima, infinite number speed ratio can be obtained in these CVT without stopping the transmission or disengaging the output shaft.

(5) As the suggested modification in the system by replacing the floating sprocket bars by steel bars, replacement of non-standard belt to standard timing belt, will increase the efficiency of the system, as weight will well be decrease of the system by making the cone hallow.

(6) The CVT have efficiencies of minimum 73 percent and maximum 95.8 percent which are slightly more than existing transmission efficiency values.

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