"Design, Development and Manufacturing of CVT for ATV through Real Time Tuning"

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Abstract - As the government enacts new regulations for automotive fuel economy and emissions, the continuously variable transmission, or CVT, continues to emerge as a key technology for improving the fuel efficiency of automobiles with internal combustion (IC) engines. CVTs use infinitely adjustable drive ratios instead of discrete gears to attain optimal engine performance. Since the engine always runs at the most efficient number of revolutions per minute for a given vehicle speed, CVT-equipped vehicles attain better gas mileage and acceleration than cars with traditional transmissions. The project aims at designing and manufacturing the Continuously Varying Transmission (CVT). The CVT is designed considering the requirements of SAE BAJA event and the engine used in the event i.e. B&S 10 hp engine. This CVT provides better acceleration and ease in handling as compared to the manual transmission and cost effective as compared to the other transmissions available in the market.

Key Words: *SAE BAJA, CVT*

1. INTRODUCTION

With growing demand for environment friendly technologies, automobile manufacturers today are increasingly focusing on 'Continuously Variable Transmissions' (CVTs) as an alternative to conventional gearbox transmission; to achieve a balance between fuel economy and vehicle performance. By allowing for a continuous band of gear ratios between the driver shaft and driven shaft, a CVT permits the engine to operate for the most part in a region of high combustion efficiency resulting in lower emissions, and higher fuel economy.

Because there are no steps between effective gear ratios, CVTs operate smoothly with no sudden jerks commonly experienced in manual transmission. Since drivers expect a car to jerk or the engine sound to change as they press the accelerator pedal further, it is very confusing for them when the car smoothly accelerates without the engine revving faster. Drivers have unfortunately perceived this as the car lacking power which is causing a marketing problem for the transmissions.

2. PROBLEM DISCRIPTION AND BAGROUND

The TEAM DURGYANAS is a student engineering project team at the SPPU University that designs, builds, tests, and competes with a fully custom off-road racing vehicle in the Baja SAE racing series. The Baja SAE series restricts teams to the use of a common engine that is not allowed to be modified. This forces teams to concentrate on the efficient power delivery to the wheels. The Baja team uses a custom Continuously Variable Transmission (CVT), similar to those used on commercial ATV's and snowmobiles. One large drawback to CVTs, as compared to a traditional gear based transmission, is the inherent efficiency loss with the transmission of torque through friction and belt slip. We are the group of four members working towards improving acceleration and general driveline performance in the 2018 vehicle by reducing these inefficiencies. Thus, the racing team has tasked us with creating a Continuously Variable Transmission (CVT)

3. ACTUATING MECHANISM OF CVT

Different types of variators are used to have desire movement of the pulley, they are roller based, slider based and cam base, these all are mechanically actuated variators, while hydraulically operated and electrically operated actuators are also available. Basically all the variator is used to actuate the pulley to have the required speed ratio. Mechanical variators are simple in construction but less accurate while the other variators are complex but accurate. In this CVT mechanical variator is used with cam based actuator, which is smoother than the roller and slider type actuators. Cam is designed base on the displacement of the driving pulley required. This displacement is converted into the rotating motion of the cam and the CG location of the cam. Profile of the cam is generated in such a way that the cam is always being in contact with the slider roller. Cam push the movable pulley of the primary clutch to make them closer to each other while the belt and the primary spring resist the motion of the pulley and try to expands the pulley. So cam has to produce enough force to overcome the belt force and the spring force. But forces in cam is generated only due to centrifugal action. Forces generated and transmitted in primary clutch is shown

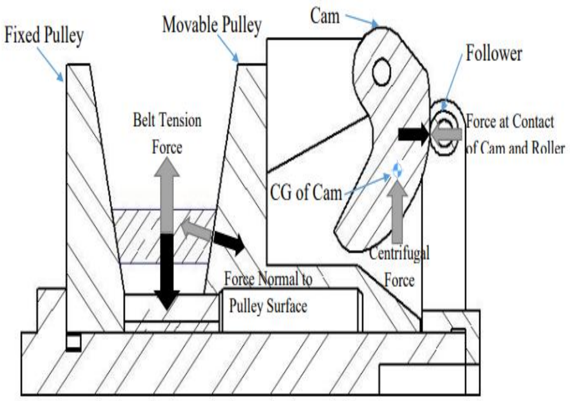


Fig-2 Actuating mechanism of cvt

4. CVT Vs STEPPED TRANSMISSION

The CVT is designed and tuned to maintain an optimal ratio between the engine and drive train to keep the engine operating at its peak power. The diagram below depicts the difference between a standard "stepped" speed transmission and a CVT. For the Baja SAE India Racing vehicle, the competition specified engine has a very narrow speed range where it produces the maximum power. Therefore, the CVT is used to avoid operating outside of the maximum power range.

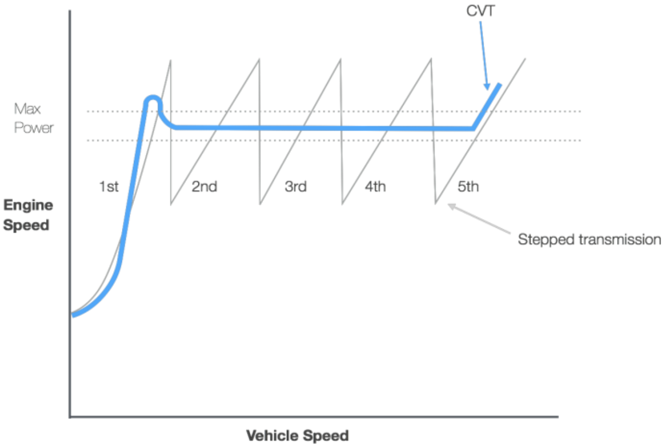


Fig-3 CVT vs Stepped transmission

4. ANALYTICAL DESIGN OF CVT COMPONENTS

Data Available

Engine power= 10HP = 7.45Kw

Frontal area of Vehicle=0.778m^2

Weight of Vehicle=250Kg (With driver)

Maximum R.P.M=3800 RPM

Minimum R.P.M =1750$\pm$100 RPM

Maximum Speed= 60KMPH

Tyre Diameter=.5842m

Design of CVT

Step (1)

Gear Ratio Calculation as per the Requirement of Vehicle

1) Speed of Tyre (N)
   $V=\frac{\pi DN}{60}$
   $16.66=\frac{\pi * 0.5842 * N}{60}$
   N=544.64 RPM
   Maximum Rpm of engine is 3800 Rpm and in the drive train two stage reduction gear box is also used with reduction ratio 7
2) So , speed reduction required in CVT is Calculated as
   $= \frac{speed\ of\ driver}{speed\ of\ driven}$
   $=\frac{3800}{7 * 544.64}$
   =.9
   So, Minimum gear Reduction Required to have a maximum speed 60KMPH is = 0.9

3) Torque Required at wheel (T_W)
   Torque Required= $\frac{total\ effort}{redius\ of\ tyre}$
   $=\frac{TE}{r}$

To calculate total resistance effort 1st up all we calculate the total resistances which are coming on vehicle

4) Air Resistance (R_A)
   $R_A = \mu_{AR} * A * V^2$
   $= 0.5*1.22*.778*16.66^2$
   =132.26 N
5) Rolling Resistance (R_R)
   $R_R = \mu_{RR} * W$
   =0.05*250*9.81
   =122.62 N
6) Gradient Resistance (R_G)
   $R_G = W * \sin\theta$
   = 250*9081*sin(35)
   (θ=35 Because of Maximum Gradient in Hill climb /sled pull Event is 35^0)
   = 1406.69 N
7) Acceleration Resistance (R_{Ac})

$R_{Ac} = a*\frac{W}{g}$

Acceleration of Vehicle (a)

Total torque of Wheel as per rated engine Torque and two stage reduction gear box and transmission efficiency

8) Torque at Wheel = Rated engine Torque * Reduction Ratio of GB

= 19*7*4

=532 N.M

9) Torque =Force*Radius of Wheel

T = F*R

$F=\frac{T}{R}$

$=\frac{532}{.2921}$

= 1821.29*.75

F =1365 N

This is the force required at wheel

F=m*a

$a=\frac{F}{m}$

$a=\frac{1365}{250}$

a= 5.74 m/sec^2

So, $R_{Ac}=a*\frac{W}{g}$

$=5.74*\frac{250}{9.81}$

= 146.02 N

10) Then Total Resistance

(1) Considering air and rolling resistance only

$TE= R_A + R_R$

= 132.2+122.62

=254.88 N …………..(1)

(2) Considering air , Gradient and rolling resistance

$TE= R_A + R_R+ R_G$

= 132.26 + 122.62 +1406.69

= 1661.57 N …………..(3)

(3) Considering air , Gradient, Acceleration and rolling resistance

$TE= R_A + R_R+ R_G +R_{Ac}$

= 132.26 + 122.62 +1406.69 +146.02

=1807.59 N …………..(3)

So Torque Required at Wheel

Torque =Total resistance*Radius

TW = 1807.59*0.2921

TW = 527.99 N.M

11) So, speed reduction required

Higher Gear Ratio $=\frac{Torque\,Requried}{Torque\,Available}$

$=\frac{527.99}{19*7}$

From equation (1) $HGR_1=\frac{254.88*0.2921}{19*7}$ =.55

From equation (2) $HGR_2=\frac{1651.57*0.2921}{19*7}$=3.24

From equation (3) $HGR_3=\frac{1807.59*0.2921}{19*7}$ = 3.5

As per above result 3.5 is the lower gear reduction ratio is selected

STEP (2)

Diameter calculation of primary and secondary pulleys as per gear ratios

Higher gear ratio = 0.8

Lower gear ratio = 4

Then assume the dia of primary pulley

D_P = 155 mm

d_P = 45 mm

(these dia are selected as per packaging space of vehicle) then

Calculation of dia. of secondary pulley

- The power transmission through pulley at pitch dia. of pulley at which v belt in direct contact So when we calculate the all dia. considering pitch dia.
- For pitch dia. 1st up all we select the belt cross section so according to power rating and max RPM we select the V Belt with C-Cross Section Which have Following Dimension.
- So We have also consider the pitch thickness of belt while calculating the pitch dia. of secondary

(1) L.G.R$=\frac{Higher\,dia\,of\,secondary}{Lower\,dia\,of\,primary}$

$3.5 = \frac{Ds-14}{540+14}$

D_s =220.5 mm

(2) H.G.R$=\frac{Lower\,dia\,of\,secondary}{Higher\,dia\,of\,primary}$

$0.8=\frac{ds+14}{Dp-14}$

$0.8 = \frac{ds+14}{150-14}$

d_S = 98.5mm

So final dimensions of primary and secondary

(1) Pitch dia. Of secondary and primary pulley

dp=59mm

Dp=141mm

ds=112.5mm

Ds=206.5 mm

(2) Edge to Edge dia. Of secondary and primary pulley

dp=45mm

Dp=155mm

ds=98.5mm

Ds=220.5mm

Step (3)

Belt Length Calculation

(1) Considering lower dia of primary and higher dia. Of secondary
D=216mm
d=54mm

$$L = 2C+\frac{\pi\,(d+D)}{2}+\frac{(D-d)^{\wedge}2}{4C}$$

C=centre to centre distance =215mm

$$L = 2{*}215+\frac{\pi\,(216+54)}{2}+\frac{(216-54)^{\wedge}2}{4*215}$$

L=884.63mm

(2) Considering higher dia of primary and lower dia. Of secondary
(3)
D=136mm

d=122.4mm

$$L = 2C+\frac{\pi\,(d+D)}{2}+\frac{(D-d)^{\wedge}2}{4C}$$

C= centre to centre distance =215mm

$$L = 2{*}215+\frac{\pi\,(136+122.4)}{2}+\frac{(136-122.4)^{\wedge}2}{4*215}$$

L=836.10mm

So maximum length of above is considered and calculate the actual length of C-section belt from manufacturing catalogue

Then C-section with 890 mm belt length is selected from manufacturing catalogue of V.B Bhandari.

Step (4)

Axial displacement of sheave (total) for transferring belt lower to Higher Dia. Pitch dia. (considering edge to edge dia of pulleys)

(1) Axial Displacement of movable primary pulley
Xp=2*(Rp-RpMin)*tan(α)

α=half wedge angle=11^0
Xp=2*(68-27)*tan(11)

Xp=15.93mm
Xpe= 2*(75-20)*tan(11)
Xpe=21.38mm

Xp=2*(68-27)*tan(11)

(2) Axial Displacement of movable Secondary pulley
(3)
Xs= 2*(Rsmax-Rs)*tan(α)

= 2*(108-61.2)*tan(11)

=18.193mm

Step (5)

calculation of maximum and minimum centrifugal force

C.F= mrw^2

N_{max}=3800 Rpm

N_{min}=1750 Rpm±100 Rpm

r_{max} =65mm

r_{min} =45mm

$w_{max}=\frac{2*\pi*3800}{60}$=397.93 rad /sec

$w_{min}=\frac{2*\pi*1750}{60}$=183.25 rad /sec

m=0.06 kg

$$C.F\ max=\frac{0.06*65*(397.93)^{\wedge}2}{1000}$$

C.F max=617.5*8

=4940 N

C.F min=$\frac{0.06*65*(183.25)^2}{1000}$

C.F min=90.66*8

=725.28N

Step (6)

spring design

(1) Spring in primary side
Material- Aluminum Spring (SW --Grade)
Sut =1440 N/mm^2
ɩ̂=.5Sut
=570 N/mm^2

Whals Factor

$K=\frac{4c-1}{4c-4}+\frac{0.615}{0}$

C=8 for spring clutches

$K=\frac{4*8-1}{4*8-4}+\frac{0.615}{0}$

K=1.184

Wire Diameter

ɩ̂ = K $(\frac{8pC}{\pi d^2})$

= K $(\frac{8*400*8}{\pi d^2}$

d=4.241mm

d≈5mm

D=c*d
=8*5
= 40mm

Deflection

$=\frac{8pD^3*N}{G*d^4}$

$17=\frac{8*400*40^3*N}{81370*5^4}$

N=4.22≅ 5
N=5
N= No of active coil

Total no of coil=N+2

Nt =5+2

=7
Actual deflection=20.135

Medium (soft) Bet^N black and orange

d=4mm

D=40mm

K=10N/mm

N=4

Nt=4+2=6

Solid length=24+16+7.5

=74mm

Spring in secondary pulley

d=4mm

D=56mm

K=1.962N/mm

N=4

Nt=N=4

Solid length=24+16+7.5

=74mm

Free length= 92+22

Solid length=24mm

5. PROCEDURE FOR TUNING

There are several methods and recommended processes for "ideal" clutch tuning. however, if one is looking for optimum output instead of simple performance improvement ,trial and error iterations is the only key.

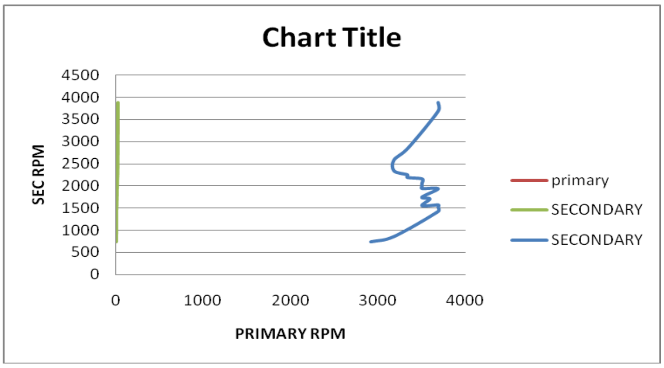
These steps can sum up the primary procedure:-

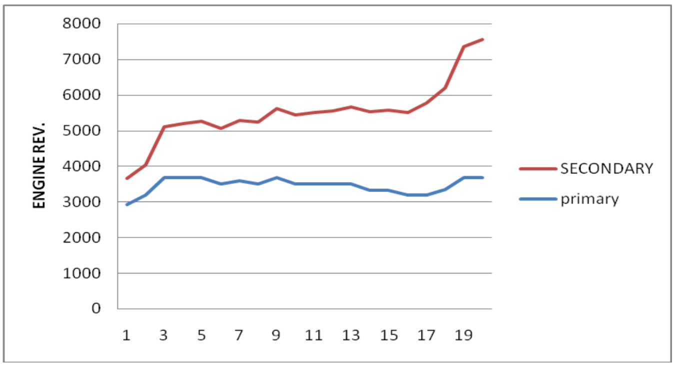
- Check the engine parameters : The entire working of CVT setup depends upon the continues input from engine and the feedback from CVT. we need to assure that the CVT feedback keeps the engine at power peak with increasing RPM .check first the rpm where you obtain maximum torque and maximum power. This rpm band will be where you have to operate your cvt within. For briggs and

Stratton engine, its generally 2300-2700 rpm for torque peak and 3500-3700rpm for power peak.

- Engagement rpm: it is preferred to have CVT engagement rpm at torque peak rpm. this helps your vehicle to propel at max possible torque to wheels and hence provide optimum thrust for further acceleration. thus, you need to set your primary clutch spring pretension and flyweight such that primary clutch sheaves come together to clutch and engage the belt at torque peak rpm.
- Shiftout rpm : the ideal shiftout should take place at power peak due to obvious reason as your transmission should reach to its least opposition to engine at power peak rpm to harness optimum efficiency.
- Coarse tuning parameters: They cause maximum impact and hence need to be checked first :1)flyweight 2)ramp profile .iterate within tolerances till you get best performance.
- Fine tuning: change the secondary spring twisting rate and helix. Continue iterations till you get best performance .
- Super fine tuning : try various combinations like low weights, low spring stiffness, high weight-high spring stiffness; high weight low –low spring stiffness ; high weight low spring stiffness to make sure your vehicle weight and its dynamic opposition is collaborating with your engine performance.

6. RESULT ANALYSIS FOR TUNING





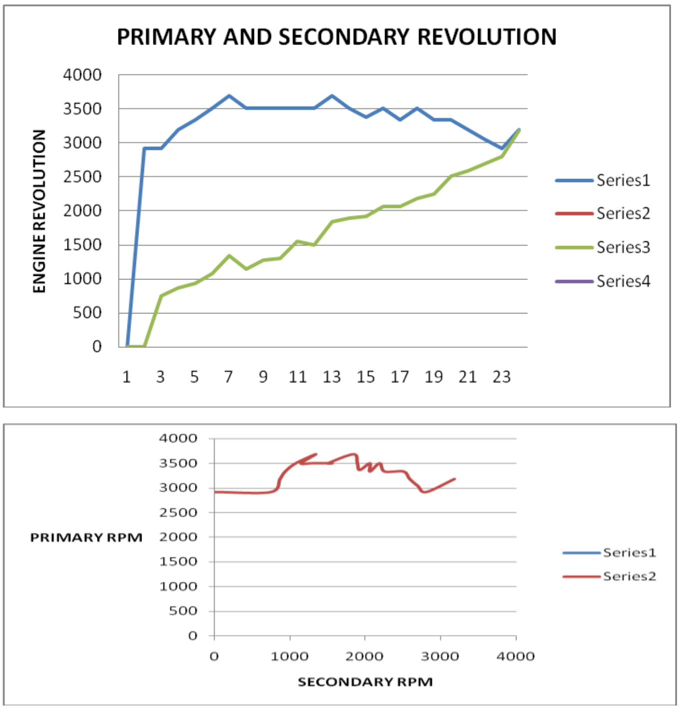


Fig-4 CVT performance curves

7 .MODELING OF CVT BY USING CATIA V5R19

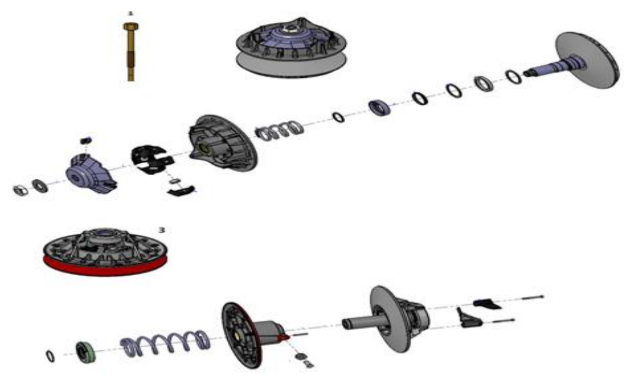


Fig-5 Catia model of cvt

CONCLUSIONS

From the above research work our team concluded that CVT has potential to increase fuel efficiency of the vehicle as well as decreasing the emission of harmful gases from exhaust

The research on CVT gives us increased acceleration and torque by using various tuning option like flyweights, helix optimization in secondary pulley and spring stiffness.

Further design and development of CVT laid to increase in safety of vehicle and reduction in maintenance cost of engine.

REFERENCES

[1] Kevin R. Lang- Continuously Variable Transmissions An Overview of CVT Research Past, Present, and. Future, SAE International, February 1998

[3]K VINOD KUMAR- study and design of automobile continuously variable transmission Science Direct 2010

[4] Akshay Kumar, Sayan Karmakar Nasit Malay- performance optimization ofcontinuously variable transmission (cvt) using data acquisition systems Scientia Iranica 23 Jule 2011

[5]Nur Cholis, Sugeng Ariyono, Gigih Priyandoko-Design of single acting pulley actuator (SAPA) continuously variable transmission (CVT),Science Direct