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Design of a Drivetrain for Sae Baja Racing Off-Road Vehicle

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Abstract— *With growing time, the participation of the students in SAE BAJA is increasing year by year. The vehicle's performance is highly dependent on the installation and appropriate use of Drivetrain components. Drivetrain includes powertrain (prime mover i.e. engine/motor) and transmission components (gearbox, shafts etc). Therefore, Drivetrain is also called as the driving force of any vehicle. The proper design of Drivetrain is thus a part and parcel for any vehicle. The lack of literature available for a optimize design of Drivetrain makes it a hard nut to crack for the students who don't have any past experience. Thus there is a need for some source by which the students can learn to design the Drivetrain for SAE BAJA. The engine vibration is another aspect which is needed to be considered. NVH consideration is another deciding parameter in BAJA vehicle's performance which if neglected could leads to lethal results. Therefore proper installation of engine mounts is required according to the need.*
Thus, this segment aims at developing the Drivetrain for BAJA vehicles which can boost up the performance of the vehicle. Properly use of a powertrain and transmission components for a vehicle along with the calculations according to the need will be discussed in detail. This segment also aims at developing the conceptual understanding of the performance parameters of a BAJA vehicle among the student which will be helpful in their academic curriculum as well.
Keywords- Baja, Drivetrain, NVH, Powertrain, Transmission.

I. INTRODUCTON

Due to lack of literature integrity for the Drivetrain design, one has to explore different section from different media in order to design even the single useful component of Drivetrain. This process is time consuming and extremely difficult to perform. There is a need of platform where students can learn all the important aspects regarding the design just like one pit stop for all the maintenance work. This paper will allow students to explore and learn all the design consideration and they can design the Drivetrain of their BAJA vehicle taking this segment as a useful handbook. The objective of this paper is to design the powertrain for SAE BAJA Racing off-road vehicle which should be Light weight, compact in size and reliable. One of the deciding factors of any vehicle's performance is the comfort level of driver, which comes with the less driving fatigue. The noise and vibration is another aspect which should be worked on, to reduce the unwanted stresses in the frame. Therefore, NVH consideration is must and should be installed properly. Performance parameters like gradiability, acceleration, top speed, transmission etc will be discussed on the basis of their influence over the vehicle under different conditions and calculations. Various other components like coupling, half shafts will be selected and customize according to the need. This paper will include- selection of Engine, transmission, differentials, half shafts, CV joint assembly, calculation of reduction ratios and Engine mounts.

II. POWERTRAIN

The powertrain acts as a power plant for the vehicle. Its main purpose is to provide the driving torque at the wheels. This applied torque at the driven wheels causes' vehicle to move. The power source should be chosen such that it should be able to provide high torque at low rpm and peak power at high rpm. For such dynamic requirement, a stock four cycles, air cooled engine would serve the purpose. This segment has considered Briggs & Stratton (B&S) 10 HP OHV intek Engine as a prime mover/Powertrain. One can choose from different options on the basis of performance curve of the engine. Following are the Baja acceptable engine:

20S232 0036-F1
205432 0536-E9
205332 0536-E9
205332 0536-B1

This engine develops maximum torque of 18.66 N-m at 2600rpm and peak power of 9.14 HP at 3800 rpm.

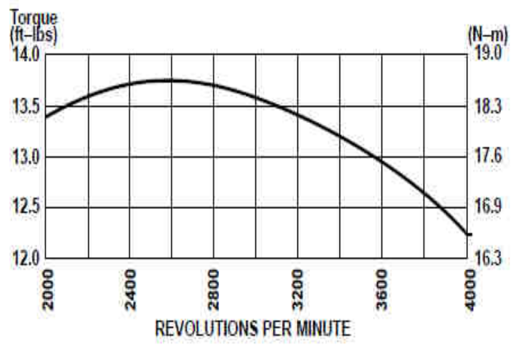

Fig. 1: Torque v/s Engine RPM

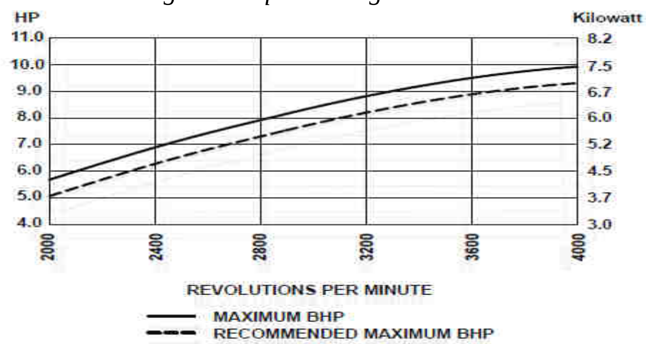

Fig. 2: power v/s engine rpm

The engine comes with mechanical governor set at 3800rpm and should not be changed. The engine is connected to the output shaft of diameter 1'' and length 4''.

III. TRANSMISSION

The main objective of the transmission is providing to the driver more than the enough torque to the wheels from engine to the wheels. The enough torque means the torque required to pull the driving wheels against the road loads. Road loads include rolling resistance (RR), aerodynamic resistance / air resistance (AR) and grade resistance (GR).To choose the transmission capable of producing enough torque to propel the Baja vehicle, it is necessary to determine the total tractive effort (TTE) requirement of the vehicle. Let us assume an imaginary vehicle with following specifications and model:

Table 1: Vehicle design criteria

Gross vehicle weight	2648.7N
Weight distribution	35:65(front:rear)
Tire static radius Dynamic rolling radius	0.2921m 0.283337m
Frontal area	$1.055m^2$
Coefficient of friction μ	1.0(concrete) 0.65(dry road)
Coefficient of rolling resistance fr	0.014(concrete) 0.05(dry road)

Students can take their specific values. In this segment, all the future calculations will be done according to the above data.

3.1 TOTAL TRACTIVE EFFORT (TTE)

The vehicle performance is mainly dependent on two variables: Engine power and Maximum adhesive force between the road and tires (i.e. μ* load on the driving wheels, TE Max). The maximum pull is required when the vehicle is moving uphill at a certain gradient. The gradiability of the vehicle is decided by the amount of torque driving wheels can transmit without reaching the maximum allowable tractive effort (TE Max). If the rear wheels have such a torque applied to them that they are on the point of slipping in the plane of the wheel, then the value of adhesive force between tire and road surface has been reached (μ*WR), where μ is the coefficient of adhesion between tire and road surface, and WR is the weight on the rear wheels. Under these conditions the engine torque has reached the maximum useful value for the present set of conditions, as any increase would only result in slip and lower acceleration. Static friction is higher than kinetic friction.

Total Tractive Effort (TTE) = RR+AR+GR

It is suggested to carry out all the calculations on Microsoft Excel for different inclinations and vehicle speed. Such set of data will provide the crystal clear requirement of TTE and the ability of a vehicle to climb without slipping. The TTE corresponding to maximum inclination will be taken as maximum torque which can be applied on wheels by Drivetrain.

3.1.1 ROLLING RESISTANCE

Rolling Resistance (RR) is the force necessary to propel a vehicle over a particular surface. The worst possible surface type to be encountered by the vehicle should be factored into the equation.

RR = GVW x fr

Where:

RR = rolling resistance, Newton

GVW = gross vehicle weight, Newton

fr = surface friction (value from Table 1)

3.1.2 AERODYNAMIC RESISTANCE

A moving vehicle, in displacing_the surrounding air, has a resultant resisting force called aerodynamic drag or simply air resistance. It can be expressed as resistive force_opposing the motion of a vehicle through the air and the work done in overcoming the force is dissipated as energy lost to the air flow. The significance of the aerodynamic

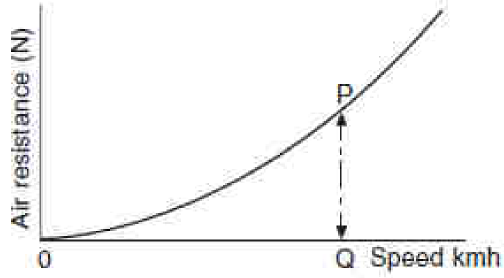

Figure 3: air resistance v/s vehicle speed

AR = ½* ρ* V^2 * A *Cd

Where

AR = aerodynamic resistance / air resistance, Newton

ρ = air density, kg/m^3 , 1.122 kg/m^3

V =velocity, m / sec

A = effective frontal area of the vehicle, m^2

Cd =aerodynamic drag coefficient, 0.44

3.1.3 GRADE RESISTANCE

Grade Resistance (GR) is the amount of force necessary to move a vehicle up a slope or "grade". This calculation must be made using the maximum angle or grade the vehicle will be expected to climb in normal operation.

To convert incline angle, α, to grade resistance:

GR = GVW x sin(α)

Where:

GR = grade resistance, Newton

GVW = gross vehicle weight, Newton

α = incline angle, Degrees

H is the gradient resistance force acting downward.

W is the Gross Vehicle weight

K is the component of the GVW acting perpendicular to the road surface.

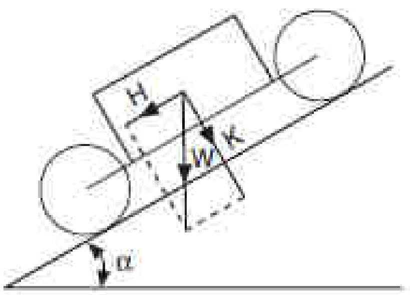

Fig. 4: vehicle on inclined surface.

3.2 PERFORMANCE CHARACTERSTICS

The performance characteristics of BAJA vehicle strongly depends upon three main factors, which are:

a. Gradiability
b. Acceleration
c. Top speed

3.2.1 GRADIABILITY

Gradiability is defined as the ability of a vehicle to climb uphill at a certain angle without the slip occurs. It is an important factor which decides the maximum pulling force that can be applied by the engine to the wheels. Generally, the maximum applied torque is not a deciding factor rather the maximum force that a tire can transmit is the deciding factor. Maximum gradient that can be travel is up to when the applied pull is less than or equal to the adhesive force between the road and tire, beyond this point slip will occur and there will be a loss in torque. In general automotive application, gradiability is define in terms of percentage i.e. 30%, 40% etc. The term "X%" means that vehicle will cover X m distance in vertical direction while moving 100 m in horizontal direction. For example by term 60% gradiability, it means that vehicle will cover 60m vertical distance per 100m horizontal distance. Under such notation, actual angle of inclination is:

α = $\tan^{-1}$(X/100)

For 60% gradiability, α = 30.96°

Thus gradiability can be calculated from the total road loads acting at different speed and the allowable maximum Tractive force i.e. TE Max.

Considering the worst case i.e. vehicle moving at maximum allowable speed of 55kmph on concrete surface.

RR= 0.014*2648.7 = 37.0818 N

AR= 1/2 *1.12*$(15.27)^2$1.055*0.44 = 0.712 N

GR= 2648.7*sin(30.963) = 1326.7 N

(60% gradiability)

GR= 2648.7*sin(34.99) = 1518.9 N

(70% gradiability)

Total Road load (at 60% gradiability)

= 1424.48 N

Total Road load (at 70% gradiability)

= 1616.8 N

Since, the maximum gradiability is dependent on the maximum tractive force (TE Max), which is given by:

TE Max = μ * WR

= 1.0*(2648.7*cos(30.96)*0.65) = 1476.3 N

= 1.0*(2648.7*cos(34.99)*0.65) = 1410 N

From the above two calculations, torque required is less than the TE Max for 60% gradiability whereas torque required is more than TE Max for 70% gradiability.

Hence, maximum gradient this BAJA vehicle can climb without slip is 60 % i.e. 30.7 degrees.

To climb this gradient, torque required at wheels to climb 60% gradient at max speed Tw, is given by:

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Tw = (Total Road Load)* (dynamic rolling radius)

Tw = (1424.8)*(0.283337)

Tw= 403.69 N-m

Low gear is required while the vehicle is moving on the gradient so that maximum torque can be achieved. The in ratios of torque at wheels (Tw) and engine torque (Te) are calculated to find out the overall reduction required in low gear.

$Tw = Te^* \, ig_{low} * \eta_{transmission}$

Where

ig_{low} is the overall reduction in low gear

$\eta_{transmission}$ is the transmission efficiency

The transmission efficiency is 92% for manual transmission whereas it is 75% for Continuous variable transmission (CVT). This segment is considering CVT as it has its own advantage which will be discussed later on.

Therefore,

$ig_{low} = Tw/(Te^* \, \eta_{transmission})$

ig_{llow}= 403.69/(18.66* 0.75)

ig_{low} = 28.84 = 30 (standardize)

Hence, transmission should be capable of providing overall reduction in low gear of 30.

3.2.2 ACCELERATION

Acceleration is rate of change of velocity with respect to time. The change can be either in magnitude or in direction. In automotive, acceleration is also referred as the pickup capability of a vehicle i.e. the time required to attain certain speed from rest. From past experiences, it is crystal clear that it's an acceleration which is important rather than top speed. The acceleration is always misunderstood. The racing vehicle doesn't require the high top speed as the track won't allow the driver to attain the wide open throttle position, before that, driver will encounter the turn and he has to partially close the throttle. What important is acceleration i.e. how fast you can attain maximum speed of your vehicle. That's the zone which makes a significant difference.

For better understanding, consider two BAJA vehicles A and B. Vehicle A has more acceleration but less top speed than vehicle B. Now, during a race, vehicle A will attain its top speed before vehicle B, and as soon as vehicle B will attain its top speed, the track will encounter a curve and vehicle B will not only losses it time to accelerate again but also will never reach the top speed all the time.

Hence, there should be a optimum selection between acceleration and top speed.

So far in this segment, one thing is clear, i.e. applied pull force on wheels should be more than the road loads and lesser than the TE Max. The difference between the Pull applied and pull require makes the vehicle to accelerate. If the applied force is more than road loads, vehicle will accelerates. If road loads are more than applied force, vehicle will decelerates. From Fig 1, the maximum torque is at 2600rpm, so it is understood that maximum acceleration will attain when the engine will be running at 2600rpm, as maximum pull on the wheel will be at maximum engine torque.

Low gear is always used for the gradient climbing and acceleration as the reduction of speed is maximum in low gear and the pulling force available at wheels is also maximum, which results in maximum acceleration of the vehicle.

F = M*a

Where

F is surplus force available at wheels, N

M is the total mass of the vehicle, Kg

'a' is the acceleration of the vehicle , m/s^2

Calculating for maximum torque at 2600 rpm

Te =18.66 N-m

Ig_{low} = 30

$Tw = Te * ig_{low} * \eta_{transmission}$

Tw= 419.85 N-m

Pull at wheels Fw = Tw/dynamic radius of tire

Fw = 419.8/(0.283337)

Fw = 1481.62 N

Total Tractive effort required (TTE) = RR+ AR+GR

RR= GVW* 0.05

RR = 132 N (dry road)

GR= GVW*sin($\tan^{-1}$(0)

GR = 0 N (0% Gradient track)

$V_{wheel} = (R_w * 2 * \prod * N_{engine})/(60 * ig_{low})$

Where

V_{wheel} is the wheel velocity at 2600 rpm

R_w is the dynamic rolling radius of the tire

N_{engine} is the Engine rpm at Tmax

V_{wheel} =(0.283337*2*3.14*2600)/(60*30)

$V_{wheel =}$ 2.5717 m/s^2

AR= ½ * 1.12* $(2.5717)^2$ * 1.055* 0.44

AR= 8.069 N

F = (Fw- TTE)

F = (1481.62-(132+0+8.069)

F = 1340 N

Acceleration, a= (1340*9.81)/(2648.7)

Acceleration, a = 4.96 m/s^2

Therefore maximum acceleration, vehicle can attain is 0.505g

The acceleration can be increased by increasing the reduction in low gear, but one has to be careful as increasing pull on wheels during hill climb may result into the loss of torque due to slip. Another way of increasing the acceleration is by reducing weight which is

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very important factor and can give you few more seconds leap in your lap

3.2.3 TOP SPEED

Unlike gradiability and acceleration for which vehicle should run in low gear, high gear is required in order to attain the maximum speed. The vehicle speed will increase if the applied pull is more than the road loads and it will decrease if the road loads are more than the applied pull. The maximum top speed of a vehicle on a level ground is dependent upon the rolling resistance, air resistance/aerodynamic resistance, maximum power at the road wheels and the choice of a suitable final drive ration. As mention in the earlier section, there is a tradeoff between maximum speed and maximum acceleration. Refer to Fig 5 on next page, the upper curve is the power at the road wheels and lower curve is the power loss due to road load i.e. resistance power. The point of intersection is the maximum attainable speed which is 55Kmph

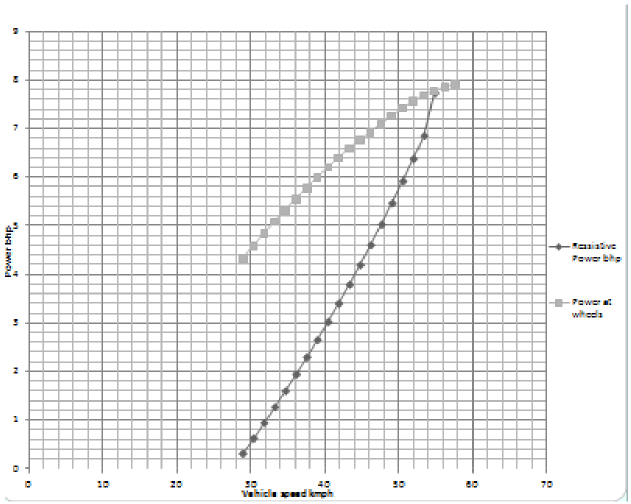

Fig. 5: power v/s vehicle speed

Taking reference from the Fig 5, if the power curve is shifted left relative to the resistance curve, no doubt that maximum speed will reduce as the point of intersection will also shift to left, but in that case the power available for the acceleration will also increase, and the vehicle will termed as under gear. Similarly if the power curve is shifted right relative to the resistance curve, the point of intersection will be at the peak power, which will increase the maximum speed but the acceleration will decrease. And as discuss above, it is acceleration that matters the most.

The maximum speed is always calculated in high gear at maximum engine rpm. To attain maximum speed of 55kmph such that:

V_{wheel} =55kmph =15.277 m/s

$W_{wheel} = V_{wheel} / R_w$

W_{wheel} = (15.277/0.283337) = 53.92 rad/s

N_{wheel} = ((W_{wheel} *60)/2∏) = 515 rpm

$N_{engine} / N_{wheel} = ig_{high}$

Ig_{high}= (3800/515) = 7.378

Therefore overall reduction in high gear required to attain maximum speed is 7.378

The graph can be potted by calculating resistance power Pr, which is (TTE*V_{wheel}) and power at wheels, which is (Fw*V_{wheel}). It is recommended to use the Microsoft excel to plot this graph by calculating different value of TTE at different V_{wheel} corresponding to range of engine rpm N_{engine} from 2000rpm to 3800rpm.

Note: while calculating TTE, take gradiability as 0% .

3.3 TRANSMISSION SELECTION

The types of transmissions which are very popular among the BAJA teams are: Manual Transmission and Continuous Variable Transmission (CVT). Manual transmission commonly known as gear box can be easily installed and coupled to engine. Use of manual transmission is easy and reliable. The top two best suited gear boxes are Mahindra Alpha and Tata Ace. One of the biggest disadvantages of manual gear box is the ride comfort. The driver comfort is compromise and the fatigue is one of the bad results of using manual gearbox. To increase the comfortability of the driver which will leads to increase in vehicle performance, it is recommended to use CVT which will not only provide the infinite gear ratios between the low and high gear but also helps in reducing the weight and driver fatigue. Therefore in this segment CVT will b discussed. However, based on the overall low and high gear ratio calculated in previous segment, one can select the type of gear box required followed by the design of final drive ratio which will be discussed later.

3.4 Continuous Variable Transmission (CVT)

The continuous variable transmission (CVT) is plays a most important part in the performance of the vehicle. As stated above, the CVT helps in reducing the driver fatigue as there will b no clutch to press, no lever to shift while changing the gear ration. Thus, it not only save the weight of other components but also provide the smooth ride by allowing driver to shift the infinite number of reductions between the low gear and high gear. Low gear is same as the first gear and high gear corresponds to fourth gear of gear box. The selection of CVT is also due to the fact that the shift in speed and acceleration is continuous with CVT which is in step with gear box. The CVT also allow the engine to run at peak power which is very much desirable for the better performance of the vehicle and good fuel economy of the engine.

3.4.1 CVT SELECTION

There are many manufactures of CVT like Polaris, Yamaha, Comet, CVTech etc. One can choose from any one of them depending upon the cost, ease of tuning and drive ratios available. Selection of belt is also an important parameter as it is the belt which will be transferring the power. More or less, the belt material is same in case of all cvt. On the basis of cost and ease of tuning, it is recommended to use CVTech AAB cvt. CVTech CVT comes with the sponsorship for the BAJA vehicle and is easily available worldwide. The driving ratio of AAB CVT is 6.976, whereas the centre to centre distance of the belt can be selected as per the space. Minimum c/c is 200mm

As mention above, the CVT has low gear and high gear as a fixed ratio CVTech CVT comes with the low ratio of 3 and high ratio of 0.43. According to the need CVT has to be tuned such that shifting occurs at the peak power of the engine and engagement occurs before the peak torque of the engine for the smooth gradual start.

Overall reduction required by transmission in low gear was 30.

Low ratio of CVT is 3.

Therefore, final drive ratio should be ig_{final} = 30/3 =10.

This final drive ratio is fixed all the time and normally comprised of larger first gear of gear box and gear box to differential reduction. But in case of CVT low gear ratio is comparably small and reduction of 10 from CVT to differential is not attainable, hence intermediate reduction is required such that:

CVT output shaft is coupled to an intermediate shaft of reduction 2.5. At the end of this intermediate shaft, rest the sprocket which drives the sprocket of differential by reduction of 4. The net final reduction thus comes out to be 2.5*4 = 10 (as required).

Therefore net reduction between CVT and Differential is now in two stages. From CVT to differential via intermediate shaft. This arrangement not only saves the space but also pack the entire Drivetrain assembly in smaller area so that the net cg of Drivetrain will lie on the centre line of the vehicle which is very much required.

Fig. 6: Drivetrain layout

Now, for the top speed, overall reduction required by transmission was ig_{high} = 7.378

Since the final drive ratio is fixed to 10, therefore high ratio of CVT is thus needed to tune at 7.378/10 = 0.7378, more or less equal to 0.74

Thus, tuning is needed to restrict the high ratio of CVT at 0.74 giving overall driving ratio of 3/0.74 = 4.

3.4.2 CVT TUNING

From the previous calculations, it is clear that high gear require to attain the top speed is 0.74 whereas default top gear of CVT is 0.43. That means we need to customize the CVT according to this ratio. This “customization” is nothing but what we called as “CVT TUNING”. Before proceeding for the tuning, one should know the detailed working of CVT. There is no rocket science behind the working of CVT rather a primary (Driving) clutch and a secondary (Driven) clutch connected via belt. The primary clutch has pretension springs and fly weights which control the engagement and shift speed of the system. The secondary clutch is a simple design doing a complicated job. The spring and cam is the key to its performance. Before one starts working on the CVT, two things should be finalized in mind:

1. The ratio required from the CVT at two extreme engine speeds i.e. according to the maximum torque and power.
2. The basic leverage of CVT should not be compromise i.e. CVT should be shifted only at peak power of the engine, allowing the engine to run at its best rated condition.

   From these two considerations, two graphs should be plotted corresponding to each. In this segment, as engine maximum torque is at 2600rpm, therefore at this instance, CVT should be in low gear. And at 3800rpm, it should be at high gear. Then the graph will comes out to be:

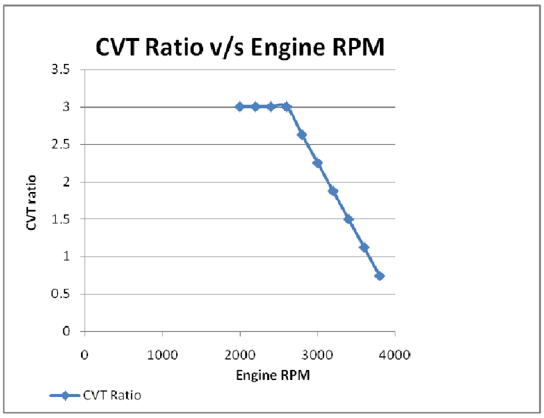

Fig. 7: CVT ratio v/s engine rpm

Here, tuning should be such that, the low gear is engaged while engine is running at peak torque and high gear is engage when the engine is running at peak power.

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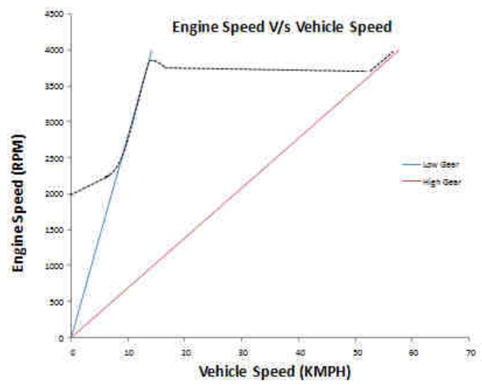

Fig. 8: speed diagram of CVT

The blue line represents the low gear and red line represents the high gear. The dotted line represents the engine speed as the vehicle speed increases. This dotted line also represents the ideal shift curve of a engine with peak power at 3800rpm. Two points are of importance, the engagement speed and the shift speed. This change in ratio is shifted due to centrifugal action of fly weights. Both clutches contains one movable sheave and one fixed sheave. The belt is slide over these two sheaves of different radius, thus reduction in speed occurs. At low gear, primary clutch sheave is at minimum diameter and secondary clutch sheave at maximum. This is the condition of engagement, as the engine speeds up.

In order to start the vehicle moving, the engine must be engage at a speed that has sufficient torque to propel the vehicle. Initially for the engine speed below 2000rpm, the centrifugal forces are overcome by pre tension of the springs and no clutching takes place at low/idle speed. At 2600 rpm, the fly weights should overcome the pre tension force of the springs so that, start moving the sheaves together until enough force is exerted on the belt to start the vehicle moving. This point is called engagement point, and at the speed this point is called engagement speed. At this stage, the centrifugal force is just equal to the pre tension of the spring. Now, after the engagement point, as the speed of the engine increases, the side pressure on the spring also increases from 0 to 100%. This phase is called clutching phase. When the belt is fully engage the speed will continue to increase in low ration up to 3800rpm. This phase is called low acceleration phase. When the engine speed will reaches to 3800rpm, the side force on secondary clutch now exceeds the pre tension of the driven clutch springs and the shifting of sheaves will start takes place, hence reducing the ratio. This phase is called a shifting point and the speed is shifting speed. The engine will now continuously run at peak power and the CVT will shift from low gear to high gear keeping the speed of engine constant. The CVT should be tuned on the above manner to attain the maximum efficiency of both the engine and CVT.

3.4.3 CVT COUPLING AND DIFFERENTIAL

3.4.3.1 CVT COUPLING

One of the major issues faced with CVT is its coupling to the engine. The good news is, the engine output shaft is 1’’ (25.4 mm) in diameter and the input diameter for CVT is also 25.436 mm which means that the output shaft can directly be used as input shaft of CVT. Refer the Fig 9 below. The flange coupling can be designed for the shaft of diameter 1’’ if space is not a restrained.

For the shaft diameter of D, mm

Hub diameter D1= 1.8D+20;

Diameter of the bolt circle D2= D1 + 3.2D

Number of bolts, I = ((1/40)*D + 2) to ((3/80)*D + 2)

Bolt diameter, d = {(0.423D)/((sqrt(I))} + 7.5

Flange outer diameter, D3 = D1 + 6d

Hub Length, L = 1.2D + 20

Flange thickness, t= 0.35D + 9

All in mm

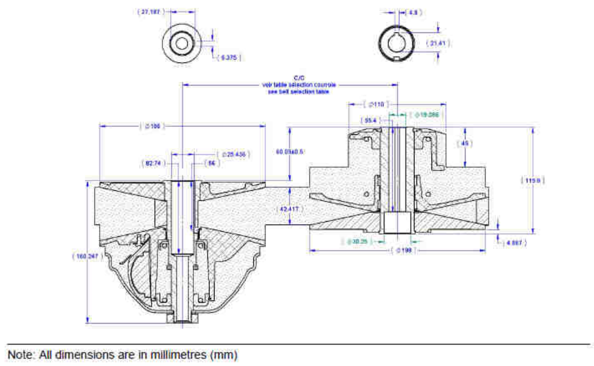

Fig. 9: CVTech CVT detailed drawing

3.4.3.2 DIFFERENTIAL

The deciding factor in the vehicle’s performance is the selection of Differential. In general term, differential is a kind of gear box which transfer the difference speeds at different wheels so that vehicle can take turn without slipping. From simplified type i.e. open differential to most complex type i.e. LSD, one can choose a differential based on the track requirement and the costing off course! The BAJA track is rough and muddy where the traction on both the wheels is required. For such requirement, Limited Slip Differential (LSD) is preferably. There is no correction required in its working and LSD can be installed as it is. However, to reduce the size of layout, differential should be chain- sprocket driven rather than shaft driven.

Next comes is the half shaft along with the CV joint assembly. The half shaft should be design as a simply supported beam of length half of rear track width (as in this segment, differential is placed in middle of the rear), subjected to bending, torsion and axial thrust. Or in other words, it should be design as a semi- floating axle. The bending loading is due to the rear weight, torsion due to

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the driving torque and axial thrust due to cornering. In order to accommodate the suspension travel, CV joints are needed. The most reliable CV joints are the outboard CV joint is manufactured by Polaris Industries, and is featured on the Sportsman and Hawkeye 300 ATV. The joint is designed to transmit 17hp and allow for 30 degrees of articulation, which is ideal for the rear suspension travel. The two joints and their axle shafts will be coupled together to the correct length, using a welded 4340 steel sleeve. The joints are very small and lightweight, and prove to be a durable and lightweight combination.

Fig. 10: CV axle assembly

IV. NOISE, VIBRATION AND HARSHNESS

Noise, Vibration and Harshness also known as NVH arises when motorized equipment such as fan, pump, and engine etc, energy can be transmitted from the equipment to the structure in the form of vibrations. This vibration often radiates from the structure as audible noise and potentially reduces performance or damages equipment. The vibrations can be isolated by using proper isolation mounts. From an internal combustion Engine, the main sources of vibration are:

1. The unequal gas pressure on the piston, this is significant during idling;
2. Un equal reciprocating and rotating masses of the engine components, this I significant during high rpm;

For a single cylinder, 4-stroke Engine, the frequency of the vibration varies from 5Hzt – 50 Hzt for 600-6000rpm. The maximum engine rpm of B & S engine is 3800rpm and exact vibration can only be calculated once the engine is dismantled. Still it is safe to use the range of 15-32 Hzt for the disturbing frequency. The frame frequency of the BAJA vehicle is normally lies in the range of 27-32 Hzt for the vehicle shown in this paper. The two most commonly used isolations with the engine are four elastic or visco -elastic mounts. The former type has poor isolation capability at low speeds and later type has excellent capability at low speeds. But the most important factor is cost, rubber mounts or elastomeric mounts are cheaper. They have the isolation coefficient of 30% at low rpm i.e. below 1000rpm. 62.5% at 2000rpm, 90% at 3000rpm and 93.3% at above. If you observe closely than you can find out that, at low rpm engine frequency is about 15 Hzt where as Frame natural frequency is about 27 Hzt which is more, therefore resonance will not occur at low rpm. This shows that the poor damping capacity of rubber mounts are compensated by the lower engine frequency and at high rpm, after damping, engine frequency will be lower than the frame frequency and resonance will not occur. Therefore, stating that rubber mounts can be used as engine mounts is considerable. However for the excellent reduction, one can use the visco- elastic mounts but they are costly.

Therefore, if the resonance condition is not reaching in the frame, then the vehicle is safe from the unwanted stresses and the pre mature failure of the components.

V. CONCLUSION

The main objective of this paper is to provide the in detail knowledge about the Drivetrain of BAJA vehicle. The first and foremost advantage of this literature is the availability of design detailing along with the specification of each and every components of the Drivetrain in one segment. For the new students, who do not have any past experience it will provide them the path to select and design their own Drivetrain depending upon their need. Each and every aspect of Drivetrain design has been discussed in detail. However, the choice of few components like CVT over manual gear box etc is just to make referral about the basic design consideration that may vary from students to students. Second advantage is the elaboration of various parameters and their effect on vehicle performance. This will help students in their curriculum as well as in the designing of any other racing vehicle like formula student. Emphasis was more given to use the scientific language which will create the curiosity in the reader's mind to discover the further about the topic. Since Drivetrain cannot be restricted to 10 pages, only the specific and necessary detail is discussed. So finally, anyone having no knowledge about the Drivetrain of the BAJA can now design and tune it by them self after learning from this segment. All the BAJA, Formula Students and other racing competition aspiring students can use this as a handful tool in their learning and process.

VI. ACKNOWLEDGEMENTS

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