Design of Powertrain system for an All-Terrain Vehicle

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ABSTRACT

The project is the part of an all-terrain vehicle built for an intercollegiate design competition called BAJA SAE. The motive behind choosing this topic for project was to get into the field of All Terrain vehicles, studying the various important parameters that are associated with the design of powertrain system for the purpose. Several transmission and final drive options were researched. The main criteria were identified and the alternatives were evaluated. This resulted in choice of fully automatic transmission using Continuously Variable Transmission (CVT) coupled with Two Stage Reduction Gearbox to achieve required torque and speed characteristics. The testing was so done to test all design parameters. Testing proved that the drivetrain was rugged and performed well.

KEYWORD: *ATV, Efficiency, CVT,Optimum Design,Weight*

1.INTRODUCTION

The Heart of Vehicle i.e. Engine used in this powertrain system is Briggs and Stratton make which is Four Stroke, Single Cylinder, 305cc, 10hp and 18.4Nm gross torque. The Engine power is to be transmitted to wheels with minimum power losses. The torque which is provided by engine is only 18.4Nm which is not sufficient to pull the vehicle. The Drive system is so designed to get desired output torque to negotiate tough terrain conditions at final BAJA event.There are different types of drive systems used in automobile are broadly classified as Manual, Automatic and Semi-Automatic transmission systems. In Manual system the gear shifting is done on the will of driver operated through different shifting mechanisms. Where as in Automatic system it is completely automated and sensed by load on the wheels. For track condition faced by an ATV the driver comfort in the most important parameter which is to be considered. With Automatic transmission system driver need not be worried about gear shifting and can concentrate more on track conditions to perform proper handling. The Continuously Variable Transmission (CVT) i.e. automatic type system is used instead of manual type.

1.1 Problem Statement

Design a drive train to connect the 10hp engine to the rear axle of the Baja SAE vehicle. The design must have a good balance of lightness, reliability, efficiency, compactness, and cost-effectiveness.

1.2 Methodology

The project approach is based on Maximum Efficiency. The target was to get optimum design for every designed component. As being a drivetrain, the target was to minimize rotating mass as much as we can thus leading to Optimum and Efficient design.

2. GEARBOX

The maximum ratio provided by CVT is 3.9:1. But the torque multiplied by CVT is also not enough for the vehicle so an auxiliary gearbox is used to achieve remaining overall ratios to get desired output torque at wheels. The specification of gearbox are as follows:

Type: 2 stage Reduction Gearbox

Types of Gears: Spur type
Overall ratio : 6.21
The gearbox contains following different parts:

1) Gears: The gears used for the application are helical gears. The material used for gears is EN36. There are two stages of reduction in gearbox so the total gears in gearbox is 4.
2) Shafts: The shafts are made up of material EN24. There are total 3 shafts in gearbox.
3) Oil Seal: These are used to prevent the leakage of oil used in gearbox.
4) Bearings: The bearings used are taper roller bearing of SKF

Fig -1: Gearbox

Fig -2: Gears

Fig -3: Shaft

Fig -4: Oil Seal

Fig -5: Bearings

2.1 Drive shafts

It is used to connect the gearbox to the wheel hub. It permits angular and well as lateral degree of freedom which is require for working of suspension system.
Make : Self designed and manufactured with tripod at inboard and six ball Rzeppa at outboard

Fig -5: Drive Shaft

2.2 Specification

Fixed input parameters are those parameters which the team is bound to use because of some restrictions.

- Maximum speed allowed: - 60 kmph
- Maximum engine speed allowable: - 3800 rpm
- Maximum Power Input: 10hp

The decided parameters are those input parameters to the design which are decided by the team prior to the design calculation stage. These parameters are decided by thorough understanding of literature used. These parameters are also decided by taking in to consideration of different subsystems of the vehicle. They are listed below:

- Radius of rear wheel : 11.5 in : Taller wheels prevent bottoming out also increases the torque transmitted to the road.
- Gross weight (kg): 250 Kg
  The weight decided for calculation is a bit on heavy side than the targeted weight to be on safer side during event like hill climb.
- Efficiency of CVT (ŋcvt): 85%[1]
- Efficiency of gearbox (ŋgearbox): 96%[2]
- Co-efficient of rolling resistance: 0.023 For dirt roads.
- Co-efficient of traction: 0.75 For ATV

Maximum angle the vehicle can climb: 38 degree

2.3 Design Procedure

The step by step process followed for designing the overall subsystem is given below

1. After getting the inputs from fixed and decided parameters, the overall ratios required for vehicle to climb 38 degrees steep hill is calculated.
2. After calculating the overall ratios, the subsystems are selected according to the applications and required ratios. The CVT and Two stage reduction gearbox are selected as the subsystems to transmit power from engine to wheels with required speed reduction and torque multiplication.
3. The selection of required CVT according the ratios is selected keeping in mind Cost, Availability, Reliability, Weight and performance parameters.
4. After selecting CVT of required ratios, the left out ratios are worked out with reduction gearbox.
5. Now the two stage reduction gearbox in designed. In this calculation for Gears, Shafts, Keys, Bearing selections and lubricant used are done. The gearbox casing is designed according to the application.
6. Now the task is to transmit output torque from gearbox to the wheel hub with minimum losses and work properly with suspension travel. This is done by selecting suitable drive shafts.

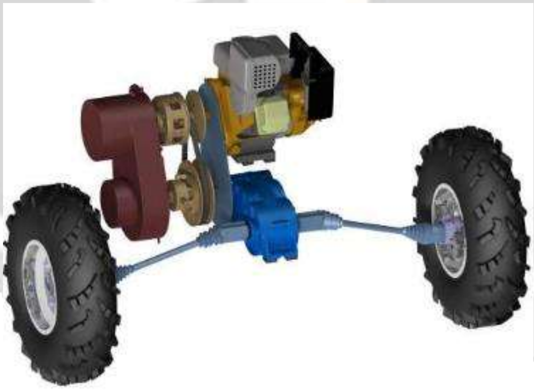

Fig 6 : Design Layout

2.4 GEAR OIL SELECTION

In automobile, gears play an important role of transmitting the motion by providing required reduction in power train. Metal gear teeth mesh with each other repeatedly providing transfer of motion. Due to this, continuous contact between two gears develops friction, thus heat is generated. Energy dissipated in form of heat adds up significantly in power loss. Lubricating the gears is efficient and accepted way to solve this problem. There are different types of lubrication such as grease lubrication, splash lubrication, spray lubrication etc.

Purpose of lubrication :

1. Reduce friction between two mating gears.
2. Limit the temperature rise due to friction.

Parameters for selecting lubrication:

1. Peripheral Velocity of gear.

2. Ambient temperature.
3. Kinematic Viscosity of lubricant.

Kinematic viscosity of oil depends upon temperature. It changes according to different temperature conditions. As per SAE graded oils for lubrication, the oil selection for gear box is done on basis of kinematic viscosity of oil at 40^{o}C and 100^{0}C.
Values of kinematic viscosity at 40^{0}C & 100^{0}C are considered, oil selected is 80W90. 80W90 represents a winter oil where 80 and 90 represents viscosity grade.

3.ANALYSIS

The Finite Element Analysis of various components of gearbox was done using ANSYS Workbench 16.0.

3.1 Shaft

Force 1: Force due to CVT pull of 915.3105 N applied at driven pulley mounting area.
Force 2: Force of 7311.2430 N due to torque applied at keyway.
Fixed Support : Bearing Surfaces.
Similar approach is used for other shafts in gearbox.

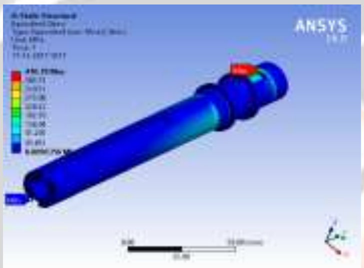

Fig 7 : Stress Distribution in first shaft

3.2 Gears

Radial force : 1478.3750 N
Tangential force : 4061.8019 N
Fixed support : Keyway surfaces

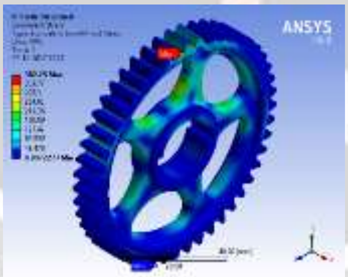

Fig 8 : Stress Distribution in first stage gear

3.3 Casing

Force 1: Bearing Load of 3348 N at bearing surface of shaft 1.
Force 2: Bearing Load of 4800 N at bearing surface of shaft 2.
Force 3: Bearing Load of 2500 N at bearing surface of shaft 3.
Force 4: Force due to caliper of 5340.20487 N

Fig 8 : Stress Distribution in casing

3.4 FEA Results :

The results obtained from analysis of the components are in terms of Equivalent Stress Induced, Total Deformation and Factor of safety. The contour plot is obtained from the software with maximum and minimum tab showing the areas of concerns.

Sr.No.	Component	Stress (MPa)	Deformation (mm)	FOS
1	First pinion	384.87	0.0141	2.5983
2	First gear	382.25	0.0759	2.6161
3	Second pinion	442.77	0.0209	2.2585
4	Second gear	371.74	0.0454	2.6901
5	First shaft	410.79	0.1861	2.1909
6	Third shaft	332.25	0.0146	2.7088
7	RHS casing	334.96	0.2987	1.1942

Table 1 : FEA Results

4.Conclusion :

The main objective of the drivetrain was to transmit the power from engine to wheel as maximum as possible, provide good acceleration, top speed and is reliable on different terrains.
Thus drivetrain was designed and manufacture in such a way that it provides good acceleration, top speed and is reliable on different terrains. To obtain an infinite range of gear ratios and to obtain the highest torque and as well to reach the maximum speed, a CVT along with a self-designed auxiliary reduction gearbox was incorporated. Also driver comfort and fuel economy were include by using CVT.
All the self-design parts were analyzed in ANSYS Workbench. Gantt Chart was used to manage the flow of the project. All results were verified testing of the vehicle.
Thus we can conclude that the Drivetrain designed for ATV satisfies all the requirements, the same was verified by testing.

6.REFERENCES

[1] SAE Research Paper 970688
[2] Automobile Engineering by Kripal Singh