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Design and Analysis of Transmission System for ATV

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Abstract: The main objective of the project is to design and fabricate a drive train for All-Terrain Vehicle(ATV). The motive to get into this project was to learn and understand more about an All-Terrain Vehicle (ATV), studying about various parameters which would affect the drive train of the vehicle. To design an All-Terrain Vehicle, it is required that the transmission system should withstand all the hurdles on the terrain. The terrain includes the mud-pool, rock crawl ,dunes ,etc. All the possible options were considered while designing the drive train for All-Terrain Vehicle. After discussions it was decided that the transmission system would be automatic consisting of continuously variable transmission(CVT) couples with a two-staged gearbox and open differential with the half shaft. Whole system was tested thoroughly and it performed very well.
Keywords: Transmission system, ATV, CVT, spur gear, gearbox, bevel gear, open differential.

I. INTRODUCTION

All-Terrain Vehicles are emerging as a new sport in new era of automobiles where various companies are investing billions of dollars on making an off-road drive more comfortable and hassle free. An ATV is designed to drive through all kinds of odd terrains, steep slopes, bumps and droops, loose muddy land, etc. Many-a-times it happens that the tires loose contact with the ground and if that be the one that provides traction to the vehicle, the vehicle gets stuck. This problem mainly arises with the two-wheel driven ATVs where the power from the engine is transmitted either to the front or the rear wheels depending on the type of transmission. Most of such ATVs are rear wheel driven. In an attempt to achieve more traction and better mobility through off roading conditions, a four wheel driven transmission can be designed. In 4WD transmission system the torque from the engine is equally distributed to all the wheels as a result improving traction and acceleration.

II. OBJECTIVE

1) The main objective is to design a system that would make a torque required to propel the vehicle and provide equal rotation to all the wheels of vehicle.
2) To design a rear gearbox which would maintain a proper center to center distance between secondary pulley and input shaft of rear gearbox and propel the rear tyres of vehicle.
3) To design front open differential which would propel front tyres and avoid slipping while taking turn.
4) The system has to be cost effective, light weight and efficient.
5) Rear gearbox and front differential is designed for an ATV with engine of following specifications:
   a) Capacity = 305cc
   b) Maximun Torque:19.67Nm @2800 rpm
   c) Maximum Power : 10HP @3600 rpm

III. DESIGN CONSIDERATIONS

Engine Torque(T_e) =19.67 N-m
Mass of the vehicle(W) =270kg
Mass of the driver = 70 kg
Static coefficient of friction (μ) =0.9
The height of the center of gravity (h) = 50.8 cm
Wheelbase =129.54 cm
Distance of the CG from the front wheel center (a) =82.55cm
The distance of the CG from the rear wheel center (a) = 46.99cm
Tire dimensions (in inches) =21*7*12

IV. PERFORMANCE CHARACTERISTICS

Vehicle resistance play a very important role in designing a vehicle. Now, these are the resistances which the vehicle has to overcome to run or to complete the perspective.

1) Wheel resistance

$R_r = fr*W$ [1]

Where, R_r = Rolling resistance
fr = Rolling resistance factor
W = Weight of vehicle

2) Air resistance

$$R_{air} = \frac{A * C_d * \rho * v^2}{2} \quad [2]$$

where, R_{air} = resistance due to air
A = area on which resistance force acts
C_d = coefficient of drag
ρ = density of air
v = longitudinal velocity of vehicle

3) Gradient Resistance

$R_g = m * g * \sin\theta$ [3]

Where, R_g = Gradient resistance
m = mass of vehicle
g= acceleration due to gravity
θ = gradient angle

4) Total Resistance

$R = Rr + R_{air} + R_g$ [4]

Where, R = Total resistance
Rr = Rolling resistance
R_{air} = resistance due to air
R_g = Gradient resistanc

V. DESIGN PROCEDURE

1) First the overall torque required for the vehicle to propel was calculated, which gave us the total torque required.
2) Engine torque was pre-defined and the ratio of the CVT was pre-defined, by dividing the overall torque to the engine torque and CVT's under drive ratio. This would give the final reduction of the gear box.
3) Except for the torque required constrain there is another constrain, that the vehicle should reach top speed of 60 kmph.
4) The maximum RPM of the engine was divided with the overdrive ratio of the CVT and the RPM of the wheels at 60 kmph. This would give the reduction required to achieve 60 kmph.
5) The reduction in torque required condition and the maximum speed condition aren't the same. So, this gave us a range to work with.
6) No. of teeth in each gear were taken as prime numbers so as to avoid tooth hunting, keeping the overall gear ratio between the torque required and maximum speed condition and maintaining the centre to centre distance between the input shaft and secondary pulley of CVT.
7) Half shaft is used to connect the gearbox to the wheel assembly. It is used to transmit torque at an angle. It has a constant velocity joint. In this case it is Rzeppa CV joint. It couples to the output shaft of the gearbox with the help of splines. The material used to make the half shaft is EN24.
8) Bevel gear arrangement was used to transfer power from intermediate shaft of rear gear box to front differential with the help of propeller shaft with universal joints.

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VI. CALCULATIONS

From above equations [1],[2],[3] and [4]
Rolling resistance = 79.46N
Air resistance = 157.7N
Gradient resistance = 1720.19N
Total resistance = 1957.35
Torque required to move a vehicle(T)

T = (Te * r)

Where, Te = Engine torque
r = Tyre radius
Gearbox reduction(G.R)

$$G.R = \frac{T}{T_e * C.R_{max} * \eta} \quad [5]$$

Where, $C.R_{max}$ = maximum CVT reduction
η = Efficiency of transmission system

Top speed condition

$$RPM_{max} = 60 * \frac{\pi}{2\omega}$$

Where, ω = Angular velocity
RPM_{max} = maximum RPM
Gearbox reduction(G.R)

$$G.R = \frac{RPM_{max} * r * \eta * 3.6}{CVT_{min} * V_{max} * 60} \quad [6]$$

Where, r = Radius of Tyre
η = Efficiency of transmission system
CVT_{min} = Minimum reduction of CVT
V_{max} = Maximum velocity of vehicle

	Gear's Materials	Gearbox Casing Materials
Material	EN24	AI6061
Tensile Strength	850Mpa	310Mpa
Yield Strength	650Mpa	276Mpa
Poisson's Ratio	0.28	0.33

The above two conditions [5] and [6] gave us a range between 8.364 and 11.77. The overall reduction decided was 9.1667, as the no. of teeth were taken as prime numbers to avoid tooth hunting.
Gear materials selection is based on the amount of total load which acts on the gears or on gear tooth in the form of tensile strength or yield strength. The gear material should have sufficient strength to resist the failure due to breakage of the tooth. Therefore these materials has been selected:

Gearbox Type	2 Stage compound gearbox
Gear Type	Spur Gear
Gear Ratio	9.1667
1st stage Reduction Ratio	3.056
2nd stage Reduction Ratio	3.000

	Stage 1		Stage 2	
	Pinion1	Gear1	Pinion1	Gear1
No. of teeth	18	55	18	54
Module	2.0	2.0	2.5	2.5
Face width	18	18	12	12
PCD(mm)	36	110	45	135
Pressure Angle	20^o	20^o	20^o	20^o

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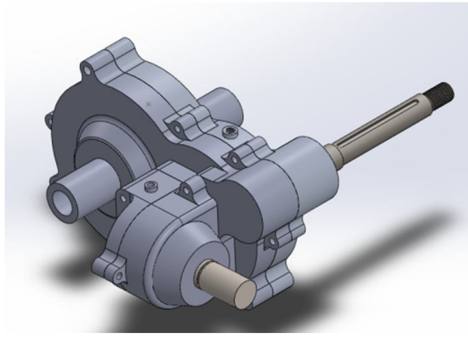
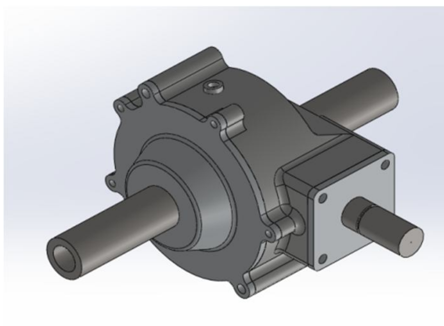
VII. GEARBOX SPECIFICATIONS

1) *Rear Gearbox:*



2) *Front Differential:*



		Gears					
SPECIFICATIONS		Intermediate bevel pinion	Propeller side bevel gear	Front differential input pinion	Front differential gear	Spider gear	Axle-side bevel gear
	No. of teeth	15	18	18	30	15	18
	Module	3.5		4		3	
	Reduction	1.2		2.5		1.2	
	Face width	24		20		16	
	Reference cone angle	39.8°	50.19°	21.8°	68.19°	39.8°	50.19°
	Pitch circle diameter	52.5	63	48	120	45	54
	Cone distance	41.006	41.006	64.25	64.25	35.14	35.14
	Working depth	6.997	5.95	6.8	6.8	5.998	5.1
	Whole depth	7.678	6.608	7.552	7.552	6.354	5.664
	addendum	3.992	2.557	4.710	2.089	3.422	2.192
	dedendum	3.666	5.641	2.841	5.462	2.932	3.471
	Tip diameter	58.633	66.274	51.702	121.55	41.258	56.807
	Face cone angle	45.36°	54.672°	26.659°	70.72°	45.362°	54.674°
	Root angle	34.69°	44.549°	19.267°	63.331°	35.03°	44.549°
	Pitch apex to crown	28.948	24.28	57.905	21.93	24.807	20.189

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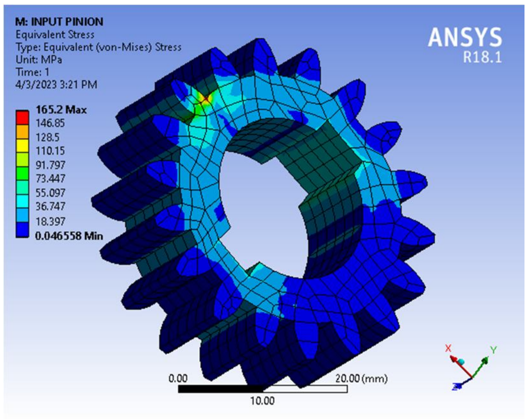
VIII. SOFTWARE USED

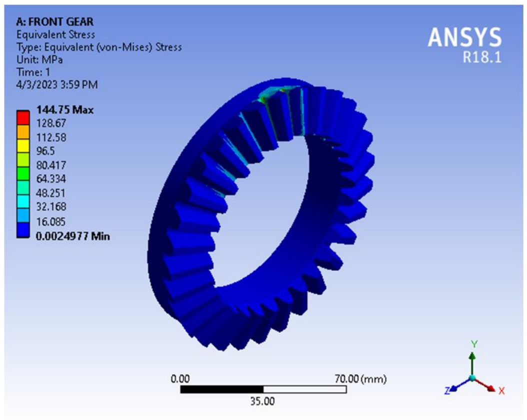
A. *Solid Works*

Solid Works is a popular computer-aided design (CAD) software program used by engineers and designers to create 3D models of parts and assemblies. Solid Works is known for its user-friendly interface, advanced modeling capabilities, and powerful simulation tools. Solid Works allows users to create complex 3D models using a variety of tools such as sketches, extrudes, lofts, sweeps, and more. Solid Works also includes simulation tools that allow users to test their designs in a virtual environment, helping to identify potential issues and improve the final product. Other features include the ability to create technical drawings, animations, and photo realistic renderings. Overall, Solid Works is a versatile and powerful CAD software program that is widely used in industries such as aerospace, automotive, consumer products, and more.

B. *Ansys*

ANSYS is a powerful software that is widely used in engineering and product development to simulate, analyze and optimize physical systems and structures. It is particularly well known for its capabilities in structural, thermal, and fluid dynamics analysis. ANSYS allows users to create virtual models of physical systems, and then simulate their behaviour under various conditions. This can help engineers to identify potential issues, optimize designs, and reduce development time and cost. Overall, ANSYS is a comprehensive tool set that allows engineers and product designers to simulate and analyze a wide range of physical systems, helping to improve the efficiency and effectiveness of the design process.





IX. CONCLUSION

The main aim of this study was to design and analyse the transmission system for AWD ATV's.The overall gear ratios have been determined to get the required speed and torque.Gear materials selection, number of teeth and gear type has been done to reduce the chances of failure. Analysis of the design has been done in the ANSYS 18.1 on workbench. And hence the transmission system is ready to transmit the required amount of speed and torque.A final reduction gear box was designed with total reduction 9.167 to propel the vehicle. The gear box is capable to move the vehicle to the speed of 60 kmph and attain 0 to 60 in under 5 sec. The design is made to meet the requirements of Driver comfort keeping it as simple and safe.An overall vehicle is made to sustain the requirement of all possible terrines.

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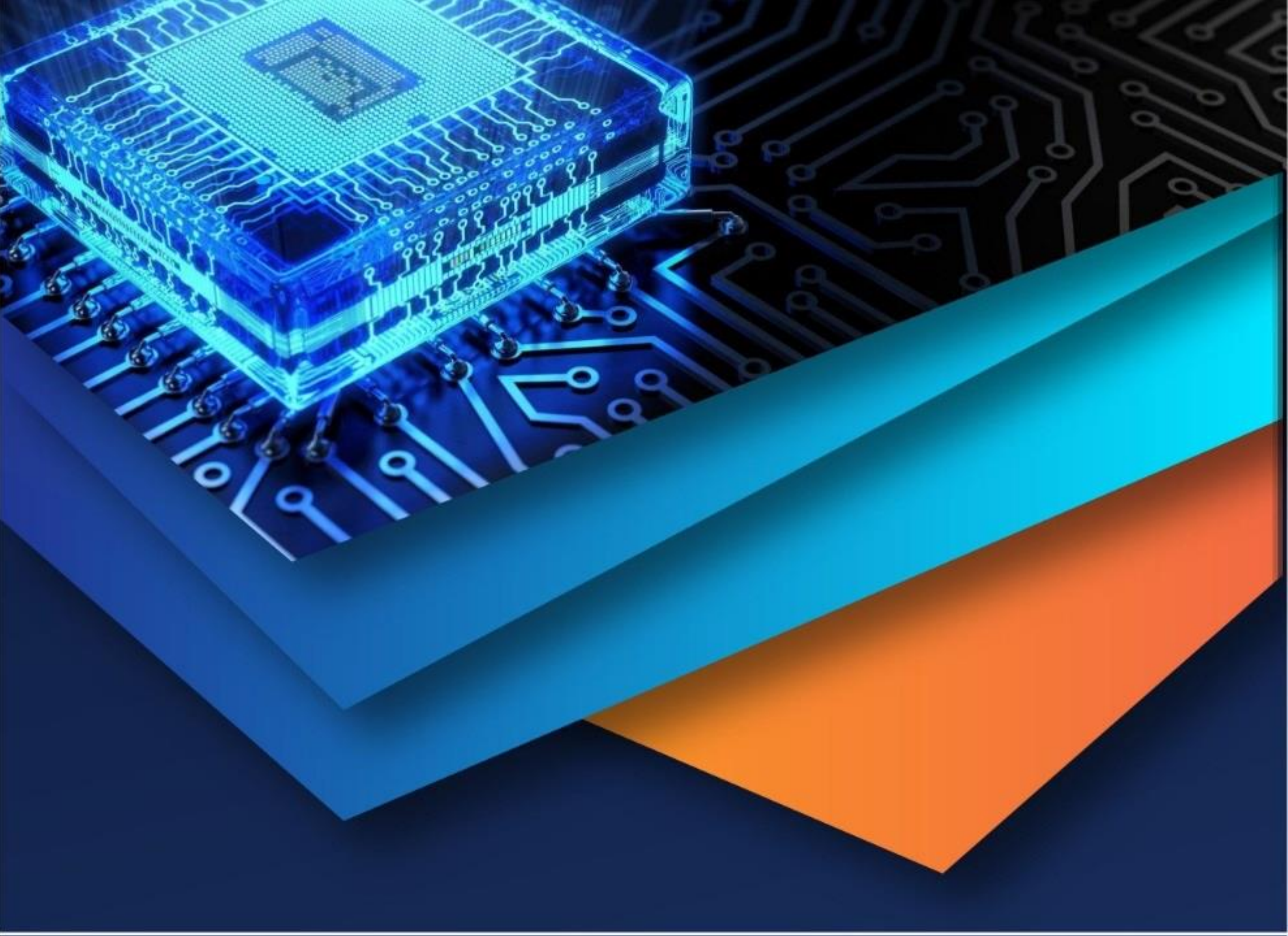

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