ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 5, May 2018

Design, Analysis, Simulation and Fabrication of a High Torque & Light weight Gearbox for ATV

[1] Manoneet Kumar, [2] K. Brahma Raju, [3] G. Chatapathi Raju
[1][2][3] Department of Mechanical Engineering, SRKR Engineering College, A.P.

Abstract:-- **To achieve high torque as compared to that of commercial gearboxes available in the automobiles, The concept of parallel line gear train has been used with required reductions in the RPM so as to achieve a High Torque required by ATVs (All-Terrain Vehicles).**

The objective of this paper is to Design and Fabricate a light weight- High Torque gearbox which must be compact enough to save the overall space in ATVs. As a series of Technological researches are going on for increasing the overall output power of commercial vehicles, my idea is far similar to the concept but the field of specialization is an All-Terrain Vehicles rather than defined range of Commercial Vehicles.

Index Terms—ATV, CNC, RPM

1. INTRODUCTION

ATVs need to have a limited maximum speed of 60 Km/hr which need to be considered primarily for designing a gearbox. Moreover it must have overall light weight as compared to that of commercial gearboxes available in the market having same range of output Torque. As the overall weight is considered less for highway vehicles as it has a defined range of applications and areas of implementations. But if we talk about an ATV then it doesn't have any defined terrain of applications. Which means the overall efficiency is directly related to the overall weight of the vehicle.

II. PROJECT REQUIREMENT

A. Reason of Fabricating a Light weight gearbox-

The increase in the demand of compactness in every field and the need of improving the manufacturing rate, weight reduction and simplicity are two main pillars of the current problem. The reduction in weight has many advantages like better stability and increased fuel. Moreover ATV efficiency depends directly to the overall weight of the vehicle.

B. Procedure for Fabricating Light weight gearbox-

The simplicity in the manufacturing can further be achieved by using spur gears in the gearbox instead of bevel gears. As spur gears are the simplest type of gears in which the teeth are cut parallel to the axis of the shaft on which the gear is mounted.

Furthermore, the differential in the gearbox assembly is replaced by the automatic locker or spool which is used to connect the crown gear to the half shafts. The final drive gear assembly provides the final stage of gear reduction in order to decrease the RPM and increase the rotational torque and thus, the wheels never spin as fast as the engine.

The purpose of the differential is to allow one input to drive both wheels as well as allow those driven wheels to rotate at different speeds as a vehicle goes around a corner. So, a fresh approach of using automatic locker called Spool in place of the differential to connect the gearbox is suggested along with replacement of bevel gears with spur gears in the design.

III. SELECTION OF ENGINE

As we need a compact and heavy duty engine which can be used in any inclination as per the application of an ATV. So we have selected Briggs & Stratton Engine-

Engine	Single cylinder for 4 stroke, air cooled
Displacement	305CC
Max. torque	19.57N-M@2400rpm
Max.power	7.5KW@3800rpm
Max.speed	3800rpm
Max. frequency	63.3HZ

Gearbox contains gear train which has been designed by considering a number of parameters. The calculation for the same is done to get the maximum torque on the wheels resulting in high Traction for the application of ATV.

GEARBOX & OUTPUT TORQUE CALCULATION

As per the selection procedure of gear train, we have taken a Pressure angle of 20 degrees, so minimum number of teeth on pinion gear must be 18 teeth.

We are using Reverted Compound Gear Train for designing the gearbox.

Accordingly I have taken 3 combinations of gears for iteration are-

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 5, May 2018

	Teeth on Gear **A**	Teeth on Gear **B**	Teeth on Gear **C**	Teeth on Gear **D**
Combination **1**	18	36	22	76
Combination **2**	18	76	28	83
Combination **3**	17	36	22	84

Gear Train Individual gear teeth numbers

Gearbox Output Torque Calculation:

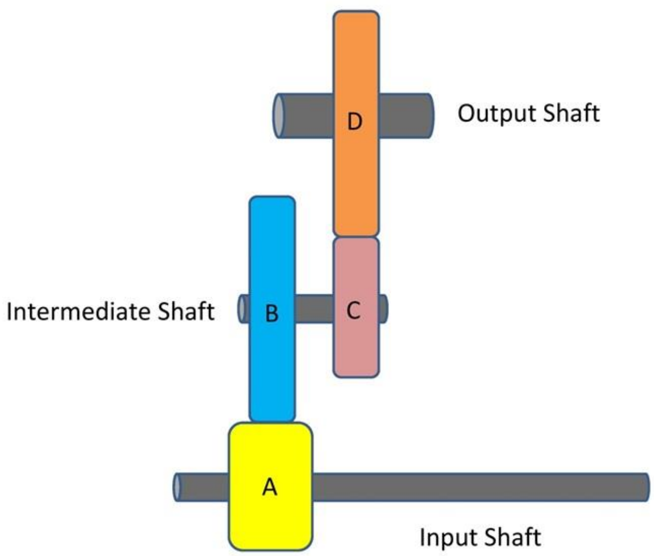

Fig1. Gear Train Outline

We are getting maximum torque on the Gear combination 2 mentioned above in the table, so I will do the gearbox ratio calculation on the combination 2.

Consider rpm on Gear A= 1 RPM
RPM output of A = RPM input at B
Also, as per above table we know A:B=18:76.
Output RPM of Gear B= 1:18/76
= 0.23685.
RPM output of B = RPM input at C
(As both are mounted on common intermediate shaft)
So, RPM of B= RPM of C= 0.23685.
Also, as per above table we know C:D= 28:83.
Output RPM of Gear D = 0.23685:28/83
= 0.07989.
Therefore the output reduction of gear/Torque= 1:0.07989= 1/0.07989:1= 12.5172 Nm.

Output Torque Calculation:

Stage-01: Engine outputs (or) CVT drive pulley inputs
Max. Speed = 3800 rpm
Max. Torque = 19.57 Nm

Stage-02: CVT driven pulley outputs (or) gear box inputs.
Max. Speed = 3800/0.43(reduction by CVT)
= 8837.2093 rpm
Max. Torque = 19.57*3(torque increment by CVT)
= 58.71 Nm

Stage-03: Gear box outputs (or) half shafts inputs.
Max. Speed = 8837.2093/12.5= 706.976 rpm
Max. Torque = 58.71*12.5= 733.875 Nm

Gearbox output
Max. Velocity = (Dn)/60
= (3.14*0.5842*706.976)/60
= 21.614 m/sec
= 77.81 Km/hr.
Max. Torque = 616.455 Nm (considering 16% losses)

Stage-04: Vehicle outputs are
Required Tractive force:
Sled pull = mgsinθ+ µrmgcosθ + (0.5xCdxAir densityxAxV2)

=1720*9.81*sin50+0.0303*1720*9.81*cos5°+ 0.5*1*1.225*0.876*(16.811) 2

= 1420.596+509.312+151.634
= 2081.542 N

Tire radius-
Required Tractive Force x Optimum Tire Radius = Output Shaft Torque.
But we know formula for output shaft torque= Engine Torque x Gear box ratio.
= 19.57 Nm * 12.5= 244.625 Nm.

Now, Required Tractive Force x Optimum Tire Radius = Output Shaft Torque.
Optimum Tire Radius= Output Shaft Torque/ Required Tractive Force.

= 244.625 Nm/2081.542 N= 0.11752m

= 4.6268 Inch = 5 Inch (Rounding off).

Hill climb = mgsinθ + µrmgcosθ + (0.5xCdxdensity of airxAxV2)

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 5, May 2018

= 220*9.81*sin27° + 0.0303* 220*9.81*cos27°+ 0.5*1.225*0.876*1*$(16.811)^2$
=979.802 + 58.265 + 151.634
=1189.701 N

Achieved Tractive force = (ɳ x igearbox x icvt x torqueengine)/radius of tyre.
= (0.84 x 12.5 x 3x 19.57)/0.11752
=5245.532 N

Assuming the transmission efficiency as - 84%.
Effective force=Tractive force – Rolling resistance - drag
Rolling resistance = (µrmg)/2
= (0.0303x220x9.81)/2
= 32.696 N
Drag = 0.5xCXdensity of airxAxV2
= 0.5*1*1.225*0.876*(16.811)2
= 151.634 N

Effective force =5245.532 - 151.634 - 32.696
= 5061.2026 N

Acceleration (a) = Effective force/mass
= 5061.2026/220
= 23 m/s2.

V. DESIGNING & ANALYSIS OF GEARBOX

Designing is the process of generating an optimized model in a design environment of the Software like CAD (Computer Aided Design) using the tools provided in it. Designing plays a vital role to give shape to our ideas so that it can be represented well to understand. Design Analysis and Simulation are the factors being used for checking the validity and sustainability of our design.

Analysis and Simulation is the sub-features being used for a design and are bundled under the same canvas of the Design environment.

I have selected the well-known Designing software- Solidworks for the complete Design and Ansys for Analysis of Gear Trains.

SolidWorks also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

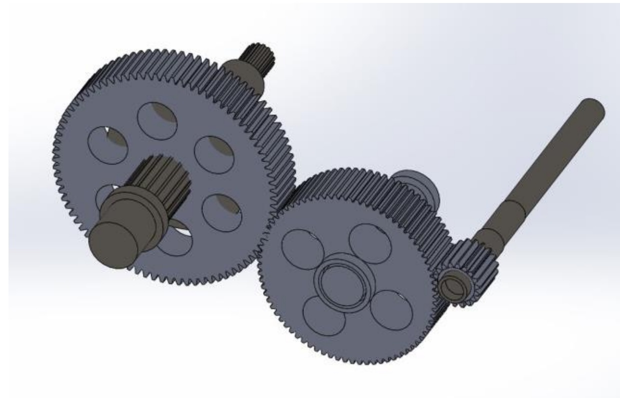

Fig1. Isometric View of gear Train (Solidworks Design)

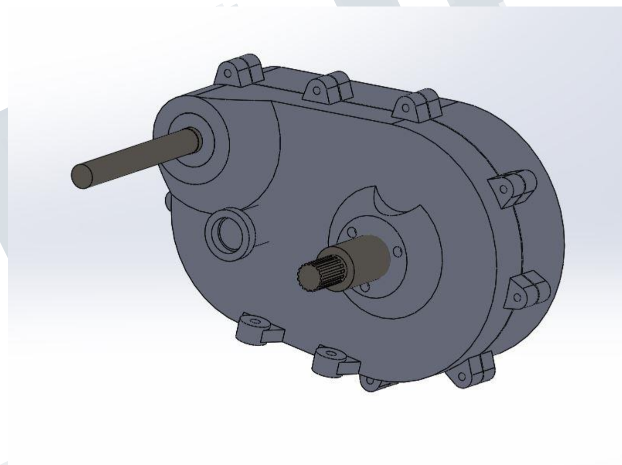

Fig2. Assembled view of Gearbox with casing

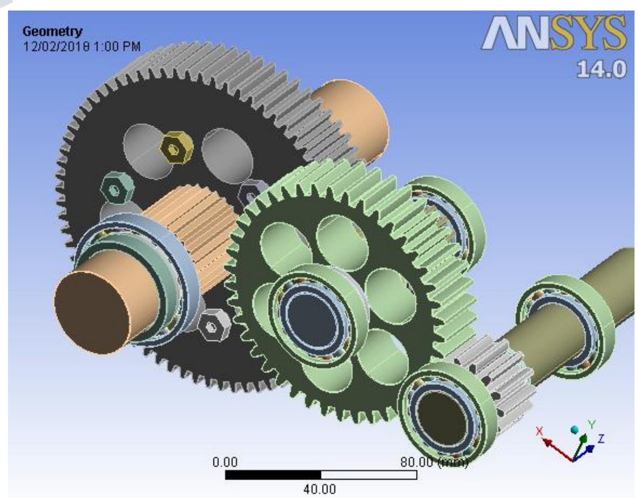

Fig3. Imported IGES file in ANSYS workbench Simulation module

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 3, Issue 5, May 2018

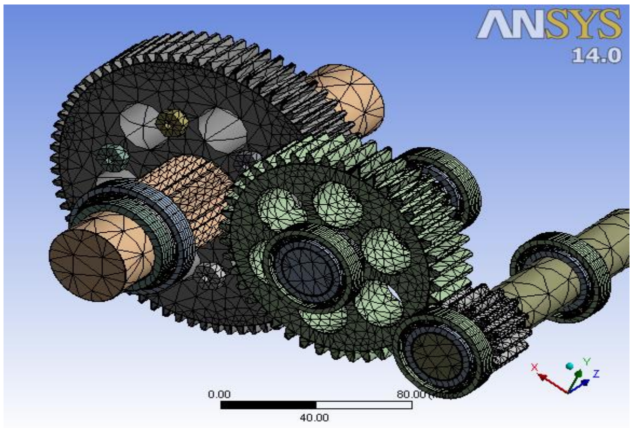

Fig4. Coarse meshing along with refined meshing on joints

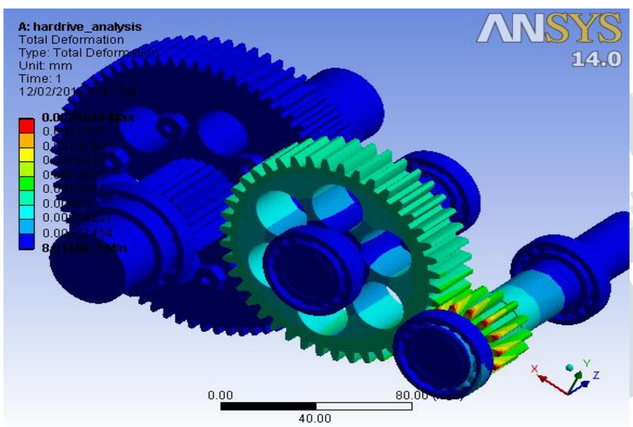

Fig5. Boundary Condition-Total Deformation

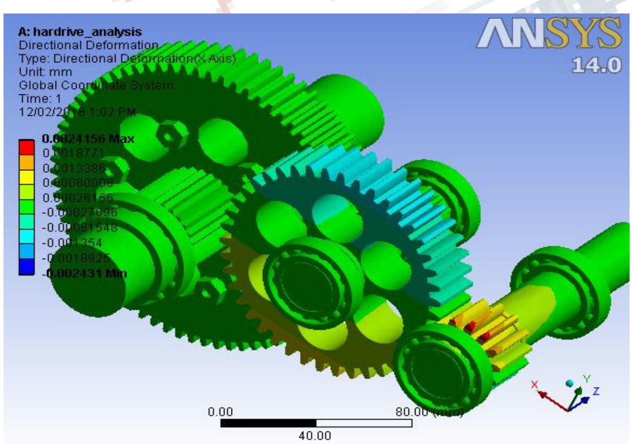

Fig6. Boundary Condition- Directional Deformation

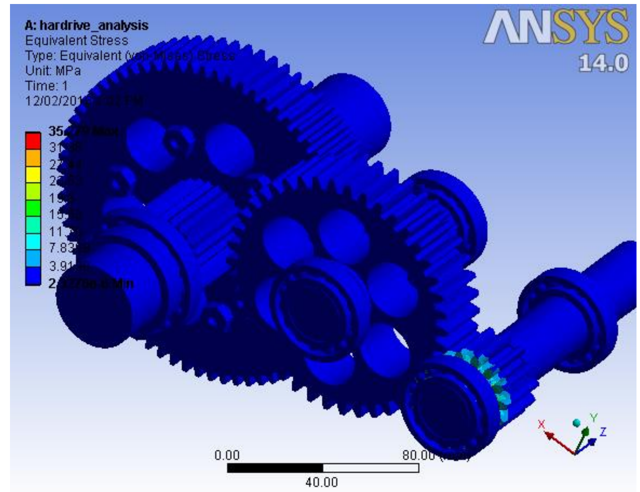

Fig7. Boundary Condition- Equivalent Stress

VI. MATERIAL SELECTION

The overall Light weight along with strength can only be achieved if we design a Gear box casing by using an Aluminium Alloy. For selecting an appropriate material for casing of Gearbox, a certain tests has been done in the college laboratory and the test results has been noted having parameters which are very essential for selection of a material for making Gearbox casing.

Mechanical Properties of Various Aluminium Alloys			
Properties	**AA-6061**	**AA-6063**	**AA-2014**
Hardness, Rockwell B	60	83	82
Ultimate Tensile Strength	310 MPa	241 MPa	483 Mpa
Tensile Yield Strength	276 MPa	214 Mpa	414 Mpa
Modulus of Elasticity	68.9 GPa	68.9 GPa	73.1 Gpa
Fatigue Strength	96.5 MPa	68.9 Mpa	124 Mpa
Density	2.7 g/cc	2.7 g/cc	2.8 g/cc

I. Selection table for Aluminium Alloys

The above 03 Aluminium Alloys only has been selected as per the market availability, overall cost of material and Machining cost.

Also for most of the Industrial Purposes the above 3 Grades are readily used.

As per the above comparison table, AA-6063 found to be more appropriate than AA-6061 and AA-2014. So the final casing of the Gearbox has been fabricated from AA-6063.

VII. PROCESSING OF MATERIAL

There are 2 processes of making a Gearbox casing –
1. Casting the material and Molding in desired shape, followed by machining for finishing and mounting points.
2. CNC processing on the Forged ingot of Wrought Alloy being obtained by Extrusion and Forging Process.

The Advantages of Forged Product over Casted product are-
1. Generally tougher than alternatives like castings.
2. Will handle impact better than castings.
3. The nature of forging excludes the occurrence of porosity, shrinkage, cavities and cold pour issues.
4. The tight grain structure of forgings making it mechanically strong. There is less need for expensive alloys to attain high strength components.
5. The tight grain structure offers great wear resistance without the need to make products "superhard".
6. Forged parts will transfer vibrations frequently rather than absorbing the vibrations as castings do.
7. Forged parts had a 26% higher tensile strength than the cast parts. This means it has stronger shackles at a lower part weight.
8. Forged parts have a 37% higher fatigue strength resulting in a factor of six longer fatigue life. This means that a forged shackle is going to last longer.
9. Cast iron only has 66% of the yield strength of forged steel. Yield strength is an indicator of what load a shackle will hold before starting to deform.
10. The forged parts had a 58% reduction in area when pulled to failure. The cast parts only had a 6% reduction in area. That means there would be much greater deformation before failure in a forged part.

As per the above mentioned points, CNC processing on the Forged ingot of Wrought Alloy is considered over Casting. Also the Gearbox casing needs accuracy for placement of gear train and fasteners, so to obtain the same we have used Vertical CNC Milling machine for processing of material.
Some of the more remarkable advantages of Vertical CNC milling machine is that it accepts output file of Design software and debug the CNC codes by itself which eliminated the manual code generation and saves the overall time of processing.

CONCLUSION

The paper reflects the overall torque output on the wheels and also justifies that the overall increment of Torque.
As a conclusion I can conclude that we have designed a Light weight-Compact gearbox for an All-Terrain Vehicle by doing all required analysis on the gear trains.
Hence the above concept can be widely used to make a vehicle which can move in any type of Terrains rather than just on normal roads.

REFERENCES

[1] E. Boyer, H. and L. Gall, T. (n.d.). Specific Material Search. [online] Asm.matweb.com. Available at: http://asm.matweb.com [Accessed 10 Feb. 2018].

[2] Pratik Goyal, R. (2016). Design and Optimization of 2-Stage Reduction Gearbox. [online] https://www.ijedr.org/. Available at: http:// www. ijedr.org/papers/IJEDR1702095.pdf [Accessed 3 Dec. 2017].

[3] Raines, T. (2013). Forging vs. Casting: Which is better? - Columbus McKinnon Blog. [online] Columbus McKinnon Blog. Available at: http://blog.cmworks.com/forging-vs-casting-which-is-better [Accessed 13 Jan. 2018].

