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Hybrid Gear for Baja ATV

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Abstract -*Nowadays, composite materials are used in every sector, from households to high-end industries. The objective of this study is to provide a way to decrease the weight of the gearbox with the use of composite gears. There are many different ways to reduce the weight of the system, but the usage of composite material for gear manufacturing not only helps in weight reduction but also minimizes inertial reduction, which leads to more responsive gear box and higher efficiency. Therefore, this study reflects a new strategy to develop a lighter gear box for an ATV specifically designed for BAJA SAE India.*

Key Words: **Composite Gears, Lighter Gearbox, Higher Efficiency**

1. INTRODUCTION

The power flows through the ATV powertrain from the engine, CVT (Continuously Variable Transmission), gearbox, half shafts (L/R), wheels and reaches the tires. In this powertrain, final drive gearbox is one of the most crucial components, as it adds a considerable amount to the overall assembly weight. It provides a fixed reduction to overcome the lack of torque produced by the CVT in pair with the specified engine [1]. Being self-manufactured, it carries a higher probability of error and is a major factor which decides the overall efficiency of the powertrain. Therefore, it is highly important to maintain certain standards and limits while designing a gearbox. In this case, a compound gear train with a two-step gear reduction is the most appropriate orientation for the gearbox, considering the space available at the rear and required tractive effort or output.

1.1 Gearbox Setup

The gearbox has a four-gear, three-shaft setup with bearings on either end, assembled in following manner -

a) Input shaft- Input pinion is an integrated part of the input shaft which couples the CVT to the gearbox through splines.

b) Intermediate Shaft-It has intermediate pinion as an integral part and intermediate gear is mounted via key way.

c) Output Shaft-Output gear is mounted with the help of key way and coupling of half shaft is done by splines.

There are multiple OEMs used such as oil seals, bearings, gasket, anabond, nuts and bolts and self-manufactured parts which are shafts, keys and gears and a casing.

The idea behind going for the approach of a lighter gearbox is that it minimises the Inertial Resistance which makes it much more 'responsive' and thus, increases the efficiency. As the heaviest gear amongst the four is the output gear which almost contributes around 20% to the total gearbox net weight, the major focus would be towards reducing the Output gear weight. Weight reduction could be done in a number of ways and the approach this paper shows is a two-material setup where if we move axially outwards, the first material will be a soft material and around the teeth region will be the second, which would be relatively harder. The two materials will be press-fitted as a billet and then machined for maximum accuracy. Apart from this, there would be holes punched across the face of the gear which is likely to reduce its weight by a considerable amount.

2. HYBRID GEAR

Advantages of light weight gear:

1. Total moment of inertia will reduce. Vehicles which have inboard braking this is a huge advantage as the load on brakes also reduces.
2. If there is a significant difference in weight then dynamic properties of vehicle like- under steer, over steer, acceleration, jounce, roll moment etc. are also expected to improve.
3. Lighter vehicle leads to increase in fuel efficiency.
4. Lighter material like aluminum has much greater thermal conductivity than Steel. Since, the whole system is submerged in oil, aluminum hybrid gears will have lower working temperatures than whole steel gears.

Taking the concept of weight reduction of gears by using 2 materials instead of one, we tried to apply it to already prepared gears which were used in our BAJA buggy (2019-2020).

1. The forces were calculated according to torque and speed considerations provided in the BAJA rulebook which is set to a maximum speed of 60 Km/h.
2. The reduction is supposed to be the same since the change in weight of the new gear is considered negligible, otherwise differentiating between gears among the same value of forces would not be possible.
2. The calculations for gears were followed for a single material (20MnCr5) so that we could find out whether the gear could sustain the same forces with the same physical structure or if the deformation increases our expectations.

3. When the gears come clean on analyzing we would then apply more weight reduction to find the maximum limit which we can reach.
4. High-Grade alloys or polymers were considered for this project and those would yield good results but core materials are preferred here as they are a lot cheaper and easily available which would be more appropriate for making a BAJA buggy.

2.1 Methodology:

We used hit and trial method to design the gear and analyze it simultaneously to find best design among them. This method is an orthodox and results of the analysis justifies the new gear concept.

1. Iteration: The first method was to verify the idea of adding two materials to form a gear. On referring other research papers and practical models we found out it was possible, but the materials they were using were expensive and not easily accessible. Hence, we tried to do it with lighter and cheaper materials. The first design was based on just the strength of the aluminum core.

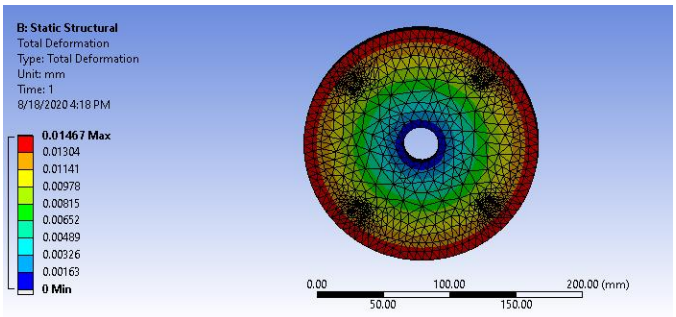

Fig -1: Iteration 1 (Analysis)

2. Iteration: This was based on the idea of using a steel core at the center of the whole gear which is moved by a key and aluminum being lighter than steel, might be deformed.
3. Iteration: Aluminum solid gear proved to be very efficient, to such an extent that there was a low level of deformation and changes can be done to make the design more efficient. Weight reduction (holes) in the gear were done to achieve the final design.

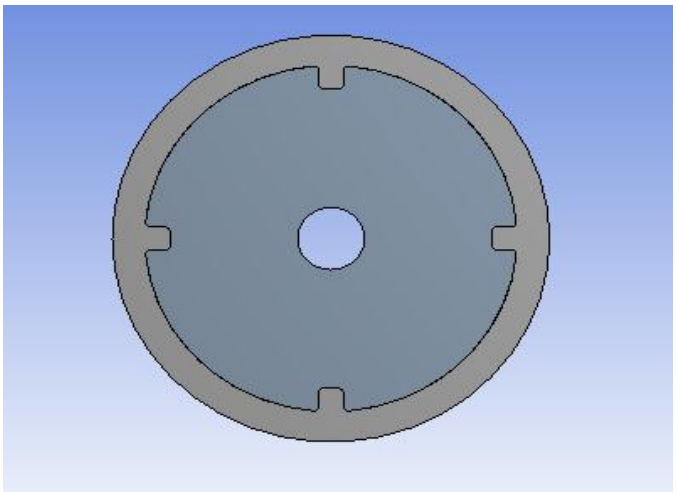

Fig -2: Iteration 1

2.2 Ideology

1. In an ATV, weight plays an important role and factors like weight reduction are a big deal when choosing between factor of safety or performance. Needless to say, factor of safety must be maintained but efficient engineering is achieved by performing iterations in the design. Hence, the initial goal was to find which components are over designed or to say which components could be redesigned.

3. Analysis

Analysis Procedure: The Analysis of the gears was conducted on Ansys version 19.1 under the Static Structural Analysis system in two separate steps, first on a pure 20MnCr5 gear and second on this new ideology of dual material gear for the sake of comparison. The variation of engineering data in the second step called for the input of two different material properties to be applied. Hence, the material properties were looked at and then the calculated loads were applied onto the gear teeth keeping a restriction of fixed support at the key slot region. The result of the comparison is given under result heading.

Torque on the gear is 126039.8987 Nmm with a face width of 12mm throughout the gear. The key is given fixed support from all sides since that is the only part constraining it. Even though a cylindrical support could be given at the steel core to restrict it according to the shaft.
The core-aluminum and aluminum-ring pair are press fitted to each other and the whole system is submerged in gearbox oil which reduced the temperature but also it seeds oil into the edges of the press fit to offer perfect sealing. Press fitting gives enough resistance to the gears toward axial deflection (resisting disassembly of parts).

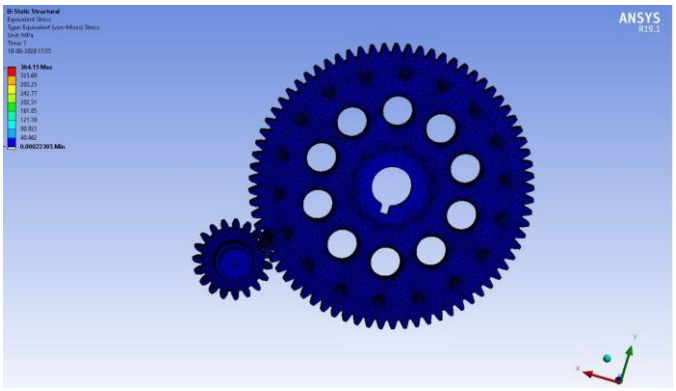

Fig -3: Equivalent (von-mises) stress

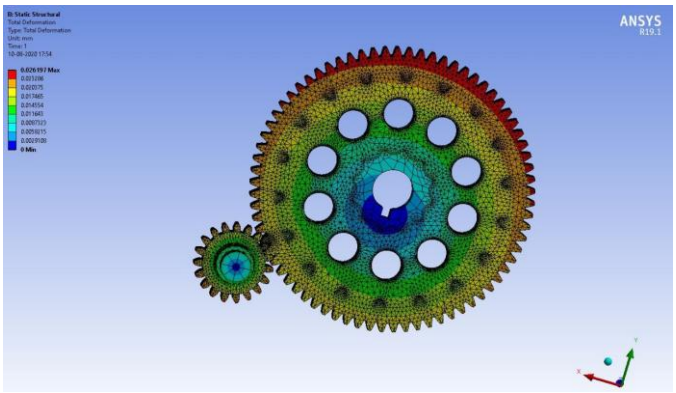

Fig -4: Total deformation

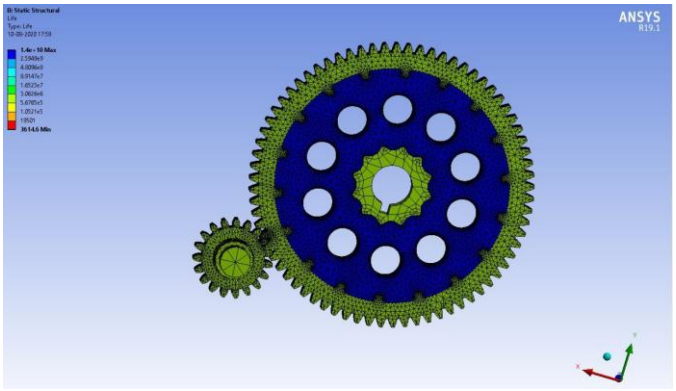

Fig -5: Life

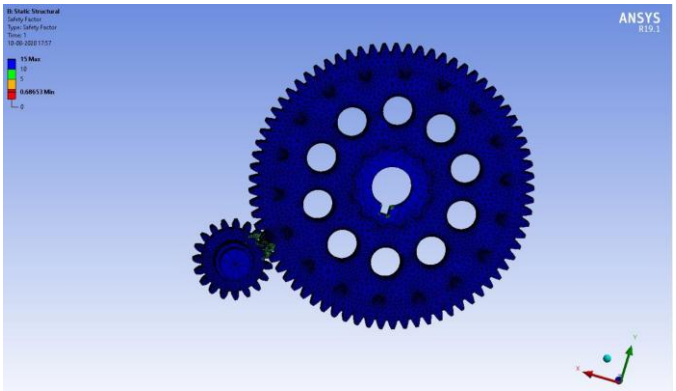

Fig -6: Factor of safety

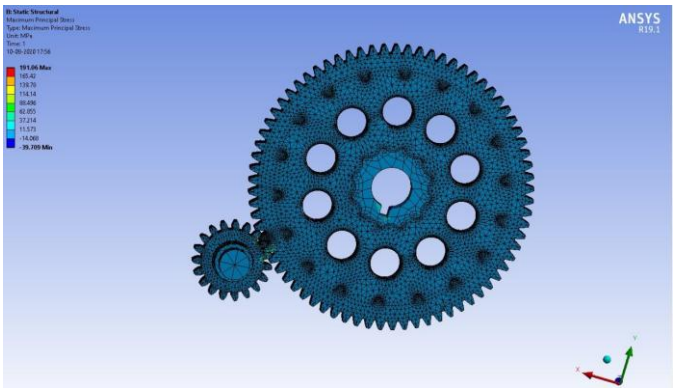

Fig -7: Maximum Principal Stress

4. RESULT

1) The assumed values for the density of aluminum and 20MnCr5 are 2.61 gms/cm^3 and 7.805 gms/cm^3 respectively.
2) Total weight for 20MnCr5 gear was found to be 2613.46 gms.
3) Total weight for the dual material gear was calculated to be 1606.52gms. Hence reducing the weight and improving the Rotational Inertia by 61%

5. CONCLUSION

Through the comparison of the two samples, it is found that at the peak performance region, both samples withstood the conditions fairly easily but the weight of Sample 2 was 61% lesser than Sample 1. This further reduces the contribution of the output gear in the overall assembly weight by 13% from 20 %. Moreover, there was a decrease in the cycle time of the second sample but it was not significant.

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