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Split Casing Open Differential without Cross pin and it's comparison with Single Piece Casing Differential

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Abstract – *Differential plays an important role in any four wheeled vehicle. Its major function is transmit power from engine to wheels in Rear wheel Drive vehicle and to bias torque and speed (rpm) in all three i.e. Rear wheel drive, Front wheel drive and All wheel drive vehicle. This thesis mainly focuses on designing of an open differential for any of the three drive vehicle mentioned above having a split casing and without a cross pin. The proposed design in feasible in assembly and dis-assembly of the components. It also weighs less than the present differential. Structural analysis has been performed on HYPERMESH. The experimental testing of differential has been performed on Formula Student Vehicle and performance parameters such as yaw rate and acceleration are recorded.*

Key Words: **Open differential, split casing, cross pin, feasible in assembly, structural analysis, acceleration.**

Nomenclature:

F_i : Initial tightening (N)
F_o : Load on each bolt (N)
K_m : Stiffness of casing material (N/m)
K_b : Stiffness of bolt (N/m)

1. INTRODUCTION

The thesis work focuses on the designing and development of open differential. Alternatively Limited slip differentials are used. But the weight of Limited slip differential is more as compared to open differential. The differential mechanism is housed inside of a roundish metal casing with an opening at the front to connect the driveshaft to it. Inside this casing lubrication is provided where one metal part rubs over the other.

Inside of the casing, the driveshaft rotates a disc using teeth (splines) on the edge of the driveshaft and the disc similar to gears. This disc can be on the left or the right side on the inside of the casing and whichever side it's on it is attached to one of the sun wheels. [1]

The shaft to both wheels has a sun wheel inside of the casing. Both sun wheels are connected to each other by two or more planet gears and the planet gears rotate from an extension off the main disc. All of these components rotate as the vehicle moves. [1]

Even with all of these components the differential allows the two shafts to each have half of the torque and horsepower and they rotate equally when moving in a straight line.

When the vehicle is cornering the inner wheel rotates slower and offers more resistance, this causes the planet wheels to rotate on its own axis and it increases the speed of the outer by the same percentage that the inner wheel slows down. [2] A rear wheel drive vehicles will have one differential, a front wheel drive vehicle will also have one differential but it is usually integrated into the transmission. A part time four wheel drive should have two differentials and a full time four/all wheel drive would have three differentials but the centre differential could be integrated into the transmission. [2]

The open differential often referred to as just a differential can also be used to split the power between the front and rear wheels in an all/four wheel drive vehicles and then two other differentials can further split the power to the left and right wheels. The ability to rotate both driven wheels at different speeds is the primary objective of the differential, it separates the both wheels by allowing them to have their own final shaft instead of one continuous shaft between the both wheels. If there is a vehicle that is required to only travel in a straight line then a differential would not be required, the driveshaft could be connected to a single final shaft. The problem with a single shaft is that it does not allow the vehicle to corner properly. The outer wheels rotate faster than the inner wheels and the lack of a differential does not facilitate this. A rear wheel drive differential will be used to explain a common configuration of the open differential and how it operates.

CATIA software is used for Computer Aided Drawing and HYPERMESH software for Finite Element Method.

2. RESEARCH WORK

2.1 Casing

The casing is the most crucial part of differential assembly. The complete meshing of gears is dependent on the inner space available in the casing. If the casing is not designed with proper tolerances, it would result in interference of the gears. This could damage the complete system and can lead to huge financial as well as time loss. Also improper meshing of gears would result in uneven torque and rpm biasing to the wheels. Thus the complete

automobile can be in danger. So it's necessary to take proper precautions while designing the differential casing. The components of differential are gears, pinions and bearings.

Fig 1- Interference due to improper meshing [3]

The casing has further two classifications depending on the type. First is single piece and the second is Split type casing. Both the casings have certain advantages as well as limitations. First, the single piece casing is discussed.

Single piece casing is easy to manufacture by casting process provided that the material used is Cast Iron. But the Cast Iron (density=7.874 g/cc) weighs more as compared to Aluminium (density=2.7g/cc) for same component. If Aluminium is selected as casting material, then the cost of production increases as the Aluminium has largest liquid shrinkage as compared to Cast Iron. For a single piece casing, the assembly and dis-assembly of the components is difficult and thus certain advanced process are required for assembling and dis-assembling the components. So in order to avoid the above difficulties a new type of casing known as spilt casing is designed.

Fig 2- Single piece casing

In Split type casing there will be two half casings which will be similar. In this casing, the bearings and gears would be installed with ease and both the casing can be joined with mechanical fasteners (here nut and bolt). But as discussed earlier, this casing also has a limitation. The lateral force, during cornering of the vehicle can separate the casing and disturb the meshing of gears. This is possible if the fasteners are not properly tightened. Working on the above limitation, a term called Pre-Loading is introduced. Pre-loading means applying some extra amount of force/torque than the actual force/torque.

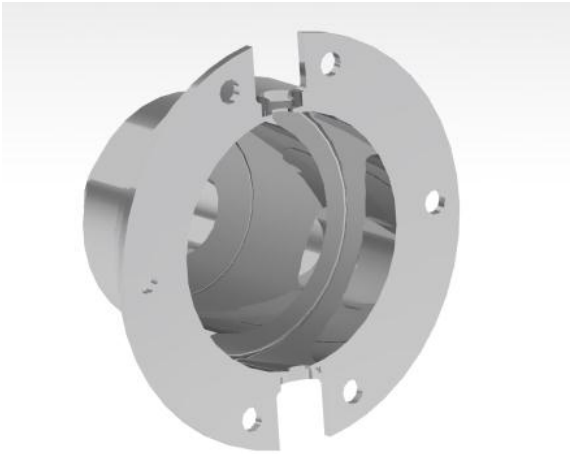

Fig 3- Split casing (Half side) - Rendered CAD model

The formula of preloading is- $F_i = (k_m / (k_b + k_m)) * F_o$

This preloading force would also create a leak proof joint and avoid spillage of grease/lubricant at high speed. The metal used for split casing is Aluminium. Thus required strength is achieved with low weight. The manufacturing process application for Split Casing is CNC Machining for better finish and high accuracy.

2.2 Cross pin

The role of the cross pin in differential system is to align the pinions while they are rotating about their axes without any lateral movement. Lateral movement is possible due to lateral force from drive wheels to gears or also due to improper alignment. The next role of differential is that they should not slide down during their motion. The cross pin weighs 0.8 pound (0.368kg). The cross pin is completely solid. It cannot be made hollow as it may fail due to bending. Without touching the function of cross pin, we have eliminated this heavy object by creating an extension on the pinion. This extension part is integrated part of the pinion and it would perform the same role as that of cross pin. This extension holds the pinion in the casing with the help of bearing and a washer nut. Even though the numbers of objects have increased but the weight has reduced.

Fig 4- Cross pin

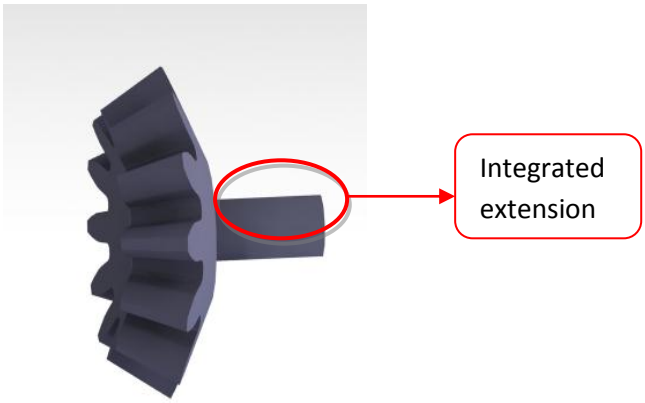

Fig 5- Integrated extension on pinion- CAD model

3. FEM [4]

The material selected for Casing is Aluminium 6061-T6 having Yield Tensile Strength of 276 MPa and Ultimate Tensile Strength = 310 MPa.
The following are the meshing and quality check specifications applied-

Meshing-

3D-→ Tetra mesh-→
Minimum element size= 0.1,
Element size= 2.00

Quality Check

Tools-→Check Elems-→3-d-→
Warpage= 0.5,
Tell collapse= 0.5,
Jacobian= 0.7,
Min angle= 20,
Max angle= 120

1. Deformation

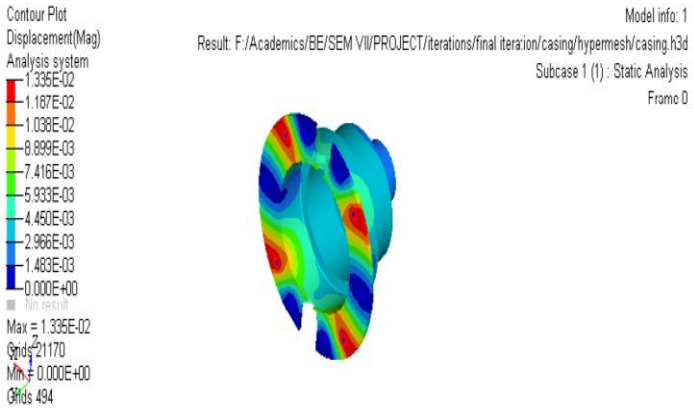

Fig 6- Total deformation
Magnitude- 0.013mm

2. Stress

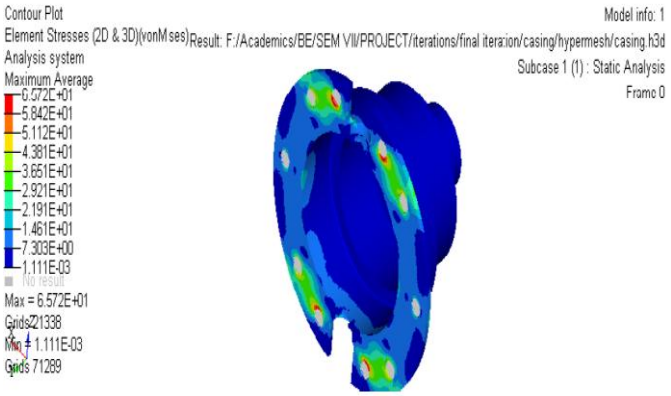

Fig 7- Von Mises stress
Magnitude- 65.7MPa

FOS= 3.93

4. MANUFACTURED PARTS

1. Casing

Fig 8- Casing

2. Pinion

Fig 9- Pinion with extension

5. RESULTS

1. Weight difference #

Single piece casing	Split casing
1. Cross pin – 0.3628 kg	1. Bearing (2 Nos.)- 0.06 kg
2. Casing* - 0.962 kg	2. Washer Nut(2 Nos)-0.02kg
	3. Casing* - 0.586 kg
Total weight= 1.328kg	**Total weight= 0.666 kg**

Table 1- Weight of individual differential

Approximately **49.72%** weight reduction has been done.

(#- excluding gears)

(* - Same shape and volume but materials changed)

2. Speed (rpm) vs time (sec)

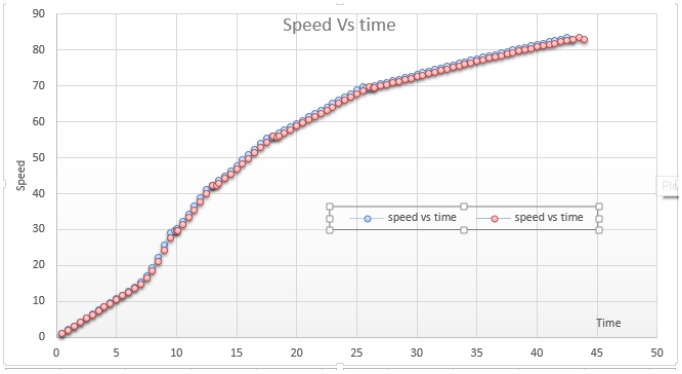

Chart -1: Rpm vs time

3. Acceleration (0-60kmph)

	Single piece casing	Split type casing
Theoretical time (sec)	4.5	4.14
Practical time (sec)	4.8	4.48

Table 2- Acceleration

6. CONCLUSION

1. Manufacturing of split casing is easier than single piece casing provided that casing material is other than Cast Iron.

2. Strength to weight ratio of split casing is more than that of single piece casing.

3. Velocity of automobile with split casing is more than that of automobile having single piece casing.

4. From acceleration chart (Table 2) it is concluded that car having split casing in faster by 0.32 sec than car having single piece casing.

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