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Design and Weight Optimization of 4Wheeler Differential Case Using FEA and UTM Strain Gauge Technique

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Abstract: *In this advanced technological era, lightweight design for fuel efficiency and environmental friendliness is essential for both conventional and hybrid electric vehicles (HEVs), without sacrificing the durability which is an important design factor for vehicle safety. To achieve these objectives, reduction of the structural mass of the full vehicle plays a vital role. The scope of this project is to describe design methodologies for the vehicle differential case applied to achieve light weight and to ensure product life. Optimization of a vehicle differential case done in this study shows that a weight reduction of up to 6% is possible without affecting the safety of the component. The manual optimization methodology used for this process can be implemented for any other cast component. In addition to this, a comparative study is performed of topology optimization using Ansys software on a control arm considering static loading conditions. Three-dimensional CAD model of 4-wheeler differential case is designed using CATIA V5R20. Finite Element Analysis (FEA) software ANSYS Version 19.0 is used to determine the total deformation and equivalent stresses, strain in a 4-wheeler differential case. For weight optimization the 4-wheeler differential case topology optimization module will be used. Experimental investigation will be done by strain gauge technique and UTM. Comparative analysis of FEA and Experimental will be done for validation of work. Conclusion and future scope will be suggested.*

Keywords: Weight Optimization, Reverse Engineering, 3D Scanning, Casting Allowance, etc.

I. INTRODUCTION

Energy economy and environmental protection are the crucial problems needed to be solved urgently facing the automotive industry all over the world in the 21st century. It is stated that oil consumption may decrease 6–8% once the lightweight effect of full vehicle reaches 10%. Vehicle weight reduction is a primary and necessary way to realise energy savings and oil economy, which promotes the lightweight technology to be a hot research area. The weight reduction in body structure plays a rather important role in decreasing the weight of full vehicle, which results from the fact that body structure possesses about 30% weight of full vehicle. A perusal of available related literature, some of which are outlined here, revealed that a quantity of study in lightweight design and application in body structures has been developed.

II. LITERATURE REVIEW

[1] "Weight Optimization of Gear Casing for 4R810 Diesel Engine" by Mr. Amey A. Patil1 Prof. Vinayak P. Gaikwad2 Mr. Suresh P. Patil, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 11 (2019).

In this research paper weight optimization of gear casing 4R810 diesel engine is carried out in order to reduce the weight of gear case. Weight optimization of engine components is an important process for maximizing the

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performance and efficiency of the any engine. Weight optimization of the casting can reflect in the cost reduction at foundry as well as the machine shop. The reverse engineering methodology is used to carry out the weight optimization of the casting of gear casing. The 3 D scanning process is used to obtain the excess, redundant allowances present on the casting and further steps of design and development are done as per the modified casting allowances. The gear optimized casing manufactured is checked for safety by industrial software packages and final checking is done on the actual running engine. The weight reduction procedure reduces the weight by 540 grams of gear casing casting which reduces the natural cost as well as machining cycle time.

[2] "Innovative Design and Development of Transmission System for an Off-road Vehicle" by Boby George, Abin Jose, Adarsh John George, Ajoy Augstine, Alvin Reji Thomas. International Journal of Scientific & Engineering Research, Volume 7, Issue 3, March-2016.
The aim of this paper to design and develop Transmission System. The transmission is an assembly of parts including the speed changing gears and the propeller shaft by which the power is transmitted from an engine to a live axle. A transmission has multiple gear ratios as the speed varies the gear switch. This switching may be done manually or automatically. In this paper they converted. A four-speed manual gearbox into single speed constant mesh gearbox. This transmission is designed for an All-Terrain Vehicle, which is to be used in Baja student competition. An All-Terrain Vehicle is a single seat, open cockpit, open wheel off road vehicle with an engine positioned behind the driver. The manual gearbox being used here is a Mahindra Champion Alfa gearbox. The manual gearbox is coupled to a continuously variable transmission (CVT). This combination of manual gearbox and CVT is designed in such a way that it provides the required gear ratio and satisfies our requirement for an All-Terrain Vehicle.

"A Study on Vehicle Differential system" by Chandrakant Singh, Lalit Kumar, Bhumesh kumar dewangan, Prakash kumar sen, shailendra kumar bohidar. IJSRM volume2 issue 11 November 2014
In this paper differential speed steering is studied to replace traditional mechanical steering by utilizing the benefits of the independent of the motor driving electric vehicle. When the inner and outer wheel are given different speeds, the steering of four wheel driving electric vehicle. During the differential speed steering with four wheels, the minimum turning radius can be zero for a pivot steering. But greater power and torque are required as a greater sideslip is encountered. Wheel slip plays a critical role in kinematic and dynamic modeling of the steering. Understanding the effect slip of the differential-steering, we can optimize the torque control of the motor to decrease the power consumption and tyre wear.

"Structural optimization methods and techniques to design light and efficient automatic transmission of vehicles with low radiated noise" by Takanori Ide · Masaki Otomori · Juan Pablo Leiva · Brian C. Watson.
This paper focus on design methodologies for automatic transmission of vehicles to achieve light weight and low radiated noise. This paper deals with the design approaches using structural optimization method for minimizing the radiation noise and the mass of automatic transmission. The weakly coupled analysis of elastic and acoustic problem is considered for evaluating the radiated noise problem, where the modal frequency analysis is first solved using the finite element method and the acoustic problem for computing a noise radiated from the surface of the automatic transmission is then solved using the boundary element method.
Three different structural optimization methods, tonometry, topography and freeform optimization, are applied for the design of outer casing of automatic transmission. The freeform optimization gives better solution compared with the result of topography optimization from the standpoint of the sound pressure reduction effect while the mass reduction effect is reduced in freeform optimization to satisfy the sound pressure constraint.

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III. IMPLEMENTATION

To study and perform static analysis on 4-wheeler differential case under loading condition. To propose an optimized model this will have better or same performance and reduced weight.CAD modelling of 4-wheeler differential case in Catia V5R20 software.To perform static structural Analysis of optimized 4-wheeler differential case in ANSYS 19 workbench.To perform topology optimization of 4-wheeler differential case for weight optimization.

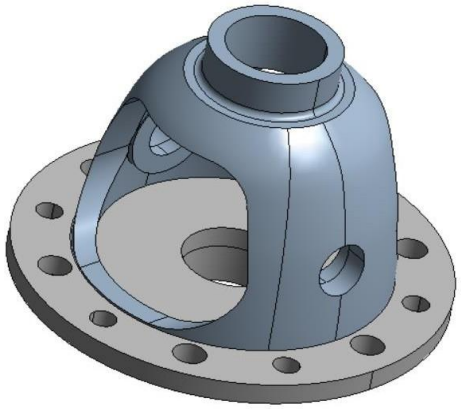

Figure: Final Optimized Casing

IV. CONCLUSION AND FUTURE SCOPE

We have successfully analysed the existing differential casing for static conditions and dynamic conditions and also performed topology analysis to find out the regions where we can remove the material and reduce the overall weight of differential casing. Weight of the casing is reduced from 1.32 Kg to 1.25 Kg. 6% of weight is reduced from Existing differential casing. The strain value of the differential casing is plotted analytically and the strain is validated by strain gauge method.

The process of manual optimization for static loading is very time consuming (as re-meshing of the model is required for each iteration), biased (as per the stress interpretation of the person designing the component) and may not lead to best possible solution. Hence, the automatic topology optimization tools must be used for initial design guess, but only if the convergence can be met and the results are feasible. The process followed in this study can be applied to any other casting component used in automobiles with minor modifications to achieve weight reduction.

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[4] "Structural optimization methods and techniques to design light and efficient automatic transmission of vehicles with low radiated noise" by Takanori Ide · Masaki Otomori · Juan Pablo Leiva · Brian C. Watson.

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