Stress Analysis and Mass Optimization of Epicyclic Gearbox Housing – A Review
Bhavik S. Modi
PG Student
A. D. Patel Institute of Technology, V. V. Nagar, 388120, Gujarat, India.

Abstract--- The gearbox manufacturing Companies are proposing three to five stage epicyclic gearboxes and it is widely used in sugar mill and wind mill drives. It was found that high volume gearbox costs are very dependent upon material cost and the weights of the planetary drives. It was difficult to quickly find an optimum solution, while the space restriction was given and weight was to be minimized. For most of the gearboxes; housing dimensions are derived from thumb rule or empirical relations. Such process of design lead to conservative dimensions leading to bulky housing and such process was very time consuming. Today’s computational hardware and software offers quick analysis and design modifications capabilities which can be used for design improvement and optimization of products. So, here aims are stress analysis of the housing using ANSYS workbench and reduce the mass of the epicyclic gear train housing by using MATLAB optimization tool box.

I. INTRODUCTION
A. Epicyclic Gear Train

Planetary gearbox is used in machineries and machine tools to obtain speed reduction, which in turn increases the torque. These gearboxes are used in many applications such as automatic automobile transmissions and hybrid transmission systems [1]. Planetary gear trains have attracted the attention of designers for the possibility of efficient and quiet transformation of rotation and the transmission of large torques with gears of relatively small dimensions [2]. The power transmission efficiency and compactness is higher. Efficiency loss is usually of order 3% per stage resulting into large proportion of the energy transmitted by the gearbox. As the load being transferred is shared between number of planets, torque capability is greatly increased. As the number of planets in the system increases, there will be higher the torque density and the greater load ability. There is a greater stability due to the even distribution of masses. Some of the disadvantages of the planetary gearbox are: High bearing loads, Constant lubrication requirement, Inaccessibility, and design complexity, the backlash of planetary gears cannot be adjusted.

B. Finite element method

For the structural analysis of epicyclic gearbox housing, Finite element method was used. The solver takes the information provided in the file (input deck) and obtains solutions for field variable. Common outputs are Displacement, Stress, Strain and Acceleration. ANSYS is an engineering simulation software which offers an entire range of multi-physics numerical solvers, providing access to virtually any field of engineering simulation that a design process may require. There are different types of analysis systems in the ANSYS WORKBENCH like Fluid flow, linear buckling, rigid dynamics, explicit dynamics, static structural, thermal-electric and etc. For the static analysis of the epicyclic gearbox housing the static structural analysis system is used. Structural analysis uses FEA tool for product design validation. ANSYS static structural provide the ability to simulate every structural aspect of the product like linear static analysis that simply provides stresses or deformations.

C. Optimization

The Optimization Toolbox is a collection of functions that extend the capability of the MATLAB® numeric computing environment. The toolbox includes routines for many types of optimization including, Linear programming, Nonlinear least squares with bound constraints, Nonlinear system of equation solving, Unconstrained nonlinear minimization, Nonlinear minimization with bound constraints and Nonlinear minimization with linear equalities etc. Optimization concerns the minimization or maximization of functions. The Optimization Toolbox consists of functions that perform minimization (or maximization) on general nonlinear functions. Functions for nonlinear equation solving and least-squares (data-fitting) problems are also provided.

II. LITERATURE REVIEW

King et al [3] presented a study on paper stress analysis of gearboxes used in sugar industries. The commercial Finite Element software ANSYS was used to analyse stresses generated in the gearbox with an objective to improve the life of the gears. The study investigated wear of gear tooth edges as a main reason for the failure of gears. The wear of edges was caused due to higher stress concentration along...
the gear tooth edges. This was caused due to high stress concentration along the gear teeth edges. The study recommended modification strategies in design of gears to relieve these stress concentration and stress levels were reduced well within allowable/safe limits. It was further observed that the stresses induced on the gear tooth were reduced considerably by providing hole at the root of the gear tooth. Prabhakar et al [1] analyzed for weight reduction planetary gearboxes using finite element analysis with an objective to reduce cost. The paper attempted reduction of weight by analysing two major components of the assembly viz., pedestal and planet carrier. The study modelled and meshed the gear box using solid modeller. The inputs necessary for analysis such as forces and torques were found using manual calculations. The meshed model was imported to FEA software ANSYS and analysis was conducted by providing the manually calculated forces and boundary conditions to the model. The results concluded that Von-Mises stresses and deflections are obtained for existing model, based on the size modifications, three different models were developed and analysis was conducted without changing the loads and boundary conditions. A new model with the change of geometry was developed for reduction of weight and significant improvement in the design was observed. Kissling et al [4] attempted weight minimization of the gearbox along with space restrictions. The study also considered factors such as the manufacturing cost, total power loss and other relevant factors. It has been observed that the solution of such multi-variable extremely time-consuming, and different variants of reducers have to be evaluated carefully. A new optimization tool, was developed based on KISSsys software to generate a different variants of gear reducers. The results were generated in 3D graphical formats, showing weight, costs and efficiency of different variants along with their dimensions and space restrictions. The results obtained using developed application provided higher reduction in weight and manufacturing price compared to earlier reported results. Nwosu et al [5] addressed premature failure of gearbox unit analysing probable causes. The gear tooth characteristics such as beam strength, maximum allowable dynamic load, allowable static load and limiting tooth wear load were analysed to cope with the duty load. The failed gear components of a gear were examined visually and metallurgical to identify probable causes of failures. A methodology has been proposed to prevent the failures of bear teeth by adequate sizing of face width as well as better choice of materials with higher allowable static stresses. Veeranjaneyulu et al [6] presented a study which is to focus on the mechanical design and analysis on assembly of gear gear assembly while transmitting power at three different speeds. The study also analyzed effect of various gear materials such as Cast Iron, Cast Steels and Aluminum Alloy with the objective of reducing weight. By observing analysis results, Aluminum Alloy was best material for Differential. Narasimhamu et al [7] analysed the cover of a gearbox used in 3-wheeler commercial automobiles with and objective of reducing the stress concentration generated due to internal pressure. While analyzing the stress concentration is found to be more at near location of its bolts. Two alternative methods by changing design and material were considered ways for reducing the stress concentration in the gearbox. The modified design was implemented and fabrication methods for dies are suggested. Chhabra et al [8] presented a comprehensive methodology for computer aided gear box design for variety of gears starting from 3- D modelling to stress and deformation analysis using FEM until generation of CNC program. The study explored the characteristics of composite material for gear box at conceptual design stage for specific weight reduction improved energy efficiency, corrosion resistance, noise reduction and higher frequency. It has been concluded that the usage of composite materials for gearbox can be metallic gearbox for weight saving. Patil et al [9] presented the process of casting design in the automotive industry using computer aided design and engineering tools. It was demonstrated that the significant benefit through the usage of computer aided tools was the direct access geometry data, from which finite element models can be quickly developed. The primary objective of the study was is to analyse differential gearbox casing of pick up van vehicle for modal and stress analysis. The theoretical modal analysis was being validated with experimental results from Fourier Frequency Transform analysis. The study showed that the usage of FEA for casing is more meaningful than empirical formulae and iterative procedures. Gupta et al [10] presented the effect of speed, torque, total ratio and efficiency of external elements in epicyclic gear boxes. The method indicated the flow of power transmitted through the epicyclic gears. The study calculated and experimentally observed the angular velocity ratios of gear train, torque ratios of gear train and efficiencies of gear train. This paper highlighted the most significant advantage of epicyclic gears in form of distribution of input torque uniformly to all of the planets. It is also observed that the epicyclic gear units are effective at balancing the torque equally between the planets. The study also attempted the compact design of epicyclic gear train with low strain on each component. Schultz et al [11] discussed gearbox architecture which including the type of gearing used, overall gear ratio, number of increasing stages, number of meshes, various ratio combinations, and the gear proportions number of meshes, the ratio combinations, and gear proportions. A case study of 2 MW wind turbine was studied applying a common set of requirements to a variety of potential gearbox designs. Each design option was also evaluated for manufacturing difficulty and relative cost estimate. The cost of high volume gearbox is greatly dependent upon material and weight of the planetary drives. Park et al [12] studied stress distribution on the planetary gear carrier. It was reported that the blowholes around the hub corner resulted into a fracture of carrier due to concentrated and repeated mechanical stress. Fatigue striations which are the typical features of fatigue failures were also observed by a scanning electron microscope. The effects of casting defect such as blowhole; stress distribution of gear carrier were evaluated by Finite Element Analysis. The stress distribution of the defect was concentrated around blowhole regions and the maximum stress of the gear carrier is increased by 26% more than the normal gear carrier. Huang et al [13] attempted the cost reduction of foundation for a large machine by optimizing the parameters which define its shape while maintaining the required stiffness. The parameters affecting the shape of foundation were considered and. The shape of foundation was optimized.
using two and three dimensional model. Both these models were optimized for different loading conditions and varying stiffness. A nonlinear unconstrained optimization technique combined with the finite element was used to obtain the optimal design of foundation. It was demonstrated that the combination of FEA and non-linear optimization technique can reduce the weight of machine foundation by almost 30%.

A. Summary of Literature survey

After studying most of the research papers, it was found that high volume gearbox costs are very dependent upon material cost and the weights of the planetary drives. It was difficult to quickly find an optimum solution, while the space restriction was given and weight was to be minimized. Most of the gearbox dimensions were derived from the empirical relations. Such process was very time consuming, if different variants have to be evaluated. In the most of research paper it was found that the optimization had been done with trial and error method. But it had been shown that using this method further and further design modification had to be done with limiting stress values. So that this optimization method was very time consuming and appropriate results are difficult to get. Hence in this present work was using quick analysis and design modifications capabilities which can be used for design improvement and explicit method of the optimization was used for time improving to arrive low cost solutions.

III. PROBLEM DESCRIPTION AND METHODOLOGY

In recent days, gearbox manufacturing companies are attempting optimization in their design in order to arrive at low cost solutions. The optimization can be carried out broadly at two locations; Housing of the gearbox and mating parts (or internals). In the epicyclic gearbox the gears are manufactured by standard company procedure. So that internals part design do not change. In the given case housing contributes one third of the total weight of the gearbox. Hence there is a scope to optimize the overall mass by reducing mass of housing. The finite element method (FEM) is a versatile numerical method widely used to solve such engineering problems. In this research, the deflection and stress distribution in the epicyclic reduction gearbox housings are estimated using FEM and also mass to be optimized by explicit method of optimization. Below steps are carried out for the research,

- CAD and FE Modelling
- FE Analysis of epicyclic gearbox housing.
- Identify Potential Area where Mass to be optimized.
- Mass optimization
- Results and discussion

IV. CONCLUSION

By carried out this methodology one can obtain deflections and stresses for different loading conditions for the existed epicyclic gearbox housing. Both the magnitude and location of large deflection and stresses were important. After implementing optimization, weight of the epicyclic gearbox housing will be reduced. FEA also be carried out on Optimized design of the epicyclic gearbox housing to check whether the optimized design is safe or not.

REFERENCES