Stress and Design Analysis of Triple Reduction Gearbox Casing

Mitesh Patel
PG Student
Department of Mechanical Engineering
S.S.G.B.C.O.E & T Bhusawal-425203 North Maharastra University, Maharastra, India

Prof. A. V. Patil
Faculty
Department of Mechanical Engineering
S.S.G.B.C.O.E & T Bhusawal-425203 North Maharastra University, Maharastra, India

Abstract

The finite element analysis of triple reduction gearbox that constitutes the driving mechanism of a double bascule movable bridge was performed. The triple reduction helical gearbox was made of ASTM A36 Steel. The triple reduction helical gearbox was a three stage gearbox transmitting 112.5 H.P. at 174 rpm with a reduction ratio of 71.05:1. The load calculation for helical gear was performed using the CAD Software package. The reactions were used to apply loads to the finite element model of housing (casing). Geometric model of triple reduction gearbox casing was built using NX-8 and meshed using the ANSYS finite element program. Static structural analysis was performed using a combination of shell and solid elements to determine the deflection and to estimate the stress distribution in the housing. The aim is to improve the strength by reducing the stress and deformation what changes can do in Design that all will discussed about the detail analysis of ANSYS software result for three different cases for gearbox casing .case (1) casing without stiffeners and rings. Case (2) casing with stiffeners. Case (3) casing with stiffeners and rings.

Keywords: Triple Reduction Gearbox, Geometric, Stiffeners and Rings, Movable Bridge, Discretized

I. INTRODUCTION

This work focuses on the stress analysis of triple reduction of gearbox casing designed and manufactured by steward machine company, Birmingham, Alabama. These gearboxes are designed for high torque and low speed applications for operating movable bridges, heavy hoisting machinery, or other lifting mechanisms. The helical and herringbone-bevel combination gearbox housings analyzed in this work form the driving mechanism of a double bascule movable bridge. . A double bascule bridge has two leafs on each side and a total of four leafs that open and close when the bridge is opened and closed. An AC motor drives the differential gearbox D of a double bascule bridge shown in the block diagram of Figure 1.2 The AC motors are typically rated for 15-150h.p. at 870 rpm. The differential gearbox D drives the triple reduction gearboxes T on both sides, which in turn drive the main pinion P. The main pinion drives the rack R attached to the leaf of the bridge. The differential gearbox allows equal load distribution between the two output shafts. The triple reduction gearbox consists of helical gears. A photograph showing the operating gearbox mechanism of a movable bridge is shown in Figure 1.

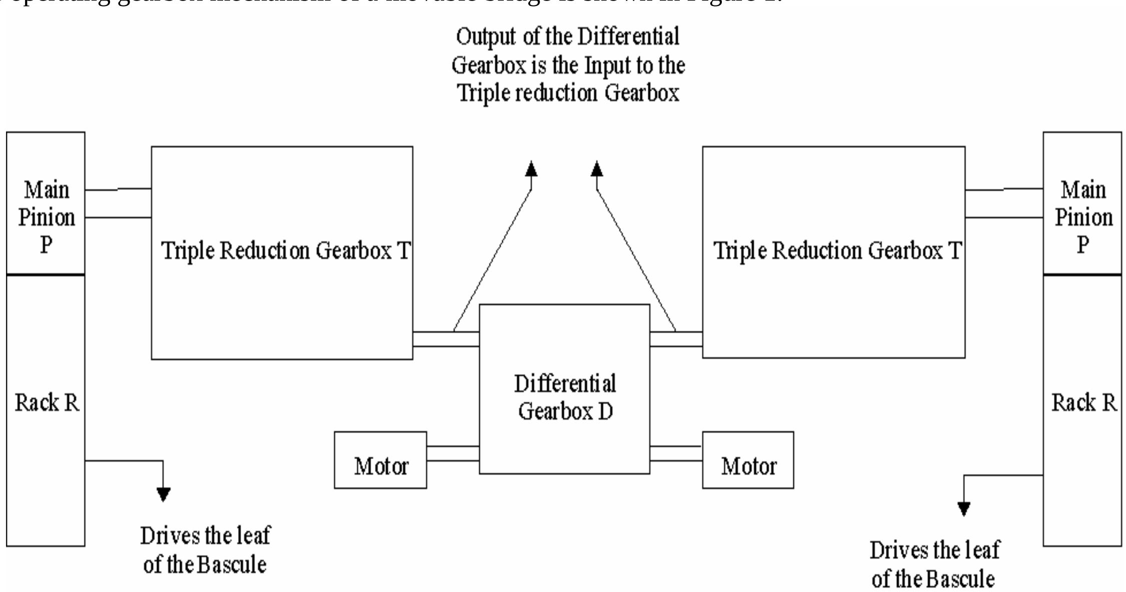

Fig. 1: Block Diagram of an Operating Mechanism of a Double Bascule Bridge

A. Gearbox Specifications

The triple reduction gearbox is the input to the main drive pinion of one leaf of the bridge. This gearbox weighs approximately 9000 kg and is driven by the differential gearbox. The material of the housing is ASTM A36 steel with a modulus of elasticity E of 30 x 106 psi and Poisson's ratio v of 0.29. The housing is joined together by a combination of welding and bolted joints. A schematic of the gearbox is shown in Figure 5.1. The triple reduction gearbox shafts are designated using capital S's and a numeral. The gearbox has two intermediate shafts S2 and S3 besides the input and output shafts S1 and S4. All shafts have helical gears and anti-friction bearing at shaft ends. The gearbox is designed to transmit 112.5 h.p. at 174 rpm with a reduction ratio of 71.05:1. The dimensions and specifications were provided by Steward Machine Company.

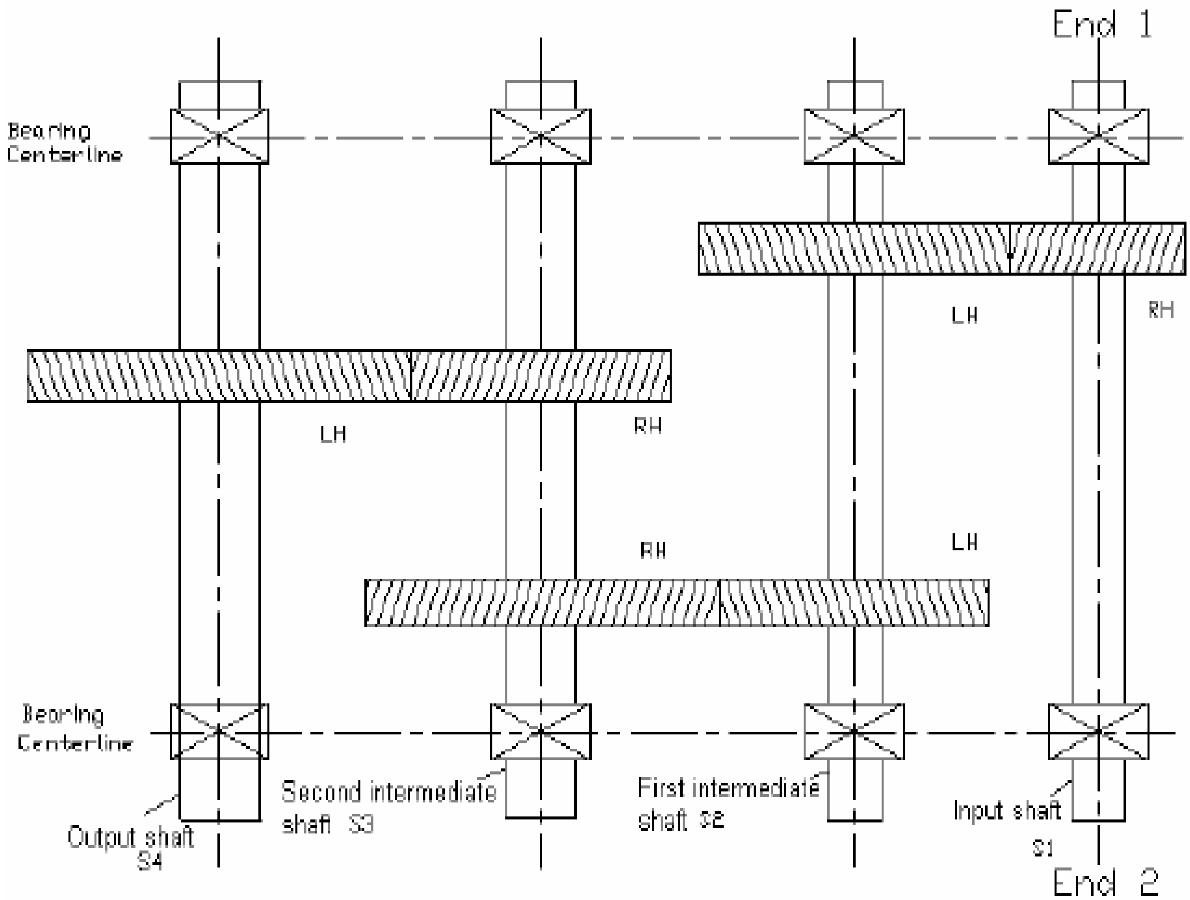

Fig. 2: Sectional View of Triple Reduction Gearbox

Table – 1
Shaft Data for the Triple Reduction Gearbox

Shaft	*Diameter(in)*	*Length between Bearing ends (in)*
Input Shaft	*4.503*	*40.876*
First Intermediate Shaft	*7.004*	
Second Intermediate Shaft	*11.005*	
Output Shaft	*12.506*	

II. FINITE ELEMENT MODELING AND ANALYSIS

This chapter describes modeling, meshing, loading, and solving the FE models of the gearbox housings, FEM is a numerical method widely used to solve engineering problems. In this method of analysis, a complex region defining a continuum is Discretized into simple geometric shapes called finite elements. A displacement function is associated with each finite element. The finite elements are interconnected at points called nodes. The behavior of each node can be give a series of algebraic equation expressed in matrix notation. Solution of this equation gives the nodal degrees of freedom in the structure. Stresses are calculated using derivatives of displacements. The evaluation of stresses requires more refined models. The type complexity of a model is dependent on the type of results required.

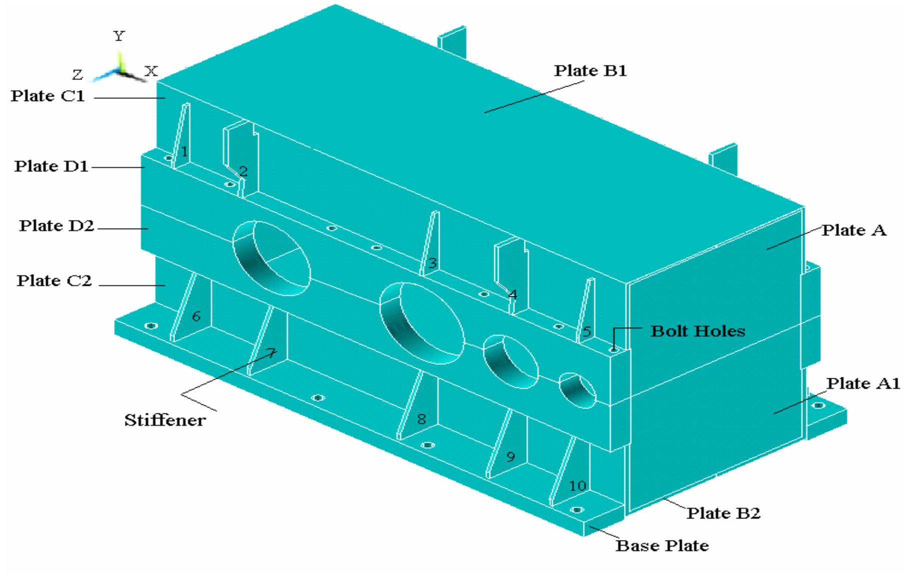

Fig. 3: Geometric Model of Triple Reduction Gearbox

B. Creating and Meshing the Fe Models

1) Modeling is based on a Conceptual understanding of the physical system and judgment of the anticipated behavior of the structure. A Model is an assembly of finite elements, which pieces of various sizes and shapes. The element Skewness should also be avoided by keeping the corner angles in quadrilateral elements close to 90 degree. A suitable mesh should minimize the occurrences of high aspect ratio and excessive skewness. In addition, the mesh must have enough elements to provide accurate results without warning time in processing and in interpreting the results. Geometric modeling and meshing of these gearboxes with suitable elements and optimum degrees of freedom was an iterative and challenging process, first, a coarse mesh was made and the overall response of structure was evaluated. Modeling was done using NX-8, meshing was done using the preprocessor in ANSYS.

C. Triple Reduction Gearbox Model Geometry and Loads

The triple reduction gearbox was first modeled with a coarse mesh and after interpretation of results the mesh was refined. All the load cases were solved on the complete model. Geometry is modified by putting Ring along the circumference of the bearing holes as Shown in Figure 4.

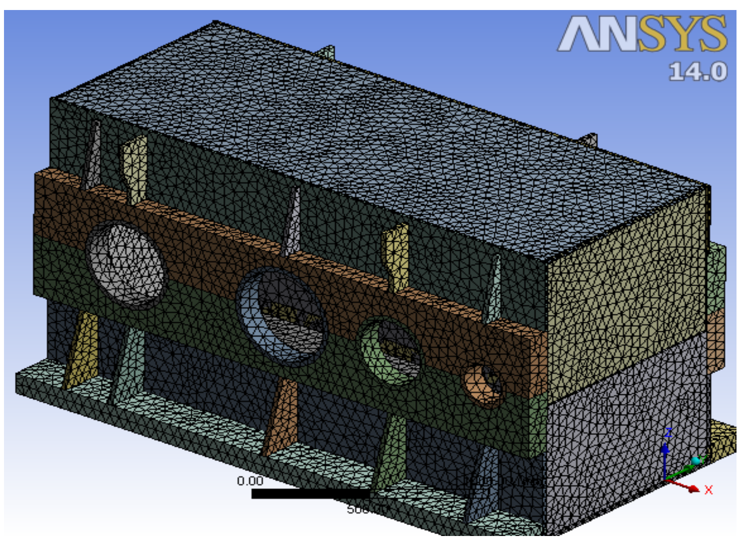

Fig. 4: Discretized Geometry of 3 Stage Helical Gearbox Casing

D. FEA Result and Discussion

The model was solved to obtain deflection and stresses for different loading condition. Both the location of large deflection and stresses were important. Steward Machine Company considers a deflection of 0.508 mm or more. A gearbox design with deflections on the order of 0.508 mm would require special evaluation. Consider the steel material as the basic material for casing.

III. DESIGN OPTIMIZATION WITH ASTM –A36 MATERIAL

A. Case 1: Casing without Stiffener and Rings

The force is acting upon casing. The analytical results for this case is shown in below figures.

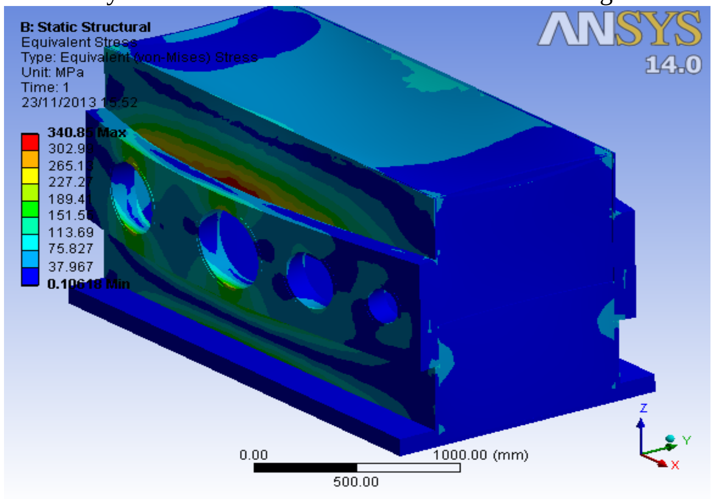

Fig. 5: Equivalent Stresses on Gearbox

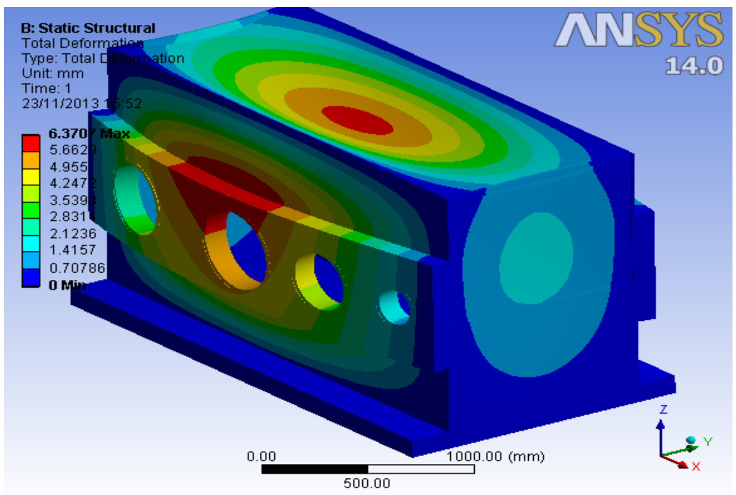

Fig. 6. Total deformation

B. Case 2: Casing with Stiffener

Here insert the stiffeners and apply same forces as above discussed.

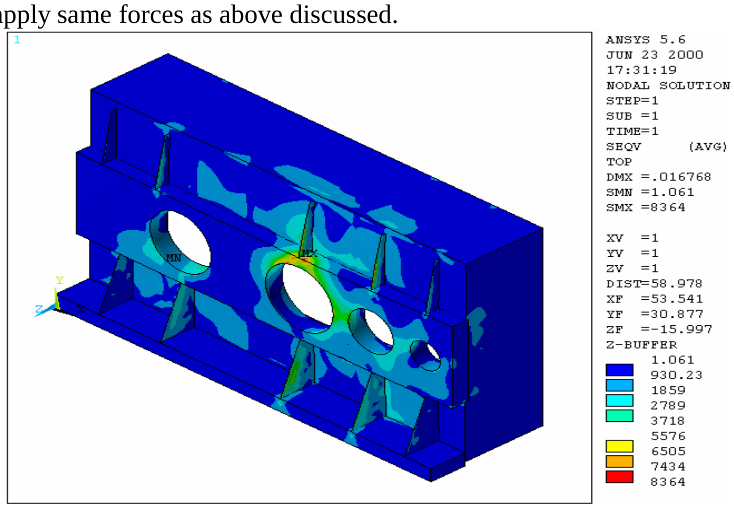

Fig. 7: Equivalent Stresses on Gearbox

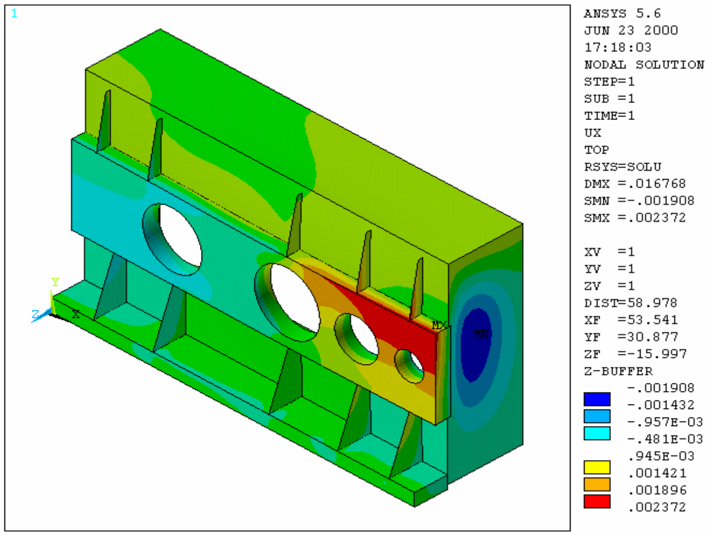

Fig. 8: Total deformation

C. Case 3: Casing With Ring and Stiffener

Here used rings with stiffener. And apply the same forces mention above and its analytical result.

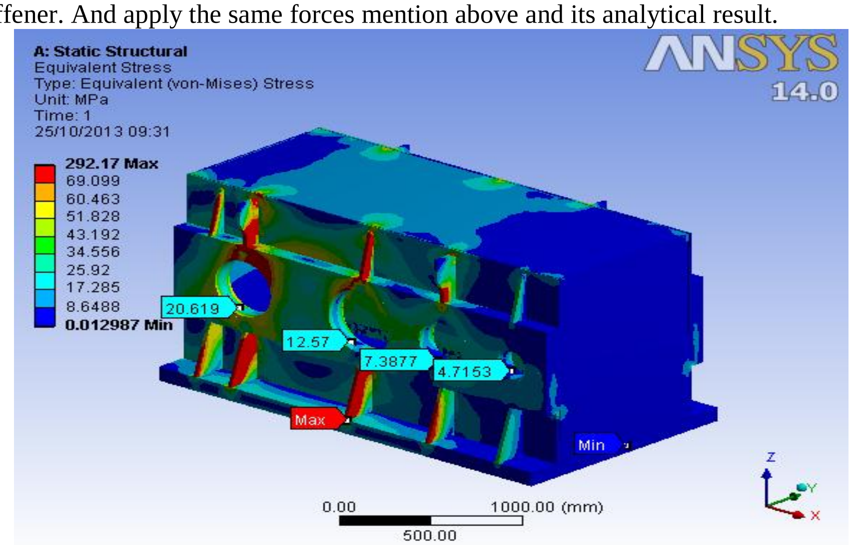

Fig. 9.Stress Result with Ring & Stiffeners

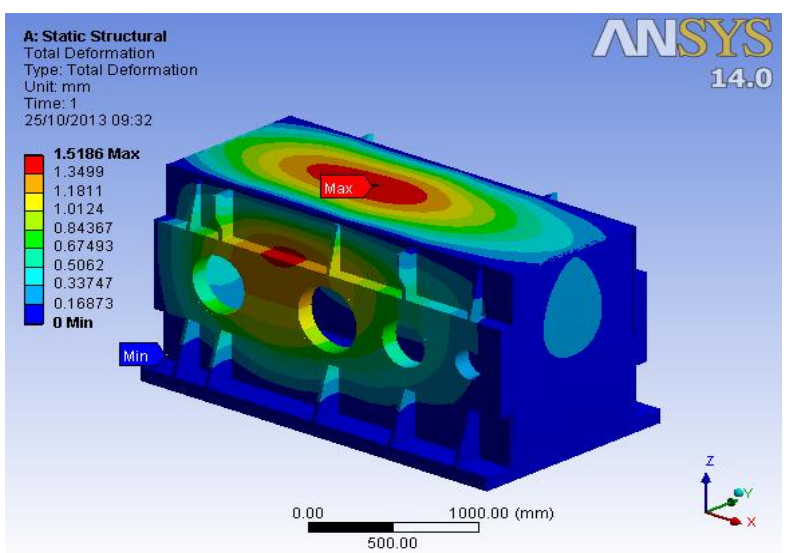

Fig. 10.Total Displacement Result with Ring & Stiffeners

Table - 2
Comparison of 3 Cases of Design

Case	*Case 1 (Only Casing)*	*Case 2 (Casing with Stiffeners)*	*Case 3 (Casing with ring & stiffeners)*
Max stress	*340.82 MPa*	*836.4 MPa*	*292.17 MPa*
Total deformation	*6.379 mm*	*2.92 mm*	*1.5186 mm*
Directional deformation X	*2.482 mm*	*0.2372 mm*	*0.6308 mm*
Directional deformation Y	*6.3433 mm*	*3.523 mm*	*1.3766 mm*
Directional deformation Z	*025284 mm*	*1.6595 mm*	*0.3809 mm*

IV. COMPARISON & DISCUSSIONS

The design of gearbox casing where steel is the best material and consider three cases of design. From the table in first case stress and deformation value is very high compare to other cases. In case two use stiffeners so that reduce deformation here stiffeners provide buckling of the material and case three used both rings and stiffeners so stress and deformation is vary less. Rings reduce the circumference stress at bearing for this load is proper distribution in casing. It is good thing for the design improvement.

V. CONCLUSION

In this project studied about the design modification and stress analysis of the three stage helical gearbox casing. The aim of this project was to modify the design of 3-stage helical gearbox casing which can withstand high load with minimum Stress and Deformation. To fulfill this aim three different cases i.e. casing without ring and stiffener, casing with stiffeners and casing with ring and stiffeners. Amongst these three cases we have better results in case of casing with ring and stiffeners.

VI. FUTURE SCOPE

In future very large scope for the different material property for the Triple reduction gearbox casing and also for this design improvement. In future modification in design can be made in order to minimize the weight and size of the casing. Also, one can test the same model for more materials and obtained the better results deformation and stores

REFERENCES

[1] Emmanual RIGUAD and Jens SABOT . "Effect of elasticity of shaft, bearing, coupling and casing on the critical rotation speed of a gear box. 36, avenue Guy de Collongue. B.P. 163. 69131 Ecully Cedex. FRANCE.
[2] Dr inż. Zbigniew Zdziennicki and Dr inż. Andrzej Maciejczyk, DESIGN BASIC OF INDUSTRIAL GEAR BOXES Calculation and Design Case Example
[3] Design & Analysis of Composite Material Gear Box by Pankaj Chhabra and Amit Bhatia.International Journal of Mechanical Science and Civil Engineering, Volume 1 Issue 1 December 2012
[4] Ramamurti, V., Arul Kumar, P.S., Jayaraman, K., "Performance Comparison of Cast and Fabricated Gearbox Casings" Computers and Structures, Vol. 37, 1990, pp. 353-359
[5] Vineet Shibe, COMPUTER AIDED ENGINEERING OF GEAR BOX,masters of engineering CAD/CAM , R. No. 8028117,Department Of Mechanical Engineering, Thapar Institute Of Engineering & Technology

Books

[6] V.B.Bhandari, Design of Machine Elements, Tata McGraw-Hill Publishing Company,NewDelhi,1994.
[7] Dudley,DarleW.,ed.,Gear Handbook,McGraw-HillBookCompany,Inc.,1962
[8] Shigley,Joseph.E.,Mechanical Engineering Design,FifthEd.,McGraw-Hill Book Company,Inc.,1989.