ISSN 2395-1621

Stress Analysis and Optimization of Rolling Mill Housing Using FEA Tool

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ABSTRACT

Rolling is defined as a process in which metal is formed through a pair of revolving rolls with plain or grooved barrels. The metal changes its shape gradually during the period in which it is in contact with the two rolls. Rolling is a major and a most widely used mechanical working technique. A Rolling mill is a complex machine for deforming metal in rotary rolls and performing auxiliary operations such as transportation of stock to rolls, disposal after rolling, cutting, cooling, melting. The problem of failure of Rolling Mill Housing was there in industry, which affects the cost of production drastically and it can be efficiently solved by using CAE. The present work involves the optimization of Rolling Mill Housings design for rigidity, to control the deflection of the housing for better gage control of the material being rolled. The stress distribution analyzed using analysis software ANSYS from which maximum static stress at critical areas of 3D model of rolling mill housing can be calculated. Structural behavior of housing under the given loading and boundary conditions using an analytical model is done. Results of stress and deformation are compared before and after optimization of rolling mill housing by ANSYS tool and analytically as well as strain and dimensions are compared by using ANSYS tool.

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

Keywords— Housing, ANSYS, Optimization, Stress, Strain

I. INTRODUCTION

Rolling mill housing as shown in Fig. 1 encloses supports and adjusts rolls in the correct position. The rolling mill housing should be so strong that even though the roll may breaks, the housing does not deform plastically as its cost of manufacturing and time of replacement is excessively high. The forces, which act on the rolls during rolling, are completely transferred on to rolling housing through the nut of the adjusting mechanism. In addition, there exists a tendency for the roll stand to turn as a result of the torques acting on the rolls, which get transmitted to the housing in case of bearing seizures or when rolls are unable to pass the metal due to lack of sufficient power. So, the housing of rolling stand requires high rigidity, sufficient strength for taking the loads and minimum cost of production.

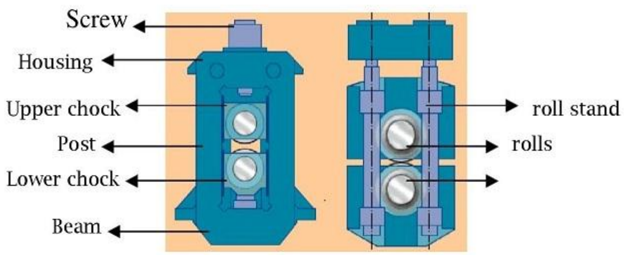

Figure 1. Rolling Mill Housing

II. OBJECTIVE OF PRESENT WORK

The present work involves the optimization of Rolling Mill Housings design for rigidity, to control the deflection of the housing for better gage control of the material being rolled.

1. Find out failures of Rolling Mill Housing by using CAE approach.
2. Optimize design of Rolling Mill Housings for rigidity. Also Study the physical responses, such as stress levels and deformations.
3. Optimize design to control the deflection of the housing for better gage control of the material being rolled.
4. Optimize a design early in the development process to reduce production costs.
5. Analysis of Rolling mill housing bending for load P=900KN which is actual Rolling mill condition. Also analysis of the housing for concern stress distribution. From which maximum static stress at critical areas have been calculated.
6. Structural behavior of housing under the given loading and boundary conditions using 3D solid model. For predict the stress and strain response detail. Validating the stresses and deformations with the analytical data.

III.METHODOLOGY

To check the feasibility of this housing we are using CAE tool using software workbench. Then test the prototype for different sizes. Then according to result of tests for Rolling Mill Housing we optimized and designed the rolling mill housing. To accomplish the objectives I have performed the following steps.

Defining Element Type

⇩

Defining the Material Properties

⇩

Build the 3D Model

⇩

⇩

Meshing of Model

⇩

Solve the model at actual boundary conditions

⇩

Finding the Stress, strain and deformation of housing before optimization

⇩

Study the Optimization Procedure

⇩

Parameterization

(Solve the model under different boundary conditions for optimization)

⇩

a) Select the suitable sizes of parameters for Housing Design

IV.LOAD CALCULATIONS

The internal force set up in the body per unit area is called stress. The external forces may be classified as surface or body forces. The surface forces are the forces distributed over the surface or boundary of the body. The surface forces are described in terms of forces per unit area and as such are often called applied stresses. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

Calculation of Roll Load

The fig. 2 shows spherical Roller Bearing. Since the forces on the roll neck and in the Housing posts are identical, and the strength of the neck (with a constant relation between its diameter and length) is approximately proportional to d^2

Where d= diameter of Roll neck bearing.

For various mills Roll load depends on the Roll material as,

Material	Roll Load, N
Iron rolls	$(0.6\text{-}0.8)d^2$
Carbon steel rolls	$(0.8 \text{ to } 1.0)\, d^2$
Chromium steel rolls	$(1.0 \text{ to } 1.2)\, d^2$

Here use of four high mills with Chromium Steel Rolls is done so Roll load is calculated from the equation 3.3 i.e. $F = (1.0 \text{ to } 1.2)\, d^2$.[2]

Since each roll neck consists of two bearings 23056 mounted on each roll neck so specification of bearing used is:

d = diameter of Roll neck bearing = 280 mm

D = outer diameter = 420 mm

B = width = 106 mm

C = Dynamic capacity = 1520000 N

Therefore, F = (1.0 to 1.2) d2= (78400 to 94080) (9.81)

= (769104 to 922924) N

Also the Rolling Load in a Rolling Mill is calculated from the dynamic capacity of the Roll bearings and their service life.

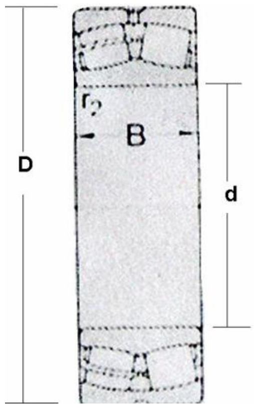

Figure 2: Spherical Roller Bearing (SAE Bearing manual)

In order to achieve a service life of about 3 Lakhs hrs minimum at 30 R.P.M the ratio of bearing capacity to load applied can be calculated from life calculation chart as shown in fig. 3

Therefore C/P = 6.5

Therefore P = 1520000/6.5 = 233 KN

I had making use of four bearings so Total load is

P * 4 = 930 KN (approximate) [1]

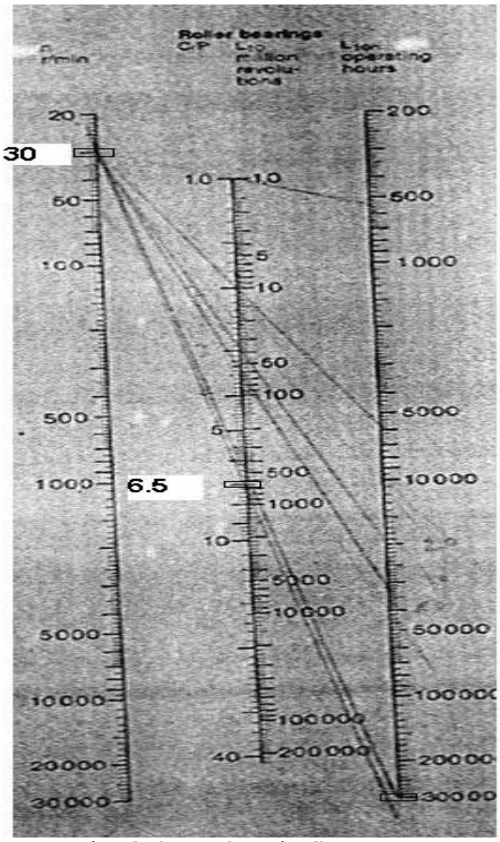

Figure 3: Life Calculation Chart of Roller Bearing (SAE Bearing manual)

V. FINITE ELEMENT METHOD

Finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis to field analysis of heat flux, fluid flow, magnetic flux, seepage and other flow problem. In this method of analysis, a complex region defining a continuum is discredited into simple geometric shapes called Finite Elements. Finite element method solves for forces and displacement over the entire object. Finite element method is used for solving many industrial problems like Automobile frames, optimization of mechanical parts, artificial limbs etc. Rolling mill housing is one of them.

ANSYS Workbench combines the strength of our core product solvers with the project management tools necessary to manage the project workflow. In ANSYS Workbench, analyses are built as systems, which can be combined into a project.

A. Steps of analysis of Rolling Mill Housing

1. Defining Element Types:

Each element type has a unique number that defines the element category. selected the Element type static structural(Brick 20 noded) to analyze 3D model of Rolling Mill Housing. Defining the Material Properties Mild Steel is selected as a material for 3D solid model of Rolling Mill Housing.

TABLE I
THE STRUCTURAL PROPERTIES OF THE MILD STEEL MATERIAL

Young's Modulus	2 E11 N/m^2
Poisson Ratio	0.266
Density	7860 kg/m3
Yield Strength	2.5e+008 N/m^2

2. Geometry (Build the Model):

First of all we have to made a 3D model of Rolling Mill Housing on ANSYS workbench Design modular as per dimensions. (fig. 4)

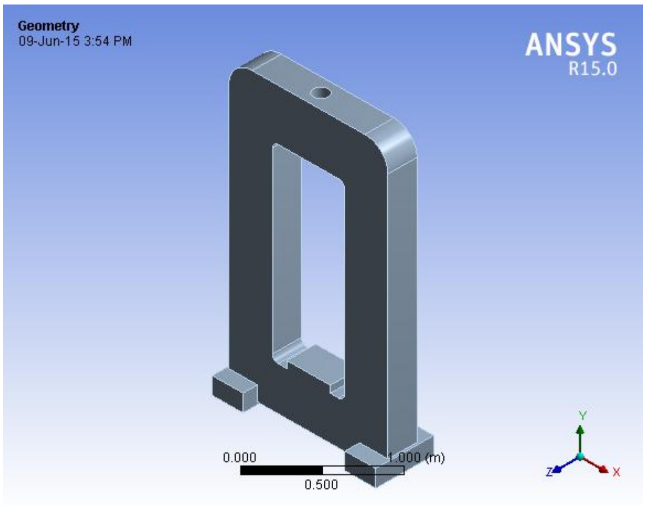

Figure.4: 3D Model of Rolling Mill Housing (Static Structural)

3. Meshing of Model:

Descritize the whole solid model into small elements. Depending upon the requirement of the accuracy of results the fineness of meshing varies. Boundary Conditions: The full rolling load is taken by the roll neck bearings, which are supported in the chocks; the bottom chock rests on a spherical liner, which in turn is supported by the bottom beam of the housing. The top chock has spherical seating on the screw. So I apply constraints on the model like I fix the base of Rolling Mill Housing and apply maximum rolling load of +900 KN on the cross section where the top chock rests and -900 KN on seating where the bottom chock rests as shown in figure 5.

4. Solver:

Solver is used to solve the simultaneous equations that the finite element method generates. The results of the solution are:

- Nodal degree of freedom values, which form the primary solution.
- Derived values, which form the element solution.

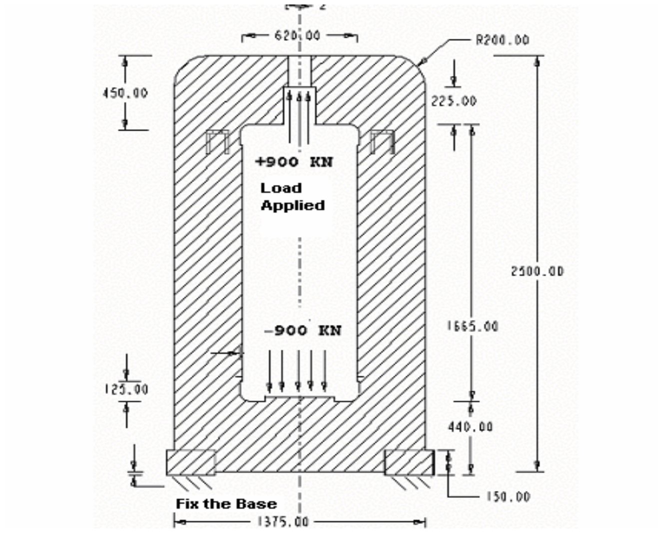

Figure 5: Boundary Conditions on Rolling Mill Housing

- 5. Parameterization

Parameterization means optimizing the results of an analysis. It is probably the most important step in the analysis.

A. B. Optimization procedure

Design optimization is a technique that seeks to optimize the design in terms of strength, rigidity and weight. By “optimum design,” we mean a design that meets all specified requirements but with a minimum expense of certain factors such as weight, surface area, volume, stress, cost, etc.

The stresses in the posts are within control limits so no needs for changing its design but the beam of the housing experienced higher stresses at the place where nut of the housing screwed is nested in the beam therefore design of the beam has to be optimized.

The optimization procedure consists of following steps

1. Design Variables:

These are independent quantities that are varied in order to achieve the optimum design. Upper and lower limits are specified to serve as “constraints “on the design variables. These limits define the range of variation for the Design variables.

D1 and D2 are chosen as design variables for optimization of rolling mill housing as shown in figure 4.5.

Where D1 = diameter of uniform circular cross section added around the nut in mm

D2 = diameter of hole where nut rests in mm

$380 < D1 < 392$

$175 < D2 < 199$

2. State variables:

These are quantities that constraint the design. They are also known as dependent variables. A state variable may have a maximum and minimum limit, or it may have one limit. Rolling mill housing model has two state variables:

(total stress) and δ (Defection). 60 – 90 N/mm^2 is the recommended stresses in the housing which should be as uniform over the cross section so as to make it balanced housing design.

Therefore $60<\sigma<90$ N/mm^2

For thin rolled products the total deflection of the rolling mill system should be such that the stock material is able to remain with-in close tolerances. Maximum limit of deflection for roll mill housing should be limited to 0.01 mm for rolling 0.3 mm material.

Therefore $\delta < 0.01$ mm

3. Objective Function**:**

It is the dependent variable that we are attempting to minimize. It should be a function of design variables that is changing the values of design variables should change the value of objective function. The weight of the housing is considered as the objective function. Weight of the steel is 7.85 gm/cc .Therefore weight of the Rolling mill housing is (7.85 e -3) V

Where V= volume of rolling mill housing.

VI. RESULTS AND DISCUSSION

This load imparts a tensile stress to the vertical pillars, a compressive stress to the screw and causes bending of top and bottom housing beams. Because of the bending of the housing beam, the posts will tend to bend inwards, and the way in which the housing distorts depends on the relationship between the resistance to bending of the vertical posts and the resistance to bending of the beams. The post will experience direct tensile stresses and bending stresses at the inner and outer end of the post. There will be compressive stresses at outer end and tensile stresses at the inner end of the posts.

A. Analysis of Rolling Mill Housing before optimization

1. Stress Analysis

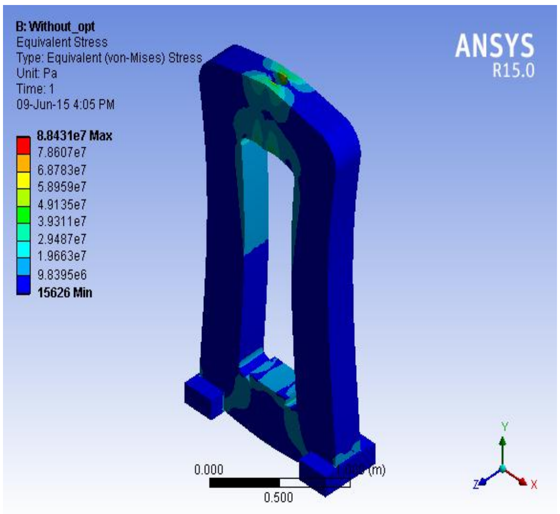

Figure 6: Von Mises Stress Analysis of Rolling Mill Housing before optimization

The above Fig.6 shows Von Mises Stress Acting on Rolling Mill Housing. From the above fig. the red portion shows the maximum stress. So it is clear that the maximum stress acting on Housing is at the Nut Rest Diameter Because of that housing bends inwards transversely and tenses outwards in longitudinal direction.

2. Strain Analysis

The above Fig.7 shows Von Mises Strain Acting on Rolling Mill Housing. From the above fig. the red portion shows the maximum strain.

3. Deformation

The above Fig. 8 shows deformation of the Rolling Mill Housing it is clear that the load imparts a tensile stress to the vertical pillars, a compressive stress to the screw and causes bending of top and bottom bridges. Because of the bending of the bridges the posts will tend to bend inwards. So the red and blue portion shows the max. deformation.

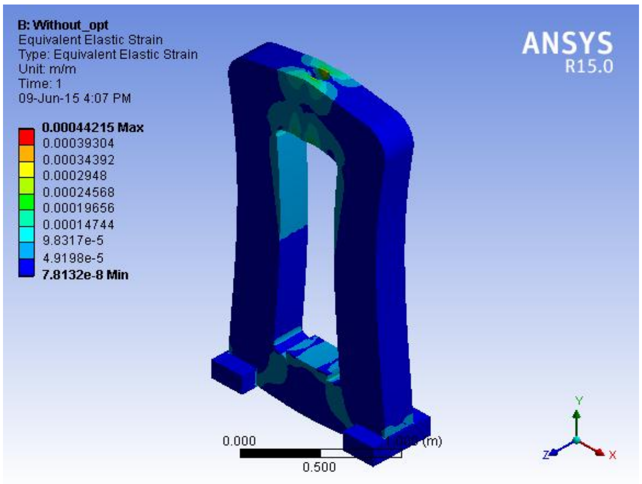

Figure 7: Von Mises Strain of Rolling Mill Housing before optimization

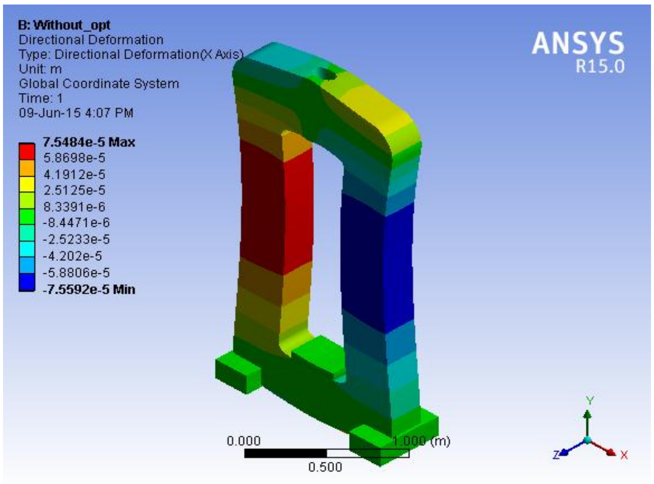

Figure 8: Deformation of Rolling Mill Housing before optimization

The above fig. 5.3 shows deformation of the Rolling Mill Housing it is clear that the load imparts a tensile stress to the vertical pillars, a compressive stress to the screw and causes bending of top and bottom bridges. Because of the bending of the bridges the posts will tend to bend inwards. So the red and blue portion shows the max. deformation.

B. Prototype of Rolling Mill Housing after optimization

From the above software results we come to know that the last yellow mark shows the optimized result and the software generates the optimized Prototype of Rolling Mill Housing as shown in fig.9.

1. Optimized value of housing thickness = 345mm
2. Optimized value of Extrude thickness = 235mm
3. Optimized value of Outer reinforcement = 392mm
4. Optimized value of Nut rest diameter = 197mm

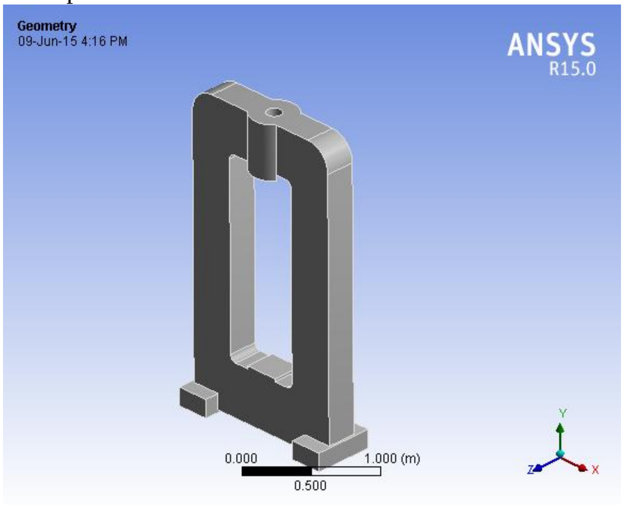

Figure 9: Prototype of Rolling Mill Housing after Optimization

C. Analysis of Rolling Mill Housing after optimization

1. Stress Analysis:

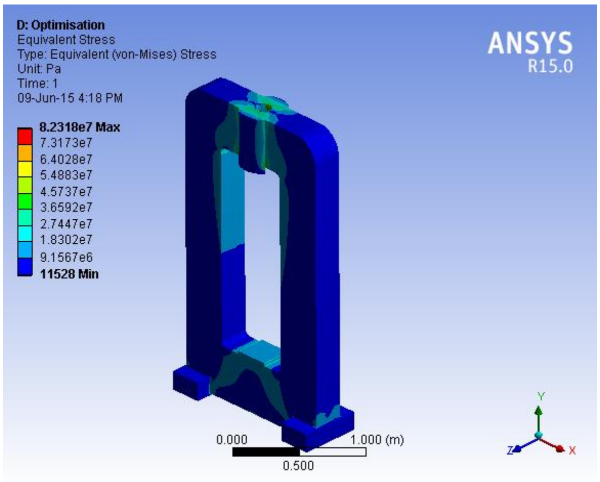

Figure 10: Von Mises Stress Analysis after Optimization

The above Fig.10 shows Von Mises Stress Acting on Rolling Mill Housing after optimization. From the above fig. the red portion shows the maximum stress. So it is clear that the maximum stress acting on Housing is at the Nut Rest Diameter is gets reduced due to increase of its Diameter. So there is no bend in transverse and longitudinal direction of housing.

2. Strain Analysis:

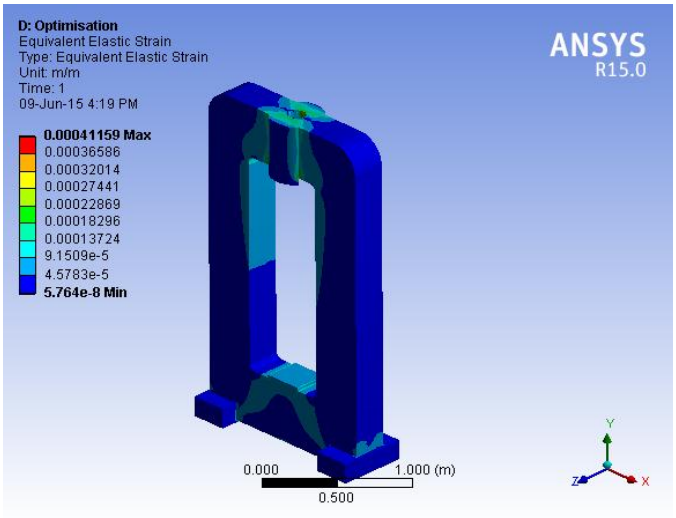

Figure 11: Von Mises Strain Analysis after Optimization

The above Fig.11 shows Von Mises Strain Acting on Rolling Mill Housing after optimization. From the above fig. the red portion shows the maximum strain and it is reduced by optimizing the nut rest diameter.

3. Deformation:

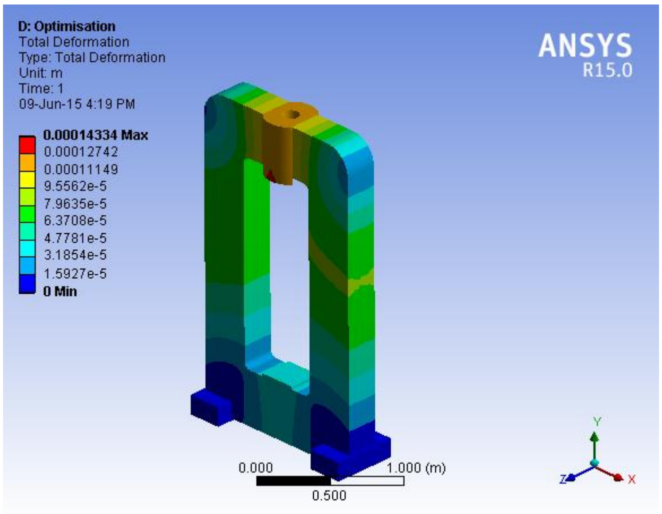

Figure 12: Deformation of Optimized Rolling Mill Housing

The above fig. 12 shows deformation of the Rolling Mill Housing after optimization it is clear that the load imparts a tensile stress to the vertical pillars, a compressive stress to the screw and causes bending of top and bottom bridges and it get reduced after optimization.

VII. COMPARISONS OF VALUES OF STRESSES AND STRAINS BEFORE AND AFTER OPTIMIZATION

It is clear from comparison of the stresses in Rolling Mill Housing before and after the optimization from the graph (Fig. 13) that the stresses after optimization have considerably been reduced under the given boundary conditions.

TABLE II
COMPARISONS OF VALUES OF STRESSES BEFORE AND AFTER OPTIMIZATION

Maximum Stress at Different Locations of Rolling Mill Housing (Mpa)		
Different Locations of Rolling Mill Housing	**Before Optimization (Figure 6)**	**After Optimization (Figure 10)**
1	9.83	9.15
2	19.66	18.30
3	29.44	27.44
4	39.31	36.59
5	49.13	45.73
6	58.95	54.88
7	68.78	64.02
8	78.60	73.17
9	88.43	82.31

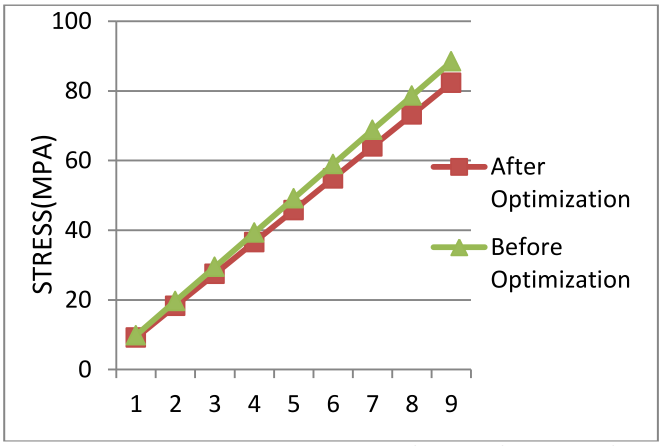

Figure 13: Graphs Showing the Comparisons of Values of Stresses Before and After Optimization

Because the steepness of the curve after optimization have been reduced and are within the recommended stresses.

TABLE III
COMPARISONS OF VALUES OF STRAINS BEFORE AND AFTER OPTIMIZATION

Maximum Strain (µs) at Different Locations of Rolling Mill Housing		
Different Locations of Rolling Mill Housing	**Before Optimization (Figure 7)**	**After Optimization (Figure 11)**
1	49.19	9.15
2	98.31	18.30
3	147.44	27.44
4	196.56	36.59
5	245.68	45.73
6	294.8	54.88
7	343.92	64.02
8	393.04	73.31
9	442.15	82.31

It is clear from comparison of the Strains in Rolling Mill Housing before and after the optimization from the graph (Fig.14) that the Strains after optimization have considerably been reduced under the given boundary conditions because the

Steepness of the curve after optimization have been red.

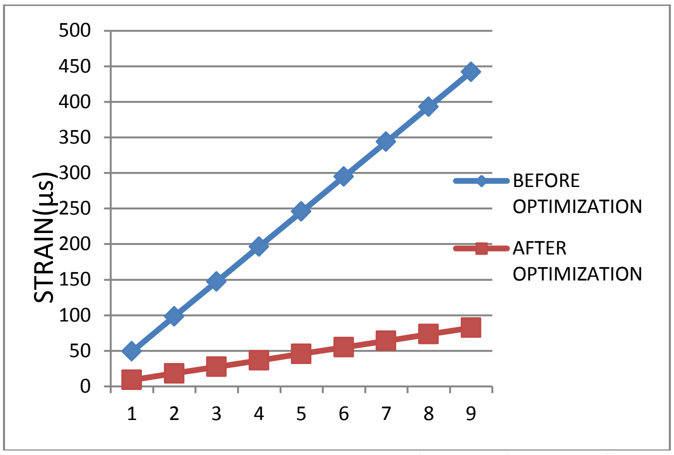

Figure 14: Graphs Showing the Comparisons of Values of Strains Before and After Optimization

VIII. COMPARISON OF DIMENSIONS BEFORE AND AFTER OPTIMIZATION

TABLE IV
COMPARISONS OF DIMENSIONS BEFORE AND AFTER OPTIMIZATION

Parameters	Before Optimization (mm)	After optimization (mm)
Housing Thickness	375	345
Extrude Thickness	250	235
Nut rest diameter	175	197
Outer reinforcement	380	392

The stresses have decreased and are more uniform than the earlier ones. Although the weight of the housing has decreases by about 223 kg, i.e. a decrease of 10.5% but the decrease in the stresses will ensure that no plastic deformation will take place even if the load increases by 28%. Since the values of the optimization variables are within control limits therefore design of Rolling Mill Housing has been optimized as shown in table IV.

CONCLUSION

By simulation of the actual housing model on the software it was revealed that the beam of the housing experienced higher stresses at the place where nut of the housing screwed is nested in the beam. Analysis showed that beefing up of the beam at the place of the hole reduced the maximum stresses substantially. There is reduction of strain of housing for better gauge control as well as deformation.

ACKNOWLEDGEMENT

I am greatly indebted to professors and lecturers of Department of Mechanical Engineering, S.N.D. College of Engineering, Yeola, without whose advice and guidance this work would have never been possible. I am indebted to Department of Mechanical Engineering for giving me an opportunity to learn and do this paper work. I once again extend my sincere thanks to the entire college for all those who directly or indirectly involved in this work.

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