MODELLING AND FEA OF HOUSINGLESS STAND HOT ROLLING MILL FOR PRODUCTION OF TMT STEEL BAR

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ABSTRACT

Rolling is described as a manner wherein steel is fashioned through a couple of revolving rolls with simple or grooved barrels. The steel modifications its form steadily all through the length, wherein it's far in touch with the 2 rolls. Rolling is a first-rate and a maximum extensively used mechanical running technique.

The present work entails the optimization of Rolling Mill Housings layout for rigidity, to manipulate the deflection of the housing for higher gage manage of the cloth being rolled. The Housing pressure distribution has been analyzed in the use of evaluation software program CATIA from which most static pressure at crucial regions had been calculated. Structural conduct of housing beneath the given loading and boundary situations, the use of an analytical version could be very difficult.

Therefore, 3-D strong version changed into selected with the intention to are expecting the pressure and pressure reaction detail. We have made a prototype of Rolling Mill Housing of optimized layout of 1:10 scale in order to affirm our outcomes which have been given via way of means of the evaluation of Rolling Mill Housing on evaluation software program.

Keywords: CAE, Rolling Mills, CATIA, Analysis.

1. INTRODUCTION

In metal-working, rolling is metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness, to make the thickness uniform, and/or to impart a desired mechanical property. This thesis deals with the analysis of Rolling Mill Housing. Brief overviews of the basics related toanalysis of Rolling Mill Housing are given in this chapter.

Hot and Cold Rolling

Hot rolling

Hot rolling is a metalworking process that occurs above the recrystallization temperature of the material. After the grains deform during processing, they recrystallize, which maintains an equiaxed microstructure and prevents the metal from work hardening. The starting material is usually large pieces of metal, like semi-finished casting products, such as slabs, blooms, and billets. If these products came from a continuous casting operation the products are usually fed directly into the rolling mills at the proper temperature. In smaller operations, the material starts at room temperature and must be heated. This is done in a gas- or oil-fired soaking pit for larger workpieces; for smaller workpieces, induction heating is used. As the material is worked, the temperature must be monitored to make sure it remains above the recrystallization temperature. To maintain a safety factor a finishing temperature is defined above the recrystallization temperature; this is usually 50 to 100 °C (90 to 180 °F) above the recrystallization temperature. If the temperature does drop below this temperature the material must be re-heated before more hot rolling.

Shape rolling design

Rolling mills are often divided into roughing, intermediate and finishing rolling cages. During shape rolling, an initial billet (round or square) with edge of diameter typically ranging between 100–140 mm is continuously deformed to produce a certain finished product with smaller cross section dimension and geometry. Different sequences can be adopted to produce a certain final product starting from a given billet. Cold Rolling

Cold rolling occurs with the metal below its recrystallization temperature (usually at room temperature), which increases the strength via strain hardening up to 20%. It also improves the surface finish and holds tighter tolerances. Commonly cold-rolled products include sheets, strips, bars, and rods; these products are usually smaller than the same products that are hot rolled. Because of the smaller size of the workpieces and their greater strength, as compared to hot rolled stock, four-high or cluster mills are used. Cold rolling cannot reduce the thickness of a workpiece as much as hot rolling in a single pass.

Classification of Rolling Mills

Rolling mills are generally classified according to their product or their layout or temperature andare specified by the number of rolls in each stand.

On The Basis of the Product

- Roughing or cogging mills: it includes mills producing semi products like blooms, slabs, billets,and tube billets.
- Section mills: it includes mills producing rails, heavy, medium and light structural sections,round and square bars and wire rods, strips.
- Plate and sheet mills including wide and medium strip mills.
- Tube mills including plants for production of both seamless and welded tubes.
- Special mills for production of machine parts like wheel tyres, balls, gears, periodic profiles

On The Basis of Temperature

- Hot Rolling: Rolling of metal is carried out at temperature above the recrystalizationtemperature. For example: Roughing, billet, merchant and tube rolling mills.
- Cold Rolling: Rolling of metal is carried out at temperature below the recrystalizationtemperature. For example: Sheet and tube rolling mills.On The Basis of Layout of Stands in the Mills
- Linear mill: in this a number of stands are placed in one line driven through each other by asingle motor. The stands may be in the same line or in two or more such lines.
- Open continuous mills: in such a mill a number of stands may be placed in tandem. However rolling is carried in single stand at a time.
- Continuous mills: in this metal is rolled simultaneously in more than one stand. This is the most modern type of mill, which gives the largest possible speed and output, and occupies the least space.

On The Basis of Number of Rolls

According to this the stand may be termed as two-high, four-high, twelve-high or twenty-high.

Mills having six or more rolls are generally termed as cluster mills.

Types of Housings

- **Closed Type Housing**: One piece cast housings of simple form (rectangular section) are used forheavy roughing mills, e.g. blooming, slabbing, billet and plate mills. These are called 'Closed Type Housing'.

- **Open Type Housing**: The housings which have a removable top for easy removal of rolls are called 'Open Type Housing'. When the housings have to withstand large horizontal forces, the pillars are made with an I-section. The integrally cast construction presents many difficulties in manufacturing. In such case the housing can be made up of two forged pillars bolted to two cast cross beams.

Experimental Methods for Determination of Stress

There are a number of methods that are used for finding the value of stress in a part. Some of the methods that are most commonly used are briefly discussed below.

Strain Gauges: A strain gauge may be defined as any instrument or device that is employed to measure the linear deformation over a given gauge length, occurring in the material of a structure during the loading of the structure. This definition is quite broad; in fact it covers the range of instruments includedbetween the linear scale and the precise optical and electrical gauges now available. The many types of strain gauges available are quite varied, both in application and in the principles involved in their magnification systems.

Numerical Methods for Analysis

In engineering analysis a theoretical model was the first choice for researchers and scientists because of accurate and unique solution. But in pragmatic design problem, the theoretical model was scarcely utilized to predict physical response because of the complex geometrical design and path. Therefore powerful numerical method was introduced to engineers to overcome difficulty.

Some of the numerical approaches are

- Finite difference method.
- Finite volume method.
- Boundary element method.
- Finite element method.

CATIA Overview

CATIA is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: Static/Dynamic Structural Analysis (both linear and non-linear), heat transfer and fluid problems, as well as electromagnetic problems.

Finite element analysis software enables engineers to perform the following tasks:

- Build computer models or transfer CAD models of structures, products, components, or systems.
- Apply operating loads or other design performance conditions.
- Study the physical responses, such as stress levels, temperature distributions.
- Optimize a design early in the development process to reduce production costs.

Do prototype testing in environments where it otherwise would be undesirable or impossible.

2. LITERATURE REVIEW

Remn-Min Guo [1] generated a method by combining the Goodman line technique, and the cumulative damage method to estimate the housing life. A method was also developed to estimate the upper and lower bounds of the housing life using the average equivalent stress. These methods can be extensively used in all machine elements subjected to cyclic loads.

G. P. Steven [2] aimed at exploring the application of the evolutionary structural optimization method to such multicriteria design problems. To evaluate the overall effect on the design of material variation due to these two optimality criteria, a weighting scheme was adopted, whereby the weight factors emphasize and/or balance the stiffness and stress criteria.

J. H. Rong[3] proposed an improved method for evolutionary structural optimization against buckling for maximizing the critical buckling load of a structure of constant weight. First, based on the formulations of derivatives for eigen-values, the sensitivity numbers of the first eigen-value or the first multiple eigen-values (for closely spaced and repeated eigen-values) were derived by performing avariation operation.

Kurt Maute [4] presented an interactive method for the selection of design criteria and the formulation of optimization problems within a computer aided optimization process of engineering systems. The key component of the proposed method was the formulation of an inverse optimization problem for the purpose of determining the design preferences of the engineer.

Theodore G.ToRidis [5] formulated a general method of elastic-inelastic analysis of rigid frames, which was based on the finite element method, and the concept of initial strain as applied to plastic strains. The analytical expressions obtained in this manner were used as a basis for the development of a general purpose computer program. This program enabled the user to exercise several options corresponding to the static, free vibration, elastic dynamic and plastic dynamic analysis of two and three-dimensional framed structures.

William Prager [6] encountered typical difficulties in the formulation of problems of optimal structural design .For the optimal design of a statically determinate or indeterminate truss of given layout, a method was presented by which necessary and sufficient conditions for global optimality may be derived when an upper bound is prescribed for the compliance of the truss under one or several sets of loads and a lower bound is prescribed for the cross sectional area of each bar.

Rafael Febres [7] discussed a model of the behavior of metallic structures subjected to flexural effects . The model focused on the description of failure due to local buckling. It was assumed that the main inelastic phenomena involved in the process: plasticity and local buckling, could be lumped at inelastic hinges.

K. G. Mahmoud [8] recognized that structural optimization using mathematical programming techniques can be employed efficiently only in conjunction with explicit approximate models. In the work an efficient optimization methodology combining a finite element-based approximate analysis model, a sequential quadratic programming algorithm incorporating an active set strategy and a direct method of design sensitivity analysis was developed.

V. Braibant [9] was focused on the use of optimization techniques in the framework of Computer AidedDesign and Finite Element Methodology. A design model was developed which could be used forstructural sizing as well as for shape design. An essential aspect of the work was sensitivity analysis,which consists of computing derivatives of the functions which define the optimization problem.

M. E. M. El-Sayed [11] presented a method for considering fatigue life requirements in the optimal design of structures. The basic concept was to use the load history data combined with the finite elementstresses of the structure and the material fatigue properties to calculate the fatigue life during the optimization process.

3. ANALYSIS

Concept of Stress and Stress Analysis

Two types of forces that act on a body may be distinguished as internal or external. The internal forces are the reactive forces that are set up in the body due to externally applied forces. The internal forces are numerically equal to the external forces. 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.

CALCULATION OF ROLL LOAD

The Rolling Load in a Rolling Mill can be calculated by the methods used by Tselikov [14].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:

1. For iron rolls approximately

$F = (0.6 \text{ to } 0.8)\, d^2$ (3.1)

2. For carbon steel Rolls

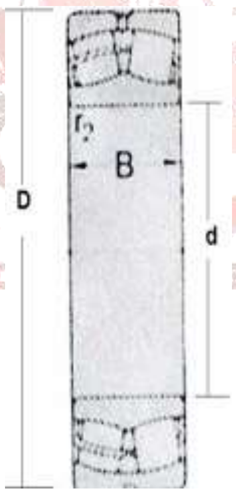
$F = (0.8 \text{ to } 1.0)\, d^2$ (3.2)

3. For Rolls of Chromium Steel (Four high mills)

$F = (1.0 \text{ to } 1.2)\, d^2$ (3.3)

We are making use of four high mills with Chromium Steel Rolls so Roll load is calculated fromthe equation 3.3 i.e. $F = (1.0 \text{ to } 1.2)\, d^2$

Figure 3.1: Spherical Roller Bearing



1) Since each roll neck consists of two bearings 23056 mounted on each roll neck so specificationof bearing used is [15]:
2) **d = diameter of Roll neck bearing = 280 mm**
3) **D = outer diameter = 420 mm**
4) **B = width = 106 mm**
5) **C = Dynamic capacity = 1520000 N**

Therefore $F = (1.0 \text{ to } 1.2)\, d^2$ = (78400 to 94080) (9.81) = (769104 to 922924) N ……… (3.4)

Also the Rolling Load in a Rolling Mill is calculated from the dynamic capacity of the Roll bearings and their service life. In order to achieve a service life of about 3 Lakhs hrs minimum at30 R.P.M the ratio of bearing capacity to load applied can be calculated from life calculation chart as shown in figure 3.2.

Therefore C/P = 6.5

Therefore P = 1520000/6.5 = 233 KN

We are making use of four bearings so

Total load is P * 4 = 930 KN (appr.) (3.5)

Comparing equations 3.4 and 3.5 we make use of 900 KN of Rolling load in our Housing design.This Rolling Load of 900 KN is transferred from the top chock to Housing which has spherical seating on the screw and through lower chock to Housing because it rests on a spherical liner as shown in figure 3.3

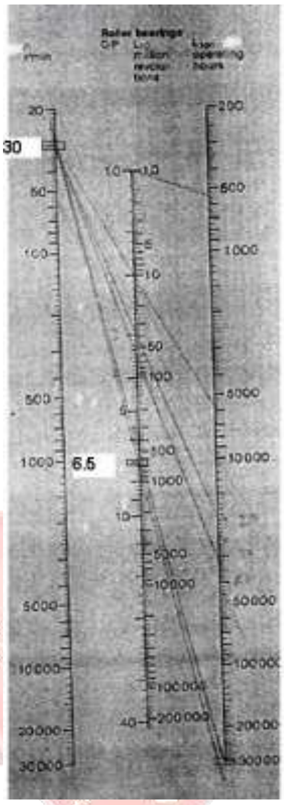
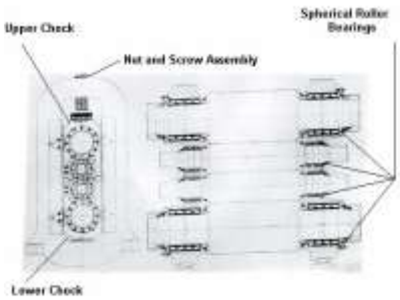


Figure 3.2: Life Calculation Chart of Roller Bearing

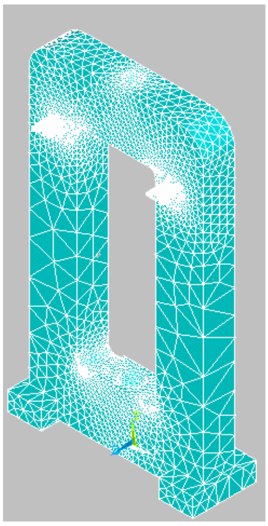
Figure 3.3: Rolling Mill showing the load transferred from the Rolls to the Housing

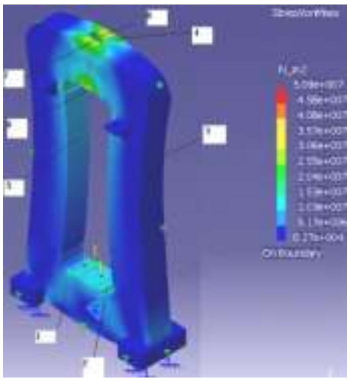


4. RESULTS AND DISCUSSION

Optimization procedure:

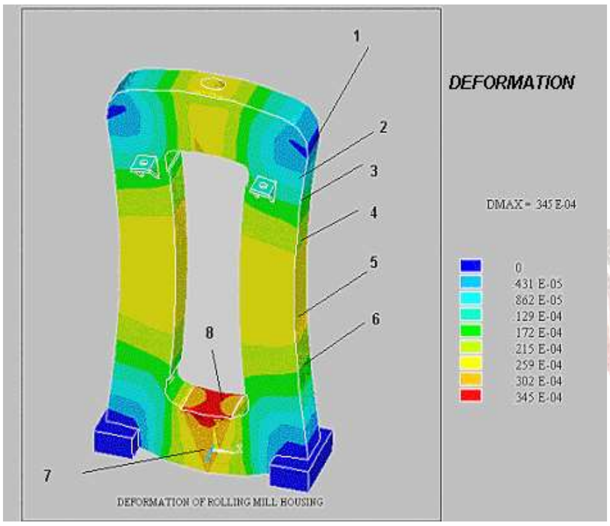
Design optimization is a technique that seeks to optimize the design in terms of strength, rigidity and weight. By “optimum design,” we mean a design that meets all specified requirements but with a minimum expense of certain factors such as weight, surface area, volume, stress, cost, etc.





6) Figure 4.1: Meshing of Rolling Mill Housing

Figure 4.2: Von Mises Stress Analysis of Rolling Mill Housing before optimization



7) Figure 4.3: Deformation of Rolling Mill Housing before optimization

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 4.6.

   Where D1 = diameter of uniform circular cross section added around the nut in mmD2 = diameter of hole where nut rests in mm

   350< D1 < 480

   175 < D2 < 240

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 (deflection).

30 – 40 N/mm^2 is the recommended stresses in the housing which should be as uniform over thecross section so as to make it balanced housing design.

Therefore 30 < < 42 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 < 0.01 mm

3. **Objective Function:** It is the dependent variable that we are attempting to minimize. It should bea 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

The design variables, state variables and objective function are collectively referred as the optimization variables. After optimization the values of Design variables, State variables so thatobjective function is obtained keeping in mind the constraints imposed on the optimization of Rolling Mill Housing are:

D1 = 400 mm

D2 = 200 mm

The stresses have decreased and are more uniform than the earlier ones. Although the weight of thehousing has increases by about 70 kg, i.e. an increase of 3.5% but the decrease in the stresses will ensure that no plastic deformation will take place even if the load increases by 36%.

Since the values of the optimization variables are within control limits therefore design of RollingMill Housing has been optimized.

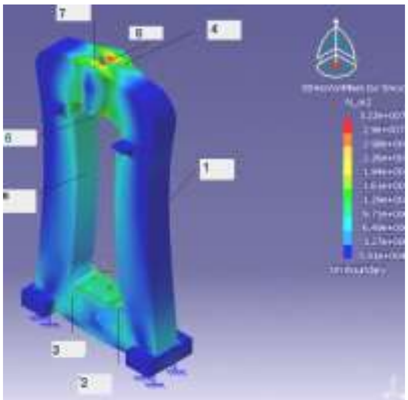


Figure 4.4: Von Mises Stress Anlysis after optimization

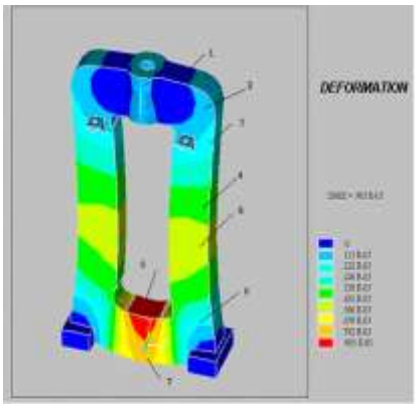


Figure 4.5: Deformation of optimized rolling housing

Table 4.1: Software Results

MAXIMUM STRESS (MPa) AT DIFFERENT LOCATIONS OF ROLLING MILL HOUSING		
Different Locations of Rolling Mill Housing	Before Optimization	After Optimization
1	0.0827	0.0591
2	5.17	6.49
3	20.4	9.71
4	25.5	12.9
5	30.6	16.1
6	35.7	25.8
7	45.8	29
8	50.9	32.2

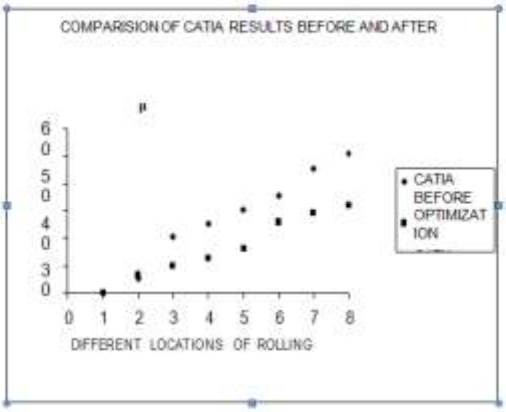


Figure 4.6: Graphs Showing the Comparisons of Values of Stresses Before and AfterOptimization

5. EXPERIMENTAL SETUP

In our experiment we have applied load on our prototype of rolling mill housing by setting it on the universal testing machine. In our experiment we have cemented strain gauges at critical points and after calibrating our strain gauges we have find out strains at these points under different loads varying from 1-10 kN.

Figure 5.1: Experimental Setup

6. CONCLUSIONS AND FUTURE SCOPE

This chapter gives the conclusions as obtained from the results of the analysis of Rolling Mill Housing using finite element technique.

Conclusions

By simulation of the actual housing model on the software it was reveled 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. The dimensions of the beam were changed such that the minimum thickness of the material at the hole is 100mm. then a model reduced 1:10 scale with modified dimensions was fabricated and strain gauge testing revealed the close correlation between actual stresses measured and simulated stresses from the software.

Future Scope

Further work can be done so that housing experiences the same stresses at all sections which then becalled a balanced housing. Further dimensions of the balanced housing can be proposed with respect of the diameter of nut and screw so that the housing failure does not take place in under loading.

REFERENCES

[1] SDRC report project number 17140, 'Final Report on ARMCO Mill StandEvaluation', June1990.

[2] G. P. Steven, 'Multicriteria optimization that minimizes maximum stress and maximizes stiffness', Computers & Structures Volume 80, Issues 27-30 , November 2002, Pages 2433-2448

[3] J. H. Rong, 'An improved method for evolutionary structural optimization against buckling'Computers & Structures ,Volume 79, Issue 3 , January 2001, Pages 253-263.

[4] Kurt Maute, 'An interactive method for the selection of design criteria and the formulation ofoptimization problems in computer aided optimal design', Computers Volume 82, Issue1, January 2004, Pages 71-79.

[5] Theodore G. ToRidis, 'Computer analysis of rigid frames, Computers', Volume 1, Issues 1-2 , August 1971, Pages 193-221.

[6] William Prager ,'Conditions for structural optimality', Computers & Structures',Volume 2, Issues 5-6 , 1972, Pages 833-840

[7] Rafael Febres, 'Modeling of local buckling in tubular steel frames subjected to cyclic loading' , Computers & Structures ,Volume 81, Issues 22-23 ,September 2003.

[8] K. G. Mahmoud, 'An efficient approach to structural optimization ' Computers & Structures olume 64, Issues 1-4, July-August 1997,Pages 97-112 Computational Structures Technology

[9] V. Braibant, 'Optimization techniques: Synthesis of design and analysis', Finite Elements in Analysis and Design Volume 3, Issue 1 , April 1987, Pages 57-78

[10] Yunliang Ding, 'Multilevel optimization of frames with beams including buckling constraints', Computers Volume, 1989, Pages 249-261

[11] M. E. M. El-Sayed, 'Structural optimization with fatigue life constraints', Engineering Fracture Mechanics Volume 37, Issue 6 , 1990, Pages 1149-1156

[12] M. Haririan, 'Use of ADINA for design optimization of nonlinear structures', Computers & Structures Volume 26, Issues 1-2 , 1987, Pages 123-133

[13] Michael A. Vehmeier, 'A new method for simultaneous structural/control optimization' Mathematical and Computer Modeling Volume 14 , 1990, Pages 248-253

[14] Tselikov, A.I., Theory of calculation of forces in Rolling Mills 1962.

[15] SAE Bearings manual.