Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **11(2),** 33-37, May **(2022)** *Res. J. Engineering Sci.*

Short Review

Analysis of roll chock for two-high rolling mill using ANSYS

Laxmikant Patil* and Mukesh Dubey
Department of Mechanical Engineering, Bhilai Institute of Technology, Durg, Dist. Durg, Chhattisgarh– 491001, India
laxmikantpatil996@gmail.com

Available online at: www.isca.in, www.isca.me
Received 3rd September 2021, revised 19th April 2022, accepted 25th May 2022

Abstract

In a rolling mill the main components are deforming rolls, roll bearings and roll bearing housings. When the rolling is in process the reactive forces exerted by the rolls is transmitted to the bearings and simultaneously to the bearing housings. The bearing housing is also known as roll chock. In a rolling mill, the roll chock is a vital component since slight deformation of the chock body will result in defects in the products being rolled. This problem can be solved using CAE tools. A rolling mill chock made up of gray cast iron was selected and its 3D CAD modelling was done using ANSYS SPACECLAIM software to perform the static structural analysis under specified bearing loading condition and the results for maximum principal stress and equivalent stress were obtained using ANSYS 2021 software.

Keywords: Cold rolling**,** roll chock, ANSYS, static structural analysis, bearing load, maximum principal stress, equivalent stress.

Introduction

The rolling mill consists of bearing at the roll necks which are placed in bearing housings known as chocks. The chock is a component that experiences highest magnitude of stresses. Due to deformation produced the chock may deform such that further production of rolled products may get halted and will result in financial losses. These losses will be much higher than the cost required for replacement of chocks[1]. Therefore, it becomes necessary for a manufacturer to determine the stresses being developed and their effects on the chock and rolling process to predict the chances and causes of failure of rolling mill in the future along with the damage the components may develop. The rolling mill components must have the required stiffness to transmit the vibrations and sufficient strength to sustain such forces[2].

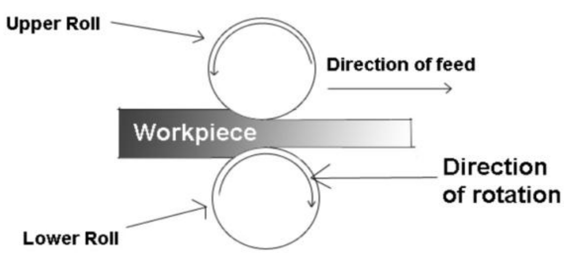

Figure-1: Two-high rolling mill[3].

There are a number of techniques are available in order to process bulk metal forming such as rolling, forging, extrusion, casting and drawing. One of the bulk metal forming techniques is roll forming. Roll forming is a type of metal forming technique in which metals & alloys are deformed plastically in continuous manner to produce semi-finished or finished product by passing them between successive pair of rolls which may be circular or contoured in shape. The process is performed until the desired section of input is achieved. Deformation of metal takes place when the deforming force exerted by the rollers on the input work piece exceeds the material's yield strength at locations where strain hardening takes place. Lubrication between roll and the rolled product plays an important role and is responsible for performance of the work rolls[4].

During rolling the increase in length of input form is the result of decrease in thickness with negligible increase in its width. For successful roll forming the material selected for processing must have low yield strength and the level of ductility must be high to make the deformation easier.

Rolling is one of the most important metals forming function in metal industries especially if steel and aluminum is used. It is a fabrication process in which the metal is made to pass through pairs of rollers. The preliminary process of cold rolling always starts with hot rolling. The casted steel is heated at high temperatures typically above its re-crystallization temperature (around 900°C). This increase in temperature results in increase in ductility of metal stock. Cold rolling starts with metal stock having temperature below its re-crystallization temperature.

The deformation produced is the result of relieving stress leading to higher yield strength, hardness. The result of metal properties being harder than before happens due to creation of flaws and reorientation of grains in crystal lattice structure of metal leading to hardening of microstructure. The deflections or dimensional deviations need to be reduced which can be done by reducing the deflections produced on the entire rolling mill stand. The prime sources of deflection are deflection due to mechanism of roll positioning, deflection in rolling mill housing and deflections due to roll forming[5]. There are other reasons for deformation of rolls during rolling process which includes conditions such as local overload, fatigue, spalling and roll neck breaking due to torsion[6].

Different types of rolling mills are available that vary in sizes and capacities. These mills vary on the basis of material cross-section, temperature, rolling speed and roll configurations such as reversing, semi-continuous etc. the fundamental process of rolling remains same in all the cases. The roll stands are used for fitting the deforming rolls. The roll stands according to their configuration consists of number of rolls from two to multiple rolls set, which depends as per requirement of rolling mill type being used. Now the problem of friction and forces being produced arises.

For this purpose, roll bearings are used. The roll bearing acts as a friction reducing agent and also as a supporting element for the rolls and reduce the energy losses as well. Roll chock is the housing of the roll bearing. It is the fundamental part of the roll stand. The roll chock assembly is supported as well as enclosed by roll stand housing. The roll chock helps in prevention of scales produced during roll forming from entering the roll neck bearings.

The roll chock's prime function in a rolling mill is to locate and support the roll neck bearings. In order to mount the roll neck accurately, the roll neck bearings are used in vertical and horizontal plane.

Figure-2: Rolling mill used for shaping thin strip into channel.

The load experienced by the rolls is directly transmitted to roll neck bearings via chock. The chock accommodates bearings such as oil film, anti-friction, slider etc. types. The installation of bearing must be done precisely and accurately for which the area of chock in direct contact with bearing must have smooth finish with negligible tolerance fit. In modern times, the use of automatic gauge control systems is widely adopted. This facilitates higher levels of accuracy that is desired in rolled product[7]. Roll chock is a component that is stressed the most in a rolling mill. It is a general idea that huge production losses occur due to failure of chock. Hence to design the chock, the maximum load acting on the chock must be estimated correctly. Also, cyclic loadings can cause fatigue failure condition in chock body. In this paper, an attempt has been made to determine the magnitude of forces that are exerted to the chock in order to understand and evaluate the design of chock[8]. The primary idea is to save the cost and time required for chock replacement. The stress analysis data gives a clear picture of area and need of optimizing the chock[9].

Methodology

In order to identify the causes of failure it is important to know about the forces that are responsible for failure of chock. For this purpose, the static structural analysis of the chock is done. By performing the analysis, the values of total deformation produced, maximum principal stress and equivalent stress (von-mises) are obtained. Using the output of structural analysis, the forces' magnitude and their corresponding effect on the chock can be interpreted.

For this, the first and foremost requirement is a CAD model of the component on which the analysis has to be performed. Along with it analysis software is also needed. So, to fulfill these requirements, ANSYS 2021 R1 package is used which provides solid modelling software named ANSYS SPACECLAIM and analysis software named ANSYS WORKBENCH.

The rolling mill considered for the chock is of Two-high roll configuration (Figure-1) in which strip of width 65mm having thickness of 22 gauge is used. After rolling the thickness is reduced to 20 gauge. For analysis purpose the following given data as in Table-1 is used:

Table-1: Detailed specifications of rolling mill.

Description	Details
Roll diameter	100 mm
Strip thickness (initial)	22 gauge
Strip thickness (final)	20 gauge
Roll rotation speed (rpm)	22
Material of chock	Gray cast iron

The rolls exert load on the frame directly. This load being transmitted is calculated by using T-selikov theory. According to the T-selikov theory the force experienced by the roll chock is equal to the force exerted by the roll via roll neck bearings[10].

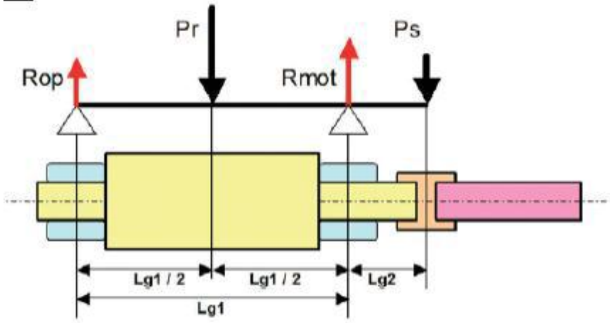

Figure-3: Free body diagram of roll chock assembly[9].

The computational modeling using FEM is done to interpret the development and magnitude of stresses. In this method the five steps are followed which are explained as following:

Step 1. Modeling of geometry: In this analysis the solid modelling is done using ANSYS Space Claim 2021 software.

Step 2. Meshing: Fragmenting the model into tiny networks of nodes and elements is called meshing. It is done for applying FEA in the geometrical section which is the CAD model of the roll chock. Table-2 represents the meshing details of the roll chock model.

Table-2: Meshing details of roll chock.

Mesh smoothing	High
Element size	0.002 m
Span angle center	Fine
Total number of nodes	32177
Total number of elements	18217

The CAD model of the chock with meshing is shown in Figure-4 below.

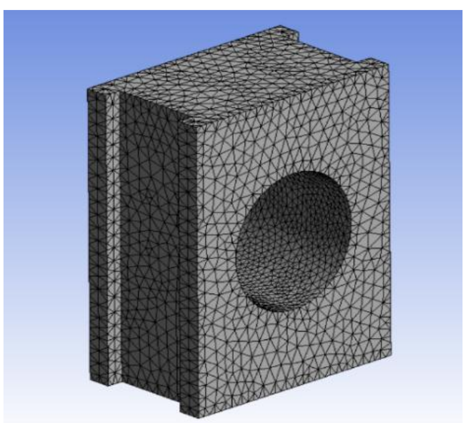

Figure-4: Roll chock model with meshing.

Step-3. Material properties specifications: In this analysis, the material of chock is selected as gray cast iron having the properties enlisted in Table-3 below:

Table-3: Mechanical properties of gray cast iron.

Property	Value (units)
Density	7250 Kg/m^3
Young's modulus of elasticity	130 GPA
Poisson's ratio	0.26
Ultimate tensile strength	450 MPA

Step 4. Specification of boundary, initial and loading condition: The surfaces that have no degrees of freedom are constraint. The roll load acts on the chock via bearing. Figure-5 represents the application of fixed supports (constraint) condition on the roll chock.

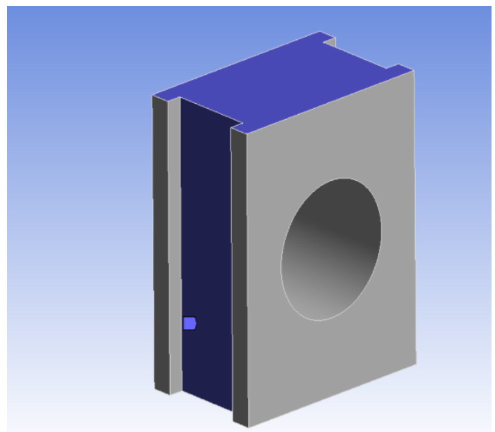

Figure-5: Fixed supports applied to the chock model.

In this case the rolls are made up of low carbon steel. In order to calculate the roll load the commonly used Tselikov theory is considered[11]. According to this theory the forces acting in the housing post (chock) and on the roll neck are identical. The roll load is calculated by the given conditions as in Table-4 below.

Table-4: Roll load of different roll material.

Material	Roll Load (N)
Iron rolls	(0.6-0.8) d^2
Carbon steel	(0.8-1.0) d^2
Chromium steel	(1.0-1.2) d^2

Where: d = diameter of roll neck bearing and, d^2= proportionate of roll neck strength (with respect to diameter and length relation).

As per the chock being used for analysis, the material of rolls is medium carbon steel and the roll neck bearing diameter is 32 mm. Therefore, the roll load acting on the chocks is as follows:

$= (0.8\text{-}1.0)\ d^2$

$= (1.0)\ (32)^2$

= 1024 N

Since the system of roll chocks on each of the roll neck act as arrangement of simply supported system, the reaction forces acting at the two opposite ends of the roll get divided into two equal parts. Hence, the bearing load condition is applied in the bore of the roll chock and the bearing load is calculated as 512 N. The maximum magnitude of the reaction force will be at the Y-component (axis).

Step 5. Post processor solutions: After applying the boundary conditions and bearing load condition and running FEA computation is done for the output results. The analysis consists of plotting the following contours: i. Total Deformation: It determines the maximum and minimum deformation produced in the chock body due to the result of forces acting on it. ii. Maximum principal stress: It determines the maximum normal stress that the element of body will experience under the specified loading condition. iii. Equivalent stress (von-mises): It determines the density of distortion energy at a particular point in the system.

Results and discussion

The contour plots obtained were studied and it was found that the stresses induced were very low in magnitude and could be eliminated[12]. The deformation produced on the chock body is very low. Hence the data obtained by static structural analysis is enough for analysis of roll chock[13]. The output of ANSYS solver for maximum principal stress and equivalent (von-Mises) stress analysis are as follows:

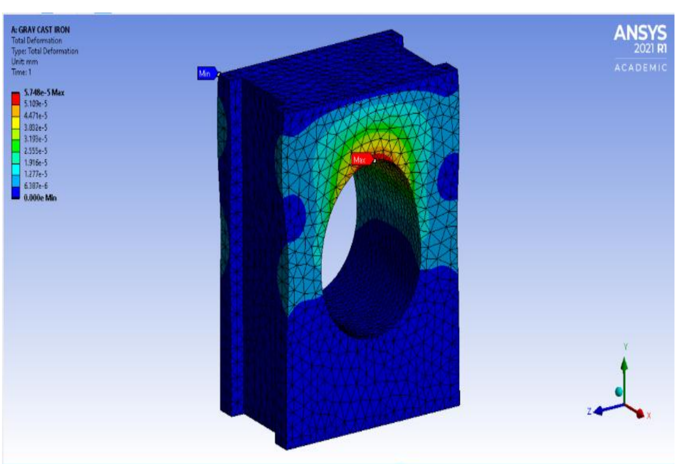

Figure-6: Total deformation produced in the chock body.

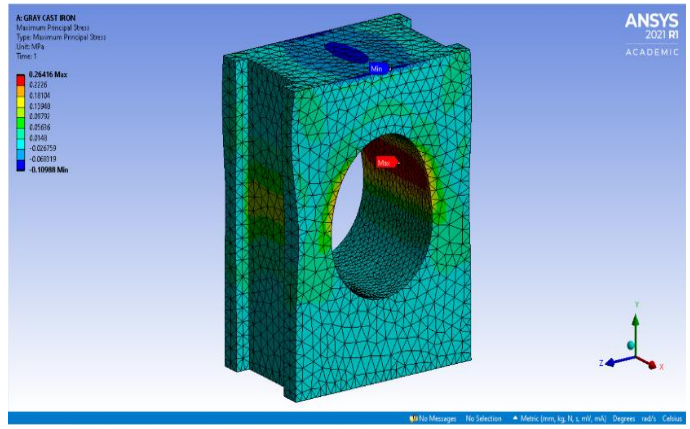

Figure-7: Maximum principal stress produced in the chock body.

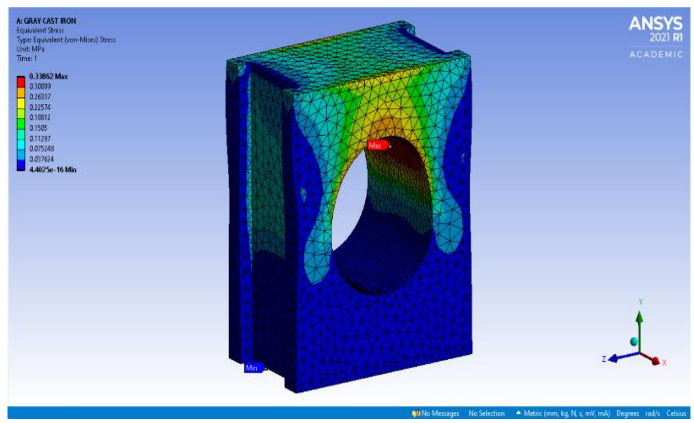

Figure-8: Equivalent (von-Mises) stress produced in the chock body.

The output of the static structural analysis is represented in the Table below:

Table-5: Result data of ANSYS solver.

Total Deformation (mm)	Maximum Principal Stress (MPa)	Equivalent Stress (von-mises) (MPa)
5.748 e-5 (max)	0.26416 (max)	0.33862 (max)
5.109 e-5	0.22260	0.30099
4.471 e-5	0.18104	0.26337
3.832 e-5	0.13948	0.22574
2.555 e-5	0.09792	0.18812
1.916 e-5	0.05636	0.15050
6.387 e-6	0.01480	0.11287
0.00 (min)	-0.10988 (min)	4.4025 e-16 (min)

Conclusion

From the static structural analysis performed using Ansys it was found that the total deformation (maximum) produced in the chock body is 5.748 e-5 mm, maximum principal stress is 0.26416MPa and the equivalent (von-Mises) stress is 0.33862 MPa for gray cast iron. Therefore, the selection of material of chock must be done such that the material can withstand the deformation produced within the chock body due to application of loads and prevent failure of the chock. Further analysis of the chock can be done to optimize the resulting stress and deformation, cost and the topology of the chock to reduce its weight as well.

Acknowledgement

I am sincerely thankful to all those who have helped to complete the project with the required professional skills, technical guidance and assistance with scientific research as well.

References

1. William L. Roberts (1978). Cold Rolling of Steel, Manufacturing Engineering and Materials Processing Book 2. Marcel Dekker, Inc., New York and Basel, pp 1-808, ISBN 978-0824767808
2. Alan Gamett Davenport (1960). The Application of Statistical Concept to The Wind Loading of Structures. *Proceedings of the Institution of Civil Engineers*, 19(4), 449-472.
3. Mechanical Walkins (2021). Types of Rolling mills – With detailed information. Two-high rolling mill. http://www.mechanicalwalkins.com/types-of-rolling-mills-with-detailed-information.Date of access.10th Oct,2021.
4. Anand Nilewar, Sharad Chaudhari and Prafulla Chaudhari (2013). A Study of Lubrication and its Effect on Steel in Cold Rolling Mill: A Review. *VSRD International Journal of Mechanical, Civil and Automobile and Production Engineering*, 3, 87-92.
5. Rohit Yadav and Tanmay Awasthi (2021). Effect of Rolling Process in Formability of Material: A Review. *International Journal of Engineering Research in Current Trends*, 3(4), 47-51.
6. Ravi Goyal, Anurag Joshi and Umesh Gurnani (2015). Review on Cold Rolling Mill Roll Deformation. *International Journal of Science and Technology*, 1, 83-95.
7. Waleed I. Breesam, Khearia A. Mohamad, Mofeed T. Rashid (2020). Simulation Model of Cold Rolling Mill. *Iraqi Journal for Electrical and Electronic Engineering*, 16(1), 72-77.
8. Ginzburg Vladimir B. (1993). High Quality steel rolling theory and Practice. CRC Press, Florida, U.S.A, 1-832, ISBN 9780429097003
9. Firoz U. Pathan and Santosh S. Shelke (2014). Structural analysis of work roll chock and backup roll chock in cold rolling mill. *International Journal of Engineering Research*, 2(1), 47-56.
10. Rafael Ferbes, Pether Inglessis and Julio Florez-Lopez (2003). Modelling of local buckling in tubular steel frames subjected to cyclic loading. *Elsevier Science. Computers & structures*, doi:10.1016/S0045-7949(03)00292-X.
11. A.I. T Selikov and V.V. Smirnov (1965). Rolling Mills. Pergamon Press, Oxford, United Kingdom, pp 1-405. ISBN 13: 9780080102313
12. Steven G.P. (2003). Multicriteria Optimization that minimizes maximum stress and maximizes stiffness. Elsevier Science. *Computers & Structures*, 80(27-30), 2433-2448.
13. William Prager (1972). Conditions for Structural Optimality. *Computers & Structures*, 2(5-6), 833-840. https://doi.org/10.1016/0045-7949(72)90041-7