Design and Development of Two High Cold Rolling Mill

AISHWARYA N. PHARANDE, PRAGATI GHAN AND SHIVAKANYA GAIKWAD

B. Tech. Student, Department of Mechanical Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere - 402103, India.

ABSTRACT

This report details the design and development of two high cold rolling mills for non-ferrous materials. The rolling mill is designed for multiple operations, including strip and rod rolling. The key components of the model such as rolls, housing, bearings, and gears are designed and analysed for stress. The aluminum strip and rod are used to conduct performance trials. This capability reduces machine setup time, investment costs, and space requirements while enabling dual operations with the same rolling force. It enhances efficiency and improves the economic viability of industries using cold rolling mills.

Keywords: Cold rolling mill, Strip Rolling, Rod Rolling, Numerical analysis, Model design.

1. INTRODUCTION

Rolling is a metal forming process where metal is compressed between rotating rollers to reduce its cross-sectional area and increase its length. Due to high production, precise control, and cost efficiency, it is widely used for producing billets, slabs, sheets, and strips. The cold rolling process is preferred for this work, as it is performed below the recrystallization temperature and enhances yield strength, hardness, dimensional accuracy, and surface finish, making it ideal for finishing. Moreover, the two-high roll stand arrangement is used, where both rolls rotate in opposite directions and can be reversed for bidirectional rolling. The roll gap is adjustable by raising or lowering the upper roll, while the lower roll remains fixed. The forces acting on the rolls during rolling are fully transferred to the housing through the adjusting mechanism's nut. The housing must also be checked for stress and rigidity. An open-type housing is used, featuring a removable top for easy roll removal. For high horizontal forces, I-section pillars are used. When integral casting is challenging, the housing can be built with forged pillars bolted to cast crossbeams.

In 2002, Dixit studied rolling mill design, identifying three stages: conceptual, embodiment, and detailed design. Conceptual design focuses on roll arrangements, power requirements, and mechanism selection. Embodiment design transforms concepts into solid forms, defining critical rolling specifications and producing detailed layout drawings. Detailed design involves precise calculations and final drawings, ensuring functional efficiency, space optimization, and cost-effectiveness. In 2004, Pathan and Shelke reviewed rolling mill design procedures, covering various methodologies for determining specifications. They discussed motor power calculations based on process demands and housing design based on roll load calculations. Taheri (2006), estimated rolling pressure and force while analyzing the effects of process parameters like friction coefficient and work material height reduction. Additionally, work by Jiang (2007) shows that the rolling force increases significantly with an increasing friction coefficient. However, the strip profile is improved when the strip edge friction increases.

2. DESIGN OF ROLLING MILL

2.1 Roll Design

In this project, rolls are designed for longitudinal rolling and are categorized into smooth and grooved rolls. Smooth rolls are used for strip rolling and rectangular or square billets, while grooved rolls are used for rod rolling. The EN8 steel is selected as roll material for non-ferrous applications. Where the material properties are: Yield strength is 510N/mm^2, Tensile strength is 650N/mm^2 and Shear strength is 880N/mm^2.

In roll body the most significant stresses are those due to bending only, while for neck both bending and torsional stresses must be considered. The driven end must be strong enough for transmission of rolling torque.

2.1.1 Design calculations

Here some abbreviations used as R=Roll radius, h_1= Inlet thickness of strip, h_2=outlet thickness of strip, μ_m = coefficient of friction.

a) <u>Roll Design</u>

- <u>Roll Radius</u>: $R \geq \frac{h_1 \times \Delta h}{8{\mu_m}^2} \approx 31$ mm
- <u>Roll body</u>: Length of rolling body for sheet

L=70mm< 75mm

- Roll Force: Horizontal projection of arc of control

$L_p = \sqrt{R(h_1 - h_2) - \frac{(h_1 - h_2)}{4}}$ = 5.54mm

Hence, Projected contact area= $b_m \times L_p$ = 277 mm^2

- Rolling Load:

$P = \sigma_0 \times b \times \sqrt{(R \times (\Delta h))}$ = 29.23 KN

- Maximum bending moment: Maximum bending moment is calculated as follows,

Bending stress in the roll: $\sigma = \frac{32M}{\pi D^3}$= 16 N/$mm^2$

- Stresses in roll neck:

Maximum bending stress, and shear stress:

$\sigma = \frac{32M}{\pi D^3}$ = 14.36 N/mm^2, $\tau = \frac{16M}{\pi D^3}$ = 7.18 N/mm^2

b) Design of bearing

The bending stress in the roll neck of length ‘l’ and diameter ‘d’ for a bearing load of ‘F’ is given by,

$F = \pi d^3 \times \frac{\sigma}{16 \times l}$ = 110.17 KN

The bearing pressure P corresponding to it would be

$P = \frac{F}{l \times b}$ = 24.48 N/mm^2

Therefore, selecting the SKF bearing having designation 31308J/QCL7DF.

c) Power requirement

Power is required to operate the rolling mill which is provided by the motor. To decide the specifications of motor to be used power requirement in rolling is calculated as follows.

The torque is given by,

M_t= 2×P×a = 146153.8 N-mm

$$P= \frac{2\pi N M_t}{60\times1000} = 0.73HP$$

Therefore, selecting standard 0.75 HP motor

3. EXPERIMENTAL RESULTS

3.1 Rolling of Aluminum Strip

Table 1 presents observations for an aluminum strip with initial thickness of 1.79mm and a length of 155mm, which is adjusted in the stoppers for proper guiding through the rolls. Where, H1=Initial thickness of strip, H2=Thickness after rolling, L1=Initial length of strip, L2= Length after rolling.

In the first pass the thickness of strip is reduced from 1.79mm to 1.71mm and length is increased to 160mm. The percentage reduction in thickness and length is calculated and plotted in the table below. Rolling load is calculated by using $P = \sigma_0 \times b \times \sqrt{R \times \Delta H}$ and plotted in the table given below.

Table 1. Observations for Aluminum Strip

No. of passes	H_1	H_2	L_1	L_2	% Reduction in Thickness	Increase in Length%	Rolling Load KN
1	1.79	1.7	155	160	4.47	3.22	8.16
2	1.71	1.5	160	175	9.35	9.37	11.76
3	1.55	1.4	175	185	4.52	5.71	7.99
4	1.48	1.3	185	200	7.43	7.50	9.99
5	1.37	1.2	200	212	8.76	5.66	9.94
6	1.25	1.1	212	225	5.60	5.78	7.88
7	1.18	1.0	225	255	9.32	11.76	9.94
8	1.07	0.9	255	270	7.21	5.56	8.21
9	0.99	0.8	270	310	15.15	12.90	11.46
10	0.84	0.7	310	342	8.33	9.36	7.66

3.2 Rolling of Aluminum Rod

The table 2 shows the observations of aluminum rod of 6.35 mm is taken and is passed through the rollers with the help of stoppers for proper guiding of the rods through the roll. After one pass diameter is reduced from 6.35 mm to 6.27 mm. The percentage reduction in diameter and rolling load is calculated and plotted in the table given below,

Table 2 Observations for Aluminum Rod

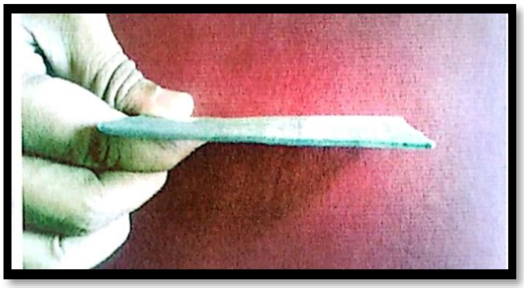
No. of Passes	D_1 (mm)	D_2 (mm)	% Reduction in diameter	Rolling Load (KN)
1	6.35	6.27	1.26	8.26
2	6.27	6.11	2.56	11.69
3	6.11	6.04	1.14	7.73
4	6.04	5.93	1.82	9.69
5	5.93	5.81	2.02	10.12

4. RESULT

Above results are obtained by rolling aluminum strip and rod shows that the reduction obtained for strip as well as rod is approximately 25%-40%.

Fig.1 strip length before rolling

Fig.2 Strip length After rolling



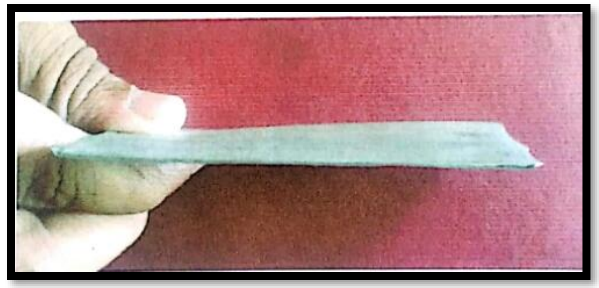


Fig.3 Thickness of strip before rolling

Fig.4 Thickness of strip after rolling

Fig.5 Diameter of Rod before Rolling

Fig.6 Diameter of Rod after Rolling

6. CONCLUSION

In this project a systematic design procedure for laboratory type two-high cold rolling mill for non-ferrous is adapted. A formal methodology of design at conceptual level as well as actual phases of design was used. An optimum roll radius is achieved by considering the required parameters. According to the design a cold rolling mill is manufactured. This rolling mill is functioning in the manufacturing laboratory. The performance of the mill is satisfactory. A design procedure is well recorded. Testing of Aluminum is done safely and result obtained is satisfactory on this two-high laboratory type cold rolling mill.

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