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Cold Rolling Mill for Aluminium Sheet

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Abstract— **Rolling aluminum and its alloys is one of the principle ways of converting cast aluminum slab from the smelters and wrought re-melts into a usable industrial form. By hot rolling, it is possible to reduce a slab of about 600 mm thickness down to plate material with thicknesses of 6 – 250 mm and further down as low as 2 mm for subsequent cold rolling to sheet with thicknesses as low as 0.2 mm. Further rolling can produce the thinnest of foil with a thickness as low as 0.006 mm, approximately one-third the thickness of a human hair.**

Aluminum rolling has very short history of about two centuries. The technology of rolling has matured and stabilized in the last decade or so , with sophistications resulting in higher degree of refinement and richness of final product. Aluminum rolling processes, principles &applications seeks to fill a perceived gap in published information available, which addresses both the theory and practice of aluminum rolling in a comprehensive manner. Although primarily focused on rolling, the book takes a much broader view, covering the entire production processes from ore to finished sheet, plate or foil product the author uses an analytical approach throughout the book and discusses various important aspects of the subject like cold rolling, hot rolling, foil rolling, quality control and technical extensions. The book is used to industrial professionals in production and marketing of finished products. It will also be helpful to the professional students and university,

Who will find a good base to work further in this field.

Index Terms— **Hot rolling, foil gauges, deformation.**

I. Introduction

Lubrication is an essential part of all aluminum fabricating operations, either directly through the metal working processes, or indirectly to lubricate machinery. One of the most important ways of converting aluminum from cast slab/ingot into a usable industrial form is by rolling. The rolling process makes it possible to reduce an ingot of metal, weighing up to 20 tones and measuring 2 m x 8 m x 600 mm thick, to plate gauges (typically 250 mm to 6 mm), sheet gauges (typically 6 mm to 250 µm) and, ultimately, foil gauges (typically 250 µm to 6 µm). In many parts of the industrialized world, approximately 50% of all aluminum alloys used is in the form of flat rolled product and over the last 35 years major changes have taken place in rolling lubricant development and understanding. It is now accepted that the rolling lubricant not only influences mill productivity, but also significantly affects the quality of metal produced. The range of processes involved in the rolling of aluminum and the types of lubricant used are presented in Table.

- As any other metal forming process, rolling can be performed hot (hot rolling) or cold (cold rolling).

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- Most rolling is carried out by hot rolling, owing to the large amount of deformation required.

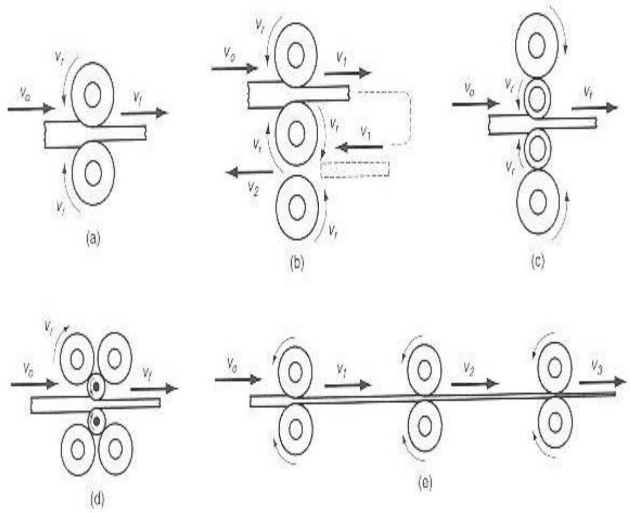
- Hot-rolled metal is generally free of residual stresses, and has isotropic properties. On the other hand, it does not have close dimensional tolerances, and the surface has a characteristic oxide scale.

- Moreover, cold rolled metals are stronger. . In this lab, you will only do cold rolling (at room temperature).[1]

II. ROLLING MILL:

Various rolling mill configurations are available:

1. Two-high rolling mill: consists of two opposing rolls. These rolls may rotate only in one direction (no reversing) or in two directions (reversing).
2. Three-high rolling mill: allows a series of reductions without the need to change the rotational direction of the rolls.
3. Four-high rolling mill:
   Using small rolls reduces power consumption but increases the roll deflection. In this configuration, two small rolls, called working rolls, are used to reduce the power and another two, called backing rolls, are used to provide support to the working rolls.
4. Cluster rolling mill: another configuration that allows smaller working rolls to be used.
5. Tandem rolling mill: series of rolling stands**.**



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SPECIFICATIONS OF ROLLING MILL:

PROCESS	LUBRICANT	TEMPERATURE (°C)	GAUGE RANGE mm
Hot Rolling	Oil-in-water Emulsion	270 - 560	2 – 600
Cold Rolling	Oil-based / Water-based	Ambient – 170	0.15 – 6
Foil Rolling	Oil-based / Water-based	Ambient – 140	0.005 - 0.6

The aluminium cold rolling mill can process the Aluminium coil in thickness of 6-10mm from casters and hot rolling. The proceed materials can be offered to produce sheet, strip, can, PS sheet, foil and precision raw material for further processing. According to the gauge of the coils, it can be divided in to cold heavy rolling mill and cold finishing rolling mill. The stand type of it is four – high cold rolling mill.

COLD ROLLING ALUMINUM:

Novelis operates a variety of types and sizes of cold roll mills at locations around the world, including some that run at exit speeds as high as 3,000 meters per minute.

STAGES IN COLD ROLLING:

Hot-rolled aluminium strip is cooled to room temperature and fed into the cold roll mill line. The strip is then passed several times between a series of rollers until it is gradually reduced to the desired gauge and wound into a coil. Cold Rolling occurs with the metal is treated below its re-crystallization temperature, which increases the strength (via Strain Hardening) by up to 20%, and enables tighter tolerances. The process also renders dimensional accuracy and surface finish to products, making them optimal for a vast variety of applications. [2]

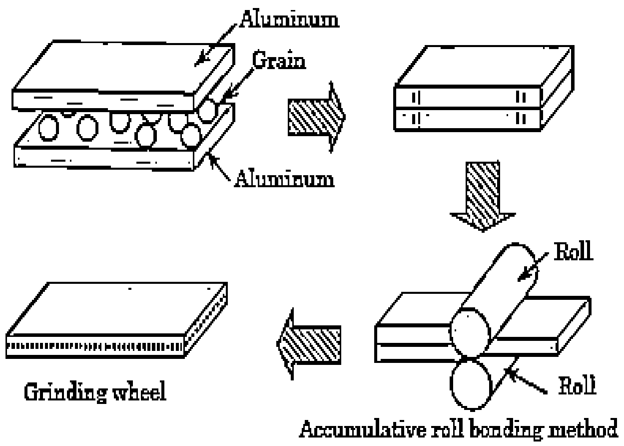

Fig.1 aluminium rolling line

III. LAB OBJECTIVES:

This lab has the following objectives:

- Introduce basic rolling parameters and some of the fundamental principles in rolling.
- Calculate the roll forces required to reduce the thickness of a given aluminum strip.
- Verify plane strain assumptions used in rolling analyses.
- Identify where plane strain assumptions are not valid and to calculate the percentage spread in such cases.
- Evaluate the strain hardening phenomena in rolling processes.
- Identify some defects involved in rolling processes.
- In this lab, you will use a scale-down model of an industrial rolling mill. The rolling mill has two rolls powered by an electric motor.
- The distance between the rolls, which is the roll gap, can be adjusted by rotating a pair of rotationally calibrated screws at the top of the roll stand (housing).
- To keep the roll gap constant, you should ensure that the two adjusting screws have been adjusted to the same calibration number. There is a mark on each roll_housing used to align the calibration marks on the adjusting screws.

PROCEDURE:

Rolling

1- Obtain the material data (K, n) from your lab instructor and record it in your datasheet.

2- Record the following initial conditions of your sample strip in the table provided:

a) Thickness
b) Length
c) Width
d) Hardness (HRC); average of three measurement

3- Set the roll gap for the first pass (set the adjusting screw to 5)

4- Start the rolling mill

5- Feed the strip through the mill (make sure not to feed the strip at an angle into the rolls).

6- In the table provided, record the:

a) Thickness
b) Length
c) Width
d) Hardness (HRC); average of three measurement

7- Reduce the roll gap by one unit per pass and repeat steps 3-6 for the remaining four passes.

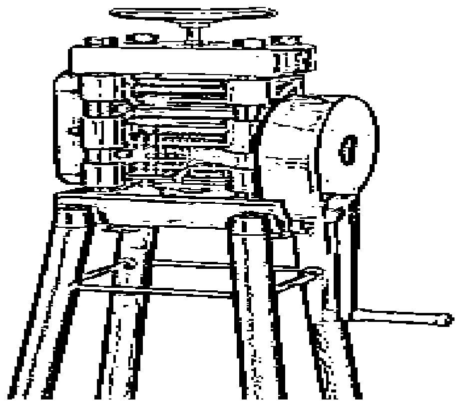

Fig 2: Estimating the coefficient of friction:

1- With a new sample, record the initial thickness.

2- Measure the roll radius.

3- Set the roll gap to 1 on the adjusting screw.

4- Start the rolling mill.

5- Very gently attempt to feed the strip through the mill, but do not force the strip into the mill. Hold the strip as level as possible and let friction between the rolls and the strip pull it in (this must be the case to get accurate data regarding the friction force). Note: the strip will not be pulled in on this first attempt.

6- Open the roll gap by steps on one-half units on the roll set screw and repeat step 5 until the mill just pulls in the strip. The number on which the roll is set is not important and only the initial and final thicknesses of the specimen are needed.

7- Record the final thickness and complete the calculations with the formulas provided.

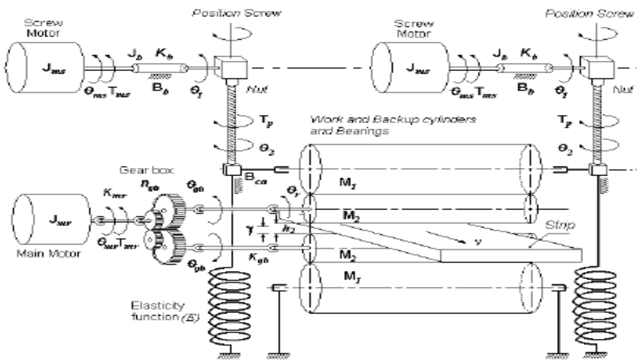

Fig 3 Transverse strains in rolling (Spread):

In this section of the lab, we will use a strip of aluminum that has lower width to thickness ratio. This section highlights the fact that plane strain

Assumptions in rolling must be used carefully and only for particular cross-sections.

1- Record the specimen initial width and thickness.

2- The lab instructor will set the roll gap to 3

3- Roll the strip and then record the final width and thickness.

You will notice that there is a change in all dimensions.[3]

IV. CALCULATIONS:

Theoretical Calculations:

1. Solve the equation

$$\frac{dy}{dx} = -2 - y + y^2.$$

Knowing that $y_1 = 2$ is a particular solution?.

Answer.

We recognize a Riccati equation. First of all we need to make sure that y_1 is indeed a solution. Otherwise, our calculations will be fruitless. In this particular case, it is quite easy to check that $y_1 = 2$ is a solution. Set

$$z = \frac{1}{y-2}.$$

Thenwehave

$$y = 2 + \frac{1}{z}$$

Which implies?

$$y' = -\frac{z'}{z^2}.$$

Hence, from the equation satisfied by y, we get

$$-\frac{z'}{z^2} = -2 - \left(2 + \frac{1}{z}\right) + \left(2 + \frac{1}{z}\right)^2.$$

Easyalgebraicmanipulationsgive

$$-\frac{z'}{z^2} = \frac{3}{z} + \frac{1}{z^2}.$$

Hence

$z' = -3z - 1$.

This is a linear equation. The general solution is given by

$$z = \frac{-1/3e^{3x} + C}{e^{3x}} = -\frac{1}{3} + Ce^{-3x}.$$

Therefore, we have

$$y = 2 + \frac{1}{-\frac{1}{3} + Ce^{-3x}}.$$

Note: If one remembers the equation satisfied by z, then the solutions may be found a bit faster. Indeed in this example, we have $P(x) = -2$, $Q(x) = -1$, and $R(x) = 1$. Hence the linear equation satisfied by the new function z, is

$$\frac{dz}{dx} = -\left(Q(x) + 2y_1R(x)\right)z - R(x) = -\left(-1+4\right)z - 1 = -3z - 1.$$

Example 2. Check that $y_1 = \sin(x)$ is a solution to

$$\frac{dy}{dx} = \frac{2\cos^2(x) - \sin^2(x) + y^2}{2\cos(x)}.$$

Then solve the IVP?

ANSWER:

$$\begin{cases} \dfrac{dy}{dx} = \dfrac{2\cos^2(x) - \sin^2(x) + y^2}{2\cos(x)} \\ y(0) = -1 \end{cases}$$

We will let the reader check that $\sin(x)$ is indeed a particular solution of the given differential equations. We also recognize that the equation is of Riccati type. Set

$$z = \frac{1}{y - \sin(x)}$$

which gives

$$y = \sin(x) + \frac{1}{z}.$$

Hence

$$y' = \cos(x) - \frac{z'}{z^2}.$$

Substituting into the equation gives

$$\cos(x) - \frac{z'}{z^2} = \frac{2\cos^2(x) - \sin^2(x) + \left(\sin(x) + \frac{1}{z}\right)^2}{2\cos(x)}.$$

Easy algebraic manipulations give

$$-\frac{z'}{z^2} = \frac{\left(2\sin(x)\frac{1}{z} + \frac{1}{z^2}\right)}{2\cos(x)} = \frac{\sin(x)}{\cos(x)}\frac{1}{z} + \frac{1}{2\cos(x)}\frac{1}{z^2}.$$

Hence

$$z' = -\frac{\sin(x)}{\cos(x)}z - \frac{1}{2\cos(x)}.$$

This is the linear equation satisfied by z. The integrating factor is

$$z' = -\frac{\sin(x)}{\cos(x)}z - \frac{1}{2\cos(x)}s$$

V. PRATICAL CALCULATIONS:

Original Dimensions of Aluminum sheet in MM
Length =100 MM
Width=30MM
Thickness = 3MM
One Pass 360˚=1mm
Strain = change in length / original length

Pass	Thik ness	Strain	Length	Strain	Widt h	Strain
Pass0	3	0	100	0	30	0
Pass1	2.7	0.1	120	0.2	37	0.23
Pass2	2.3	0.23	140	0.4	44	0.47
Pass3	2	0.33	160	0.6	46	0.53
Pass4	1.7	0.43	180	0.8	52	0.73
Pass5	1.3	0.57	200	1	59	0.97
Pass6	1	0.67	220	1.2	64	1.13

GRAPHS:

GRAPH 1 LENGTH VS STRAIN

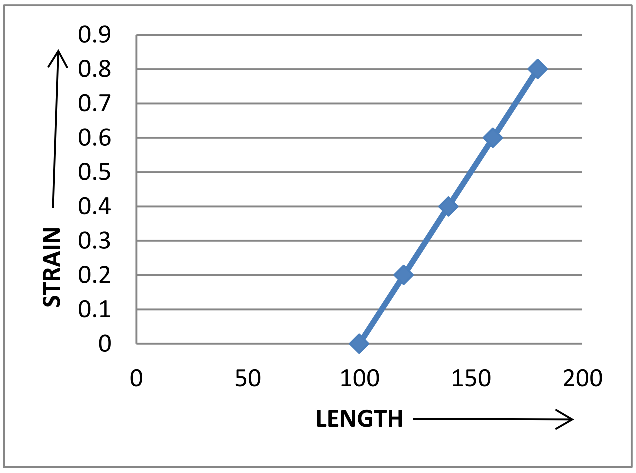

Fig.4 Length VS Strain

From Fig.4, the length of aluminium sheet increases the strain values of aluminium sheet also increases gradually.

GRAPH 2 WIDTH VS STRAIN

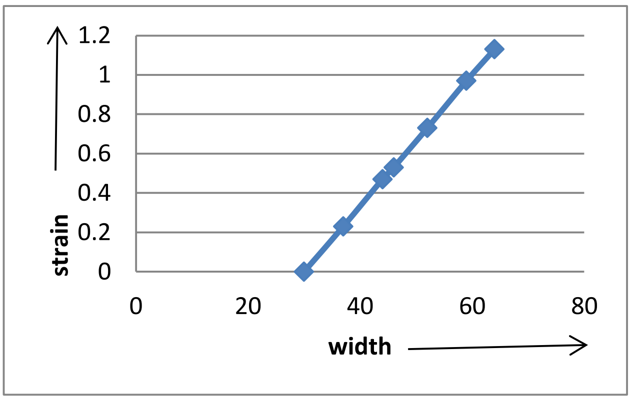

Fig.5 Width VS Strain

From Fig.5, the width of aluminium sheet increases the strain values of aluminium sheet also increases gradually.

GRAPH 3 THICKNESS VS STRAIN

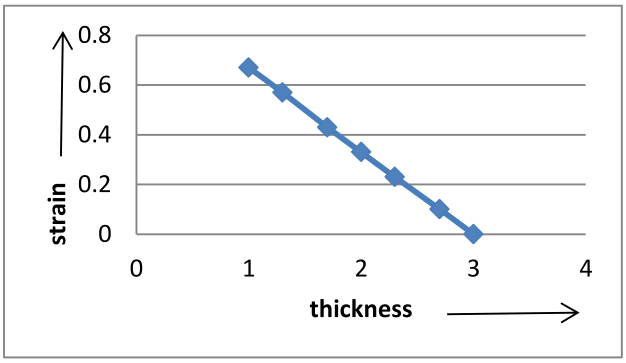

Fig.6 Thickness VS Strain

From Fig.6, the thickness of aluminium sheet decreases the strain values aluminium sheet also increases gradually.

GRAPH 4 WIDTH VS THICKNESS

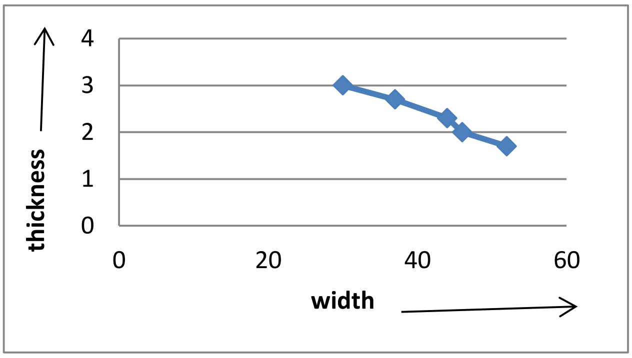

Fig.7 Width VS Thickness

From Fig.7, Here the thickness of aluminium metal decreases then the width of the metal increases.

GRAPH 5 PASSES VS LENGTH STRAIN

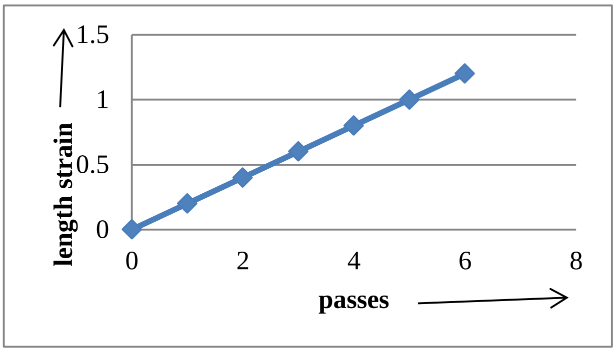

Fig.8 Passes VS Length Strain

From Fig.8, the number of passes increases then the length strain of aluminum sheet also increases gradually.

GRAPH 6 PASSES VS WIDTH STRAIN

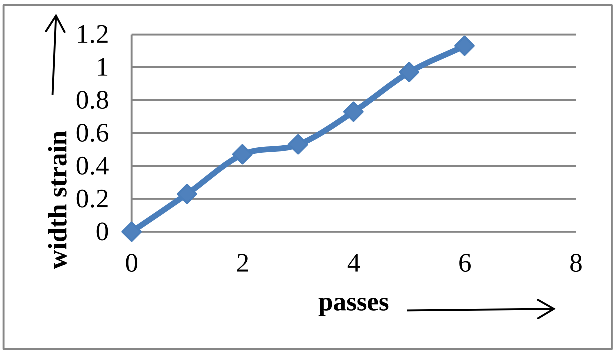

Fig.9 Passes VS Width Strain

From Fig.9, the number of passes increases then the width strain of aluminum sheet also increases gradually.

GRAPH 7 PASSES VS THICKNESS STRAIN

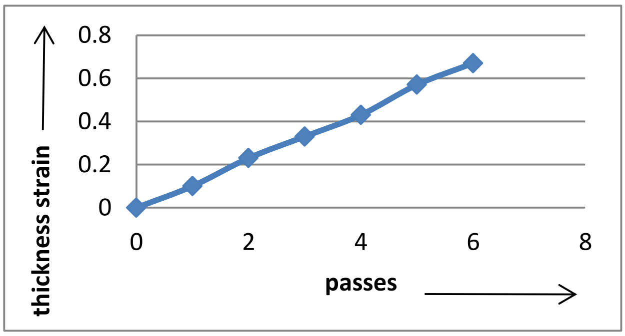

Fig.10 Passes VS Thickness Strain

From Fig.10, the number of passes increases then the thickness strain of aluminum sheet also increases gradually.

VI. FEATURE SCOPES:

- TMT Bar Mill and Wire Rod Rolling Mill up-to 500,000 tons/year
- Customized Light, Medium & Heavy Section Rolling Mill up-to 500,000 tons/year for Hot Rolling Mill Industry
- Rolling Mill Stands for Hot Rolling Mill Plants up to 1000 mm
- Wide range of Gears up to 4000mm – 30 modules for any type of Hot Rolling Mill Stand.
- Speed Reduction Gear Boxes up to 6000 kW rating for New Hot Rolling Mill Stand or Any Existing Rolling Mill Plant
- EOT Cranes up to 100 tons capacity
- Hardened and Ground Gears and Gear Boxes up to 2000mm - 25 modules.

VII. APPLICATIONS:

Aluminium Sheets / Coils

For commercial quality & general engineering use, these are produced at Manaksia'sHaldia Plant, West Bengal. The Sheet & Coil are produced via Caster Route and facilities comprise of Casters, Heavier Gauge Cold Rolling Mills & modern Light Gauge Mills with sophisticated control devices and precision finishing equipments to ensure better shape & closer tolerances of the Aluminium Sheet & Coil. Manaksia's Aluminium Sheet & Coil are well accepted across the Globe.

ADVANTAGES:

- Aluminium being anti-corrosive
- maintenance-free
- non-inflammable finds application in Fan Blade
- Bus Body
- Utensils
- Sliver Can
- Insulation and many more

DISADVANTAGES:

- Plant take more place
- Plant cost is more
- It should take long process when while doing production
- Low out put
- High roll consumption
- Large production of one size product.
- If the temperature difference is great enough cracking and tearing can occur.[4]

VIII. SUMMARY:

The three main functions of a lubricant in aluminum rolling are to prevent direct contact between the rolls and aluminum surface, remove the heat generated by friction and deformation and to transport fines and debris away from the roll bite area to the filter. The majority of hot rolling mills are lubricated and cooled by oil-in-water emulsions, whilst the majority of cold and foil rolling mills are lubricated and cooled by oil-based lubricants. In hot rolling the major component of the emulsion is water, with less than 10% oil phase, whereas in cold and foil rolling the base oil is the major component, accounting for more than 90% of the total lubricant volume. In all types of rolling lubricant the base oil functions as a solvent for the additive components which, in turn, provide load bearing capacity and control friction in the roll bite. Finally, during use the lubricants must be adequately monitored and maintained to ensure their optimum performance.

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