Elasto-Plastic Deformation Process of Cold Rolling

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Abstract - Based on the important boundary condition of flat rolling simulation including friction, heat condition interactions of the work piece as well as rolls, the flat rolling process is identified as the problem of study for aluminum metals using FEA. Thus simulation results show that it is safe to produce flat rolling. There are concave surface and increased widths occurring at the end of rolled billet. For the materials Al-360 & Al 7475 at the 10%, 20% and 30% reduction rate with a 12 mm plate, the analysis by using Ansys software and also the experimental work for both materials by using same radius of rollers have been conducted.

Key words: Cold rolling, aluminum, stress, rolling pressure, rolling load, torque, Ansys.

I. INTRODUCTION

In metalworking, rolling is a metal forming process in which metal stock is passed through a pair of rolls, below its recrystallisation temperature i.e cold rolling produces strip with superior surface finish and dimensional tolerances (usually at room temperature). Flatness defects are like symmetrical / asymmetrical edge wave, center /quarter buckle and draft .Surface defects are lap , mill-shearing , rolled-in scale , scabs , seams , slivers.

Earliest rolling mills were slitting mills, which were introduced from what is now Belgium to England in 1590. Flat bars were passed between rolls to form a plate of iron, which was then passed between grooved rolls (slitters) to produce rods of iron. Later this began to be re-rolled and tinned to make tinplate. Hot rolling is a metalworking process that occurs above the recrystallisation temperature of the material. After the grains deform during processing they recrystallize which maintains an equi-axed microstructure and prevents the metal from work hardening. Cold rolling occurs with the metal below its recrystallization temperature (usually at room temperature) which increases the strength via strain hardening. Flat rolling is the most basic form of rolling with the starting and ending material having a rectangular cross-section. The material is fed in between two rollers, called working rolls that rotate in opposite directions. DRAFT: The difference between the thickness of initial and rolled metal piece is called Draft. Thus if t_0 is initial thickness and t_f is final thickness, then the draft d is given by $d = t_0 - t_f$

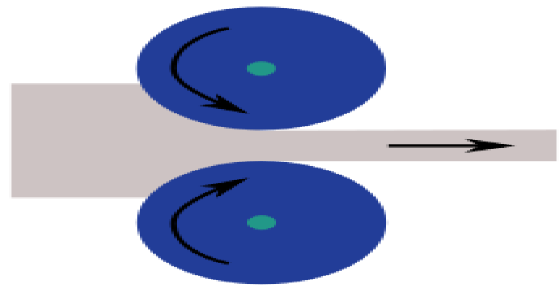


Fig .1: A rolling schematic

Bars of circular or hexagonal cross section and structural shapes like I beams, channels, and railroad rails are produced in great quantity by hot-rolling. 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 work pieces 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 work piece as much as hot rolling in a single pass.

Forces & geometrical relation in rolling have been calculated. The arc of contact is circular without elastic deformation of the rolls and lateral spread. Power is applied to a rolling mill by applying a torque to the rolls and by means of strip tension to overcome frictional forces in the bearings.

Fig.2: Roll bending

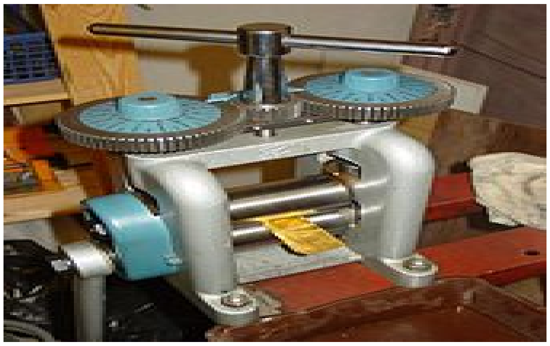


Fig .3: Rolling mill for cold rolling with metal piece of brass sheet.

The contact area between the metal and the rolls is equal to the product of the width of the sheet 'b' and the projected length of the arc of contact L_p i.e

$$L_p = \left[R(h_0 - h_f) - \frac{(h_0 - h_f)^2}{4}\right]^{1/2} \approx \left[R(h_0 - h_f)\right]^{1/2}$$

II. THEORETICAL CALCULATIONS

LOAD CALCULATIONS OF COLD ROLLING

Material: Aluminum Alloy A360

FOR 10% REDUCTION OF THICKNESS

v_f = 41.67 mm / sec, L_p = 9.482 mm

P = 0.0099246 N

Maximum thickness reduction=0.75 mm

FOR 20% REDUCTION OF THICKNESS

v_f =46.875 mm / sec, L_p = 13.36 mm

P = 0.022315 N

Maximum thickness Reduction=0.75 mm

FOR 30% REDUCTION OF THICKNESS

v_f =53.57 mm / sec, L_p = 16.33 mm

P = 0.038 N

Maximum thickness Reduction=0.75 mm

Material : ALUMINUM ALLOY 7475

FOR 10% REDUCTION OF THICKNESS

v_f =41.67 mm / sec, L_p = 9.4678 mm

P = 0.0103533 N

Maximum thickness Reduction=0.75 mm

FOR 20% REDUCTION OF THICKNESS

v_f =46.875 mm / sec, L_p = 13.36 mm

P = 0.023276 N.

FOR 30% REDUCTION OF THICKNESS

v_f =53.57 mm / sec, L_p = 16.33 mm

P = 0.039899 N

Maximum thickness Reduction=0.75 mm

MATERIAL PROPERTIES

A360: Density=2.68g/cc

Tensile strength=165 Mpa

Melting temperature=649-760^{0}c,

Machinability=50%

Composition: Al=89.2%,Fe=1.3%,Ni=0.5%,Si=9%
ALUMINUM ALLOY Al7475

Density=2.81g/cc,Tensilestrength=448 Mpa

MeltingTemp=649-760^{0}c

Machinability=50%

Composition:Al=92%,Fe=0.2%,Zn=5.2%

Mg=2.6%

III. STRUCTURAL ANLYSIS

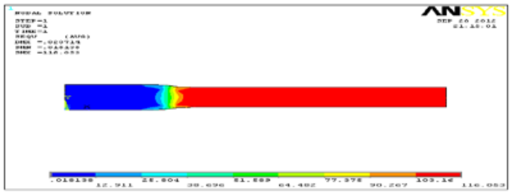
M/L=A360

E=80,000 MPa

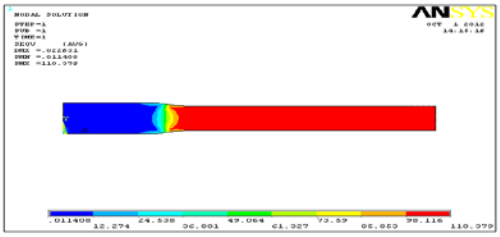
Poisson's Ratio= 0.33

Density = 2680Kg/m^3=0.00000268 Kg/mm^3

Modeling is done by creating key points to obtain a Meshed mode and Loads are applied to calculate structural displacements.



is the simulation results for 10 % reduction



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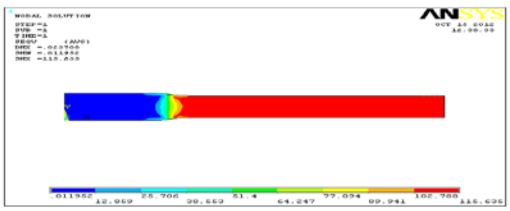
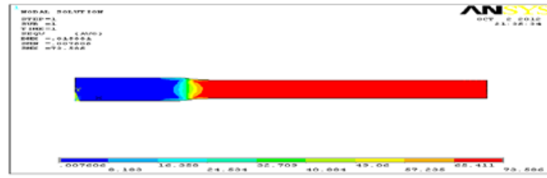


is the simulation results for 30% reduction .

Al-7475
E=75,000 Mpa,
Poisson's ratio= 0.33
Density=2810 kg/m^3= 0.0000028 kg/mm^3

Modeling is done by creating key points to obtain a meshed mode and loads are applied to calculate structural displacements



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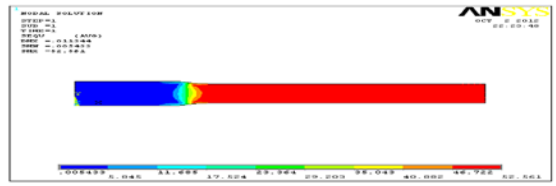

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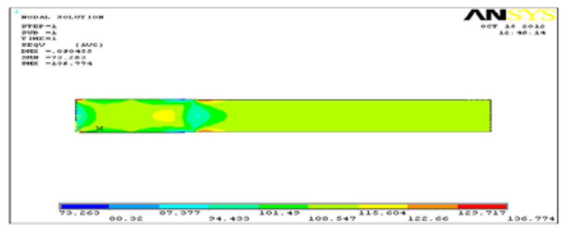

is the simulation results for 30 % reduction

IV. RESULTS: FEA RESULT

Reduction	ALUMINUM A360		ALUMINUM 7475	
	DISPLACEMENT (mm)	STRESS (N/mm^2)	DISPLACEMENT (mm)	STRESS (N/mm^2)
10%	1.44	116.053	1.239	73.856
20%	2.757	110.379	2.477	52.561
30%	3.29	115.635	3.097	136.774

EXPERIMENTAL RESULT

Reduction	ALUMINUM A360		ALUMINUM 7475	
	DISPLACEMENT (mm)	STRESS (N/mm^2)	DISPLACEMENT (mm)	STRESS (N/mm^2)
10%	0.73	-	.7	-
20%	1.8	-	1.7	-
30%	2.6	-	2.52	-

V. CONCLUSIONS

old rolling operation of a flat plate having thickness of 12 mm has been investigated via calculation and FEA based model. The developed FEA model shows the deformation and stress developed inside the plate by varying pressure distribution from the projected length to the end of rolling. Analysis and calculation are done for the materials aluminum A360 & 7475 by varying thickness reduction of 10%, 20% and 30%.

By observing above FEA and Experimental result for same roller size of 150 mm diameter, it has been observed that Aluminum 7475 is less deformed than Aluminum A360.

The deformation is less since its hardness and tensile strength are more compared with that of Aluminum A360.

From above result, to get actual thickness reduction for Aluminum 7475, roller diameter should be increased more.

It is observed that the deformation is more for 30% thickness reduction than 10% & 20% for any m/l or any roller.

It is also observed that there is slight difference in deformation among theoretical, analytical and experimental results.

Using cold rolling process, the uniformity in the thickness reduction and superior surface finish have been attained with no material wastage in less time.

VI. FUTURE SCOPE

The thesis can be extended by finding the strength and grain structure for two materials Aluminum A360 and 7475 in cold rolling process before and after heat treatment. Comparison can be done between cold rolling and hot rolling to verify the strength, cost, time and surface finish. Also it can be extended to compare the same between non ferrous and ferrous metals.

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ACKNOWLEDGMENT

First and foremost, I would like to express my profound and sincere gratitude and indebtedness to my esteemed friends. My heartfelt thanks for having given me free hand in my research work and pin pointing to my observations at right time for M/S Prasad industries Ltd,Hyderabad. Plain“Thanks"cannot express my gratitude for technicians who supported me in real-time process.

I am deeply indebted to my colleagues for stimulating and untiring suggestions and constant encouragement. I could not have finished this work successfully without their help. Their doors were always opened to me for discussion. I am really touched upon by unconditional scientific inputs and humanity.

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