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SIMULATION AND ANALYSIS OF COLD ROLLING PROCESS OF COOPER ALLOY NL

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A B S T R A C T

Now a days the Finite Element ((FE) technique is applying in the metal forming process, mostly in the steel and aluminum industry. In the cold rolling process, roll diameter, roll speed, and contact length play very important role. In the present study, a finite element 3D model has been developed to investigate the effect of the rolling parameters on Copper alloy NL during the cold rolling process.Ansys software was used to develop the FEA model. Athree-dimensional Elastic-FEA model has been developed to simulate the cold rolling process of thick strip at different work roll angular velocity and work roll diameter. The angular velocity of the work rolls ranged from 30 to 480 revolutions per minute (r.p.m.) and the rigid roll diameter ranged from 100 to 300 mm. At the initial level of strip feeding, speed of the plate and friction between it was kept constant. The main aim of this study is to determine the effect of work roll speed and work roll diameter on the contact pressure and the residual stress in cold rolling process of copper alloy NL.

Keywords: Cold rolling process, Stress, Strain and Deformation

1. INTRODUCTION

Rolling is the process of reducing the thickness or changing the cross section of a long work piece by compressive forces applied through a set of rolls (backup rolls and work rolls) as shown in figure 1

In modern cold-rolling practice, two-high, four-high, and cluster-type mills, including Sendzimir mills, constitute the principal examples of single-stand mills as shown in Figure 1.5. However, the Steckel mill has found considerable commercial use, but in steckel mill, the strip should be thought of as drawn rather than rolled since the deformation energy is supplied by the tensile force exerted on the strip on the exit side of the mill.

As the years progressed various rare types of mills have been proposed to provide certain advantages, such as flatter or thinner strip and greater simplicity of construction and/or operation. Although some of these mills have been developed in the laboratory to the extent that they have reduced samples of strip, they have not as yet found acceptance for commercial cold-rolling operations.

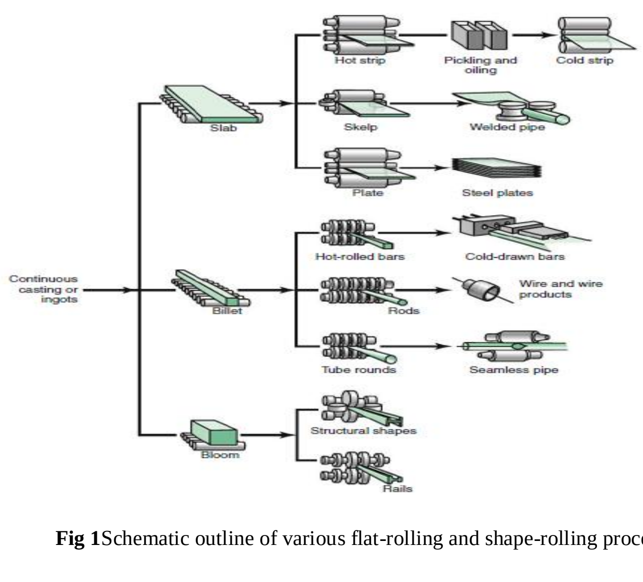


Fig 1 Schematic outline of various flat-rolling and shape-rolling processes

The two-high mills are the oldest type mill which used for the cold reduction of the steel sheet. But in the 1920's the two high mills were used mainly to flatten the steel sheet by eliminating dents, creases, and some types of waves, bow to improve the surface of the steel sheet and produce the smooth surface. However in this process, it is not necessarily a glossy, polished surface, glossy polished surface[1-10].

In the previous year, the shape of the work piece was generally corrected by the hot rolling and therefore the use of the two-high cold mills was basically for temper rolling.Elongation of the strip during the rolling was observed as an annoyance, subsequently, it was not sufficient to be useful and only enough to be troublesome.An early example of a two-high mill [11-15]. It is similar to the hot rolling mill then in use but the screws were designed to be moved only by the use of significant force, such as by striking the screw bar with a wooden hammer" since operating experience dictated only infrequent adjustment of cold-mill rolls. Moreover, only the bottom rolls of such mill stands were usually driven and no rolling lubricants were applied to the mill.

The rolls themselves had no camber or crown and possessed hard, chilled surfaces. They were ground and polished prior to use in a manner similar to today's practice, except that marks on the rolls developed during mill use were frequently ground out while the rolls were still in place in the mill stand[16-24].

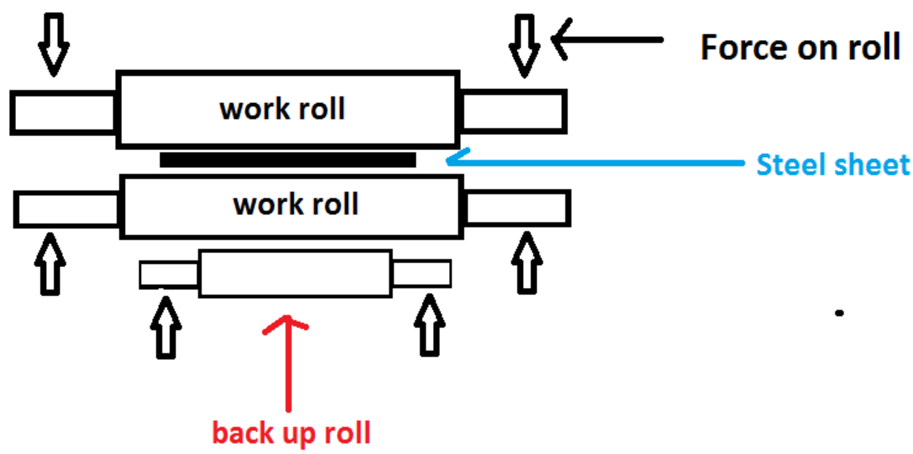


Fig. 2 Schloemann two high mill with bending roll

Recently, still, two-high mills have staged a return back as skin pass mills, and Usinor-Schloemann have developed this type of skin pass mill with a bending roll positioned below the lower work roll as depicts in Figure 2. The skin pass mill has hydraulic roll with screw down and polishing of the rolls during mill operation. The rolls of the mill shown are 104 centimeter in diameter with a face length of 219cm and the roll arrangement may be quickly changed by means of a hydraulic device.

Shangwu et al. applied the combined finite-element boundary element method to attain stress field in the work-rolls during rolling process [21].

Chang D F developed the finite-element model along a steady-state rolling condition and a non-uniform heat flux in the deformation zone to calculate the work-roll temperature profile and thermal stresses during the rolling process [22].Li CS et al they employed the two-dimensional finite-difference method to apply to solve the heat-conduction equation in the work-rolls along with the plane strain rolling conditions. 3D finite element method was used for prediction of the temperature during the hot strip rolling [23].Fischer et al. predicted temperature profile and thermal stresses with the benefit of the analytical solutions. Thus, numerical uncertainties due to convection term in the heat-transfer equation is avoided [24].Kim et al. used a dimensionless model to analyze the thermo-mechanical behavior of sheet and work-rolls during rolling process however this mode can be used as an on-line program for modifying the rolling program [25].

Zhang Tao er al. to analyzethe temperature profile of aluminum alloy thick plate during the hot rolling, finite element method based thermo-mechanical models were established. Effects of different process parameters on temperature profile in the aluminum alloy plate and the bending behavior due to temperature difference were investigated. The results indicate that the temperature profile of plate is unequal. The rolling velocity and speed ratio increase the asymmetric coefficient. The Heat is exchange in different way and it play different roles in the temperature distribution. The weight influences of friction heat 47% and deformation heat 69% were observed hot rolling process and pass interval time. The temperature difference and pass reduction increases the bending curvature meanwhile the slab thickness decreases the temperature difference [26].

2. METHODOLOGY AND 3D BASED FEM MODEL

2.1 Material selection

Copper alloy NL have been used in this study. Copper alloy NL sheet are generally used in the automotive industries, puff panel, corrugation and profile sheet. Table 1 show chemical composition of the copper alloy. Dimensions of cold rolling mill component are mentioned in Table 2.

Table 1 Chemical Composition of copper alloy

Element	Cu	Sn	P
% of composition	89.75	10.0	0.25

Table 2Copper Alloy NL properties

Parameter	Value
Density	8300
Specific Heat	8.75e+005 mJ kg^-1 C^-1
Young's Modulus MPa	110000
Poisson's Ratio	0.34
Bulk Modulus MPa	1.14*10^11
Shear Modulus MPa	4.05*10^10
Yield Strength MPa	33.3
Tensile Ultimate Strength MPa	210

2.3. Development of 3D model

The Finite Element Method (FEM) provide a platform to achieve the approximate solution of the real word problems. Finite element method is a numerical approach for determined the approximate solution of the engineering & sciences problems.

In the FEM, a complex region defining a continuum is discretized into simple geometric shapes termed elements. The properties and the governing relationships are assumed over these elements and expressed mathematically in terms of unknown values at specific points in the elements called nodes. An assembly process is used to link the individual elements to the linked system. When the effects of loads and boundary conditions are considered, a set of linear or nonlinear algebraic equations is usually obtained. Solution of these equations gives the approximate behaviour of the continuum or system.

2.4 Finite Element Model

In this rolling process there is elastic entry zone. This elastic entry zone is basically plastic deformation zone, elastic compression zone and elastic recovery zone at the exit of deformation zone, shown in Figure 3

Where

H0= Strip thickness at entry

Hf= Strip thickness at exit section

V0= strip velocity at entry

Vf= strip velocity at exit

W0= Width of strip

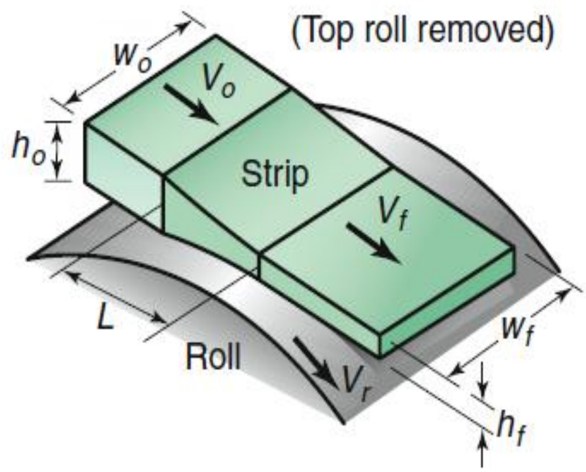
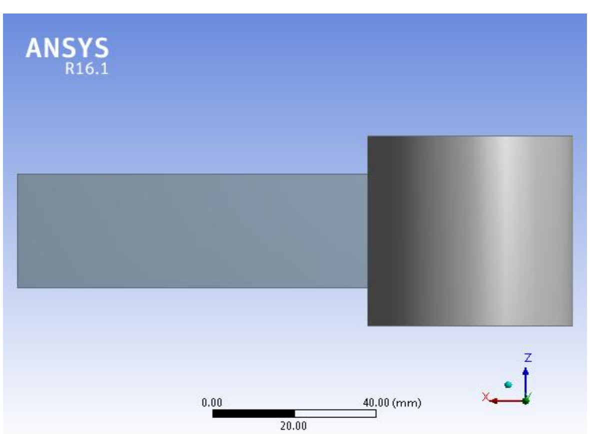


Fig. 3 Schematic of the rolling process of cold strip

2.3 Model development

The Ansys software used to design the rolling process. Ansys software is capable to develop the different type of geometry, assembly, sheet metal work and so on with using different type of module. Figure 4 shown the model of cold rolling process.



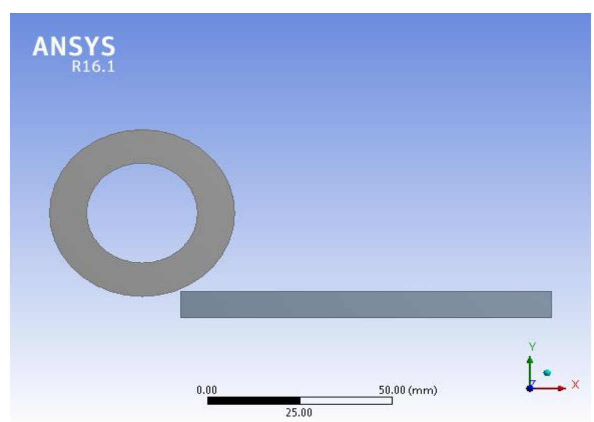


Fig. 4 3D model of the Rolling Process

Fig. 5 Side View of 3D model of the Rolling Process

2.4 FE mesh

Meshing play very important role in the finite element analysis. Meshing divide the one element in to the finite number of element. Generally, as per requirement researcher takes the fine, medium and coarse mesh size. Simulation time is directly proportional to the Mesh size.

Six meshing methods available for 3D geometries:

- Tetrahedrons: Patch Conforming (TGrid based) & Patch Independent (ICEM CFD based).
- Sweep: Generates prisms or hexahedral
- MultiZone: Mainly hexahedral elements
- Hex Dominant
- CutCell mesh: Generates Cartesian CutCell mesh

- Automatic: Combines Tetrahedral Patch Conforming & Sweep Mesh based on complexity of the geometry
- Interoperability between different meshing methods

2.5 Preparing the Analysis

2.5.1 Create Analysis System:

There are several types of analyses can perform in the Mechanical application. For example, if natural frequencies and mode shapes are to be calculated, you would choose a modal analysis.

Each analysis type is represented by an analysis system that includes the individual components of the analysis such as the associated geometry and model properties. Most analyses are represented by one independent analysis system. However, an analysis with data transfer can exist where results of one analysis are used as the basis for another analysis. In this case, an analysis system is defined for each analysis type, where components of each system can share data. An example of an analysis with data transfer is a response spectrum analysis, where a modal analysis is a prerequisite.

2.5.2 Define Engineering Data:

A part’s response is determined by the material properties assigned to the part. Depending on the application, material properties can be linear or nonlinear, as well as temperature-dependent. Linear material properties can be constant or temperature-dependent, and isotropic or orthotropic. Nonlinear material properties are usually tabular data, such as plasticity data (stress-strain curves for different hardening laws), hyperplastic material data. To define temperature-dependent material properties, you must input data to define a property-versus-temperature graph. Although it can define material properties separately for each analysis, you have the option of adding your materials to a material library by using the Engineering Data tab. This enables quick access to and re-use of material data in multiple analyses.

Define Part Behavior: After attaching geometry, can access settings related to part behavior by right-clicking on the Model cell in the analysis system schematic and choosing Edit. The Mechanical application opens with the environment representing the analysis system displayed under the Model object in the tree. The Mechanical application uses the specific analysis system as a basis for filtering or making available only components such as loads,

3. RESULTS AND DISCUSSION

.In this study, 278 nodes and 30 element has been selected in meshing zone for the sheet and 672 nodes and 96 element has been selected in meshing zone for the both work roller. The node is the junction of the elements. This numbers are clearly indicate the density of the meshing. The 10 mm element size has been selected in this study.

3.1 Analysis of Copper alloy NL

The dynamic analysis of rolling process has been investigated with respect to copper alloy and boundary conditions as mentioned in material specifications Table 1 & 2. The friction less solid to solid contact has been assigned. In the contact selection, the roller outer surface has been selected as a contact body and the sheet upper surface as a target body. Furthermore, the joint module has been applied on the roller and sheet. The revolute ground to roller was assigned to roller. The translation ground to sheet was applied for the steel. This both is the boundary condition of the roller and the sheet for their movement. Upper roller was rotate in 180 degree clock wise direction on the aluminum alloy sheet for the analysis. In this simulation the sheet is moving in the X direction and work roller is moving at their own axis. The nonlinear effect and displacement both are consider in the dynamic analysis. The total deformation of the aluminum alloy has been recorded. The Figure 6 shown the total deformation of copper alloy sheet. The maximum deformation 112.81mm has been observed in sheet. 553MPa normal stress has been observed in the simulation. Figure 7 shows the normal stress intensity in X direction.

The equivalent stress also has been recorded in this analysis. Figure 8 depicts the equivalent stress in the aluminum alloy sheet. The value of maximum equivalent stress 1189MPa was observed during the rolling process. 0.25 mm/mm equivalent plastic strain has been recorded as shown in figure 5.9. 0.00042 mm/mm equivalent elastic strain has been recorded as shown in figure 5.5.**Table 3** Stress and strain of rolling sheets

Type of Material	Equivalent stress (MPa)	Normal stress (MPa)	Equivalent plastic strain	Equivalent elastic strain
Aluminum alloy	820.6	289.91	0.25	0.0055

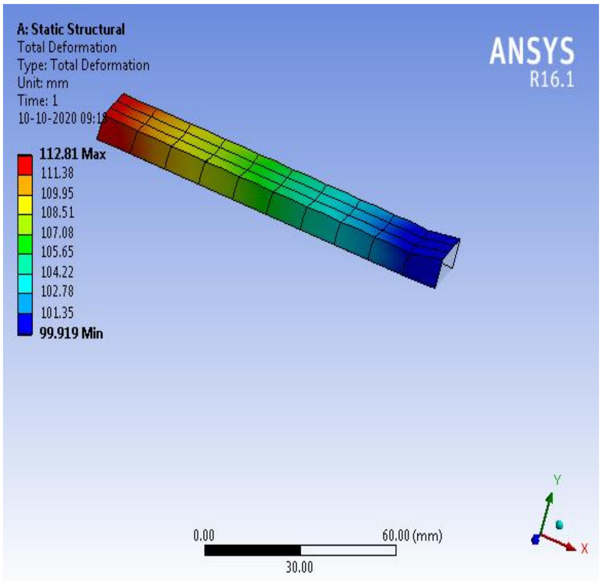
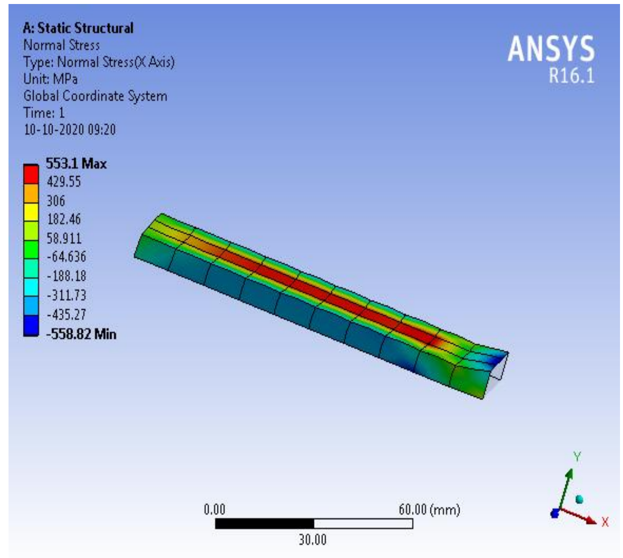


Fig. 6 Total deformation of copper alloy



Fig, 7 Normal stress intensity in X direction.

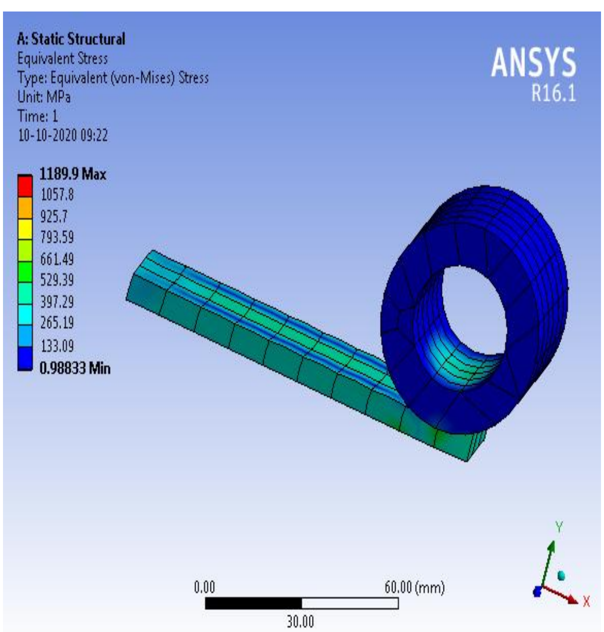


Fig 8Equivalent stress in the copper alloy

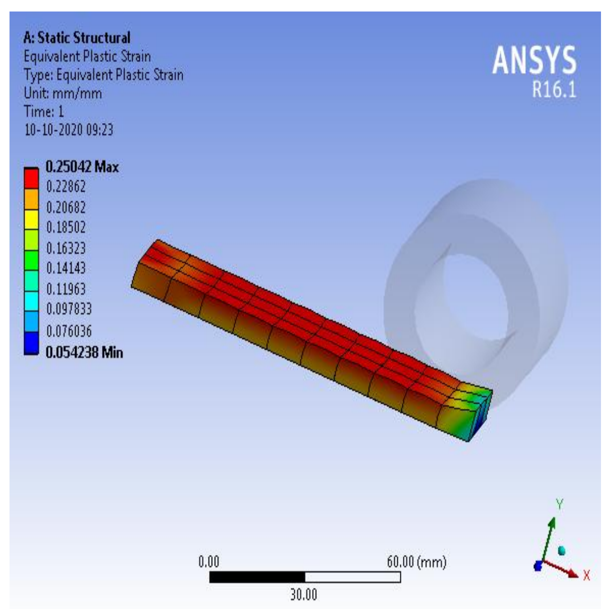


Fig 9 Equivalent plastic strain in copper alloy sheet

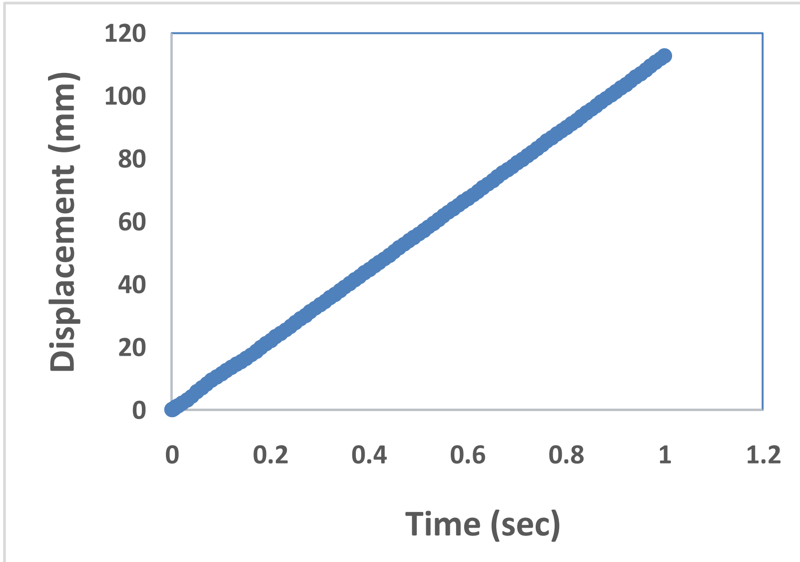


Figure 10 Displacement of copper alloy sheet with respect to time

4. CONCLUSION

The present project work based on the comparative investigation and analysis of a copper alloy for the automobile industries and sheet fabrication industry. The dynamic analysis of rolling process, responses are stress, strain and deformation of rolling sheet has been analysed.

The following conclusion has been drawn from the results analysis:

1. The equivalent stress (vonmises stress) induced in copper alloy is 1189MPa.
2. The equivalent elastic strain induced for copper alloy is 0.0042.
3. The normal stress in copper alloy is 553MPa.
4. The deformation induced in copper alloy is 112.8MPa.

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