Optimization of Rolling Process of Al-Plate Using Finite Element Method

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Abstract

A component's thickness is decreased to a specific thickness by exerting a desired pressure as it travels between two opposed rolls in the cold rolling process, an industrial shaping technique. This study looked at how aluminum plates' mechanical properties developed. In order to reach the appropriate thickness without annealing, the rolling process of aluminum plates was simulated, and the feasibility of substituting the hot rolling method of the aluminum plates manufactured in Ur Company/Iraq with a cold rolling process was studied. The residual stresses on the rolled plates were theoretically simulated by looking at several parameter windows. The effects of the process parameters on residual stresses and ultimate tensile strength were optimized and simulated using ABAQUS 310. (UTS). As a governing criterion for validation, the Von Mises method and an analogous plastic strain were applied (PEEQ). When studying high-temperature elastoplastic deformation of material during roll bite in a hot rolling process, the finite element method (FEM) is an effective tool. When the material composition of the workpiece varies, the roll bite stress field significantly alters. In this work, DEFORM-3D software is used to analyze roll bite deformation during the plate rolling process for a microalloyed steel grade.

Keywords: Rolling, Cylinder speed, thickness, ABAQUS, FEM, Von Mises, (PEEQ).

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Introduction

Rolling is a production method that reduces the thickness of the rolled metal (usually plates) by compressing it between two rollers that rotate in opposing directions [1]. Flat rolling, among other types of rolling processes, is one of the most practical and popular in manufacturing processes; as a result, in industrial sectors, flat rolling forms around 40% to 60% of all rolling products [2]. Rolling can be applied in two types based on the working temperature of the workpiece. The thickness of the rolled product is decreased by passing between two opposing rollers in the direction of rotation due to the pressing force created of the rollers' movement. The temperature of the rolling mill determines whether it is hot rolling or cold rolling.

Cold rolling has several advantages, including the ability to produce pieces with precise dimensions and satisfied surface finish without the need for other forming processes, as well as enhanced tensile strength, wear resistance, and do not need to heat [3]. This makes cold rolling a common manufacturing process for a variety of industrial products such as automobiles, electronics. The rolling process is classified into three types based on the manufacturing form; flat rolling, thread rolling, and ring rolling [four].

Numerous studies have been conducted in several rolling process research fields. The effects of roller settings on Von Mises, effective stresses, effective strain, and shear stress for AISI-1055 steel alloys were examined by P.L. Srinivasa et al. [5] using the AFDEX software. They discovered that the effective stress may be reduced by utilizing a larger roller diameter and a slower speed. Anjami and Basti [6] used the FE approach with the goal of obtaining the driver and idle rolls' optimal size, which decreased strain and temperature. Jian-liang et al. created the vibration model of the moving strip in the rolling process [7]. They created a distributed stress model based on the rolling theory and tested it using a moving strip with distributed stress. Numerous research focus on the relationship between various rolling conditions and chatter prevalence. Rolling speed, friction, inter-stand tensions, reduction, inter-stand distance, and material properties were some of the variables they looked into.

Kumar Bashisht Using FE 3D software, Kushwaha, 2017 [8] calculated the equivalent stress and plastic strain of hot-rolled items to evaluate the product quality. The effect of rolling vibrations on the profile flaws of the completed metal sheet was studied by Niziol and Swiatoniowski [9]. They offered various chattering prevention suggestions based on their numerical investigation. A simulation method was utilized by Shahani et al. [10] to examine the hot rolling process of the AA5083 aluminum alloy. By using the results of the FE simulation to train the network, the parameters of the slab shape, thickness reduction, rolling speed, frictional coefficient, and load are used in the creation of an artificial neural network (ANN). Thus, this network [11] forecasts the behavior of the workpiece during the rolling operation. According to Péricles Guedes Alves et al. [12], the model developed here is appropriate for control, making it useful for studies and research on cutting-edge control strategies utilized in tandem mills. The outcomes are reliable and resistant to design elements. Because the changes brought on by the input disturbances have a small amplitude, the linearized model appears to be adequate. Using this method, a step for linearization and a step for system identification for control are obtained together with a modeling process for tandem cold metal rolling. The

tandem cold rolling process is described by a mathematical model based on algebraic equations developed for control purposes and actual correlations. Extensive open loop evaluations are provided about the sensitivity to changes in process parameters and results for the use of a state-space model that has been created. K. Devarajan et al. [13] proposed a two-dimensional elastic-plastic finite element model to simulate the cold rolling of thick strips with different roll angular velocities and roll diameter models. The stiff rollers had diameters between 100 and 300 mm and rotational velocities between 30 and 480 per minute (r.p.m.). It is discovered that the roll speed may be easily controlled by modifying the roller diameter and watching how stress and contact pressure impact the procedure and the quality of the finished goods.
Xiaodong Wang et al [14] examined the Finite Element model for hot-rolled steel strip residual stress prediction. The phase transition has a significant impact on the prediction of residual stresses, according to the paper's conclusion. Vivek Anil Vaidya et al. [15] in a single stand cold rolling mill, the Taguchi technique is used to optimize the rolling parameters and increase the quality of the steel strip. Entry tension, exit tension, percentage reduction, rolling speed, coefficient of friction, and work roll bending pressure are the input parameters. The output parameters include production rate, power consumption, fluctuation in output strip thickness, flatness, and form. The optimization's goals are to reduce output thickness variation to a reasonable level, maintain the flatness and form of output strips at a reasonable level, reduce power consumption, and increase production rate Wang and Tseng. [16] examined the cold rolling case's thermal contact resistance. They came to the conclusion that interface resistance, which is dependent on surface roughness, contact pressure, coolant, lubricant, or oxide layer between the roll and the work piece, prevented heat transfer from the strip to the roll, and as a result, the temperature difference between the roll and the work piece significantly increases as the thermal resistance increases. Hong Yue et al[17] investigation on the cold rolling production process' robust operation optimization challenge. The work established an enhanced particle swarm optimization and built a mathematical model to reduce the overall power of the rollers. The study discovered that these models aid in lowering energy usage and improving power distribution to the rollers.
It was demonstrated that the pressure gradient along the contact when thin goods are cold rolled therefore, in contrast to the work-roll profile According to Hitchcock's formula, the distortion of rolls occurs in a way that the a thin interface roll profile that is still circular. There is an area with deeper indentation on the rolls in rolling narrow strip, a procedure. Lau et al [18] have utilized the elastic-plastic finite element approach. Malinowski and Lenard [19] to assess stress distribution during cold rolling of aluminum flakes. Lin and Lin [20] to forecast the thermal and mechanical behavior of have used a mixed finite element-finite difference model during.
Cold rolling procedures, aluminum strip. In the study's primary goal is to determine the ideal cold rolling process parameters, to prevent fermentation and enhance the mechanical qualities of the manufactured plates.

2.1 Modeling of Materials and Final Elements

For a three-dimensional model of rolling, the aluminum rolling process on the bar was simulated using the software ABAQUS version 6.131 (Explicit). The dimensions of the reel, length (400 mm) and diameter (400 mm) have different starting speeds (60-90 revolutions per minute). The dimensions of length (500 mm) and width (300 mm) represented the aluminum sheets, and the thickness is in three values (10mm), where the thickness of the plate is reduced to thickness (0.8). Due to symmetry, only one panel is intended, as indicated in Figure (1) the following assumptions must be considered during the analytical process:

- The sheet material is homogenous, with density ($2700 {kg}/{m^3}$),
- Young's modulus (75Gpa), and Poisson's ratio (0.3), and the hardening characteristics are listed in Table (1).
- The cylinder is hollow, and the friction pattern between it and the item is visible at the entrance point.
- In all rotational speed values, the feeding velocity of plate in the Z-axis direction is equal to the horizontal component of the cylinder velocity used in the study.

The following tables show the stress values that have been entered into the program

Table (1) Strain hardening properties of aluminum at thickness (10mm)

Yield stress (MPa)	Plastic Strain
176	0
166	0.1
161	0.2
160	0.3

2.1.2 Finite Element Method (FEM)

Abacus program (software) is a comprehensive engineering simulation software suite based on the finite element method that can simulate the processes using simple linear analyses or complex nonlinear simulations [21]

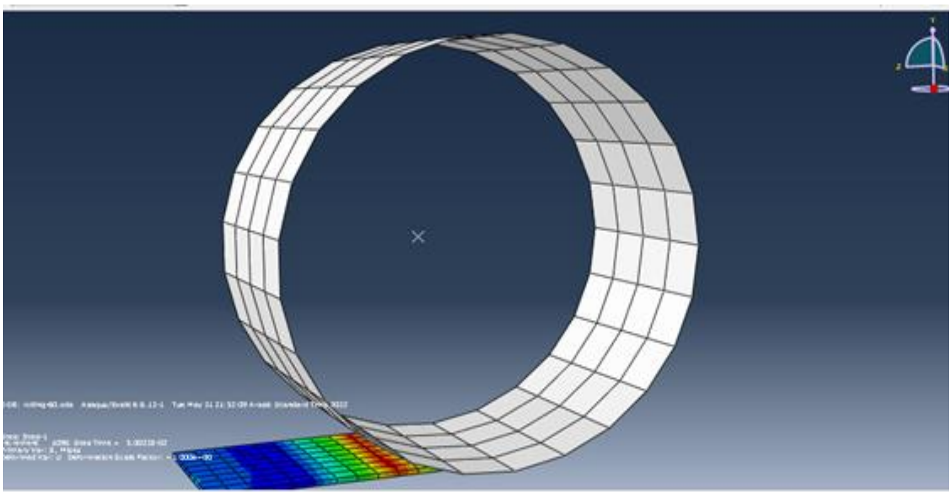


Fig (1) FEM rolling modeling

3- Results and Discussion

3.1 Effect of rolling speed and slip thickness on equivalent plastic strain (PEEQ)

Figure (2) illustrates the differences in equivalent plastic strain values, and it is clear that the higher the reel's speed of rotation, the lower the equivalent plastic strain values. This is because the increased cylinder bit shortens the time that the rolled materials and this agree with [1].

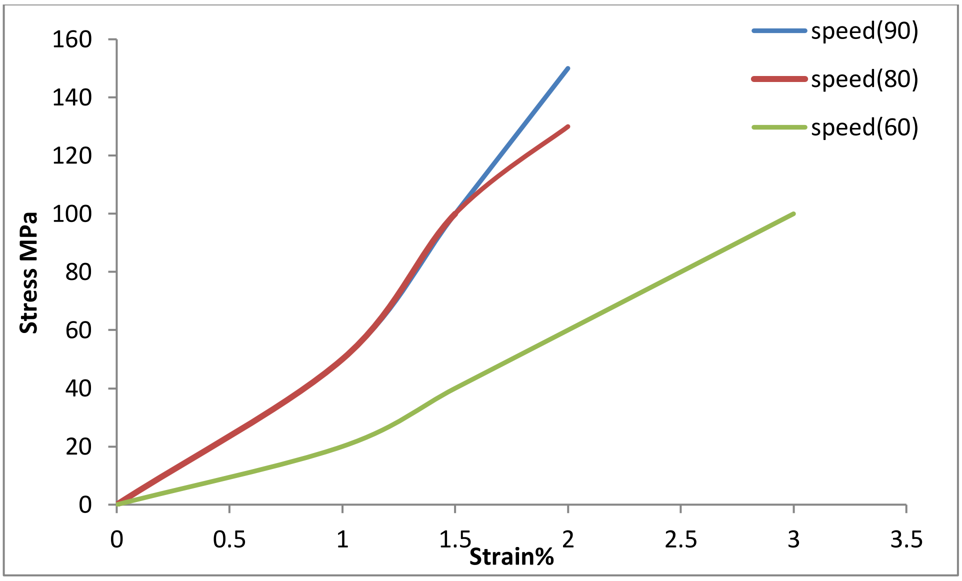
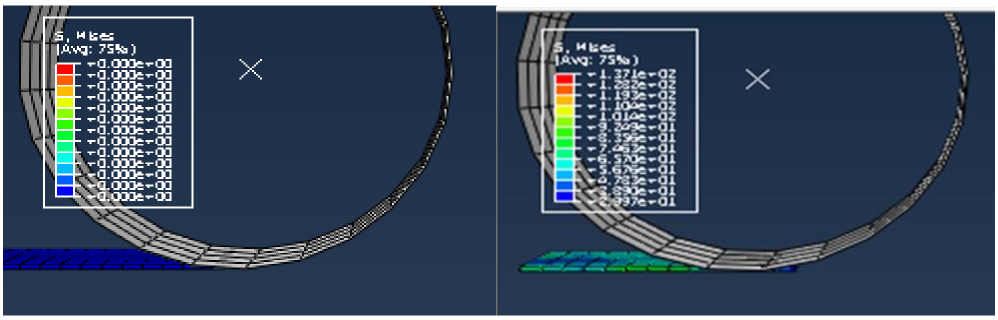


Fig.2. the stress - strain diagram of different speed

3.2 Effect of rolling speed and slip thickness on Von Miss Stress

Figure (3) shows the distribution of the von miss stress value, which is equal to (371 mpa) immediately after entering the plate between the Rollers. After an increase in the rolling time, its value increases to (616 mpa) and then gradually decreases. This is because plastic deformation occurs when the strain reaches a certain value, then the material hardens, so the material becomes more resistant to plastic deformation.



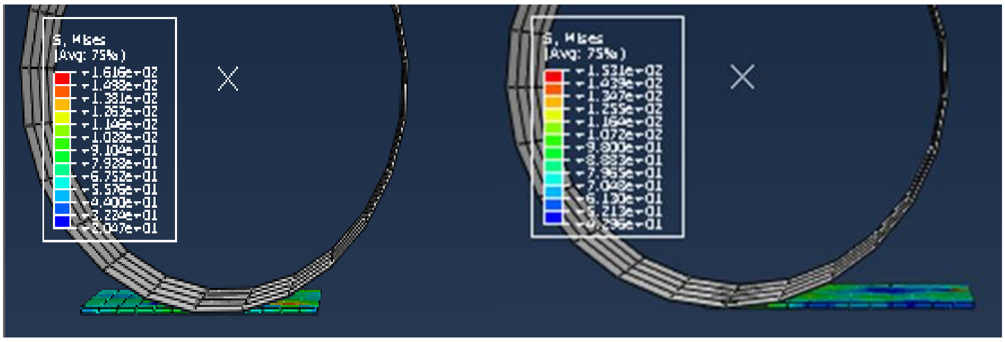


Figure (3) Distribution of vonMises stress during rolling process for rolling speed (60rad/sec, 80rad/sec, 90rad/sec).

4. Conclusion

The finite element analysis of the cold rolling process for A4 aluminum sheets was carried out using the APAX simulation program. Where the roller is rotated at three different speeds, :the following conclusions can be drawn

1. The higher the rotational speed, the lower the equivalent stress (peeq), which represents the strain values.
2. The cutting resistance to stress increases when the rotational speed increases, which its von-miss counterpart represents
3. The production capacity increases when the rotational speed increases, in addition to the mechanical properties.

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