

Design and Analysis of Force, Torque, and Tension of Twin Roll for Thermomechanical Treatment Process

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Abstract: The process of roll are promising method to improve mechanical properties of aluminum alloys by modified of microstructures. A common roll consists of minimum two drums made of hard steel with a small clearance between drum. The effectiveness and lifetime of the roll machine influenced by many parameters such as the maximum force, torque, and stress occurred. In this project the twin roll used to reduce thickness of aluminum plate from 10, 20, 30, 40, and 50% with constant temperature and revolution. The aim of the present work to analysis the parameters of rolling introduce in to main components. To solve these problems some equations in static condition were used to analysis. The results show that the increasing of reduction of thickness influences some parameters of rolling machine process. The 105 KN, 39.8N.m and 2.63×10^{10} N/m² of force, torque, and bending stress respectively was obtained for 50% of reduction.

1 INTRODUCTION

Roll machine is a common mechanic tools in engineering field. The principle rolls consist of minimum two rolls which rotated opposite direction and pulling a plate to flow into the cavity of roll. The roll machine have been used in many areas and material such as rolling on AA8006 aluminum sheets (Cieslar and Republic, 2014), continuous roll casting of aluminum (Lela, 2010), carbon steel and stainless steel (Lindgren, 2007). The advantage of rolling process could improve the mechanical properties of aluminum alloys without melting. S.Roy, et al., reported that the strength improvement of aluminum by using accumulative roll due to grain refinement and strain hardening (Roy et al., 2017). Furthermore, the modification of grain size increased the hardness in which correspond with hall pecth equation ($H = H_o + K_h d^{-1/2}$) where H is hardness, H_o is the hardness intercept at $d^{-1/2} = 0$, and k_h is the hall-pecth slope (Sathiyamoorthi et al., 2017). It is believed that strain hardening, higher strength and hardness of alloys could be obtained by cold work process. Based on work temperature, it could be divided minimum two main group rolling process i.e. cold roll (Lindgren, 2007; Mohammad et

al., 2017) and hot rolling (Roy et al., 2017; Sahoo, 2016; Chandramouli, n.d.; Na et al., 2019). Y.S. Lee et al. (2014) investigated that roll separation force during twin roll casting influenced by roll speed and melt temperature (Lee et al., 2014). Furthermore, a relative rolling velocity results interest and tension and influences the roll load and torque (Bayoumi and Lee, 2008). The roll separating forcet end to decrease with the increases of the roll speed in twin roll casting process (Sahoo, 2016; Lee et al., 2014). M. Lindgren (2007) reported that both of force and torque are two important parameters of rolling process, they needed for bending in a forming stages as a function of thickness (Lindgren, 2007) of materials and an important indicator of optimum process in production system (Jurkovic et al., 2014). Front/back tension also is important parameter to maintain the neutral plane placement of rolling system (František et al., 2008). Therefore, in the rolling design is important to consider the analysis of forces, torque, and tension of twin rolling parameters to obtain optimum process. Based on previous work, only a few researchers investigated these problems in their project.

In the present study, the design and fabrication of twin rolling have been done for aluminum casting plates. The analysis of forces, torque, and tension

calculated for the main components by using static equation to estimate the construction of roll machine.

2 METHODS

Twin roll was designed by using CAD to determine the main components, dimension, and ideal arrangement in its frame. The simplicity in operation has been a priority of this design, so that the machine has an ability to serve a rolling process of aluminum sheet in different thickness. Furthermore, the parameters of forces, torque, and tension/stress for different reduction (10, 20, 30, 40, and 50%). The 1 hp electric motor have been used as a driving force. Further, roll has 75 kg of mass with 200 mm diameter and 230 mm length. The high of aluminum plate 11.5, 12.5, 14.2, 16.6 and 20 mm were used to analyzed parameters in rolling process.

3 RESULTS AND DISCUSSION

3.1 Rolling Machine Design

The design of twin roll machine as shown in Fig. 1, the main components of the machine consists of two steel rolls, electrical motor, pulley and frame. These components arranged as simple as possible to make it easy movement and handling.

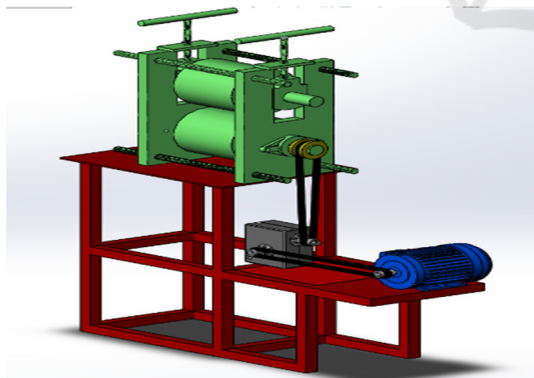


Figure 1: Rolling machine design

The roll components made of steel material (ST 60) are important part to obtain a good dimension corresponding with reduction of plate thickness. The roll system completed with a pair of high adjuster to lift and down of upper roll, see Fig. 2. Furthermore, the single phase induction motor with 1 HP and 220

of power and voltage respectively were used to drive this machine.



Figure 2: Portable twin roll machine model.

3.2 Analysis of Force, Tension (Stress), and Torque of Roll Machine

The analysis of direct compressive forces are important to understand the capacity of roll machine. The forces generated compressive stress along contact point during rolling process, deformation and reduced a cross section area. In the present work the analysis have been done. According to the equation (1) below, the compressive force of different reduction plate could be calculated.

$$P = \frac{\sigma \cdot I}{L \cdot h} \quad (1)$$

The bending stress/tension (σ), inertia (I), length of roll (L) and plat thickness (h) are important parameters to determine the pressure force (P). The inertia is a function of geometry of specimen, by this data the ability of plate withstand a bending phenomenon measured. In this research the specimens has plate form with different thickness and or dissimilar % reduction. Fig. 3 shows the inertia for different reduction (10-50%). The increases of reduction cause the inertia rise linearly, the maximum inertia $2,2953 \times 10^{-9} \text{ m}^3$ obtained at 50% of plate reduction.

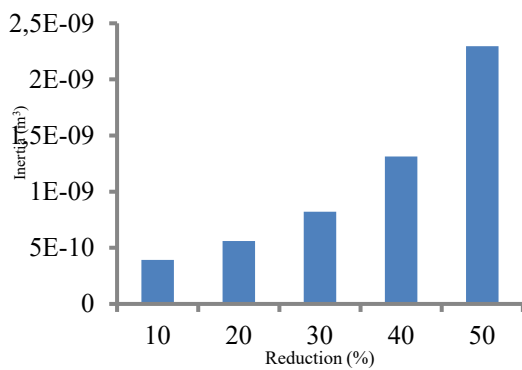


Figure 3: The moment inertia for different reduction.

The bending stress could be calculated by equation (2) below

$$\sigma = \frac{m}{z} \quad (2)$$

From the equation we can conclude that the bending stress influenced by two parameters i.e. moment (m and cross section modulus (z) respectively), which is a moment equal to a total force multiplied by radius of roll. Fig. 4 show the bending stress in various reduction of plate. It is clear was observed that the bending stress tend to decrease linearly with the increase of reduction.

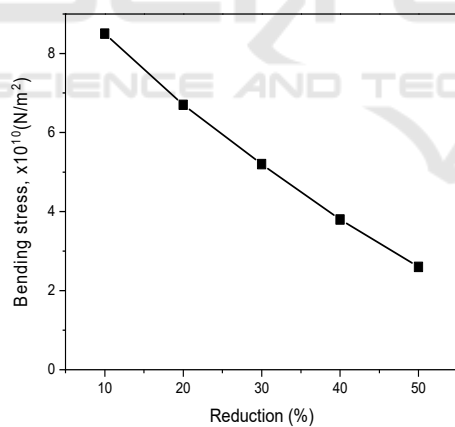


Figure 4: The bending stress for different reduction area.

The compressive stress is the function of bending, inertia and geometry, see equation (1). Length of roll 230 mm constant for all reduction. This stress about 105076,6667 N for different reduction. It is believed that the similarity of stress due to the existence of bending stress going to low was offset by the increases inertia as well the constant geometry factor such as length and diameter of the roll. The force for plate feeding should be overcome the friction force ($F_{friction}$) between roll and aluminum plate. The

friction is multiplied friction and compressive stress, furthermore, the 49386 N friction forces were obtained for various reduction. Fig. 5 shows the distribution of pressure and $F_{friction}$ in rolling machine system. Two roll has similar dimension were assembled with different direction of revolution induce the plate flow between roll with dissimilar reduction. In order to get the roll could operate properly the thrust must be greater than friction force.

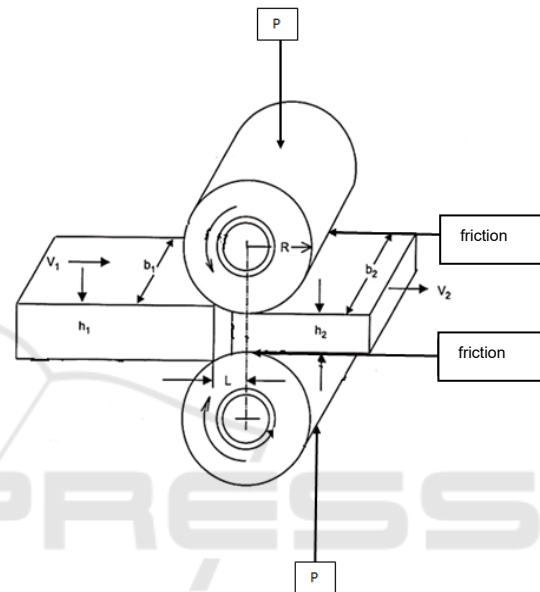


Figure 5: Scheme of distribution of pressure and $F_{friction}$ at free body diagram.

4 CONCLUSIONS

The design, analysis of forces, stress, torsion of twin roll machine were studied in the present work. A simple design twin roll have been finished fabricated. The results show a compressive force, $F_{friction}$ and torque are similar for various reduction. Conversely, the bending stress decreases with the increase of reduction. The inertia moment as a function of geometry show increase linearly with the increase of % reduction.

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