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Numerical Analysis of the Influence of the Rolling Speed on the Cold Rolling under Specific Thermal Condition of the AA 5052-O Aluminum Alloy

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ABSTRACT

In this study, the behavior of the rolling process of the AA 5052 aluminum alloy plate has been investigated using numerical data. An FEM technique was utilized in order to make a prediction regarding the impact that the rolling speed has on the cold rolling of the AA 5052-O aluminum alloy. In order to carry out the simulation procedure, the static structure tool was considered. The geometry of the situation. The total deformation, stresses, including von and normal stresses, and energy have all been the subject of investigation for the simulation that is now being performed. In both the axial and radial directions, the deformation has been investigated using numerical methods. It is possible to get a maximum result of 550 and 140 mm, respectively. at a speed of 200 revolutions per minute, the energy reached 8 kilojoules. It has been established that both normal and von mises stresses have been established. A total of 3.6 and 1.9 MPa are the numerical results that the stress has produced.

1. Introduction

Over the past few years, aluminum alloys have become an extremely desirable commodity due to their low density, high strength, ease of recycling, and high specific heat capacities. Because of the attractive qualities that they possess, there has been a substantial increase in the utilization of these materials in the automotive industry as well as in other areas of engineering, such as the aerospace and telecommunications industries [1]. On the other hand, broad aluminum alloy sheets have a restricted usage due to the fact that they are expensive, the processing processes that are involved are difficult, and they have a range of applications [2]. In the process of fabricating wide sheets of aluminum alloy, the cold rolling procedure is an essential component. The rolling reduction is an important element pertaining to the rolling process, and the following annealing temperature is also

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an important factor. If you want better results while shaping, you should apply this heat treatment that involves annealing. Therefore, it is of the utmost importance to investigate the ways in which rolling reduction and annealing temperature influence the microstructure and mechanical properties of aluminum alloys [3]. The development and investigation of ring rolling methods that include rings that are either extremely accurate, extremely lengthy, or have a complicated form has become a controversial topic in the business that deals with the manufacturing of metal plastic [4]. Due to the nature of the process and the high nonlinearity it possesses, it is difficult to adequately define the process exclusively via the use of analytical methodologies. Quantitative explanations are adequate for the system on which they are based; nevertheless, extending findings in an appropriate manner might be challenging [5,6]. Consequently, the finite element approach, which is denoted by Sharaf *et al.,* [7], is being utilized in the process of researching and developing novel ring rolling procedures. How to effectively monitor guide rolls is a difficulty that arises while trying to achieve a successful 3D finite-element ring rolling simulation. This is especially true for rings that are intricate in design, large in size, or require a high level of precision. An essential problem that has to be solved is the creation of a realistic three-dimensional finite-element ring rolling model. A significant problem that arises with the twin-roll casting procedure is the presence of splits and other defects in the hardened strip [8]. In a thermomechanical approach, these defects present themselves as stresses and strains that are brought about by temperature gradients, pressures, and loads. Having the knowledge of how these stresses and strains grow and generate faults in the cast strip is an extremely important piece of information to possess. Over the course of the past few years, there has been a substantial amount of advancement made in the field of computer simulations of the casting and solidification processes [9]. In order to examine the processes of solidification, heat transfer, and fluid movement that take place during the manufacture of thin strip casting, a variety of models have been built. On the other hand, stress modeling in thin strips is a topic that has received less attention in the bodies of research that have been published. In the past, researchers have devoted a considerable amount of time and effort to the task of forecasting the stresses that are induced during the DC casting of aluminum1-5. Jeng *et al.,* [10] built a fully linked, three-dimensional, transient finite element model by making the assumption that the metal would exhibit elasto-plastic behavior that was dependent on the strain rate. This allowed them to develop the model. The model makes predictions about the changes in temperatures and thermal stresses that will take place throughout the process of DC casting aluminum slabs [11]. It is essential to do elastic stress calculations in DC cast aluminum alloys in order to ascertain the likelihood of cold fractures occurring in these alloys [12]. Regarding the mathematical modeling of stresses and strains in twin roll thin strip casting processes, there has been a lack of direct attention in the literature. This includes both direct and indirect emphasis. Using a mathematical model that was two-dimensional, Sharaf *et al.,* [13] was able to identify the stresses that were present inside the horizontal thin strips themselves. This was accomplished by using the model. They failed to take into account the effects of the edge and instead felt that the problem was just a matter of strain. The amounts of shear deformation that were found along the boundary between the solidification zone and the exit were found to be quite high, as was discovered [14]. Sharaf *et al.,* [15] put out a thermo-mechanical model for the purpose of casting alloys utilizing the three-dimensional roll casting process. This model was presented for the purpose of casting alloys. The mechanics of deformation brought about by rolling activities were taken into consideration, together with the thermokinetics of solidification, in order to generate the appropriate physical condition [16]. It has been shown that the contact pressure between the strip and the rolls is the most important variable [17]. This pressure is the one that determines the transmission of heat as well as the development of stress and strain in a manner that is entirely organically tied to each other. In the process of rolling creating an aluminum alloy ring, nonlinearity is present in both the material and the boundary conditions, which include temperature and stress [17]. This nonlinearity is a defining characteristic of the entire process. It is the combination of the parameters of processing conditions and temperature that results in the formation of residual stress [18]. When the size of the ring rises, it is becoming more and more clear that the local strains and the residual strains are not distributed in an equal manner [18]. To add insult to injury, the connecting ring for rocket storage tanks must be of a high grade once the ring rolling forming procedure has been completed. After that, this ring needs to be transformed into an aircraft thin-walled ring, which is susceptible to deformation while it is being produced [19]. Aluminum alloy suffers a considerable reduction in its strength, stability, and fatigue resistance when residual stress is present [20]. This is because of the existence of residual stress. This tension also causes it to become less resistant to stress corrosion cracking, which is another consequence of the stress. Furthermore, investigations have shown that the initial residual stress in the blank is the most significant element that leads to the deformation that takes place throughout the machining process [21,22]. As a result, the purpose of this study is to conduct a numerical analysis of the impact that the rolling speed has on the cold rolling of the AA 5052-O aluminum alloy under certain temperature conditions.

2. Methodology

2.1 Modeling and Meshing Process

This specific Model was created with AutoCAD as the tool of choice during the development process. This model is made up of two rollers that are positioned at radial elevation (Yz) and a plate that has a head that is just slightly pointed. The purpose of this model is to ease the process of rolling. It is done in this manner in order to simplify the rolling process and make it easier to do. There are three different parts of the mesh that have been made up to this point by the manufacturer. Not only are the rollers asymmetrical components, but they have also been made with a non-linear mesh arrangement being employed in their construction [23]. This is a significant difference between the rollers and other components. Solid conduct has been conferred onto each and every one of the 160 divisions that have been formed on the edge of each roll. This has been the case with each and every one of them. It has been assigned a soft behavior, which is distinct from the behavior of the elements, as opposed to the behavior of elements that are related with the plate. This behavior is distinct from the behavior of the elements. It is via the use of the components technique that the idea of a sweep has been established and successfully brought into existence. The simulation has reached 11900 elements, as indicated in Figure 1. This indicates that the total number of components that are necessary for the simulation to reach the convergence stage has occurred. Because of the evidence, this is the conclusion that can be derived from them.

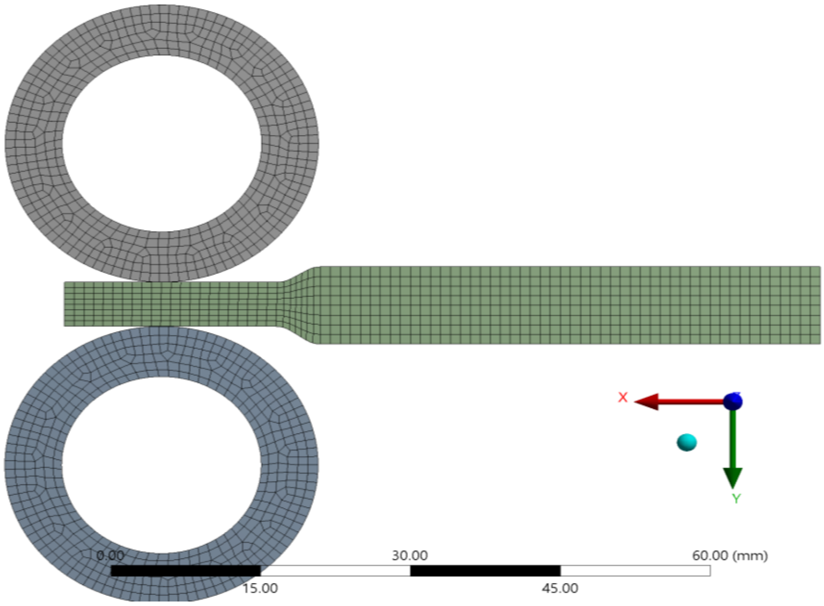

Fig. 1. Meshed model of the roller and plate of AA5052-O

2.2 Boundary Condition

To carry out the simulation technique, a swept mesh was constructed in order to simulate the large deflection that takes place as a result of a high load. This was done in order to ensure that the procedure was carried out successfully. Ansys, which is comprised of four cores, has been employed in an acceptable manner in addition to that. Over the course of this study, the rolling speed was investigated at 50, 100, 150, and 200 revolutions per minute [24]. Both rollers have been positioned in such a way that they will rotate against one another. This arrangement was made. It has been found that the friction factor between the roller and the plate is equal to 0.3. This number has been determined throughout time.

2.3 Mechanical and Thermal Properties of AA 5052-O

A significant amount of magnesium and chromium are added to the aluminum–magnesium alloy that is often referred to as AA5052-O from the very beginning. It is not possible to heat treat AA 5052 since it is an aluminum alloy; rather, it can be hardened by the technique of cold working. There are 2.68 grams of density for every cubic centimeter. The modulus of elasticity is 72,3 gigapascals (GPa) [25,26]. Examples of thermal qualities are Specific Heat Capacity, which is 0.88 J/g-°C, and Thermal Conductivity, which is 138 W/m-K. Both of these values are possible. There is a value of 0.33 for Poisson's Ratio.

2.4 Contact Regions and Joints

During the process of this investigation, a number of different procedures have been carried out, and the simulation approach has been carried out in line with those procedures. Before going on to the next phase, the most crucial thing that needs to be done is to figure out where the contact zones are. Within the framework of this paradigm, a variety of various contact points are made available. picture 2 presents information that suggests that it is located on both sides of the plate and is accompanied by a roller. This information is given in the picture. Both the contact region at the plate and the contact region at the rolled are referred to as the contact region. The contact region at the plate has been designated as a target. This was uncovered over the course of the inquiry that was carried out. It has been determined that the joints will be described in the horizontal elevation of the rollers at the same stage as the step that came before it. The fact that it has been regarded a relational joint in order to enable the roller's revolute in the appropriate manner is demonstrated in Figure 2. The purpose of this action was to make it possible for the roller to undergo a revolute behavior.

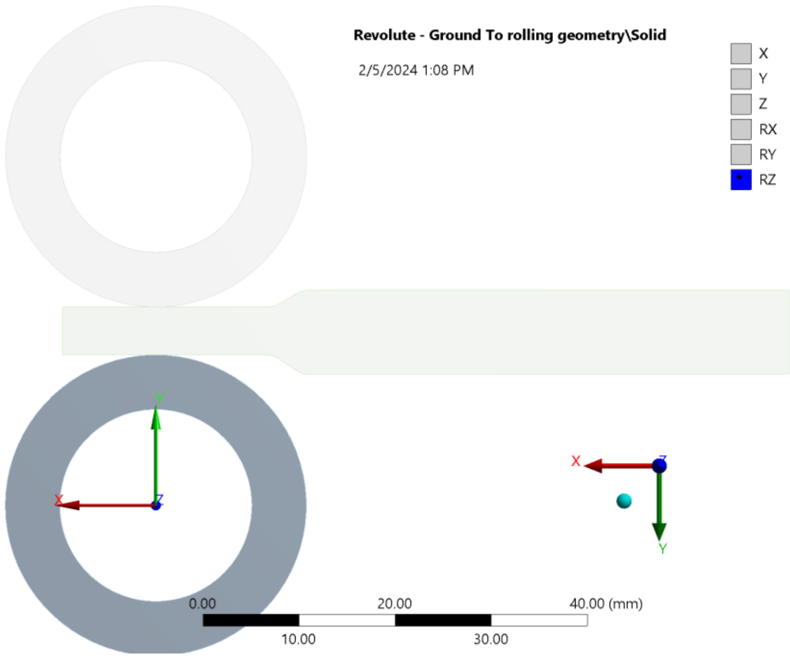

Fig. 2. Explanation of rotating joints in this mesh

3. Results and Discussion

3.1 Deformation in the Aluminum Plate

Within the context of this simulation, the rolling process has been investigated in both the radial and axial directions. An investigation has been conducted on the extent to which the rolling process is causing the material to undergo deformation or decrease. It is necessary to have a velocity of at least fifty rotations per minute in order for the axial distortion to reach 550 millimeters. As the velocity increases, the axial deformation reduces, as the findings of the simulation revealed, which established this link between the two variables. With regard to the redial deformation, it achieves a length of 140 millimeters at an angular velocity of fifty rotations per minute, and it acts in the same manner as the axial deformation that is depicted in Figure 3.

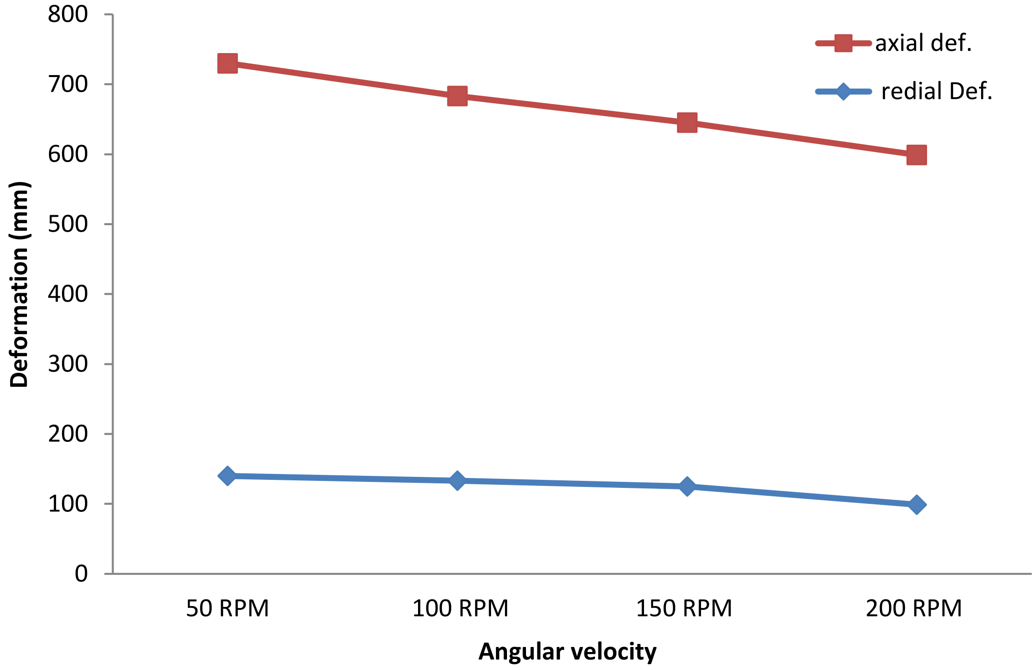

Fig. 3. Deformation due to angular velocity

An instance of the complete deformation that occurred as a result of the rolling operation that was carried out is presented in the form of a graphical representation in Figure 4. The static structural tool that is a part of the Ansys software was utilized in order to accomplish the task of customizing the technique that is present in the process of being carried out. When the plate first comes into touch with its surroundings, the deformation begins. This is the moment at which the plate begins to undergo deformation. The elongation that takes place reaches its maximum degree at the neck of the aluminum plate, as can be seen by glancing at Figure 4, which makes this information very evident.

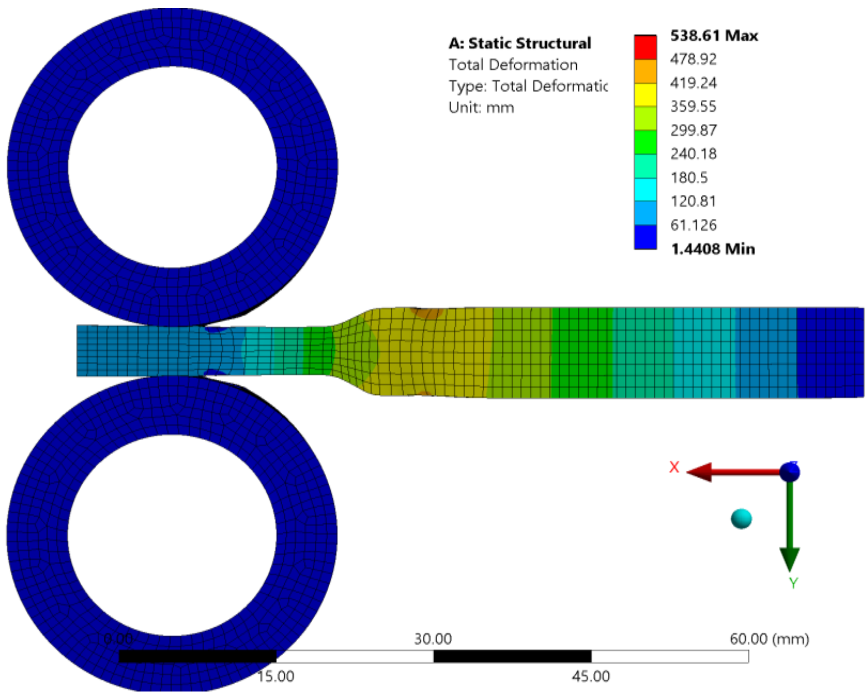

Fig. 4. Graphical effect of the simulated deformation

3.2 Investigation of the Stress Analysis of AA5052-O

In this simulation, the finite element technique (FEM) was utilized to study two distinct types of stresses to determine their respective effects. The application of both stresses was carried out at four different rotational speeds, as shown in Figure 5. These rates were fifty, one hundred, one hundred fifty, and two hundred revolutions per minute. When it comes to various pressures, the similar stress is the first one that will be explored. According to the conclusions of the numerical analysis, the maximum von Mises stress that may be placed on the rollers is 3.6 MPa, and this stress starts to drop as the rollers' speed rises. It is getting closer and closer to the lower value of 3.1 MPa while it is at 200 rotations per minute. On the same note, the behavior that is expected of you is the same as it is for the typical stress. A typical stress level of 1.9 MPa is reached at a rotational speed of 50 revolutions per minute, and then it increases to 1.01 MPa.

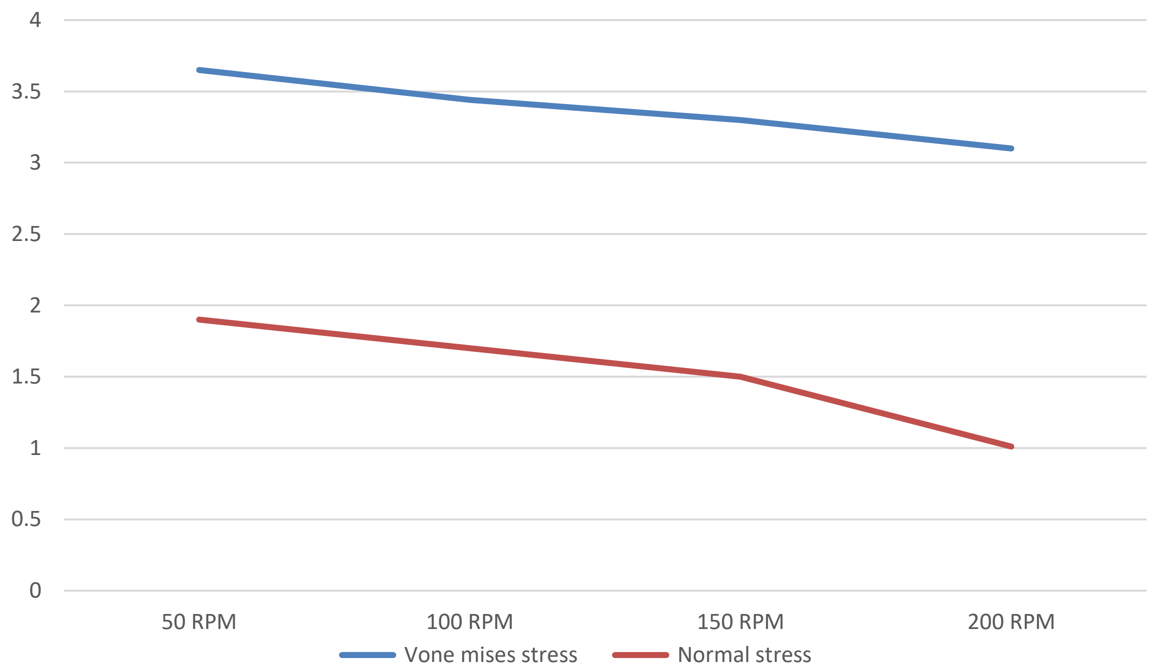

Fig. 5. Stress analysis of the AA5052-O

Figure 6 is a graphical illustration of the normal and von Mises stresses that are in existence as a consequence of the rolling process. These stresses are there because of the rolling process. The numerical findings led to the conclusion that the maximal von mises stress reached its highest feasible value toward the beginning of the aluminum plate. This conclusion was reached based on the data. At the beginning of the aluminum sample, the influence of von Mises stress, which was brought about by the rolling process, was observed throughout the sample, commencing at the top and working its way down to the bottom. At the same time, the impact of normal stress has only been noticed on surfaces that have been contacted with rollings. They have not been observed on any other surfaces.

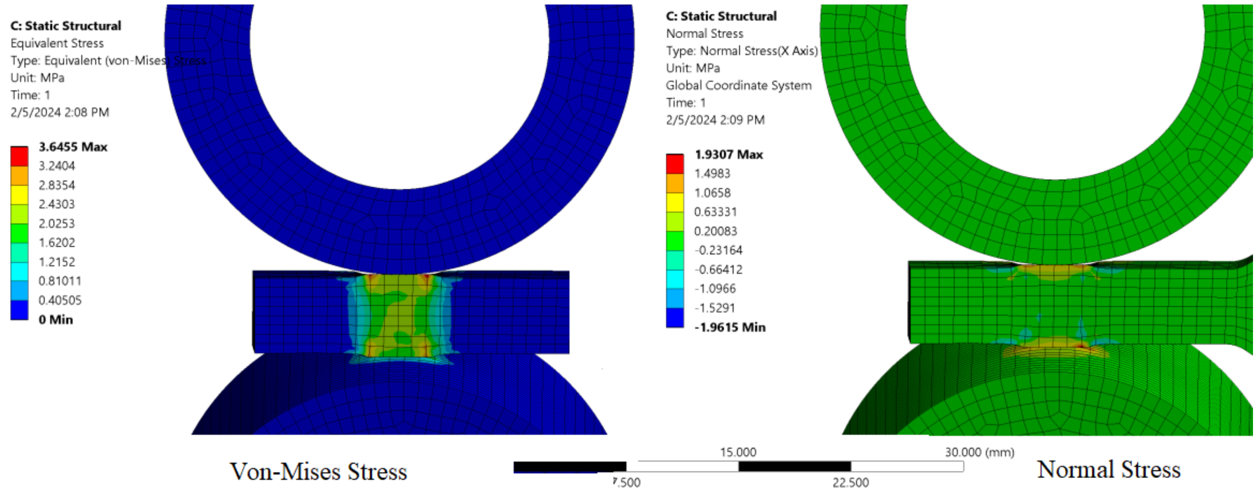

Fig. 6. Graphical effect of the simulated of stresses

3.3 Investigation of Strain Energy

Figure 7 is a visual representation of this specific portrayal, and it shows the strain energy that is present as a result of the rolling process. This particular portrayal is illustrated by this particular figure. Near the beginning of the aluminum plate, the findings of the numerical analysis revealed that the maximal strain energy reached its highest conceivable value. This was the case because the plate was very thin. This information was uncovered as a result of the fact that the plate was constructed out of aluminum. Starting with the aluminum sample, the rolling process generated energy in a path that was traveling from the top of the sample to the bottom of the sample. The rolling operation resulted in the generation of this energy as a consequence. 8.1 kilojoules is the value that is obtained when the starin energy is measured into the system.

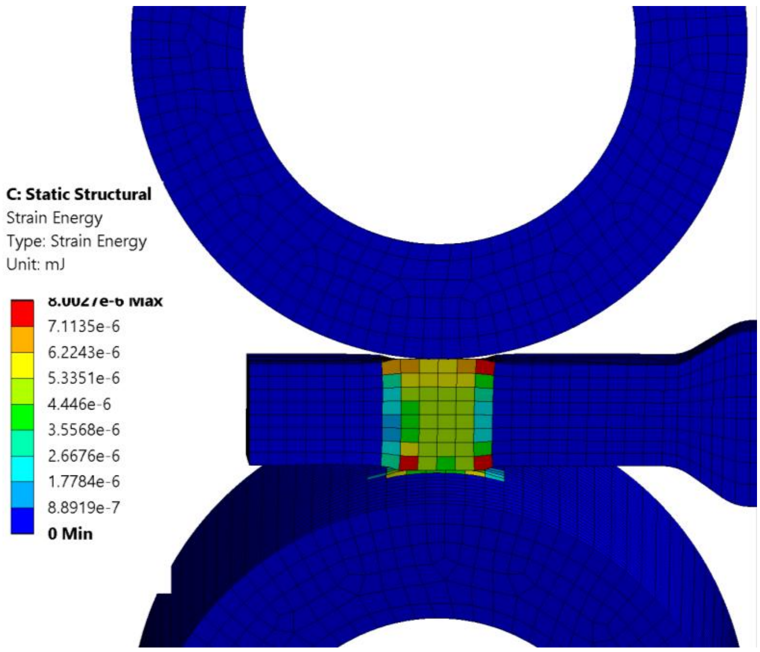

Fig. 7. Graphical effect of the simulated strain energy

At the maximum speed, the strain energy reaches 8.1 kilojoules at 200 revolutions per minute (RPM), as was demonstrated by the numerical data in Figure 8. This indicates that the strain energy was at its highest during the maximum speed. This energy is reduced when the angular velocity of the rolling lowers, and it reaches 3.8 kilojoules when the rolling is moving at a speed of 50 revolutions per minute.

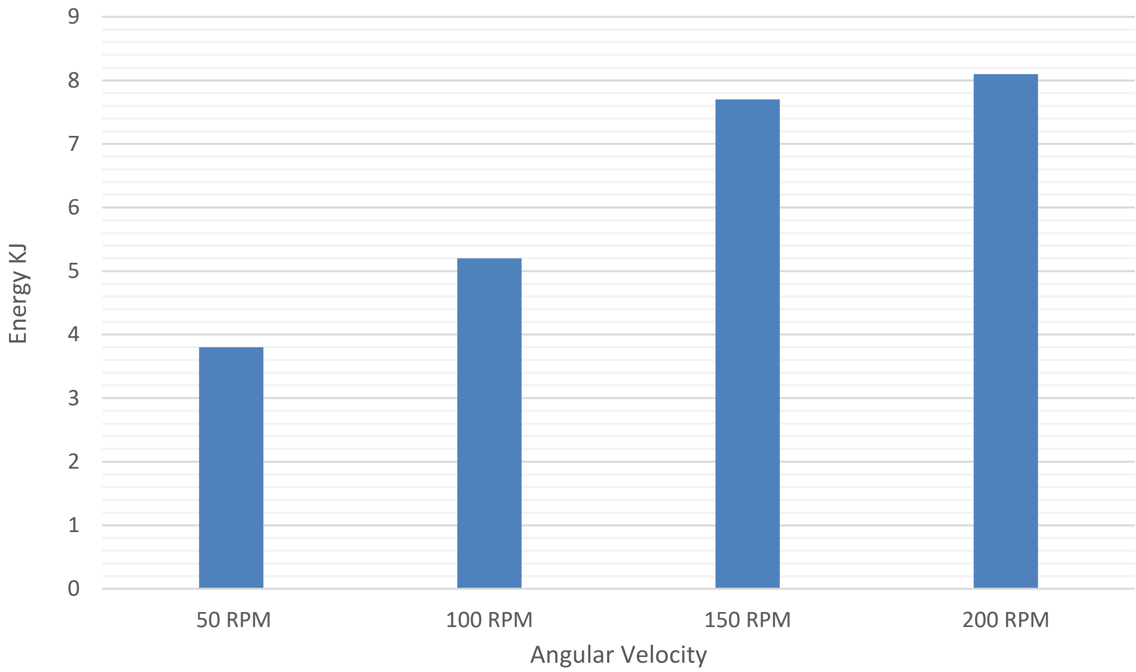

Fig. 8. Simulation results of strain energy due to various roll speeds

4. Conclusions

In conclusion, the behavior of the rolling process of the AA 5052 aluminum alloy plate has been evaluated with the use of numerical data. It was demonstrated that this is the case. When it comes to the cold rolling of the AA 5052-O aluminum alloy, a finite element method (FEM) approach was utilized in order to provide a forecast about the impact that the rolling speed has on the process. For the purpose of carrying out the simulation operation, the tool for static structures was taken into consideration. How would you describe the geometry of the situation? As part of the simulation that is now being carried out, the total deformation, stresses, including von and normal stresses, and energy have all been taken into consideration as possible topics of investigation. It has been determined via the application of numerical methods that an inquiry into the deformation has been carried out in both the axial and radial directions. The maximum outcomes that may be accomplished are 550 millimeters and 140 millimeters, the two highest possible values. When the speed was adjusted to 200 revolutions per minute, the total amount of energy reached 8 kilojoules. Since it has been demonstrated, it has been established that both the normal stresses and the von Mises stresses are present. The stress has resulted in a total of 3.6 and 1.9 MPa of pressure, respectively, as the numerical numbers that have been created.

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