Analysis for Stress Prediction in Hot Rolling with Different Process Parameters by Finite Element Method

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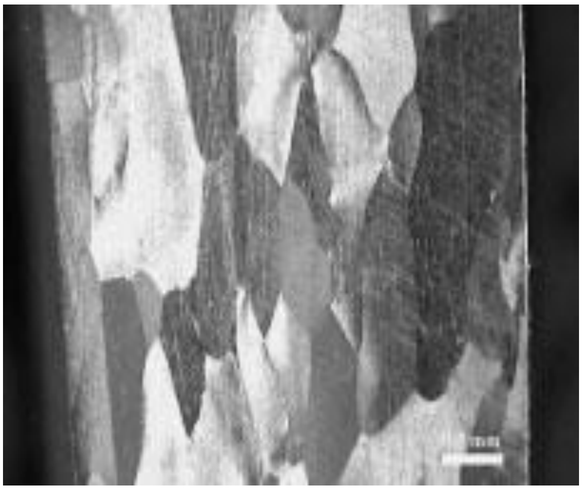
Abstract – *In hot rolling mill process the rollers is subjected to heating and cooling cycles with different processing parameter. This nature of heat and processing parameter found some cracks, wear and tear in hot roller. In this work, the study of existing process was done to find the root cause of the cracks in roller mills. The analysis of the rolling process was done and results obtained in terms of equivalent stress and effective plastic strain. It has been found that mill speed and friction coefficient are the two major factors that significantly affect the quality of rolling products. Lower value of friction coefficient requires that number of mill passes be increased. Higher value of friction coefficient increases the sticking between rollers and the incoming metal leading to defects in steel angle bar.*

Key Words: Hot Rolling, Cold Rolling, Cracks, Coefficient of Friction, Stress, Strain

1. INTRODUCTION

The sizing press followed by horizontal rolling is more efficient in width reduction than deformation by a heavy edger mill followed by horizontal rolling. The finite-element analysis results for the deformation of a slab also show reasonable agreement with measurements from an actual mill test, and from physical modelling experiments [1]. The effects of process parameters such as the cooling condition of the work-rolls, the rolling speed, and the roll metal interfacial heat-transfer coefficient on the temperature distributions in the work-rolls as well as in the rolling metal. The comparison between the model predictions and experimental results shows the validity of the proposed model [2]. The rapid development of computer technology and the improvement of general finite element analysis software, especially with the development of parallel computing technique, it has become possible to analyze cold strip rolling process and calculate the strip deformation with 3-D finite element contact model of rolls and strip [3]. The temperature of H-beam was a downward trend in the hot rolling process, however, local temperature display rising trend, uneven deformation of flange lead to more complex temperature distribution, there is certain correlation between equivalent plastic stress and temperature distributions, increasing of equivalent plastic stress as the temperature increases, research results can provide theoretical basis for rolling regulations and reference of the production of hot rolling for H-beam [4-7]. The vertical roller mill 3-D model established in Pro/E is imported into ADAMS through the data interactive software Mech/pro to analyze its stress, and then carry out the FEA of the model loaded in ANSYS. After Comparing with the material yield limit, the both stresses are reasonable which will meet the demand of design. This co-simulation method provides a reliable basis for vertical roller mill design and can also be applied to other mechanical system design process [8]. A coupled thermo-mechanical finite element method computation on steel pipe rolling process, gets the residual stress and strain change rule in the rolling process. They analyzed the influence of roller spacing and velocity parameters on residual stress and strain, which provides a reliable theory basis for improving the performance of hot rolling seamless steel pipe and the optimization of rolling technological parameters [9]. The roll cross angle, rolling press quantity, intersection position and rolling speed can change the size of the axial force, axial forces may float small by the pressing ratio increases, lager by rolling speed increases, bigger by adding more far intersection point position, This conclusions have realistic significance in cross rolling schedule making, and provide basis theory reducing rolling axial force [10]. The ring can approximately maintain its round shape at the initial rolling period, when the process is entering the medium period, the roundness of the ring becomes worse, and it tends to be improved at the final rolling period. A series of ring rolling experiments were conducted. So the reliability of the finite element model of the vertical hot ring rolling process with measurement and control was validated [11]. The formation of edge defects in hot strips, resulting from slab corner cracks generated in continuous casting. They developed a model-based concepts for the identification of such initial slab cracks. To accomplish this task a systematic finite element tool Deform-3D was utilized. The numerical results clearly pointed out the significant morphological changes of the cracks during rolling and afford valuable indications for a deeper understanding of the underlying process details [12-14]. A two dimensional elastic plastic model was used to simulate the cold rolling of thick strip. They found the speed and diameter of rolls have influence on the quality of rolling products [15]. The mechanical properties of high strength steel and mild steel at elevated temperatures. They found that yield strength, tensile strength and elastic modulus of steels at elevated temperatures decreases [16]. The investigating the mechanism of thermal crack growth while taking into account the complex thermal and mechanical interactions during the rolling process. They utilized the concepts of FEM for the estimation of rolls life, from the perspective of thermal fatigue. Their work described the methodology of predicting thermal fatigue crack growth using innovative modelling techniques and they highlights the importance to the operating conditions [17]. The accuracy of the FE model was analysed through a dual comparison by geometrical and by physical aspects. The effectiveness of a new numerical subroutine was tested by a comparison with experimental values acquired from an industrial plant tool wear, the author characterized the extent of the tool wear by wear depth. Twenty points were used to measure tool wear depth with different area reduction, forming angle, and stretching angle [18].There was good agreement between experimental results and the simulation in terms of wear and rolling friction under different operating conditions. The analysis of disc-disc interaction has been presented by using FEM technique. However this work gives rise to thoughts about possible applications in various fields [19]. The finite element model for the prediction of the steady-state thermo-mechanical behaviour of the roll-strip system and of roll life in hot strip rolling. The model was comprised of basic finite-element models, which are incorporated into an iterative-solution procedure to deal with the interdependence between the thermo-mechanical behavior of the strip and that of the work roll. However, the model addressed only a part of roll wear–related problems, leaving the rest for future works [20]. They used finite element analysis technique to investigate behavior of rolls related to bending, shifting and levelling. The effective utilization of these methods, leads improvisation of the flatness in the cold rolled sheet. Apart from the profile of sheet, the shape was also significantly affected by the vibrations developed in mill housing [21]. The developed procedure for the simulation of the hot rolling process. They stated that rolling is a 3D process but using the generalized plane strain method, the real 3D problem can be solved using a 2D Finite Element Model, saving an important computing time [22]. FEM software are able to describe the kinetics of recrystallization during the process, taking into consideration grain size refinement and grain growth. By incorporating such mathematical models, it is possible to predict the formation process as a whole, including the final microstructure obtained for the forged part, allowing process optimization that focuses on a higher-quality final product [23]. They developed a computer system to detect shape defects in the rolled product and determined the degree of deformation of metal at the design stage, which allows the initial plans to approximate the final design as closely as possible. So this system is very helpful for future researchers, would make it possible to avoid having to perform a large number of costly and time-consuming commercial trials and to predict the defects might be formed in the rolled product [24].The variation of the blade cross-section, the deformation stress and strain of the work-piece keep changing during the rolling process and the conventional rolling theory is no longer valid. The complexity and diversity of the blade cross-section determine it impossible to establish a universal theoretical model for the rolling process [25].Finite element method is reliable and versatile analytical method that avoids bold hypothesis, which are often involved in the classical methods such as the slab method or the energy method [26].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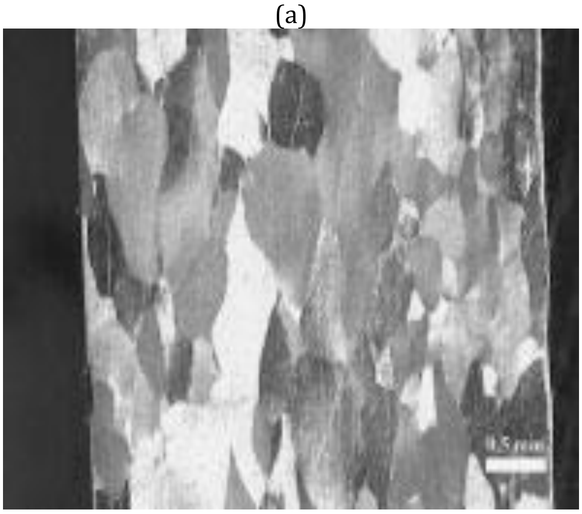
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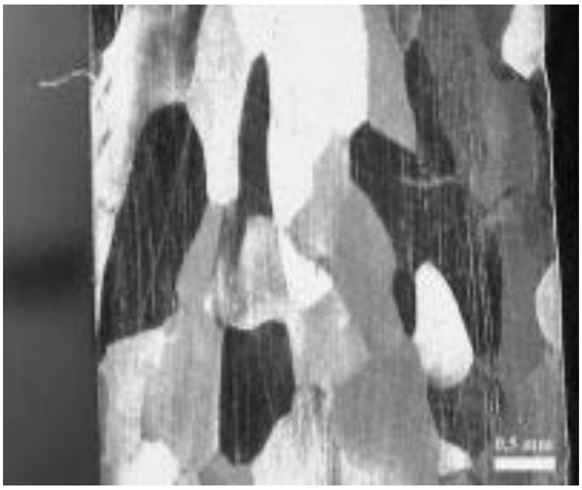
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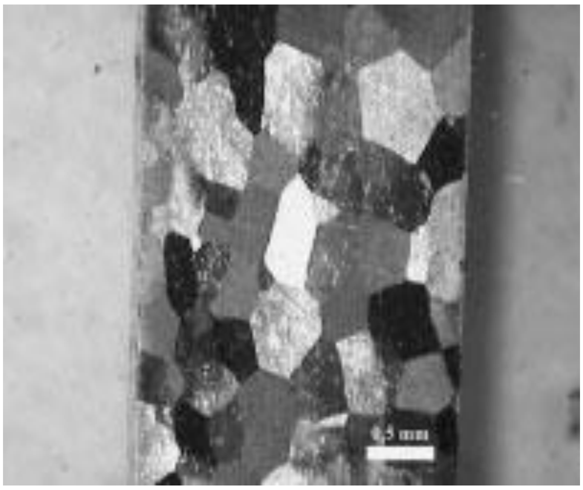

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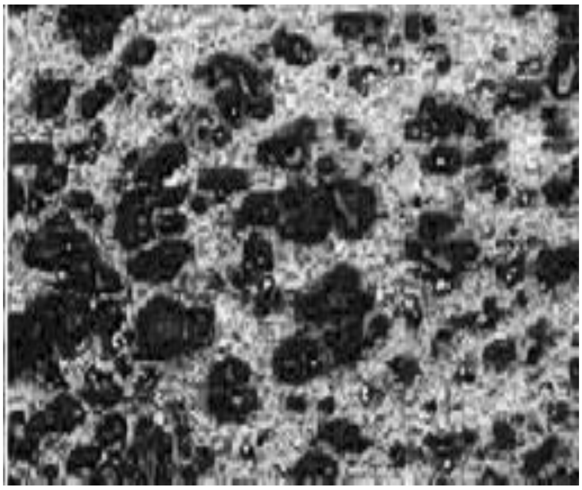
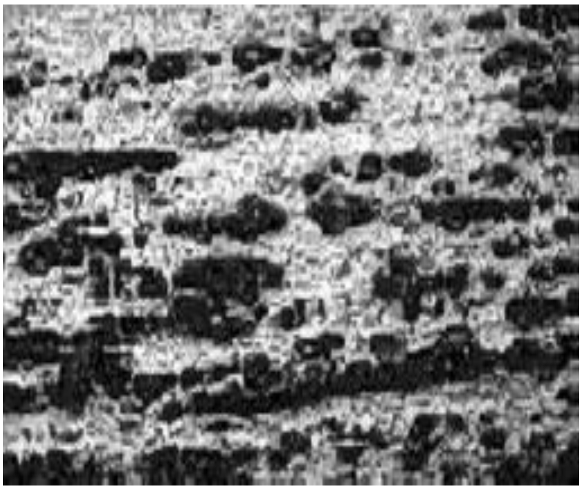
Fig:1 The structure of the material after (a) rolling at 750⁰C, strain 0.14, (b) rolling at 900⁰C, strain 0.19, (c) rolling at 1000⁰C, strain 0.2, (d) rolling at 1300⁰C, strain 0.18 [27]

The investigation of the Fe28Al3Cr iron aluminide microstructure after rolling with draught of approx. 0.2 was performed both by optical and transmission electron microscopy. The recrystallized grains after rolling at 1000⁰C and 1300⁰C are visible as shown in figure 1. The shape of grains after rolling at 750 and 900⁰C does not enable any clear interpretation. Transmission electron microscopy provides unambiguous information about the microstructure [27].



Transverse Section



Longitudinal Section

Fig: 2 Effect of successive hot rolling particles uniformity in Al6063-SiC particle size= 152µm [28]

In the case of the as-cast slabs, prepared with the application of the optimum composite preparation route, the particle distribution was found to be similar in both longitudinal and transverse section. Application of successive hot rolling resulted in a uniform particle distribution with particle alignment in the rolling direction [28] as shown in figure 2.

2. PROBLEM DESCRIPTION

In this work the effective stress and strain is carried out in steel angle bar during hot rolling operation with optimum process parameter for prevent the edge crack in angle bar as shown in figure 3.

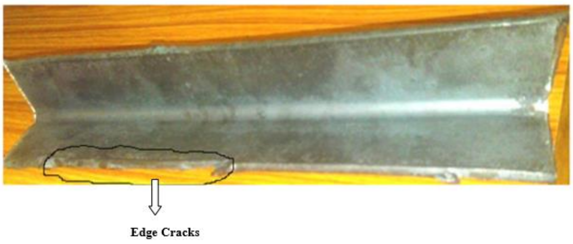
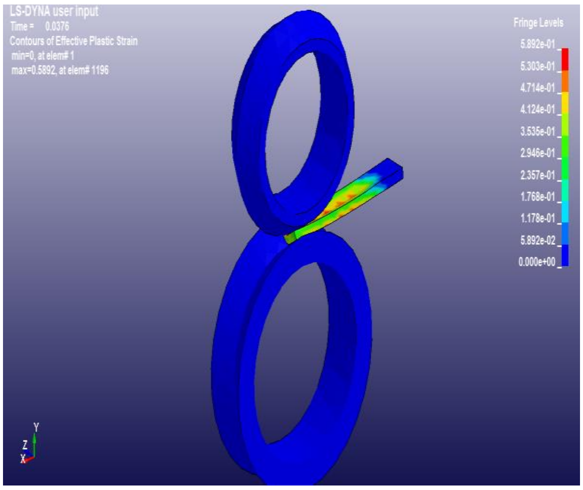


Fig 3: Edge Crack

3. RESULTS AND DISCUSSION

The effective stress and strain is carried out in steel angle bar during hot rolling operation with optimum process parameter for prevent the edge crack in angle bar. The diameter of the rollers and temperature of the material were not changed as per industry requirement. Also limit of mill speed was taken 110 rpm.

The simulation results were obtained in the terms of effective plastic strain and effective stress distribution. The acceptance criteria of plastic strain is 0.5 in hot rolling [29]. So the plastic strain value exceeds this limit then it will lead edge cracks in steel angle bar.



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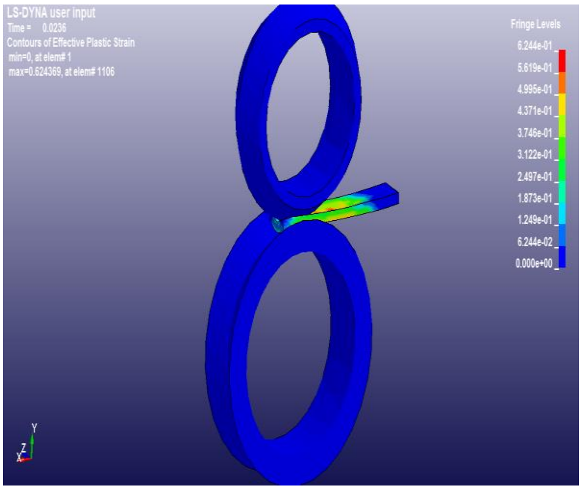

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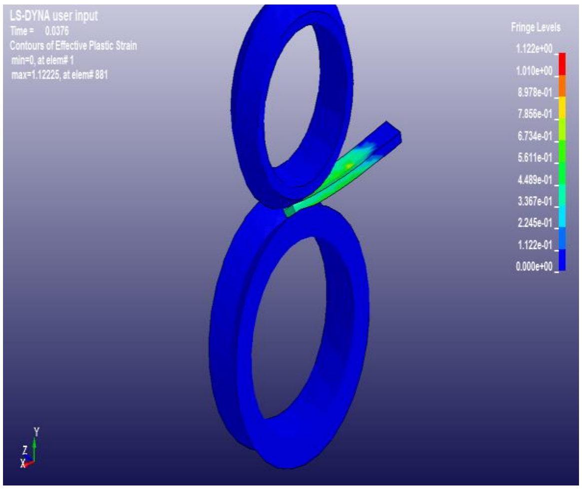

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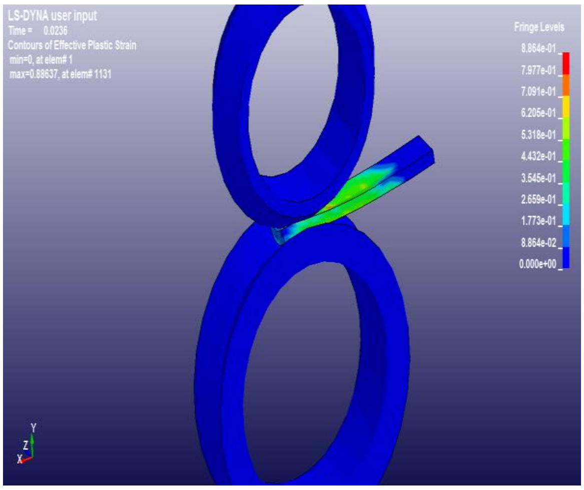
Fig. 4: Effective Plastic Strain Distribution in Angle Bar at N=105 rpm, μ=0.20 (b) μ=0.25 (c) μ=0.30



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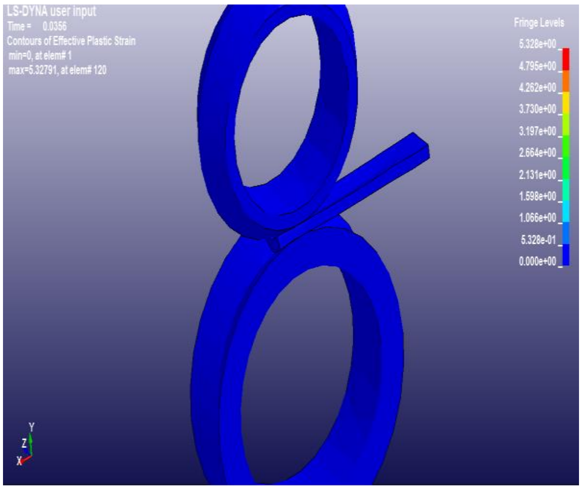

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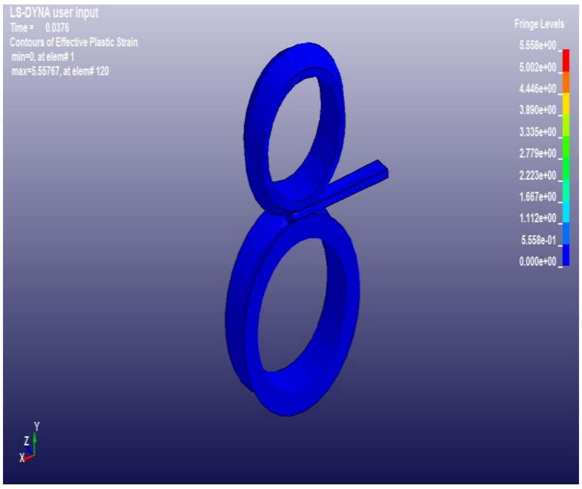

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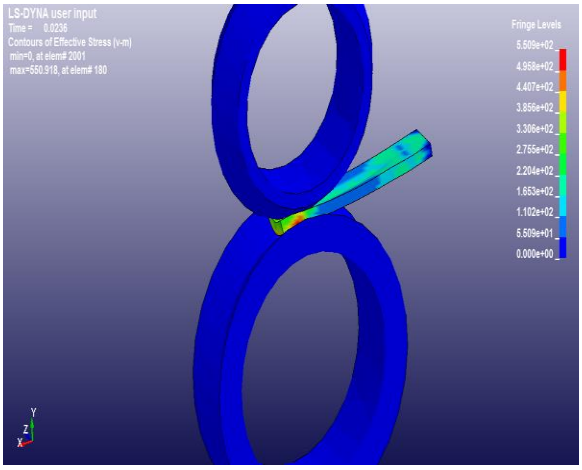
Fig. 5 : Effective Plastic Strain Distribution in Angle Bar at N=110 rpm, (a) μ=0.20 (b) μ=0.25 (c) μ=0.30

In this work the ingot and rollers assembly was subjected to mill speed of 105 and 110 rpm with friction coefficient 0.20, 0.25 and 0.30. The minimum effective plastic strain was produced 0.5892 at N=105 rpm with friction coefficient 0.20 and maximum effective plastic strain was produced 0.8864 at N=110 rpm (μ=0.20) as shown in figure 6.



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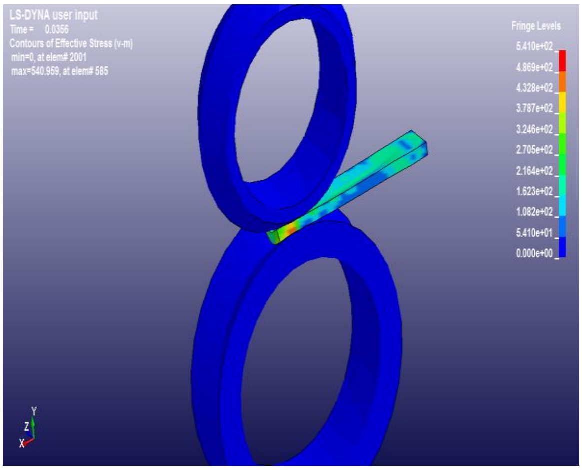

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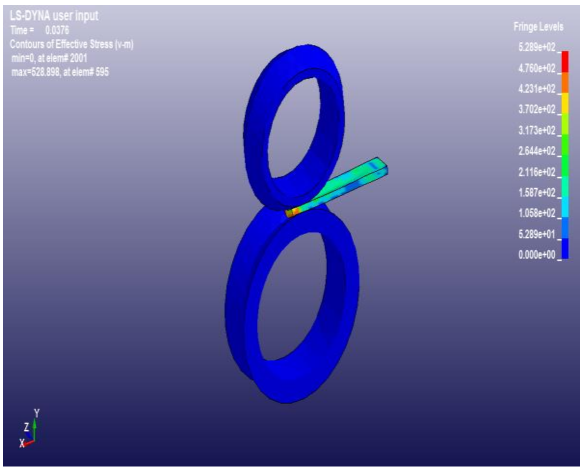

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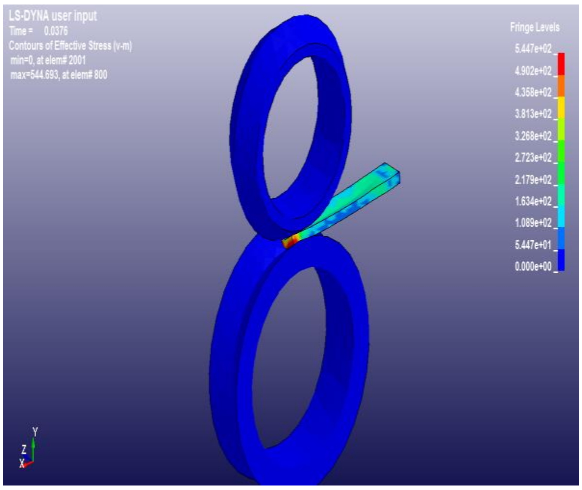
Fig. 6: Effective Stress Distribution in Angle Bar at N=105 rpm,(a) μ=0.20 (b) μ=0.25 (c) μ=0.30



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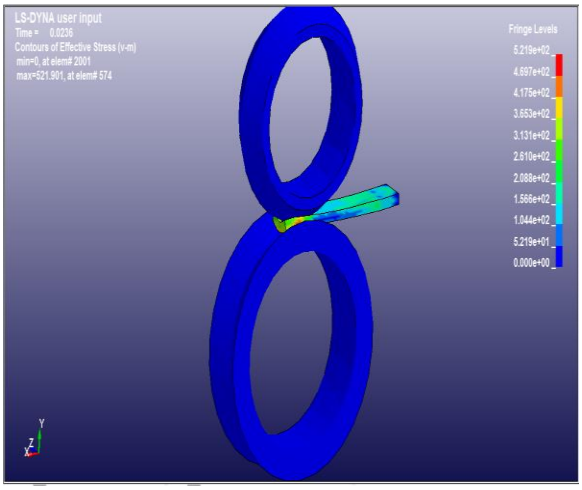

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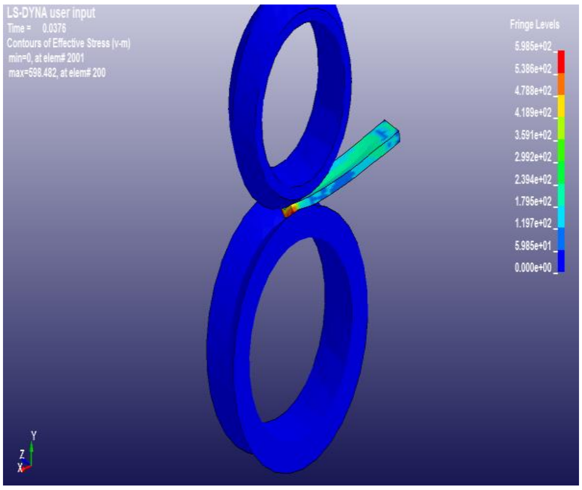

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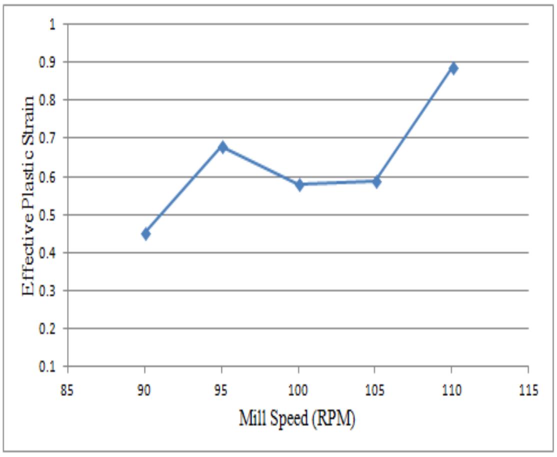
Fig. 7: Effective Stress Distribution in Angle Bar at N=110 rpm, at μ=0.20 (b) μ=0.25 (c) μ=0.30

The ingot and rollers assembly was subjected to mill speed of 90 rpm, 95 rpm and 100 rpm with friction coefficient 0.20, 0.25 and 0.30. The maximum effective stress was produced

598.48 MPa at N=105 rpm with friction coefficient 0.30 and minimum effective plastic strain was produced 528.89 MPa at N=110 rpm (μ=0.30) as shown in figure 7.



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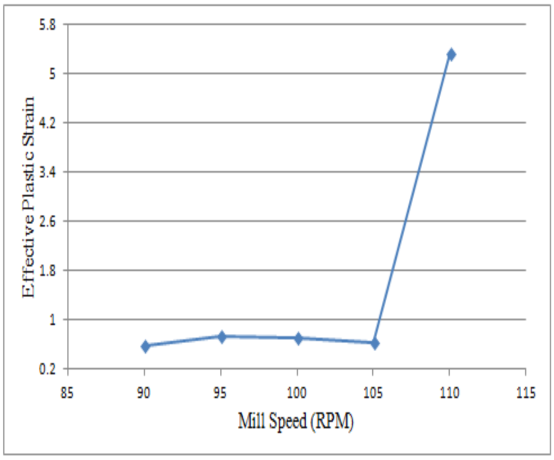

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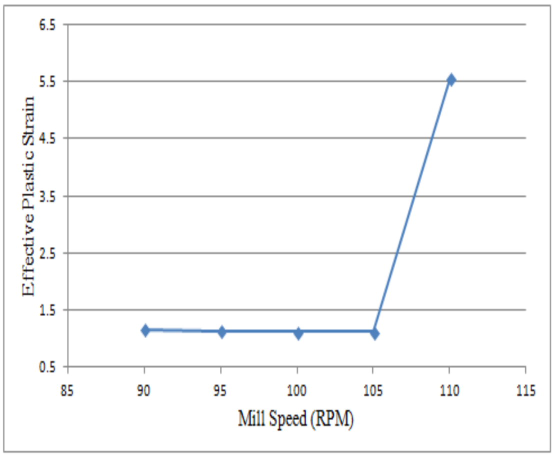

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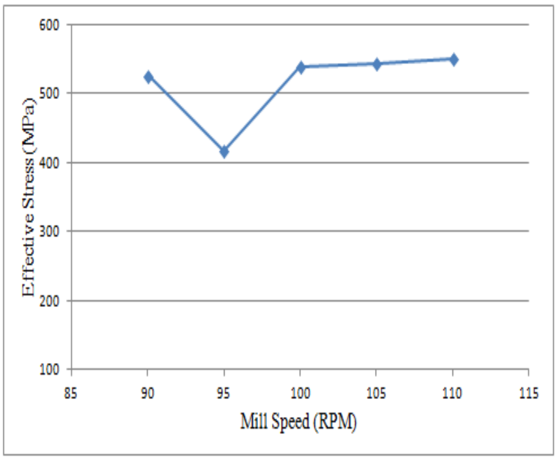
Fig. 8: Effective Plastic Strain Variation with Mill Speed at (a) μ=0.20 (b) μ=0.25 (c) μ=0.30

The effective plastic strain variation leads to some interesting observation. The plastic strain is increased or decreased between mill speeds 90 to 105 rpm at all coefficient of friction, but after mill speed 105 rpm, the plastic strain always increased rapidly as shown in figure 8.



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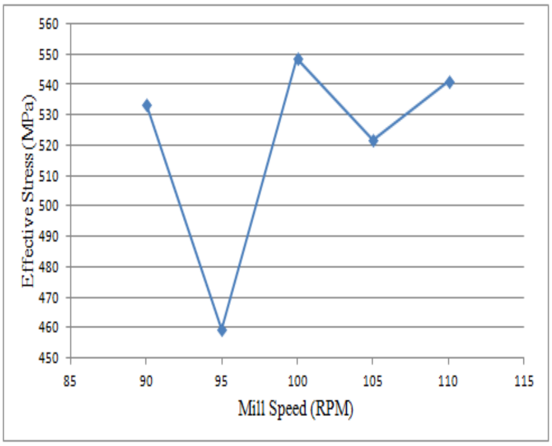

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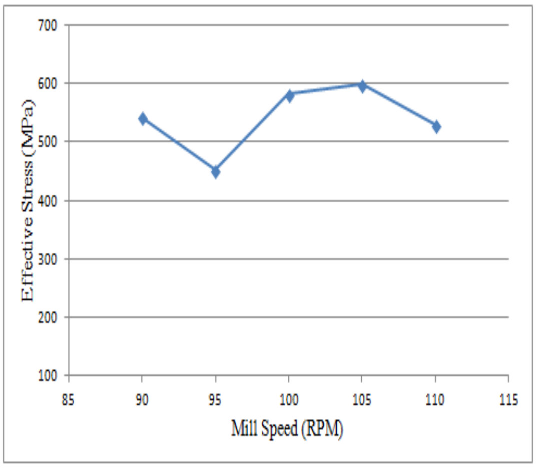

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Fig. 9: Effective Stress Variation with Mill Speed at μ=0.20 (b) μ=0.25 (c) μ=0.30

The effective stress variation also leads to some interesting observation in hot rolling mill operation. The stress increased and decreased throughout the rolling mill speed, and the maximum stress was observed at 598.48 MPa at N=105 rpm with friction coefficient 0.30 and minimum effective plastic strain was produced 528.89 MPa at N=110 rpm (μ=0.30) as shown in figure 9.

4. CONCLUSIONS

The analysis of the rolling process was done and results obtained in terms of equivalent stress and effective plastic strain. The effects of the friction on the rolling of steel angle bar were studied for friction coefficient values of 0.20 to 0.30. The simulation results indicate that the value of friction coefficient affects the effective stress and effective plastic strain. The minimum effective plastic strain was produced 0.5892 at N=105 rpm with friction coefficient 0.20 and maximum effective plastic strain was produced 0.8864 at N=110 rpm (μ=0.20), whereas the maximum effective stress was produced 598.48 MPa at N=105 rpm with friction coefficient 0.30 and minimum effective plastic strain was produced 528.89 MPa at N=110 rpm (μ=0.30).

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