ISSN 2277 – 5528
Impact Factor- 4.015

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES &MANAGEMENT

ASSESSING THE INFLUENCE OF ROLLING PARAMETERS ON THE SPREAD OF HOT ROLLED ALUMINUM ALLOY SLAB USING MANUFACTURING SIMULATION

Hemanth T S[*1], Y. Arunkumar[2] & M.S.Srinath[3]

[*1]Department of Industrial and Production, MCE, Hassan, India, Affiliated to Visvesvaraya Technological University

[2]Professor and Head, Department of Industrial and Production, MCE, Hassan India

[3]Professor, Department of Mechanical Engineering,, MCE, Hassan India

ABSTRACT

Flat-rolled aluminum based semi-products are used for wide varieties of applications in transportation, building and packaging industries. Simulation plays a vital role in reducing the defects caused by incorrect rolling process parameter selection and increasing the quality of rolled products. Simulation is used for analyzing the metal flow in slab rolling using a finite element method based on Lagrangian approach. The elastic plastic three dimensional simulation of rolling process that allows the detailed analysis of flow, including the spread in the width of workpiece is carried out. The effect of process parameters such as rolling speed and roller diameter on the spread of slab and effective stress is presented. Simulation results are compared with the published theoretical results. It is observed that the simulation results match with the theoretical values with marginal difference.

Keywords: *Hot-Rolling process, Rolling diameter, Spread, Von Mises stress, Aluminum, AFDEX*

I. INTRODUCTION

Metal rolling operation is one of the important manufacturing processes in today's world. At some point or the other, all the metal products produced are processed through metal rolling. It is the first process which is created in form of raw metal. Therefore, rolled product represent significant portion of the manufacturing economy and can be found in many field. The rolled product varies from columns and beams used in construction of buildings to airplane bodies. Railroad tracks and automobile components are made from rolled steel whereas the airplane components and bodies are made from rolled aluminum and titanium alloys. Wires, which are used in many applications, are derived from the rolled rods [1]. Spread is significant aspect of rolling and is calculated only through the experimental and the numerical method. It is important to be able to predict the metal flow in all possible directions in order to control the properties [2]. From long period, the designing of metal forming tools and process was based on the experience and design optimization through trial and error method. Today because of advent of high performance computers with increased processing capacity are used to perform the numerical using different techniques and algorithms to predict the process in par with the real world process [3].

In this paper, the effect of roller speed and roller diameter on the spread and effective stress of the workpiece is studied using the numerical calculations and through the finite element simulation software called AFDEX for the aluminum based alloy AA_2017(200-500^{0}C).

II. LITERATURE SURVEY

Numerous studies have been on the effect of process parameters on the quality of the rolled product. The effects of several process parameters such as thickness reduction, rolling speed, initial thickness of workpiece and heat transfer coefficient were considered. A three dimensional thermos-mechanical approach was applied to the hot slab rolling of aluminum alloys. The heat transfer phenomenon was considered simultaneously [4]. In this work finite element package ABAQUS was used, the material taken was AA1100, the slab size taken was 51.4mm in width and 6.12 mm in thickness. The final thickness was 3.978 mm. The rolling temperature was 507.90C. The roll diameter taken was taken as 127mm with 7.3 rpm. It was found through simulation that rolling speed is very important parameter that controls the other parameters such as strain rate, flow stress, roll force, heat of deformation. The influence of speed on the cold rolling operation using commercially available finite element package ABAQUS and it was found through varying the speed and diameter of roller that the residual stress and the roll separating force decreases with increase in diameter [5]. Das et al investigated the effect of rolling speed on the microstructural and mechanical properties on the newly developed Al-Mg alloys processed by twin roll casting method. It was found that strength and hardness decreases with increase in the speed of rolling [6]. Azushima et al predicted the effect of the rolling speed on the coefficient of friction was studied using the tribo simulator testing machine for hot rolling. The workpiece used was SPHC and roll material was SKD11. The tests were carried out at temperatures of 800oC using colza oil as lubricant. It was found that the coefficient of friction at an emulsion decreases with increasing rolling speed for the rolls and it increases in increasing speed [7]. Shahani et al studied the hot rolling process of AA5083 aluminum alloy using simulation. The main parameters such as the geometry of the slab, rolling speed, thickness reduction, load and frictional coefficient are used to develop an Artificial neural network (ANN) using the output of the FE simulation for the purpose of training the network. This network can be used to predict the behavior of workpiece or slab during the rolling process [8].

III. PROBLEM STATEMENT

The primary object of the rolling process is to reduce the cross- sectional area of the workpiece and to obtain the desired output like mechanical properties and geometrical tolerances. A three dimensional analysis was done in this study on the aluminum plate of square cross section of 40 mm by 40 mm with length of 100 mm is reduced to 30 mm thickness by rolling through the one roll stand with the physical parameters similar to a problem discussed in [5] and [9].

IV. METHODOLOGY

Simulation Procedure

The procedure followed for present analysis is shown in Fig. 1. Modeling plays the important and foremost role in the analysis. The model of Rollers and the slab is created using NX which is a powerful CAD based tool. Once the model is created the alignment should be made such that it can represent actual rolling process. Once the model is finalized, rolling simulation is carried out using the Forming simulation software called AFDEX (Advisor as friend for Forging Design Experts) [10]. After the simulation, corrections can be made on the position or parametric change to obtained the desired results. These changes can be easily implemented in the design stages to improve the quality of the desired product. This iteration can be performed to get the optimal results. Once the results are obtained as intended, the product can go to the actual manufacturing process.

Geometric Modeling of Elements of Rolling Process

As seen in the flow diagram of rolling process, the primary stage for simulation is modeling of Rollers and slab in CAD by converting the data into part data. In the process of conversion, the required roller diameter, center distance between the rollers, alignment of rollers in the same axis and width of the rollers are modelled. The models have to be converted to the. STL (Stereolithographic) format individually i.e. in the form of upper roller, lower roller and slab. Preferred orientation is Y-axis as the AFDEX software identifies in the same direction for easier understanding. The modeled rollers and slab is as shown in the Fig 2. Once the rollers and billets are designed and converted to the .STL format, it should be exported to AFDEX software library. As the rollers have to be rotated, the rotation axis must be identified in the software for giving rotation. The slab is assigned with the material property of AA_2017 which is a predefined material in the material library of AFDEX software. The material composition and mechanical properties are shown in Table 1 and Table 2

ISSN 2277 – 5528
Impact Factor- 4.015

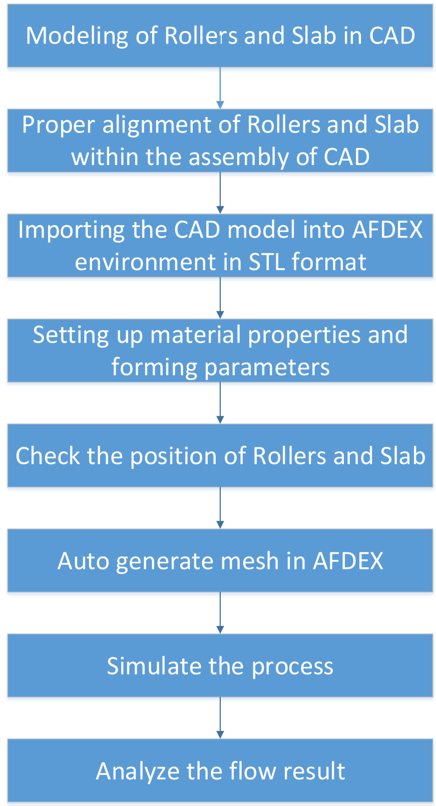


Figure 1 Flow diagram of Rolling Process

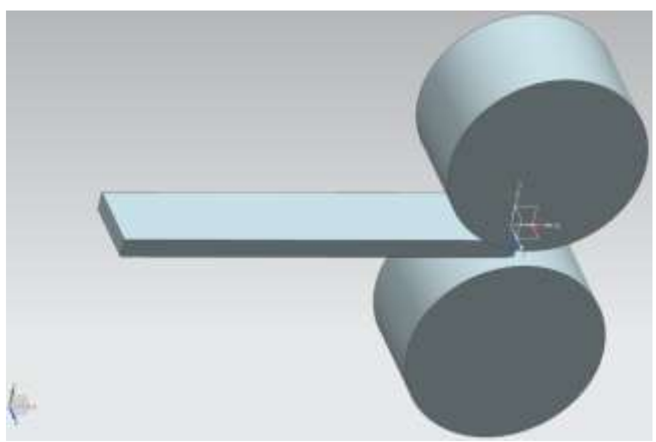


Figure 2 Model drafted in NX Software

Table 1 Composition of Element Weight %

AISI Number	AA_2017
Al	91.5-95.5
Cu	3.5-4.5
Fe	Max 0.7
Mg	0.4- 0.8
Mn	0.4-1
Si	0.2-0.8

Table 2 Mechanical Properties of AA_2017 Aluminum

AISI Number	AA_2017
Modulus of Elasticity	72.4 GPa
Poisson's Ratio	0.33
Density	2.79 g/cc
Ultimate Tensile strength	427 MPa
Tensile Yield strength	276 MPa
Rolling Temperature	200-500^{0}C

V. ANALYSIS OF SPREAD IN ROLLING PROCESS

Significant work on spread has been going on for number of decades. It was being extensively evaluated and there have been several developments in theoretical prediction of the geometric and deformation in rolling [11]. There are many formulae for predicting spread in the hot flat rolling process. The spread which occur during hot flat rolling is expressed as the difference between the width of the section after rolling and before rolling. This spread depends on the factors which can be grouped as follows [11].

1. The temperature of the metal being rolled, the composition of the metal and speed of the rollers.
2. The initial bar width to bar thickness ratio, the roll radius to thickness ratio, the reduction, and bar width to length of arc of contact ratio i.e. geometrical variables.
3. The surface of the rolls and of the slab i.e. frictional effects.

The most notable formulae for the spread is the work of Sparling and Hill has been found to produce acceptable estimates. Hill suggested the formula

$$\frac{\log\frac{W1}{Wo}}{\log\frac{h0}{h1}} = \frac{1}{2}e^{-\frac{1}{2}Wo/\sqrt{D\delta}} \quad (1) \qquad \alpha + \beta = \chi. \quad (1) \quad (1)$$

This relation is based on the point that the strain ratio does not exceed the value $\frac{1}{2}$ but it is shown experimentally that it can exceed the value 0.68 [11]. The relation derived by the Sparling is given by

$$\log\frac{W1}{W0} = \log\frac{h0}{h1}.0.981e^{-1.615[\frac{Wo^{0.9}}{R^{0.55}h^{0.1}\delta^{0.25}}]} \quad (2)$$

Where, W_0 and W_1 are the inlet and outlet width, h0, h1 are the inlet and outlet thickness, R is the radium of the Rolls, D is the diameter of the Rollers and δ is the thickness reduction. It can be seen that the width ratio depends on the thickness reduction ration and radius of the rollers. The term in the (1), $\sqrt{D\delta}$ is nothing but the arc of contact which means that spread increases with the increase in the radius of the rollers.

VI. SIMULATION

The cross sectional reduction of slab through the roller leads to the flow of metal and this flow is studied through the simulation process using the FEM based tool called AFDEX. The initial parameter is selected as hot forming operation with flow analysis in newton units. The table 3 presents the parameter selected for the simulation. The models are imported in the. STL format as described in the methodology part which involves importing the converted file from NX to .STL files. The rollers and slab is imported to the AFDEX environment initially and after selection of the other parameter leads to the 3D tetrahedral meshing shown in the fig. 3. No rate dependence and temperature dependence are taken into account. The slab is not given any velocity initially and it is placed such a way that it pulled inside the roller as soon as it comes in contact with the rollers. Six cases of different Rolls rpm and Roll diameter is considered keeping the shape of the slab constant. The main study interest is to find out the material spreading with respect to the diameter and RPM in Hot rolling. The table 4 shows the different values of parameters used in the simulation.

Table 3 Rolling Parameters selected for Simulation

Type of forming	Hot Rolling
Type of Simulation	3D with Flash
Type of Analysis	Flow analysis
Deformation	Rigid Plastic
Billet Material	AA_2017(200-500^{0}C)
Lubrication Used	Graphite + Water (μ = 0.25)
Translation Velocity	Rotation (Depending on the roller diameter)
Mesh Size	12000

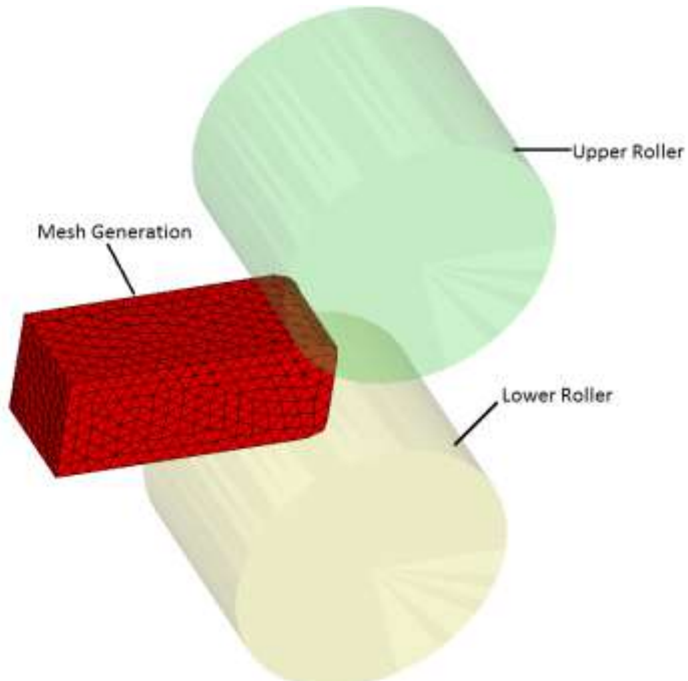


Figure 3 Mesh Generation during Simulation Process

Table 4 Values of parameters Used in Simulation

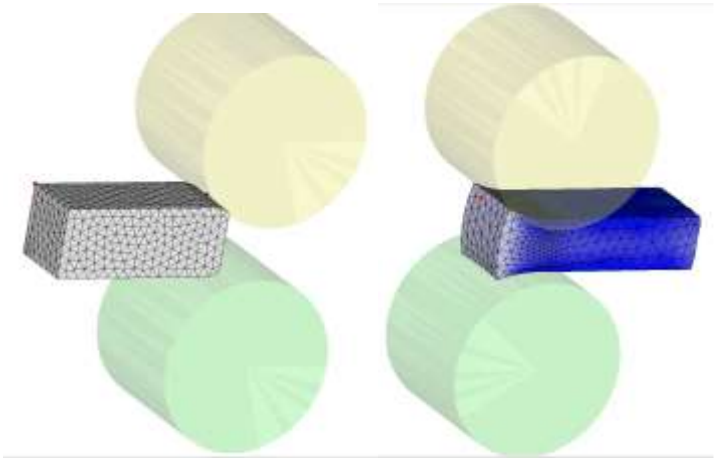
Case No	Roll rpm	Roll Diameter in mm	Friction
1	30	100	0.25
2	60	150	0.25
3	120	200	0.25
4	240	250	0.25
5	320	275	0.25
6	480	300	0.25

VII. RESULTS AND DISCUSSION

Lagrangian approach is used to perform the simulation. Results are obtained after the simulation in the post processor window of AFDEX software. The main focus in this work has been to assess the influence of the rolling diameter on the spread of the slab and Von Mises stress for different cases considered. Fig 4 shows the simulation of initial and final step of rolling for 100mm diameter roll. Table 5 shows the comparison of the spread obtained theoretically and through the simulation. Fig 5 shows the graph showing the different values of spread with respect to the Diameter of the rolls.

ISSN 2277 – 5528
Impact Factor- 4.015

It can be seen from the graph that spread obtained through simulation matches the theoretical values and is in between the Hills relation and Sparling relation.



a. Before Rolling *b. After Rolling*

Figure 4 Rolling Operation of 100 diameter rollers performed using Simulation

Table 5 Comparison of spread obtained theoretically and by simulation

Case No	Spread using Hill Relation	Spread using Sparling Relation	Spread obtained through simulation	Deviation with Hill Relation	deviation with Sparling Relation
1	3.176	1.525	2.20	-0.976	0.674
2	3.584	2.306	2.735	-0.849	0.428
3	3.853	2.943	3.74	-0.113	0.796
4	4.048	3.473	3.88	-0.168	0.406
5	4.128	3.707	3.867	-0.261	0.159
6	4.199	3.923	4.19	-0.009	0.266

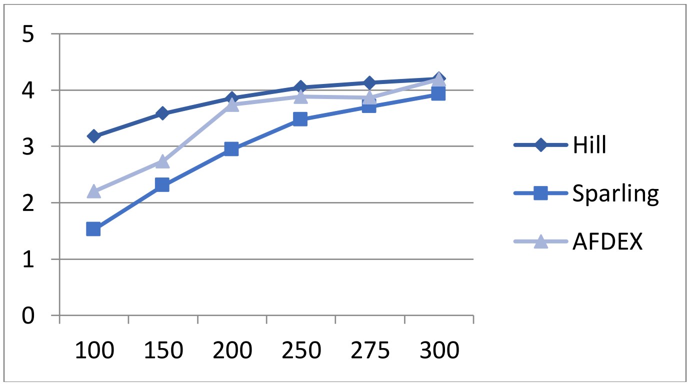
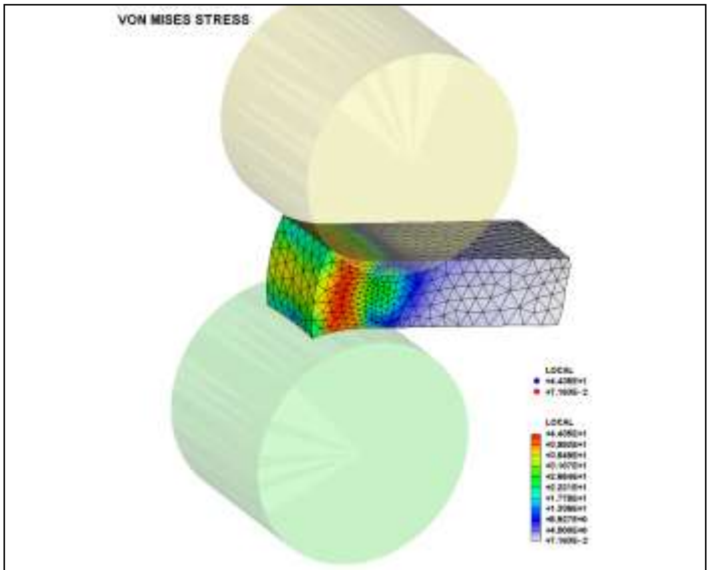


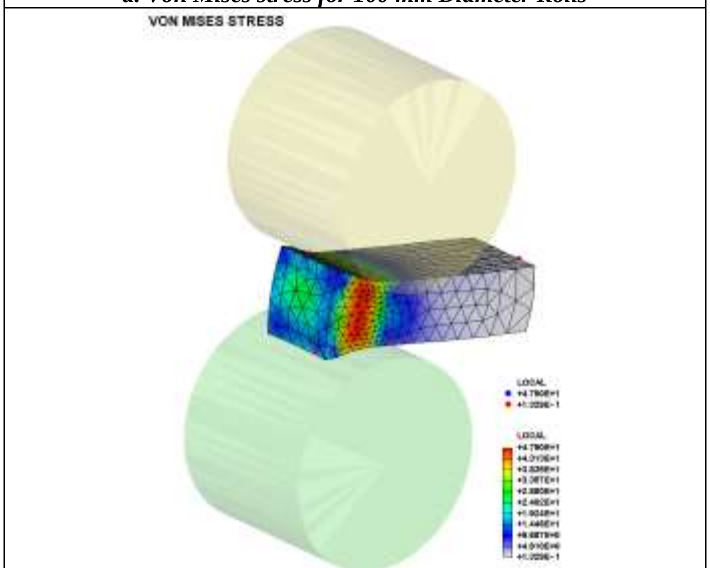
Figure 5 Graph showing the spread obtained by different methods

Fig 6 shows the Von Mises stress for all the cases. It can be seen from the flow analysis result that the Von Mises stresses increases with increasing Roller diameter and Roller speed. It can also be seen that the stresses does not increases in large number and are almost equal at stress levels. Different literature have shown that there should be decrease in the roll separating forces and Von Mises stress [5] [9]. This difference in pattern can be justified by the increase of stress due to increase of weight of the rollers considered within the software package.

ISSN 2277 – 5528
Impact Factor- 4.015

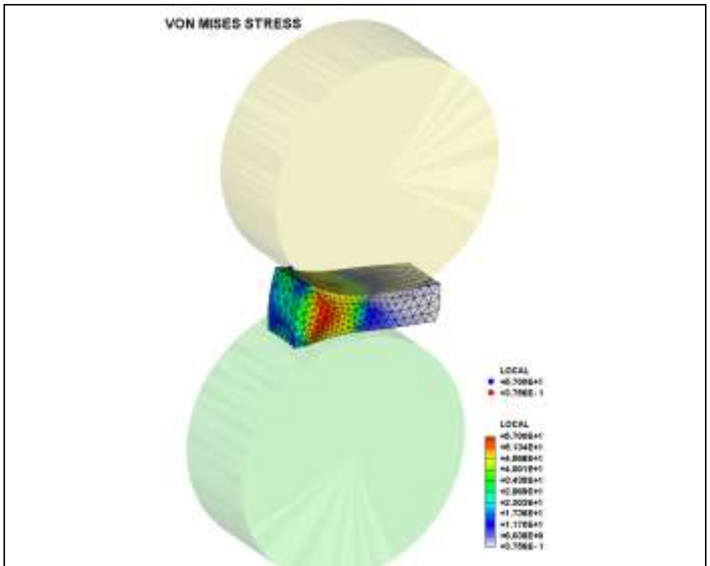


a. Von Mises stress for 100 mm Diameter Rolls

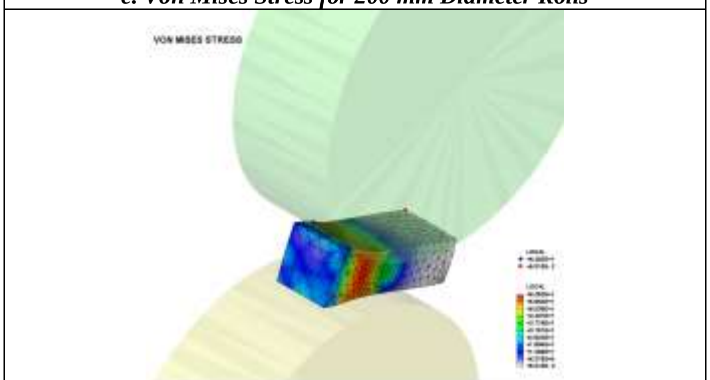


b. Von Mises Stress for 150 mm Diameter Rolls

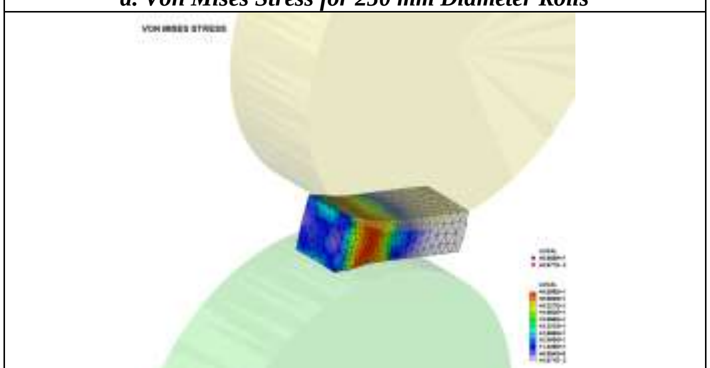
ISSN 2277 – 5528
Impact Factor- 4.015



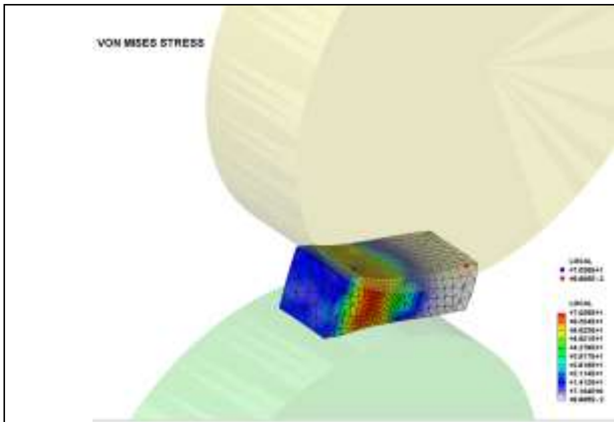
c. Von Mises Stress for 200 mm Diameter Rolls



d. Von Mises Stress for 250 mm Diameter Rolls



e. Von Mises Stress for 275 mm Diameter Rolls



f. Von Mises Stress for 300 mm Diameter Rolls

VIII. CONCLUSION

Spread in sheet rolling is the transverse flow of metal resulting from the reduction in the sheet thickness and it is measured by the change in sheet width. Different parameters have different effect on the spread of the sheet. In this work, the effect of roll diameter on the spread is assessed using the commercially metal forming simulation software. It was found that the spread obtained using the software are matching the theoretically obtained values of spread with marginal differences. The effect of roller speed and roller diameter on the Von Mises stress is also been observed and it was found that with the increase of the roll diameter and roll speed. The study of parameters of rolling benefits the industry in various aspects like increasing the quality of the workpiece and obtaining desired geometrical shape. In future work, effect of other parameters like temperature, friction etc can be studied on spread.

IX. ACKNOWLEDGMENT

Authors would like to acknowledge for providing research grants from TEQIP-II, World Bank grants, Govt. of India and DHIO, Research and Engineering Pvt. Ltd. Bangalore for their research support.

REFERENCES

1. *G. D. Lahoti and S. Semiatin, "Flat, Bar, and Shape Rolling," in ASME Handbook Volume 14 Forming and Forging, ASM International, 1996, pp. 741-742.*
2. *C. Liu, P. Hartley, C. E. N. Sturgess and G. W. Rowe, "Finite-element modelling of deformation and spread in slab rolling," International Journal of Mechanical Science, vol. 29, no. No. 4, pp. pp. 271-283, 1987.*
3. *K. Roll, "Advanced Simulation Techniques - Exceeding Reality?," in Material Science and Technology, Detroit, 16-20 September, 2007.*
4. *M. Bagheripoor and H. Bisadi, "Effects of rolling parameters on temperature distribution in the hot rolling," Applied Thermal Engineering , vol. 31, no. 10, pp. pg. 1556-1565, 2011.*
5. *B. Wang, W. Hu, L. Kong and P. Hodgson, "The Influence of Roll Speed on the Rolling of Metal Plates," Metals and Materials, vol. 4, no. 4, pp. pp. 915-919, 1998.*
6. *S. Das, N. L. J. S. H. Kim and C. Park, "Effect of the rolling speed on microstructural and mechanical properties of aluminum–magnesium alloys prepared by twin roll casting," Materials and Design, vol. 31, p. pp. 1633–1638, 2010.*
7. *A. Azushima, Y. Nakata and T. Toriumi, "Prediction of effect of rolling speed on coefficient of friction in hot sheet rolling of steel using sliding rolling tribo-simulator," Journal of Materials Processing Technology, vol. 210, p. pp. 110–115, 2010.*
8. *A. Shahani, S. Setayeshib, S. Nodamaiea, M. Asadic and S. Rezaiec, "Prediction of influence parameters on the hot rolling process using finite element method and neural network," journal of materials processing technology, vol. 209, p. pp. 1920–1935, 2009.*

ISSN 2277 – 5528
Impact Factor- 4.015

9. *K. Devarajan, K. P. Marimuthu and A. Ramesh, "FEM Analysis of Effect of Rolling Parameters on Cold Rolling Process," International journal of Industrial Engineering and Management Science, vol. 2, no. 1, p. 3540, 2012.*
10. *"www.afdex.com," Metal Forming Research Corporation, 10th March 2016. [Online]. Available: www.afdex.com.*
11. *F. Sassani and N. Sepehri, "Prediction of Spread in Hot flat rolling under Variable Geometry Conditions," Jounal of Material shaping Technology, vol. 5, no. 2, pp. pp. 117-123, 1987.*
12. *L. M. Sparling, "Formula for Spread in Hot Flat Rolling," International journal of Mechanical Engineers, vol. 175, no. 11, pp. pp. 604-610, 1961.*
13. *Zhaobin Chen, Xujun Liu, Renguo Lu and Tongsheng Li, "Friction and wear mechanism of PA66/PPS blend reinforced with carbon fiber", Journal of applied polymer science, 105 (2007), pp. 602-608.*
14. *Zhaobin Chen, Xujun Liu, Renguo Lu and Tong sheng Li, "Mechanical and tribological properties of PA66/PPS blend reinforced with glass fiber". Journal of applied polymer science, 2006, 102(2006), pp. 523-529*
15. *Abdulkadir Gullu, Ahmet Ozdemir, Emin Ozdemir, " Experimental Investigation of the effect of glass fibers on the mechanical properties of Polypropylene and Polyamide 6 plastics" , Materials and Design ,27 (2006) , pp. 316-323*
16. *Li Jian and Sun Tao, " The mechanical and tribological properties of CF/PPS composite filled with PA6", Journal of thermoplastic composite materials , (2012), pp. 1-9*
17. *Shufan Cao,Hangtao Liu, Shirong Ge and Gaofeng Wu, " Mechanical and tribological behaviors of UHMWPE composites filled with basalt fibers", Journal of reinforced plastics and composites, vol.30(4),pp.347-355*
18. *Shaofeng Zhou, Qiaoxin Zhang , Chaoqun Wu and Jin Huang , " Effect of carbon fiber reinforcement on the mechanical and tribological properties of polyamide6/ Polyphenylene sulfide composites ", Materials and Design ,44(2013), pp. 493-499*
19. *Shang - Han Wu , Feng –Yih Wang, Chen – chi, M. Ma, Wen – Chi Chang , Chun – Tiang Kuo, Hsu – Chiang Kuan , Wei – Jen Chen , " Mechanical , Thermal and morphological properties of glass fiber and carbon fiber reinforced Polyamide 6 and polyamide 66/ clay Nano composites " , Material letters , 49(2001) , pp. 327-333*
20. *B Mouhmid, A Imad, N Benseddiq, S benmedakhene, A Maazouz, "Study of the mechanical behavior of a glass fiber reinforced polyamide 66: Experimental investigation, Polymer testing, 25 (2006) , pp. 544-552.*
21. *Rudresh B M and B N Ravi Kumar , " Effect of SGF loading on the mechanical behavior of PA66/PTFE blend", Transactions of Indian Institute of metals , DoI.10.1007/s12666-016-0925-5 2016*
22. *Jia N Y and Val A, " effects of time and temperature on the tension –tension fatigue behavior of short fiber reinforced Polyamides", Polymer composites , 19 (1998) , pp. 408-414*