International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 05, May-2015

The Effect of Force Parameter on Profile Ring Rolling Process

Abhinav Kalyani, Anand Mattikalli and Amol Deshmukh*
Dept. of Mechanical Engineering, Maratha Mandal Engineering College,
Belagavi, Karnataka, India.
*Bharat Forge, Baramati, Pune (MS), India.

***Abstract*—The effect of force parameter on profile ring rolling process was studied at 60 and 180 seconds. The analytical results were calculated and compared with the simulation results of TRANSVELOR FORGE 2011 software and are in good agreement. It is evident that the force is increased with increase in time and decrease in temperature.**

Keywords—Profile ring rolling, Radial and axial forces; thickness reduction

I. INTRODUCTION

Ring rolling is one of the metal forming operations that decreases the thickness (cross section) and increases the diameter (circumference) of the workpiece by squeezing effect as it passes between two rotating rolls [1]. It is an advanced technique, extensively used to produce seamless rings which are commonly used as flanges, pipe flanges, ring gears, structural rings, gas-turbine rings, nuclear reactor parts, aero-engine casing and various connecting flanges [2]. John and Lugora and Bramley [3] studied the spread in plain ring rolling using Hill's general method of analysis. Fast and slow mandrel feeding may cause the ring blank to stop rotating and expanding respectively.These situations represent two extreme draft conditions. Xavier [4] studied the various factors influencing the mechanics of the ring rolling process and optimization with process parameters to achieve the desired product. In this paper, they detailed about process parameters influencing the formation of different ring sizes in the light of finite element approach. Alfozan and Gunasekera [5] described about the main advantages of ring rolling process and other general process conditions are two set of rolls requirement namely, a radial set to form the ring material and an axial set of rolls which need to exert sufficient force to set the rings in the position fixed. Anjami and Basti [6] studied the effects of rolls sizes on the PEEQ and temperature distributions, rolling force, and rolling moment in hot ring rolling. They obtained the optimal rolls sizes for more uniform PEEQ and temperature distributions of rolled rings. Wen Meng et al. [7] established an advanced plastic forming technology, the radial conical ring rolling process with a closed die structure (RCRRCDS) on the top and bottom of driven roll. The effects of the ring's outer radius growth rate and the radii of the driven roll and mandrel on the PEEQ and temperature distributions, average rolling force and average rolling moment were studied. In this paper the effect of force was studied and compared with the simulation software results.

II. METHODOLOGY

A. Working Principle of ring rolling machine

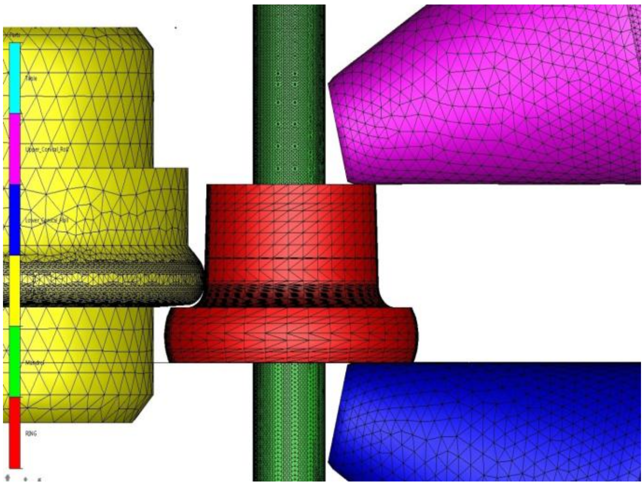

Figure 1. Radial-axial ring rolling machine

The ring blank is placed over an undriven mandrel and rests on table plates that form part of the radial carriage. A separate roller support carriage is used for larger rings. A backing arm with a mandrel upper bearing is lowered to support the mandrel. This backing arm is connected to the radial carriage so that they move as a unit, hydraulically activated toward the fixed-axis main roll. The main roll rotates at a constant, preselected speed. The ring begins to rotate as the mandrel squeezes the ring wall. This, in turn causes the mandrel to rotate.

The lower conical roll is held in a fixed position such that the upper roll (horizontal) surface is typically 3 to 5 mm above the level of the table plates. Both conical rolls are driven and the upper roll is moved hydraulically. The upper roll slides toward the lower roll to cause axial height reduction of the ring. The axial rolls withdraw as the ring diameter increases, maintaining minimum slip rolling conditions between the conical rolls and ring end faces.

A pair of guide rollers, connected through gear segments, contacts the ring outside diameter and ensures that the ring stays round and in the correct position in relation to the longitudinal axis of the mill. The centering force is automatically reduced as rolling progresses and the stiffness of the ring decreases.

The relationship between radial (wall thickness) and axial (height) reduction is preselected to ensure the absence of ring surface defects, and it is maintained by computer control. Similarly, the pattern of diameter growth is predetermined and computer controlled. The mill operator has to set blank and finished ring dimensions at the control desk and initiate the rolling cycle. Rolling automatically stops when finished outside diameter, inside diameter or mean diameter (selected by the operator) is reached [8].

B. Units

TABLE 1 Symbols Description Units

Symbols	Description	Unit
F_r	Radial force	KN
F_a	Axial force	KN
d_r^1	Mean roll diameter of ring	mm
d_m^1	Mean diameter of Mandrel	mm
d_k^1	Mean diameter of king roll	mm
d_k	Diameter of king roll	mm
d_m	Diameter of mandrel	mm
d	Inner diameter of ring	mm
D	Outer diameter of ring	mm
Δs	Thickness reduction of ring	
h	Height of the ring	mm
$\sigma_{y.s}$	Restrained flow stress of the material	MPa
Δh	Represents the total reduction per pass shared by both rolls.	
tanβ	Tapered rolls generally have a curve angle varying between 30^0 and 45^0	
m	Represents the distance between the centre of the ring and the tip of the axial roll	mm
I_a	Contact length	mm
s	Thickness of the ring	mm

C. Theoretical Calculations

Calculation of Main (King) Roller RPM for 60 sec.

Main Roller outer diameter (OD) = ϕ 936

Motor RPM = 1850

Gear ratio = 46.66

Motor speed 1850 rpm and reduction of 46.66 (Gear ratio)

$$\text{Main roller RPM} = \frac{1850}{46.66} = 39.64\text{rpm}$$

$$\text{Surface Speed} = \frac{\pi DN}{60} \quad (1)$$

$$= \frac{\pi \times 936 \times 39.64}{60}$$

= 1942.7 mm/sec

The total time taken to complete the operation from pancake to final ring will be 180 sec.

TABLE 2 Diameters of Pancake and Final ring

	Hot Conditions		
Sl. No.	*Pancake Upper ID*	*Final Ring Upper ID*	*Difference*
1	ϕ 187mm	ϕ 380mm	ϕ 193mm
Sl. No.	*Pancake Upper OD*	*Final Ring Upper OD*	*Difference*
2	ϕ 410mm	ϕ 543mm	ϕ 133mm

Therefore the time required for material reduction per second.

$$\text{For Outer Diameter} = \frac{\phi 133}{180} = 0.74\text{mm}$$

$$\text{For Inner Diameter} = \frac{\phi 193}{180} = 1.07\text{mm}$$

Calculating the ring diameters for 60 sec

Therefore the Inner Diameter of ring growth at 60 sec

= 1.07 x 60 = 64.2 mm

Therefore the Inner Diameter will be = ϕ 251.2

Therefore the Outer Diameter of ring growth at 60 sec

= 0.74 x 60 = 44.4mm

Therefore the Outer Diameter will = ϕ 454.4mm

The initial height of the Pancake ring in hot condition is 320mm

The height of the final ring in hot condition is 307mm

Therefore the difference is 320-307 = 13mm

Therefore the time required for height reduction per second.

$$\text{Height reduction} = \frac{13}{180} = 0.07\text{mm}$$

Therefore the height reduction for 60 sec is 0.07 x 60 = 4.2

h = 320-8.4 = 315.8mm

Calculations for Ring RPM at 60 sec.

Outer diameter = ϕ 454.2

Inner diameter = ϕ 251.2

Height = 315.8mm

Wall thickness = 101.6mm

Surface Speed at outer Surface = 1942.7 mm/sec

$$\text{Ring RPM} = \frac{\text{Surface speed x 60}}{\pi \text{ x Outer Diameter}} \quad (2)$$

$$= \frac{1942.7 \times 60}{\pi \times 454.4}$$

= 81.65 rpm

Main roller and ring surface contact area is same, but the diameters are different, so the speeds are different respectively Surface speed at inner surface will be

$$= \frac{\pi \text{ x Inner Diameter x Ring speed}}{60} \quad (3)$$

$= \frac{\pi \text{ x } 251.2 \text{ x } 81.65}{60}$

= 1073.9 mm/sec

Average Surface speed of the ring

$$= \frac{\text{Surface speed of OD} + \text{Surface speed of ID}}{2} \quad (4)$$

$= \frac{1942.7 + 1073.9}{2}$

= 1508.3 mm/sec

Calculations for Axial Roller RPM at 60 sec.

Ring outer diameter is considered to be at 200mm inside from axial roll big end.

Diameter of axial roll at average ring speed is 423.9mm

RPM of axial roll at 60 sec

$$= \frac{\text{Average surface speed of the ring x 60}}{\pi \text{ x Diameter of axial roll at average ring speed}} \quad (5)$$

$= \frac{1508.3 \text{ x } 60}{\pi \text{ x } 423.9}$

= 68 rpm

Prediction of Radial force according to Thyssen Wagner for 60 sec.

The Contact zone in axial roll gap is not only dependent on the initial and final ring cross section [4].

$$\text{Radial force, } F_r = h\, \sigma_{ys} \sqrt{\Delta s d_r^1} \quad (6)$$

Where,

$$d_r^1 = \frac{1}{\left(1/d_k^1 + 1/d_m^1\right)} \quad (7)$$

$$d_m^1 = \frac{1}{\left(1/d_m - 1/d\right)} \quad (8)$$

$$d_k^1 = \frac{1}{\left(1/d_k + 1/D\right)} \quad (9)$$

Where

$d_k = \phi 936$

$d_m = \phi 175$

$d = \phi 251.2$

$D = \phi 454.4$

Δs = 1.07 mm

h = 315.8 mm

$\sigma_{y.s}$ = 80MPa

Main Roller RPM = 39.64 rpm

The total time taken to complete the rolling operation from pancake to final ring is 180 seconds.

Total No. of revolutions

$$= \text{Time in minutes x Main roller rpm} \quad (10)$$

= 3 x 39.64

= 118.92 rpm

$d_k^1 = \frac{1}{\left(1/936 + 1/454.4\right)}$

$d_k^1 = \phi 306$

$d_m^1 = \frac{1}{\left(1/175 - 1/254.4\right)}$

$d_m^1 = \phi 588.2$

$d_r^1 = \frac{1}{\left(1/306 + 1/588.2\right)}$

$d_r^1 = \phi 201.3$

$h = \frac{13}{180} = 0.07$ mm

F_r = **370.8 KN**

The above value is the radial force for one pass at 60 sec.

Prediction of Axial force

The Contact zone in axial roll gap is not only dependent on the initial and final ring cross section [4].

$$I_a = \sqrt{\Delta h \text{ x } \tan\beta \text{ x } m} \quad (11)$$

$$\text{Axial force } F_a = I_a \text{ x } s \text{ x } \sigma_{ys} \quad (12)$$

Where

$\sigma_{y.s}$= 80MPa

Therefore the time required for height reduction per second.

Height reduction = $\frac{13}{180}$ = 0.07mm

Calculating axial force for 60 sec

$s = \frac{\phi 454.4 - \phi 251.2}{2}$ = 101.6 mm

Consider $\beta = 30^0$

$\tan 30^0 = 0.577$

$m = \frac{187}{2}$ = 93.5mm

I_a = 15.05

F_a **= 122.3 KN**

The above value axial force for one pass at 60 sec.

Similarly for 180 sec. force calculation can be done

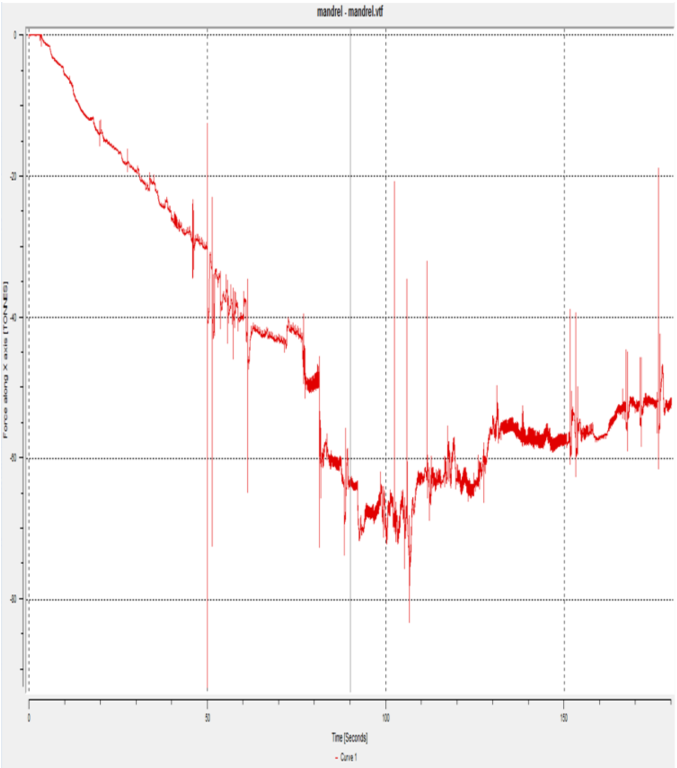

Figure 2 Radial Force with respective to time

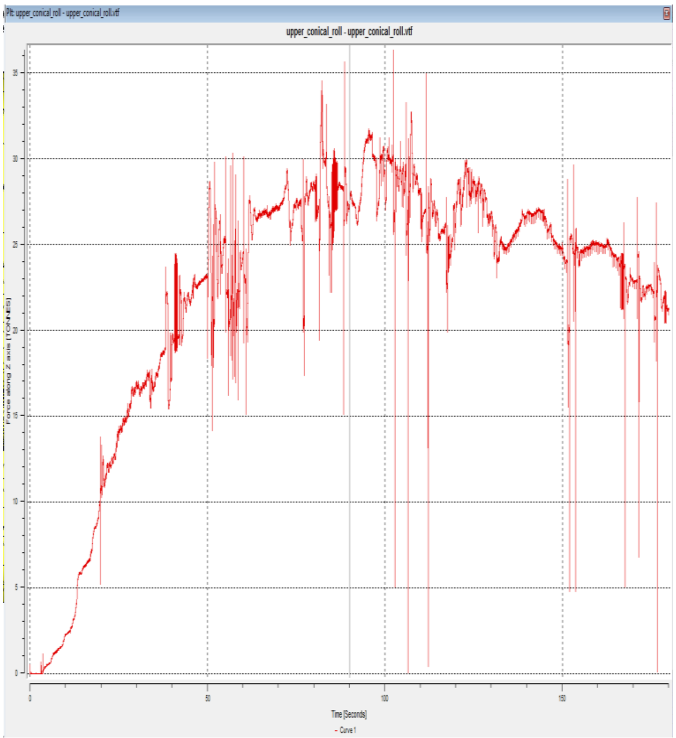

Figure 3 Axial Force with respective to time

D. Results and Discussions

The results obtained from the theoretical calculations and compared with simulation results of TRANSVALOR FORGE 2011 software were illustrated in Table 3.

TABLE 3 Comparison of Forces of Theoretical results and Simulation results

	Temperature (^{0}C)	**Theoretical Calculations KN**	**Simulation Results KN**	**% of Error**
Radial Force at 60 sec.	1191.76 to 966.95	370.80	392.40	5.5
Axial Force at 60 sec.		122.30	147.15	16.9
Radial Force at 180 sec.	1100.24 to 910.05	483.40	500.30	3.4
Axial Force at 180 sec.		254.60	225.63	11.4

Table 3 illustrates the values of radial and axial forces at 60 and 180 seconds and at different temperature variations were calculated and compared with simulation results. The simulations results were graphically represented in figures 2 and 3. At 60 seconds, the radial force obtained was 370.80 KN, axial force was 122.30 KN and 392.40 KN, 147.15 KN as compared to simulation results respectively at temperature range from 1191.76 to 966.95^{0}C. The percentage of variation observed was 5.5 and 16.9 respectively.

Similarly, at 180 seconds, the radial force was found to be 483.40KN and 500.30KN as compared to simulation results and the axial force was 254.60KN and 225.63KN at temperature range from 1100.24 to 910.05 ^{0}C. The percentage of variation was observed was 3.4 and 11.4 respectively. From the results, it is evident that the force is increased with increase in time and decrease in temperature.

ACKNOWLEDGMENT

The authors would like to thank the Bharat Forge, Baramati and MM Engineering College, Belagavi for support given to this project work.

REFERENCES

[1] Hua, L., Huang, X.G., Zhu, C.D. Ring Rolling Theory and Technology. China Machine Press, Beijing, 2001, pp 1-16.

[2] Kluge, A., Lee, Y., Wiegels, H., Kopp, R. Control of strain and temperature distribution in the ring rolling process. Journal of Materials Processing Technology, Vol 45, 1994, p137

[3] Lugora C.F., Bramley A.N. Analysis of spread in ring rolling. International Journal of Mechanical Sciences 1987. Vol. 29, pp 149-157.

[4] John Alexis, S and Xavier Satheesh, A. An analysis on the parameter optimization in Ring rolling process. Kovarenstvi (A Czech Republic International Journal), Vol. 24, 2004, pp 11-17.

[5] Alfozan Adel and Gunasekera, Jay S.Development of an experimental ring rolling mill and associated instrumentation, Journal of Material Processing Technology, Vol. 3, 2007, pp 90.

[6] Anjami, N and Basti, A. Investigation of rolls size effects on hot ring rolling process by coupled thermo-mechanical 3D-FEA. Journal of Materials Processing Technology, 2010, vol. 210(10), pp. 1364-1377.

[7] Wen Meng, Guoqun Zhao and Yanjin Guan. The Effects of Forming Parameters on Conical Ring Rolling Process. The Scientific World Journal, 2014, Vol. 2014, pp1-11.

AUTHORS' BIOGRAPHIES

Mr. Abhinav Kalyani student at Maratha Mandal Engineering College, Belagavi, completing his M.Tech in Mechanical Machine Design of Visvesvaraya Technological University, Belagavi, Karnataka, India.

Mr. Anand Mattikalli is a Professor, Dept. of Mechanical Engineering, Maratha Mandal Engineering College, Belagavi, and he is my project guide.

Mr. Amol R. Deshmukh, Manager, Engineering FMD & Ring Rolling CAM at Bharat Forge, Baramati, Pune (MS), India.