Forces and optimum angle of guide rolls in 3D-FE simulation of ring rolling

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Abstract

Forged shell is widely used in industry, especially as key component in power industries, process industries and heavy engineering industries. Ring rolling is used to manufacture a wide variety of seamless ring shaped component for small part such as bearing races to large ring for turbine.in this process an annular blank is formed between two rolls. In ring rolling mandrel press the shell and drive roll rotates the shell. Mandrel inside the shell free to rotate and hydraulic pressing punch applies pressure another end at the end required diameter achieved procedure stop and shell has taken out from the press machine for further processing objective of presented work to study and analysed guide roller mechanism presently in used based on published literature and performed numerical simulation of shell forged rolling process and to predict force and torque for drive roller, mandrel and guide roller for achieving shell of target dimensions and analyse the effect of guide roller traverse on force acting on guide roller, mandrel and drive roller. Simulation was performed for Ti6Al4V material to validate proposed FE model.

Keyword: ring rolling, guide roll, finite element, velocity control

1 Introduction

Ring rolling is a versatile metal-forming process for manufacturing seamless annular forgings that are accurately dimensioned and have circumferential grain flow. Ring rolling usually requires less input material than alternative forging methods, and it is applicable to production in any quantity.In ring rolling mandrel are placed instead of hammer, mandrel which is small diameter than the hole in the blank [1-2]. Mandrel is a free to rotate and feed only axial direction.The ring expand continuously in ring rolling process, the guide roll is placed to entry side to ring rolling and moves continuously and initiatively with the ring expansion [2]. The ring press the guide roll, thereby the guide-roll support the ring, makes ring rolling steady, and keeps the ring round.Ring rolling involves both mechanical and thermal behaviours.Most of physical and mechanical properties and boundary condition are thermal related [1]. Pair of guide rolls which is usually controlled by a linkage mechanism, keeps the ring central and maintain circularity [3]. Ring rolling is different from the standard rolling process in the fact that the ring rolling process is non-steady state throughout and a large number of ring rotation are required to finish the product. Compared to the rolling force, the force of the guide roll acting on the ring workpiece is much smaller, so that it can be neglected.

Applications for seamless rolled rings include anti-friction bearing races, gear rims, slewing rings, railroad wheel bearings, commutator rings, rotating and non-rotating rings for jet engines and other aerospace applications, nuclear reactor components, bevel ring gears, and flanges of all kinds, sheaves, wheels, valve bodies, food processing dies.

It has good surface finishing and dimensional accuracy. Due to dimensional accuracy post machining are reduced which is turn save in material cost. Uniform material, flow is obtained so more uniform material properties are achieved.

2mechanical model of guide rolland its derivation

According to the guide-roll position angle constancy[2], the coordinate components of the centre point of the guide roll should be as follow

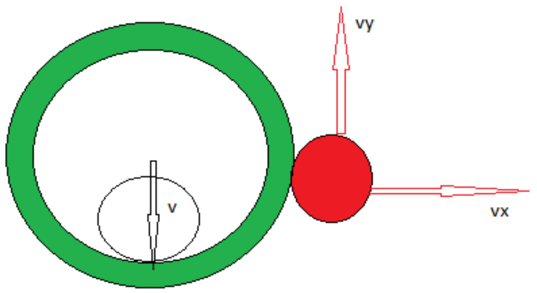

Fig1 guide roller model

$$x = -R(1 - \cos\alpha) + R_3 \cos\alpha \quad (1)$$

$$y = R\sin\alpha + R_3 \sin\alpha \quad (2)$$

$$\frac{dx}{dt} = -\frac{1}{2} v_D (1 - \cos\alpha) \quad (3)$$

$$\frac{dy}{dt} = \frac{1}{2} v_D \sin\alpha \quad (4)$$

$$v_d = \left(\frac{D_o + d_o}{2}\frac{H_0}{H^2} - 1\right) v \ (5)$$

$$v_x = \frac{dx}{dt} = \frac{1}{2}\left(\frac{D_o + d_0}{2}\frac{H_o}{H^2} - 1\right) v(1 - \cos\alpha) \ (6)$$

$$v_y = \frac{dy}{dt} = \frac{1}{2}\left(\frac{D_o + d_0}{2}\frac{H_o}{H^2} - 1\right) v(\sin\alpha) \ (7)$$

Where,

$H = H_o - vt$

Where Do and do are original outer and inner diameter of ring Ho and H are original and process wall thickness of ring

3 3Dcoupled Thermo-mechanical FE model

Based on the finite element model established and the above determined computational conditions, the hot ring rolling process was simulated for Ti-6Al-4V material and the roll-size effects on strain and temperature distributions at the end of the process have been investigated through comprehensive numerical simulation as follows.

Table 1

Work piece information

Ring material	Ti6Al4v
Initial temperature of ring (^{o}c)	950
Co efficient of friction	0.3
Density of material (kg/m^3)	4429
Thick ness reduction	0.25

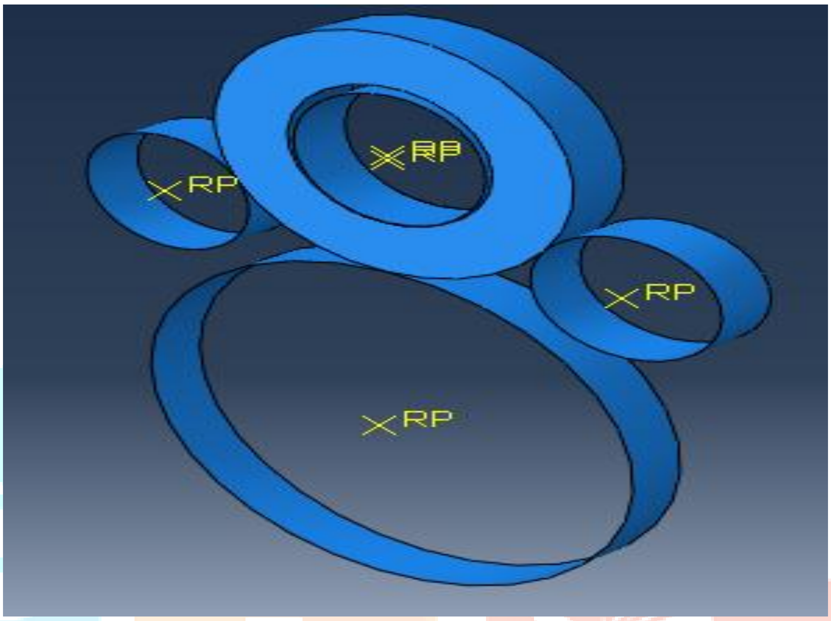

Fig 3D FE Ring rolling model

Ring material is Ti6Al4V which is deformable while guide roll, mandrel, and drive roll are analytical rigid bodies. Applying boundary condition the ring were simulate there are eleven boundary condition with including displacement and velocity

3.1 FE model validation

Effective strain distribution along the thickness from inner radius to outer radius of ring Material is also shown in fig 4for different radius of drive roller. Results of strain distribution are in agreement with paper results as shown in fig

Effect on drive roller radius on strain distribution given below

It is observed that the contacting time of ring and rolls is long, so there would be more heat loss, and temperature of ring surface falls rapidly while for further increasing of $R_{D,}$ the instantaneous radius of the ring R increases as the process goes on. As the result the rotational velocity of ring augments, leading to less contact time of ring and rolls.

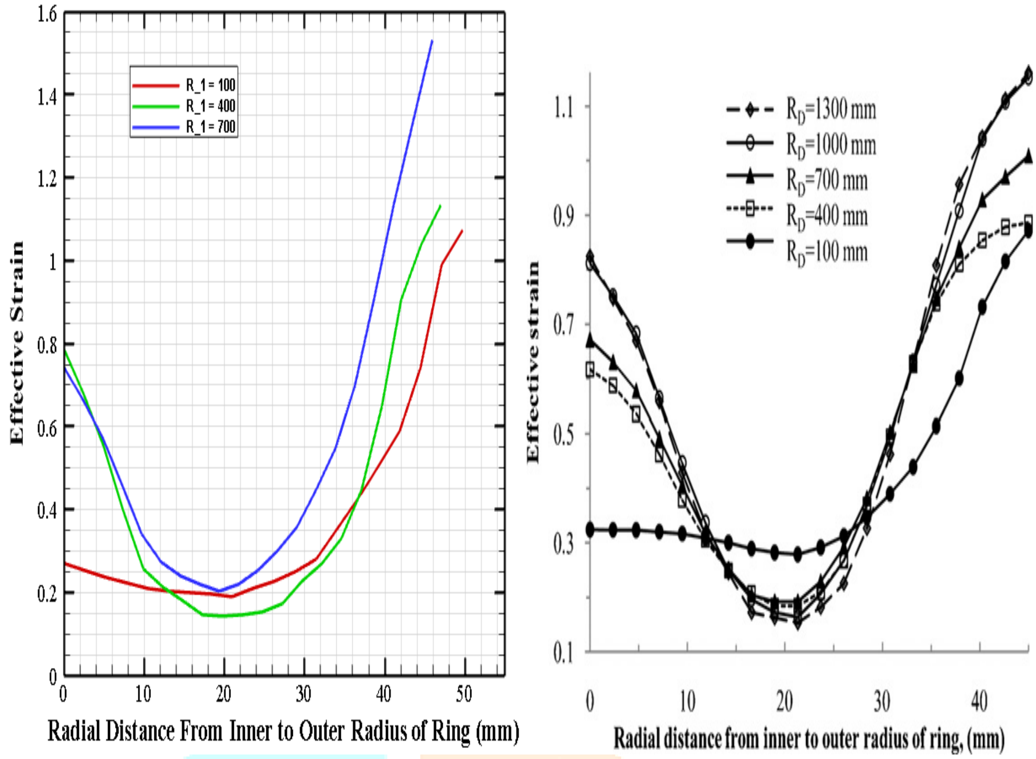

Fig 4 strain distribution along the thickness of ring under various drive roller radius: (left) Simulation,(right) paper

- **Temperature distribution**

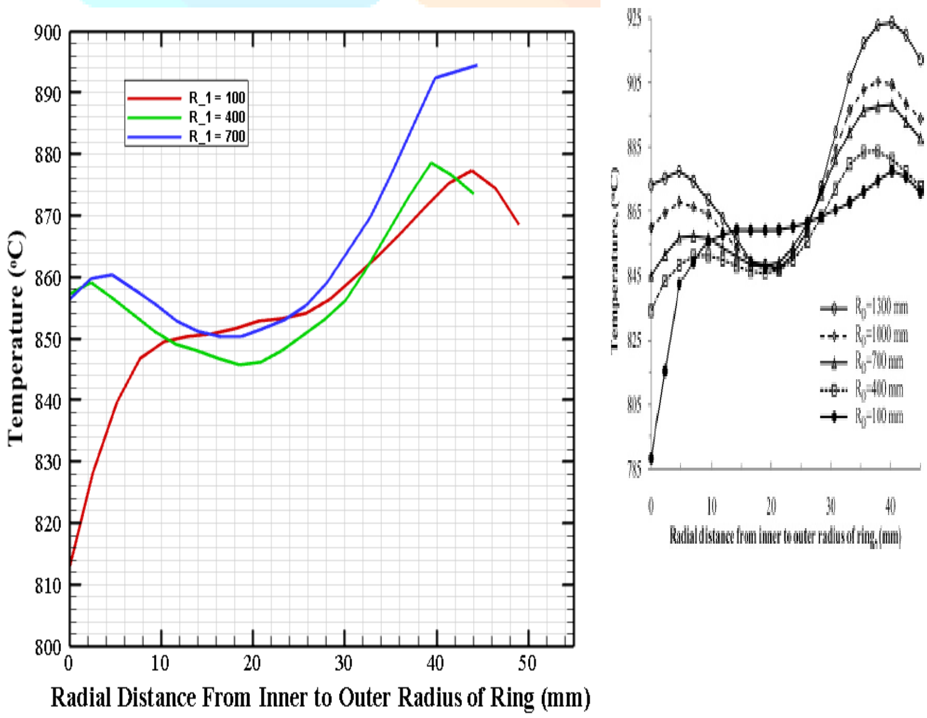

Fig 5 Temperature Distribution Along Thickness of Ring Under Various Drive Roller Radius:(left)Simulation, (right)Paper

As shown in fig 5, minimum and maximum temperatures are increasing with increase in driver roller radius. The reason is that at first when R1 is small, rotational speed of the ring (nR)which can be approximated by the following equation[1], is small

$$n_R = n_{D*} R_D / R \quad (3.1)$$

Hence, the contacting time of ring and rolls is long, so there would be more heat loss, and temperature of ring surface falls rapidly. While for further increase of R1, the instantaneous radius of the ring R increases as the process goes on. As a result, the rotational velocity of the ring augments, leading to less contact time of ring and rolls, less heat loss and much more increase in temperature of ring surface especially its inner and outer surfaces as shown in fig

Case 2

Similar FE simulations were performed for obtaining the effect of variation of mandrel radius. Results of strain distribution and temperature distribution are shown below.

Strain distribution

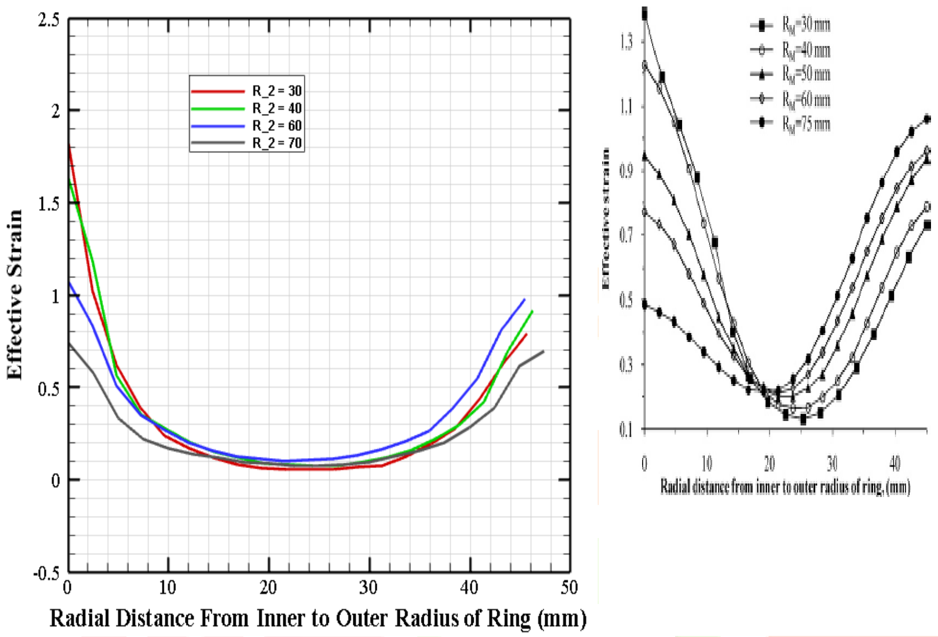

Figure 6 : Strain Distribution Along Thickness of Ring Under Various Mandrel Radius:(left)Simulation, (right)Paper

Temperature distribution

It observed from figure 7 that when the size of mandrel roll is too small, the inner surface of the ring has very high temperature, even more than that in outer surface of the ring due to larger plastic deformation in inner surface or the ring than its outer surface of the ring due to larger plastic deformation in inner surface or the ring than its outer surface.

As a result of minimum and maximum temperature with mandrel radius shown in fig 7
In both the cases strain distribution and temperature distribution were validated.

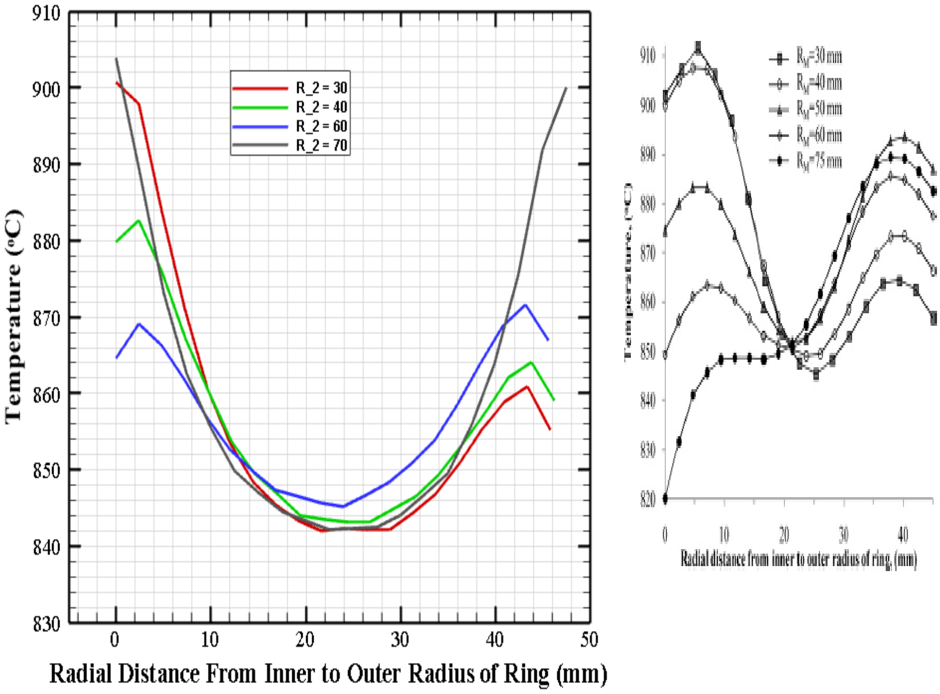

Fig 7 Temperature Distribution Along Thickness of Ring Under Various Mandrel Radius :(left)Simulation, (right)Paper

4 guide roll and mandrel forces at different angle

Force on guide roll and mandrel at angle 60 degree

Here the force on guide roll is determine at the angle 60degree of guide roll both guide rolls rotate opposite to the ring direction as well as each other due to stress difference both guide roll forces different and maintain the contact on ring also different

- **Force on gr 1**

The maximum forces on guide roll 1 is 55 KN due to stress comparatively high on ring

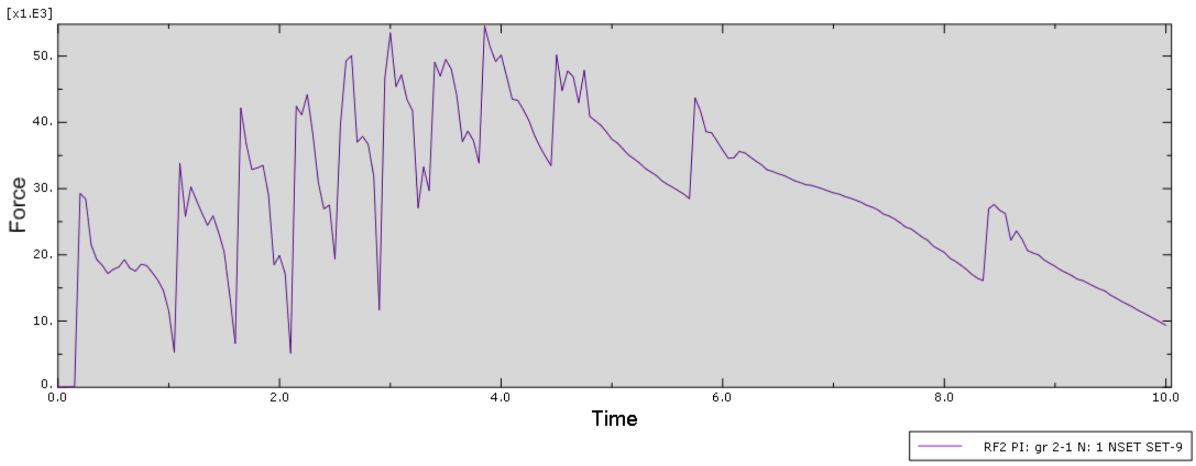

Fig 8 force on guide roll 1 at angle 60^0

From fig 8 it can be shown that when guide roll contact on ring gradually increase the force on guide roll also increase and after some step time force gradually reduces

- **Force on gr 2**

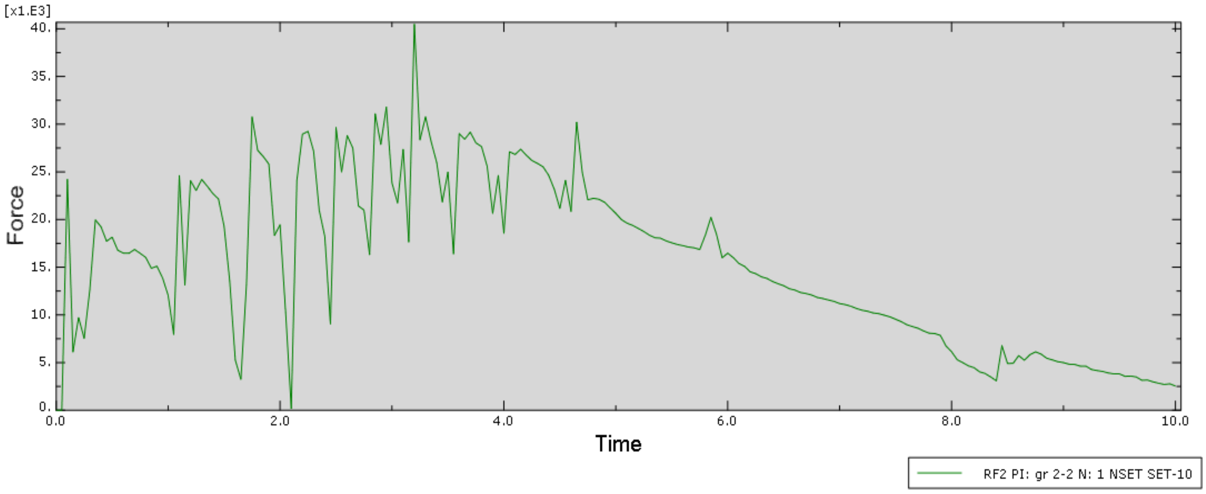

Fig 9 force on guide roll 2 at angle 60^0

Here force on guide roll 2 is lesser compare to guide roll1 because guide roll 2 lose their contact on ring compare to guide roll 1. Maximum force on guide roll 2 is 40KN

Force on gr 1 and gr 2 at angle 70 degree is 40KN and 13KN respectively which is comparatively less than guide roll angle 60 degree. Force on mandrel at angle 60 degree is 78 KN and 60KN for angle 70 degree

5 conclusion

The result show that there are optimum sizes of mandrel and drive rolls under which the strain and temperature distribution of ring. Although selecting mandrel diameter with too small beneficial to the reduction of material waste. Guide roll angle 60^0 is most preferable angle compare to 70^0, because guide roll play more active role in ring rolling. At 60^0 degree angle ring maintain their roundness shape and stability while 70^0 guide roll angle the guide roll loses the contact and found the ovality in ring shaped. Below 60^o angle the guide roll touches the drive roll so it not possible. After some result concludes that at 60^0 angle of guide Roll is optimum angle.The achievements obtain from this study can not only serve as to find the optimum angle but also find the ring parameter which is affected to the ring quality.

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