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Effect of feed rate of idle roll on hot ring rolling of AZ31 magnesium alloy by 3D FE simulation

Xiao-dong Luo[1,2]*, Hao Liu[1]

[1]College of Metallurgical and Materials Engineering, ChongqingUniversity of Science and Technology, Chongqing, 400041 (CHINA)

[2]College of Materials Science and Engineering, ChongqingUniversity, Chongqing 400044, (CHINA)

E-mail: lxd336@163.com; liuhao_023@163.com

ABSTRACT

In this paper, a 3D elastic-plastic and coupled thermo-mechanical FE model of radial ring rolling is developed to simulate the rolling process with different feed rates of idle roll v based on the dynamic explicit code ABAQUS/Explicit. Theeffect laws of on the uniformity of strain and temperature distribution, fishtail coefficient, roll force, contact area and roll moment are disclosed respectively. One optimum is obtained, under which the deformation is the most uniform, another optimum is obtained, under which the temperature distribution is the most homogeneous. Moreover, an optimum is obtained, under which the quality of end-plane of rolled ring is the best. The result obtained can provide a valuable guideline to quality control and optimum of hot ring rolling of magnesium alloys. © 2013 Trade Science Inc. - INDIA

KEYWORDS

Hot ring rolling;
AZ31 magnesium alloy;
The feed rate of idle roll;
FEM.

INTRODUCTION

Ring rolling is widely used in the production of railway tires, anti-friction bearing races, flanges of various geometry and rings of different materials and dimensions used in the chemical, aerospace, automotive and nuclear industries[1]. Magnesium alloys have been used widely as their light structures. However, magnesium alloy's formability is bad owing to its hexagonal packer crystal structure. In recent years, differential speed rolling has been proposed and the research results show that differential speed rolling can improve magnesium alloy's ductility[2-3]. As ring rolling is one type of differential speed rolling forming process, applying ring rolling to fabricate magnesium alloy rings has its own special advantages.

During hot ring rolling of AZ31 magnesium alloy, the plays a significant role in ring quality control, because different will generate different deformation. Consequently, it has considerable influence on the uniformity of strain and temperature distribution (STD), which is in close relation to microstructure of ring and ring's mechanical property. Moreover, the defects will occur with unreasonable feed rate. Therefore it is necessary to research the effect of feed rate of idle roll in hot ring rolling.

Up to now, there have been lots of studies on hot ring rolling. Song et al.[1] developed a coupled thermo-mechanical model of the deformation processes occurring during the hot rolling of IN718 rings. Wang et al[4] solved the key technology and realized virtual hot ring rolling of 20MnVB. Wang et al.[5] proposed a new FE modeling method of hot ring rolling of tellurium lead by saving key technologies. Lots of woks have been done on hot ring rolling concerning on titanium alloys[6-11]. Some studies have been taken on hot ring rolling using the material of AISI 4140 steel[12-14]. Zhou et al[15] took a study on forming defects in the rolling process of large aluminum alloy ring via adaptive controlled simulation. SUN et al[16] analyzed the effects of on the deformation filed temperature filed and their nonuniformity in hot ring rolling of AISI 5140 steel using the rigid-plastic FEM. Wang[8] et al studied the influence of on the uniformity of STD with different ring blank. Sun et al [17] revealed the effects of on microstructural evolution during hot ring rolling of AISI 5140 steel. However, the fishtail coefficient, roll force, contact area and roll moment were not concerned in [8,16,17].In terms of previous works, there are few ones cover the hot ring rolling of magnesium alloys via a special and comprehensive study. In present paper, a 3D elastic-plastic and coupled thermo-mechanical FE model of ring rolling of AZ31 magnesium alloy is developed and the effect laws of on hot ring rolling are revealed by a special and comprehensive study.

FE MODELING

Adopting the FE model method as Wang et al[8] and the FE model has the same features asexcept taking the whole ring into account instead of just the upper half of the ring. The model of hot ring rolling developed is shown in Figure 1. The ring material is AZ31 magnesium alloy, its density is 1780, Poisson's ratio is 0.35, and thermal expansion coefficient is 2.6E-5. The thermal caducity, specific heat, Young's modulus and their temperature dependence are from[18]. Figure 2 shows the true stress-strain curves at strain rate 5/s under various temperatures given by[18]. The simulation conditions are summarized in detail in TABLE 1.

RESULTS AND DISCUSSION

Evaluation indexes

Evaluation indexes of uniformity of STD

The standard deviation of equivalent plastic strain (SDP) and temperature (SDT) of the rolled ring are employed to evaluate the STD. SDP and SDT are defined respectively as[13]:

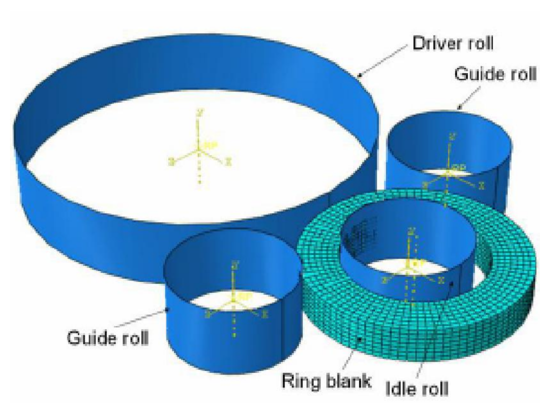

Figure 1 : Coupled thermo-mechanical 3D FE

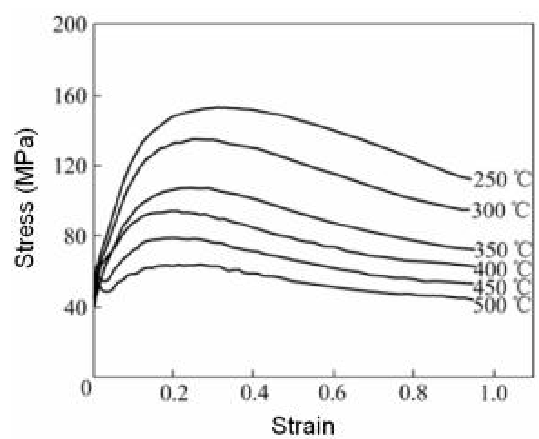

Figure 2 : The true stress-strain curves model for hot ring of AZ31 magnesium alloy

TABLE 1 : Simulation conditions

Process parameters	Value	Process parameters	Value
Radius of driver roll (mm)	104.8	Feed rate of idle roll (mm/s)	0.5, 1, 1.5, 2, 3, 4
Radius of idle roll (mm)	34.9	Temperature of ring blank (℃)	400
Radius of guide rolls (mm)	34.9	Temperature of driver rolls (℃)	100
Outer radius of ring blank (mm)	61.915	Temperature of idle roll (℃)	100
Inner radius of ring blank (mm)	39.685	Temperature of environment (℃)	20
Axial height of ring blank (mm)	20	Friction coefficient	0.3
Thickness reduction (mm)	6.23	Contact heat conductivity ($W.m^{-2}.℃^{-1}$)	6000
Angular velocity of driver roll (rad/s)	3	Convection coefficient ($W.m^{-2}.℃^{-1}$)	40
Emissivity	0.7		

$$SDP = \sqrt{\sum_{i=1}^{N}(PEEQ_i - PEEQ_a)^2 / N} \quad (1)$$

$$SDT = \sqrt{\sum_{i=1}^{N}(NT11_i - NT11_a)^2 / N} \quad (2)$$

where $PEEQ$ is the equivalent plastic strain, $PEEQ$ is the $PEEQ$ of the node i, $PEEQ_a = \sum_{i=1}^{i=N} PEEQ_i / N$ is the average $PEEQ$ of the all nodes, N is the sum of the nodes, $NT11$ is the node temperature, $NT11_i$ is the $NT11$ of the node i, $NT11_a = \sum_{i=1}^{i=N} NT11_i / N$ is the average $NT11$ of the all nodes. The largerSDP and SDT are, the more nonuniform STD is, the more nonuniform of the microstructure of the rolled ring, and the worse mechanical property is.

Evaluation indexes offishtail coefficient

The axial spread of the rolled ring is shown as Figure 3. The fishtail coefficient is defined as $F_t = \frac{B_{max} - B_{min}}{B_0}$, where B_0 is the initial axial height of ring, B_{max} is the maximum of axial height of rolled ring, B_{min} and is the minimum of axial height of rolled ring. The less fishtail coefficient is, the better quality of the end-plane of the rolled ring is, and the more homogeneous deformation in axial direction of the rolled ring is.

Effect of on strain distribution

Figure 4 illustrates the effect law of theon SDP. From Figure 4, it can be discovered that the SDP firstly decreases gradually, then increases with the increase of . That is to say, the deformation of the rolled ring firstly becomes more homogeneous then less homogeneous as the v increases. So an optimum is obtained, under which the deformation is the most homogeneous.

Figure 5 shows the equivalent strain distribution of rolled ring. From Figure 5, it can be seen that the variations of equivalent strain in inner surface and central region of the rolled ring is small, but the equivalent strain in outer surface of the rolled ring decreases with the increase of v. So the deformation of the rolled ring is more and more uniform. This can be explained by the following aspects: firstly, when the increases v, the radial feed amount per revolution increases, it is easier for the plastic deformation zone to penetrate the ring from the surface to middle region; secondly, the larger v, the shorter rolling time, leading to less strain accumulation; thirdly, the larger v, the larger deformation and the more heat generation, meanwhile, the shorter rolling time and the lees heat loss, resulting in the higher temperature of the ring, so it is easier for material to flow. The synthetic effects of the above factors cause the deformation more uniform.

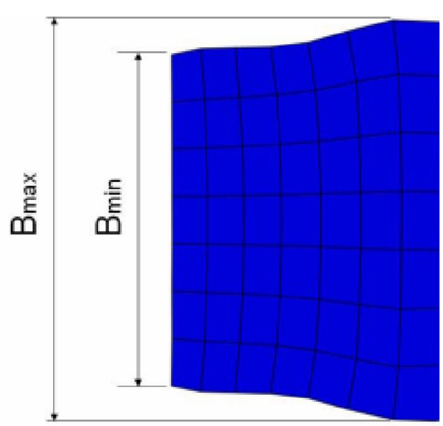

Figure 3 : The axial spread of the rolled ring

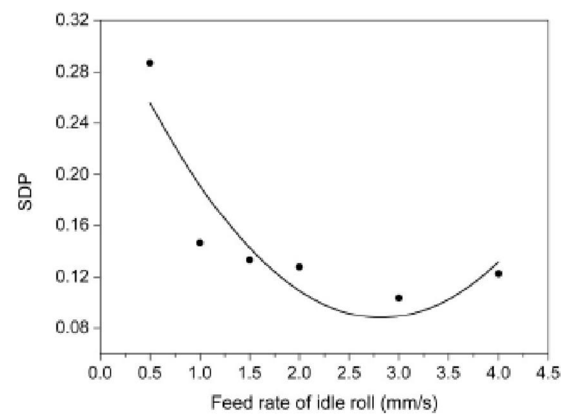

Figure 4 : Effect of feed rate of roll on SDP

When the v reaches the defined value, the deformation of the rolled ring begins to become nonuniform. That is because the angular velocity of driver roll is low, the linear speed of the ring is low too; when the v increases, the radial feed amount per revolution increases i.e. the compression is larger, resulting in the deformation of the partial region of the ring far larger than the others, the difference of the deformation per revolution leads to the deformation of the rolled ring nonuniform.

Effect of on temperature distribution

Figure 6 illustrates the effect law of the v on SDT. From Figure 6, it can be obtained that the SDT firstly decreases gradually, then increases with the increase of v. That is to say, the temperature distribution of the rolled ring firstly becomes more homogeneous then less homogeneous as the v increases. Therefore an optimum v

is obtained, under which the temperature distribution is the most homogeneous.

Figure 7 shows the temperature distribution of rolled ring. From Figure 7, it can be found that the temperatures of the surface region and central region argument with the increase of *v* simultaneously, thetemperature distribution of the rolled ring becomes more uniform. That is because that: the larger *v*, the larger deformation and the more heat generation, meanwhile, the shorter rolling time and the lees heat loss, resulting in the higher temperature of the ringoccurring thus the temperature distribution of the rolled ring becomes more uniform.

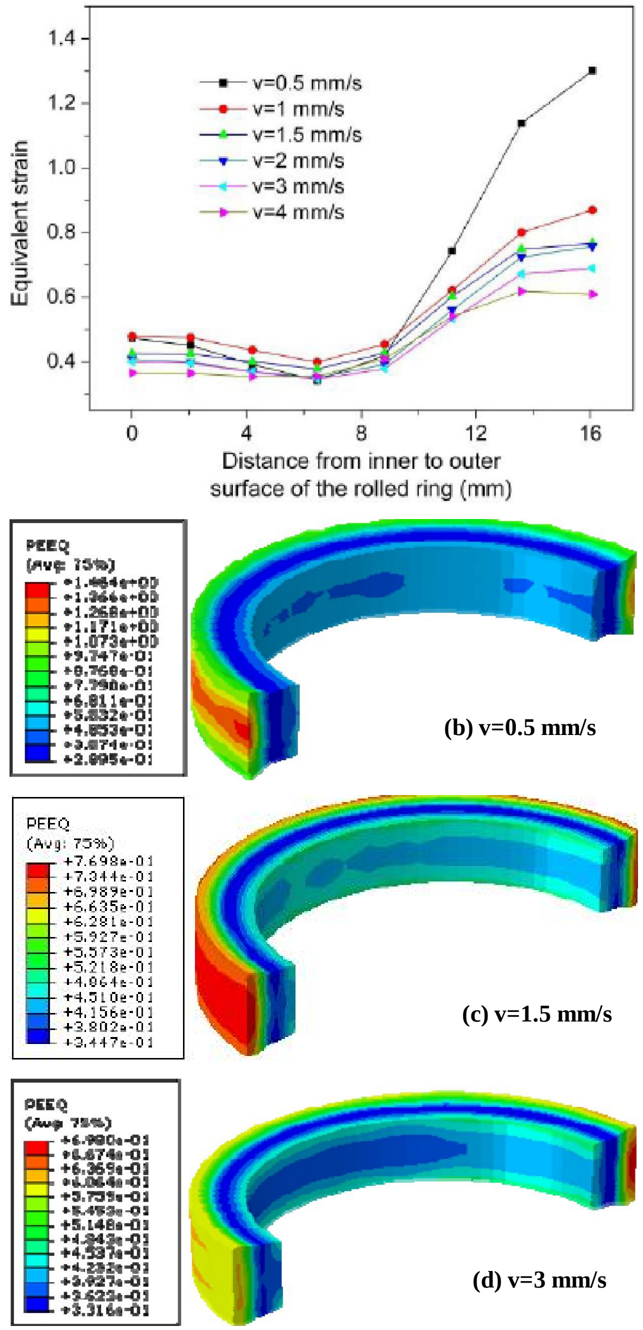

Figure 5 : Equivalent strain distribution of rolled ring

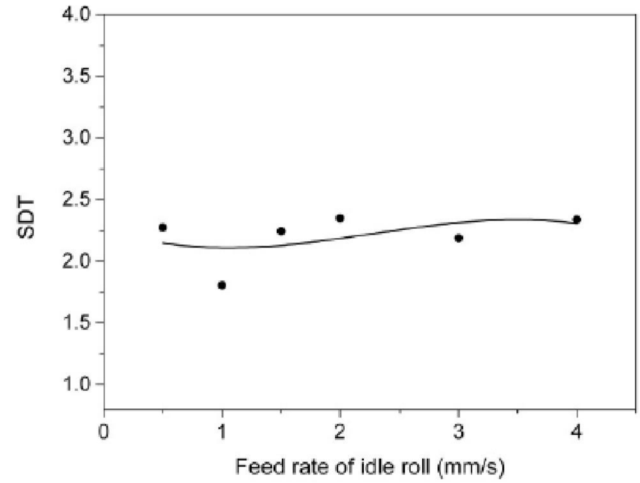

Figure 6 : Effect of v on SDT

When the *v* reaches the defined value, the temperature distribution of the rolled ring begins to become nonuniform. That is because the angular velocity of driver roll is low, the linear speed of the ring is low too; when the *v* increases, the radial feed amount per revolution increases, the compression is larger, resulting in the deformation of the partial region of the ring different, consequently, the difference of the temperature occurring in the circumference of the ringleads to the temperature distribution of the rolled ring nonuniform.

Effect of on fishtail coefficient

Figure 8 illustrates the variation offishtail coefficient with the *v* changing, From Figure 8, it can be seen that the fishtail coefficient firstly decreases then increases with the increase of *v*. It indicates that the quality of end-plane become better then worse with the increase of *v*. In that case, an optimum *v* is obtained, under which the quality of end-plane of rolled ring is the best. That can be explained according to the section 4.2.

Effect of onforce and power parameters

Figure 9 and Figure 11 shows the variation curves of force and power parameters (including the roll force and roll moment) with the *v* changing.

From Figure 9, it can be observed that the roll force arguments with the increase of *v* but the amplitude of the increment decreases. That can be attributed to that: on the one hand, when the v increases, the radial feed amount per revolution increases thus the more

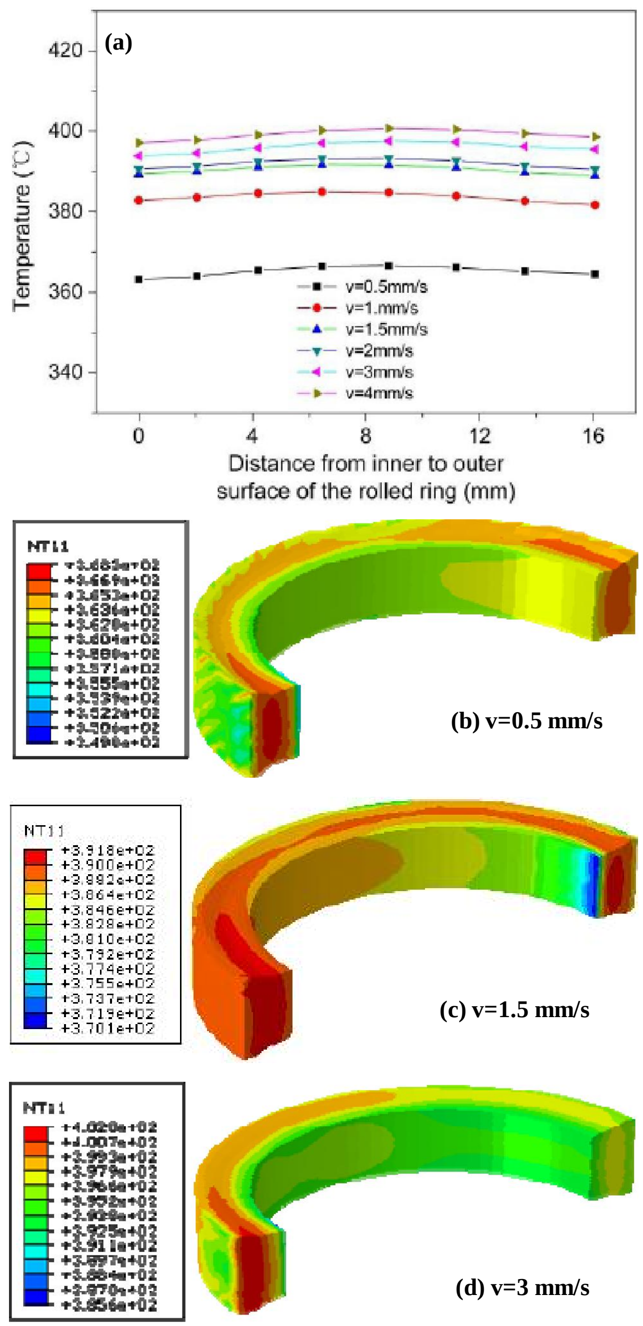

Figure 7 : Temperature distribution of rolled ring

metal particulate in the plastic deformation resulting in a more power needed to produce plastic deformation; on the other hand, the heat generated by plastic deformation causes the increase of the temperature of the ring, with the result that the deformation resistance of the material decreases. The above two factors lead to that influence law.

From Figure 11, it can be got that the roll momentarguments with the increase of v though the amplitude of the increment decreases. The reason for this is that: when the v increases, the roll force increases while the amplitude of the increment decreases, furthermore,the contact area between the ring and the driver roll become larger, as shown in Figure 10. The above two aspects lead to that influence law.

CONCLUSION

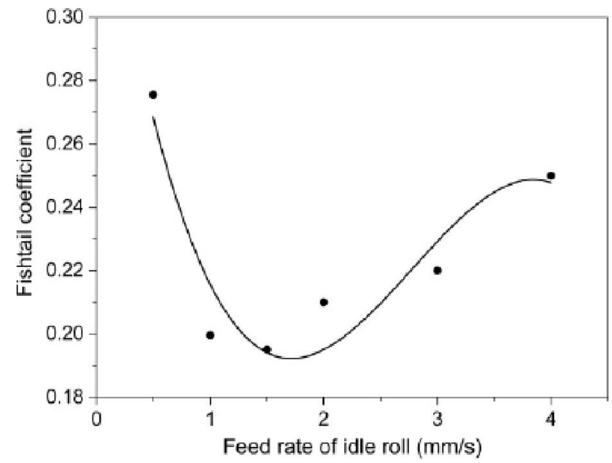

Figure 8 : Effect of v on fishtail coefficient

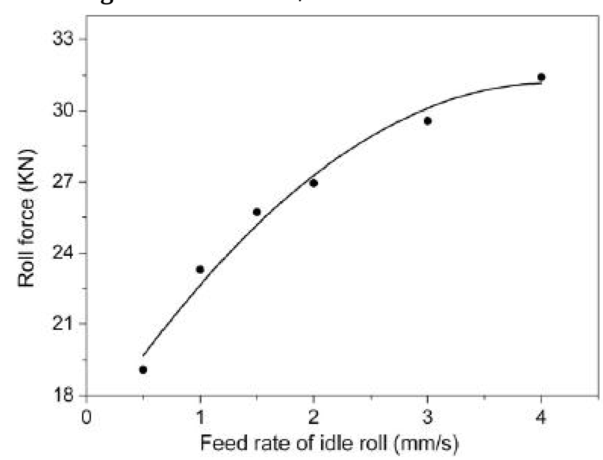

Figure 9 : Effect of v on roll force

A 3D elastic-plastic and coupled thermo-mechanical FE model has been developed to discuss the effect of on hot ring rolling of AZ31 magnesium alloy. The results are shown as follows:

(1) As v increases, the deformation of the rolled ring firstly becomes more homogeneous then less homogeneous. So an v optimum is obtained, under which the deformation is the most homogeneous.

(2) As v increases, the temperature distribution of the rolled ring firstly becomes more homogeneous then

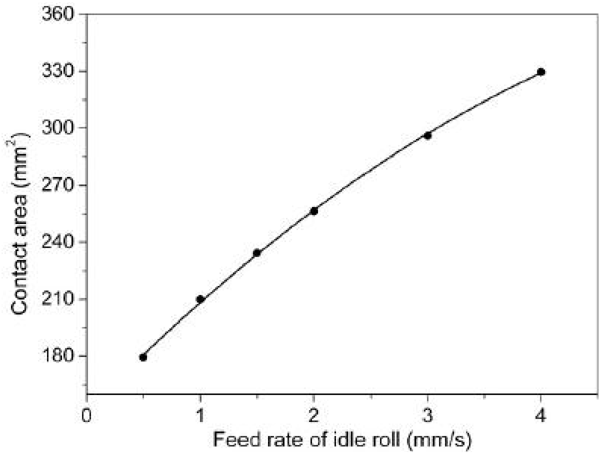

Figure 10 : Effect of v on contact area

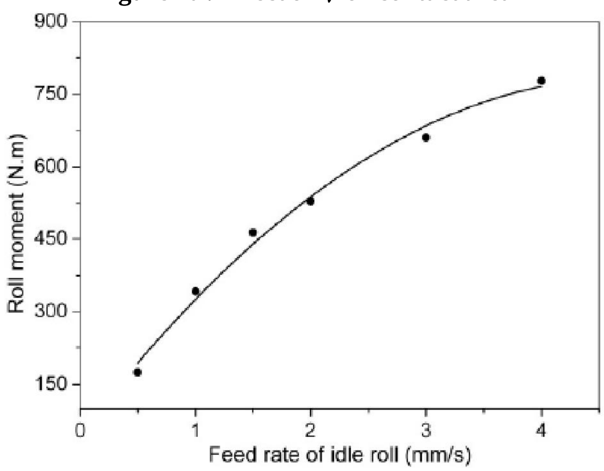

Figure 11 : Effect of v on roll moment

less homogeneous. Therefore an optimum *v* is obtained, under which the temperature distribution is the most uniform.

(3) The qualityof end-plane of the rolled ringfirstly becomes better then worse with the increase of *v*. In that case, an optimum *v* is obtained, under which the quality of end-plane of rolled ring is the best.

(4) The roll force and roll moment argument with the increase of *v* but the amplitude of the increment decreases.

(5) The contact area between the ring and the driver roll increases as *v* increases.

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REFERENCES

[1] J.L.Song, A.L.Dowson, M.H.Jacobs, J.Brooks, I.Beden; Journal of Materials Processing Technology, **121**, 332-340 **(2002)**.

[2] W.J.Kim, J.B.Lee, W.Y.Kim, H.T.Jeong, H.G.Jeong; Scripta Materialia, **56(4)**, 309-312 **(2007)**.

[3] L.L.Chang, J.H.Cho, S.B.Kang; Journal of Materials Processing Technology, **211(9)**, 1527-1533 **(2011)**.

[4] Z.W.Wang, S.Q.Zeng, X.H.Yang, C.Cheng; Journal of Materials Processing Technology, **182**, 374-381 **(2007)**.

[5] Min Wang, He Yang, Zhi-chao Sun, Liang-gang Guo, Xin-zhe Ou; Transactions of Nonferrous Metals Society of China, **16(6)**, 1274-1280 **(2006)**.

[6] H.Yang, M.Wang, L.G.Guo, Z.C.Sun; Computational Materials Science., **44**, 611-621 **(2008)**.

[7] Min Wang, He Yang, Lianggang Guo, Zhichao Sun; Rare Metal Materials and Engineering., **38(3)**, 393-397 **(2009)**.

[8] M.Wang, H.Yang, Z.C.Sun, L.G.Guo; Journal of Materials Processing Technology., **209(7)**, 3384-3395 **(2009)**.

[9] Nassir Anjami, Ali Basti; Journal of Materials Processing Technology., **210**, 1364-1377 **(2010)**.

[10] Wang Min, Trans; Nonferrous Met.Soc. China., **21**, 1611-1619 **(2011)**.

[11] S. Zhu, H.Yang, L.G.Guo, R.J.Gu; Computational Materials Science., **65**, 221-229 **(2012)**.

[12] G.Zhou, L.Hua, J.Pan, D.S.Qian; Computational Materials Science., **50**, 65-76 **(2010)**.

[13] G.Zhou, L.Hua, D.S.Qian; Computational Materials Science., **50**, 911-924 **(2011)**.

[14] Dongsheng Qian, Yan Pan; Computational Materials Science., **70**, 24-36 **(2013)**.

[15] Jie Zhou, Feng-lin Wang, Meng-han Wang, Wu-jiao Xu; The International Journal of Advanced Manufacturing Technology., **55**, 95-106 **(2011)**.

[16] Sun Zhi-chao, Yang he; Ou Xin-zhe, Trans; Nonferrous Met.Soc. China., **18**, 1216-1222 **(2008)**.

[17] Sun Zhichao, Yang He, Ou Xinzhe; Computational Materials Science., **49**, 134-142 **(2010)**.

[18] Yu Kun, Wang Xiao-yan, Cai Zhi-yong, Wang Ri-chu, Shi Di; Journal of Central South University., (in Chinese), **40(6)**, 1535-1539 **(2010)**.