Y. CHANG, X. D. SHU, T. Z. CHEN

ISSN 0543-5846
METABK 59(3) 317-320 (2020)
UDC – UDK 621.771.008.04:62.001.57:513.1.002:338.4=111

THE INFLUENCE LAW OF PROCESS PARAMMETERS ON END CONCAVITY OF HEXAHEDRAL BLANK CROSS WEDGE ROLLING (CWR)

Received – Primljeno: 2019-11-26
Accepted – Prihvaćeno: 2020-03-06
Original Scientific Paper – Izvorni znanstveni rad

In order to expand the range of the cross wedge rolling (CWR) product, realize CWR of hexahedral blank. In this paper, the three-dimensional Finite element model (FEM) of hexahedral blank CWR is established by DEFORM finite element software. The influence of forming angle, spreading angle and section shrinkage on the length of concavity is analyzed, compared with the round billet rolling results under the same parameters, the concavity length of the hexahedral blank is slightly larger than that of round billet, and the influence of process parameters on the concavity is basically the same. The research results provide theoretical guidance for the rational determination of process parameters for CWR of hexahedral blank.

Key words: CWR, FEM, hexahedral blank, process parameters, concavity length

INTRODUCTION

The CWR is a new process and technology for forming shaft parts, and is an integral part of advanced manufacturing technology. With the development of the economy, the improvement of material utilization rate is particularly urgent. Scholars at home and abroad are also expanding the research range of CWR, from the traditional symmetrical part rolling to the asymmetric, change from ordinary mold to special mold, the shape of the blank is also gradually expanding [1]. Pater Z. of Lublin University, Poland, is mainly engaged in the development of new molds and the research of CWR. Through the design of the mold and parameters, technical research on forming ball by CWR process is realized [2], expanding the product range of CWR. Academician Hu of Beijing University of Science and Technology [3] mainly studied the CWR and deformation law including: The influence of process parameters on axial force, tangential force and radial force. However, the research on the end quality of hexahedral blank CWR is rarely reported. In production, the process parameters are important factors affecting the end concavity, so it is necessary to discuss the influence of process parameters. In this paper, the FEM of hexahedral blank CWR is established by DEFORM finite element software. The influence of forming angle, spreading angle and section shrinkage on the length of the concavity is analyzed, and compared with the round billet rolling results under the same parameters. The research results provide theoretical guidance for the rational determination of process parameters for CWR of hexahedral blank.

Y. Chang, X. D. Shu, T. Z. Chen: Faculty of Mechanical Engineering and Mechanics, Ningbo University, Ningbo, China, e-mail: shuxuedao@nbu.edu.cn

FEM AND SIMULATION

The geometric model is built and assembled in the CREO software, imported into DEFORM-3D simulation software. The simulation of the FEM is completed after the pre-processing. The simulation model is shown in Figure 1. The blank is set to a plastic body, the rolling temperature is set to 1 050 °C, and the material is 42CrMo; The mold is symmetrical, in order to save the simulation calculation time, take the 1/2 rolling model and set the symmetry constraint at the boundary of the symmetry surface. Using tetrahedral meshing and mesh number is set to 80 000, set volume compensation to avoid material volume loss; simulation step is 0,008 seconds per step, rolling speed is 230 mm/s; The shear friction coefficient between the blank and the mold is set to 2 [4].

Using the above model for finite element simulation, the effective strain after simulation is shown in Figure 2. It can be seen from Figure 2(a) that in the wedging stage, the strain of the surface metal at the end

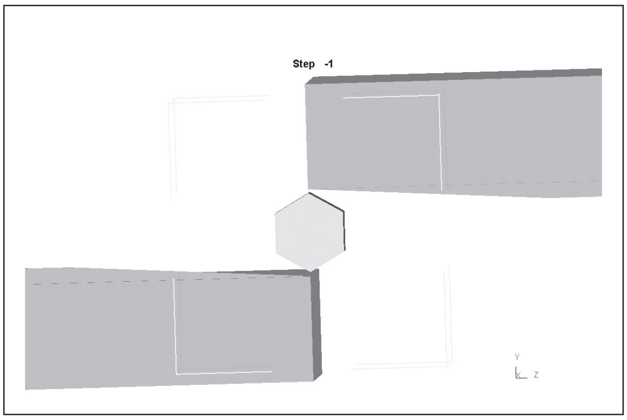


Figure 1 FEM of hexahedral blank CWR

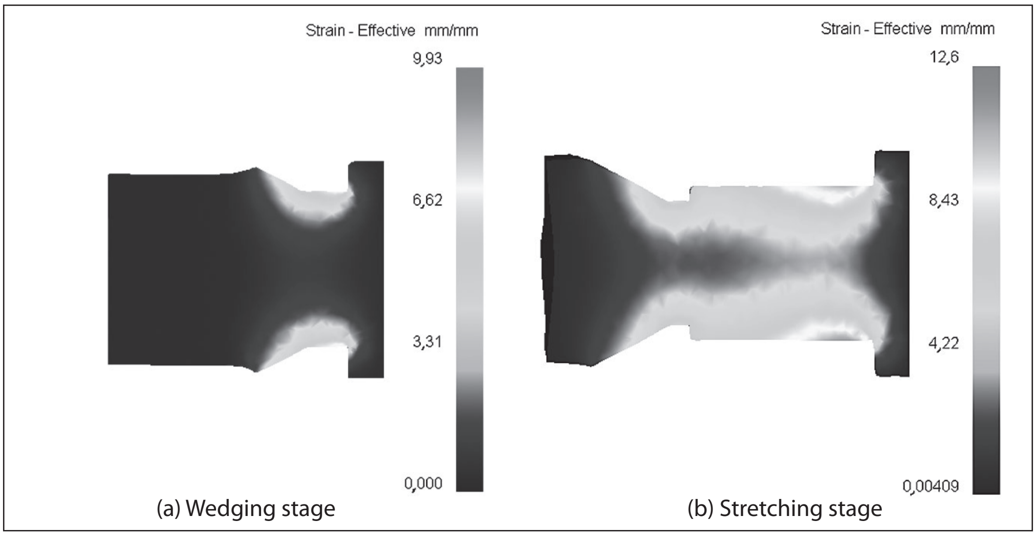


Figure 2 Effective strain for the wedging and stretching stage

of the rolled piece is larger. Due to the action of mold, the ends of the rolled piece are subjected by the axial compression of mold, the strain at other parts is small. From Figure 2(b) that in the stretching stage, the strain at two ends of the rolled piece is relatively uniform and relatively large, and gradually becomes smaller from the outside to the inside, which is because the end metal of the rolled piece is far away from the rolled plate during the stretching.

The concavity directly reflects the quality of the end of the rolled piece, and it is especially important to measure the length of the concavity effectively. The calculation method of the concavity length is shown in Figure 3, and the calculation formula is as shown in Formula 1 [5].

$$Y = \frac{1}{25}\sum_{i=1}^{25} S_i - \frac{1}{25}\sum_{i=1}^{25} S_j \qquad (1)$$

Where: Y – is the concavity length; S_i – is the Z-coordinate of the heart node; S_j – is the Z-coordinate of the outer node.

THE INFLUENCE LAW OF PROCESS PARAMETERS ON END CONCAVITY OF HEXAHEDRAL BLANK CWR

The numerical simulation is using a total of 9 simulation schemes of 3 factors and 3 levels, and the length

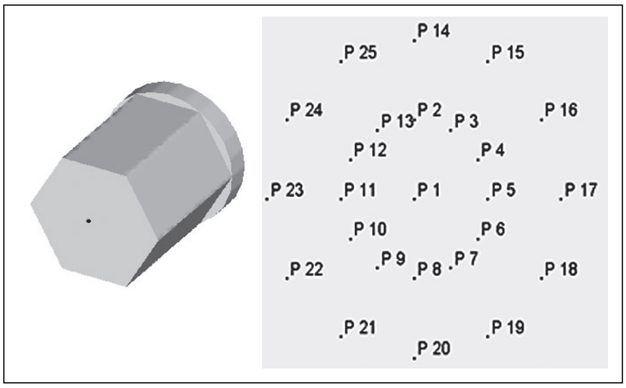


Figure 3 Feature point distribution

Table 1 **Process parameter setting**

Number of groups	Forming angle α/ °	Spreading angle β/ °	Section shrinkage Ψ/ %	Concavity length / mm
1	28	7,5	40	6,18
2	30			5,83
3	32			4,52
4	30	6,5		6,23
5		7,5		5,02
6		8,5		4,76
7		7,5	30	4,27
8			40	6,85
9			50	6,14

of the corresponding concavity of the rolled piece under various working conditions can be obtained. The data summary processing is shown in Table 1:

The value of the concavity length corresponding to the different forming angle α is shown in Figure 4(a). It can be seen from the trend of the concavity in the figure that the length of the concavity length decreases as the forming angle increases. When the forming angle is 28 °, the length of the concavity is 6,18 mm. When the forming angle is increased to 32 °, the concavity is reduced to 4,52 mm. According to the analysis of the mechanism of the concavity in the CWR, the generation of the concavity is mainly in the wedging stage, the mold generates a force on the blank, which can be decomposed into radial force and axial force, with the increase of the forming angle, the axial bulge is intensified, and the axial force becomes larger, so that the difference in the flow velocity of the metal in the axial direction becomes smaller, resulting in a smaller concavity length. As the forming angle gradually increases, the length of the concavity gradually becomes smaller.

The value of the concavity length corresponding to different spreading angle β is shown in Figure 4(b). It can be seen from the figure that the length of the concavity decreases as the spreading angle increases. When the spreading angle is 6,5 °, the length of the concavity is 6,23 mm. When the spreading angle is increased to 8,5 °, the concavity length value is reduced to 4,76 mm,

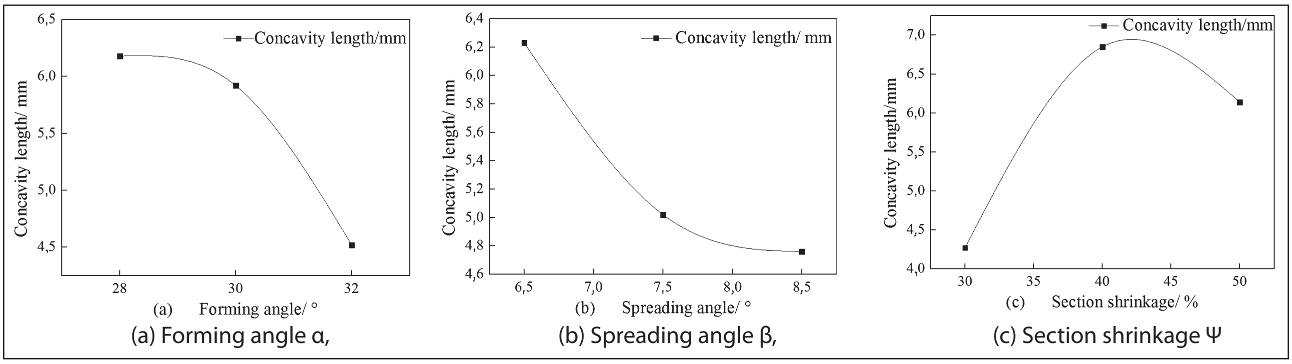


Figure 4 The influence law of process parameters on end concavity of hexahedral blank CWR

a decrease of 23,6 %. The formula for calculating the length of the wedging stage and the stretching stage is as shown in Formula 2.

$$\begin{cases} L_w = h \cot \beta \cot \alpha \\ L_S = L_w \cot \beta / 2 \end{cases} \quad (2)$$

Where: L_w - is the length of wedging stage; L_s - is the length of stretching stage; h – is the height of wedge top. It can be known from Formula 2 that when the spreading angle is increased, the length of the wedging stage and the stretching stage are correspondingly reduced, thereby shortening the uneven deformation time of the end surface of the rolled piece and the metal of the core, so that the end concavity is reduced. During the stretching stage, the concavity length grows slowly.

The value of the concavity length corresponding to the different section shrinkage Ψ is shown in Figure 4(c). When the section shrinkage is 30 %, the length of the concavity is 4,27 mm, when the section shrinkage is 40 %, the length of the concavity is 6,85 mm, while the section shrinkage is 50 %, the concavity is slightly reduced. It can be concluded that when the section shrinkage varies between 30 % and 40 %, the length of the concavity increases with the increase of that; when the section shrinkage varies between 40 % and 50 %, the length of concavity decreases as that decreases. As the section shrinkage increases, the amount of metal deformation during the CWR increases gradually, so that the metal axial displacement accumulated by the metal and the core accumulated on the shaft end surface has a large difference, resulting in a larger concavity length and the end quality is not ideal; When the section shrinkage exceeds 40 %, the metal action of the hexahedral blank metal is obvious, and the difference between the end metal and the core metal is small, so the length of the concavity is slightly decreased. This shows that when the section shrinkage reaches a certain value or more, the length of the concavity can be effectively controlled.

A dimensionless influence factor λ and influence coefficient η are introduced [6]. The influence of various factors on the length of the concavity is shown in the Figure 5. The larger the curvature of the polyline, the greater the influence of this factor on the concavity. The figure shows that the section shrinkage has the greatest influence on the concavity, followed by the spreading angle, and finally the forming angle, wherein the forming angle and the spreading angle have little effect on the concavity.

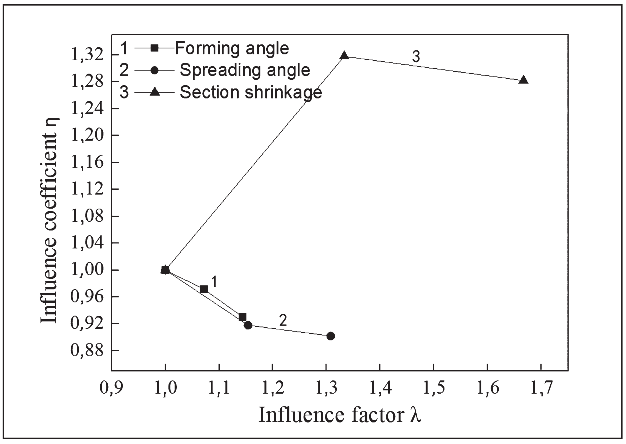


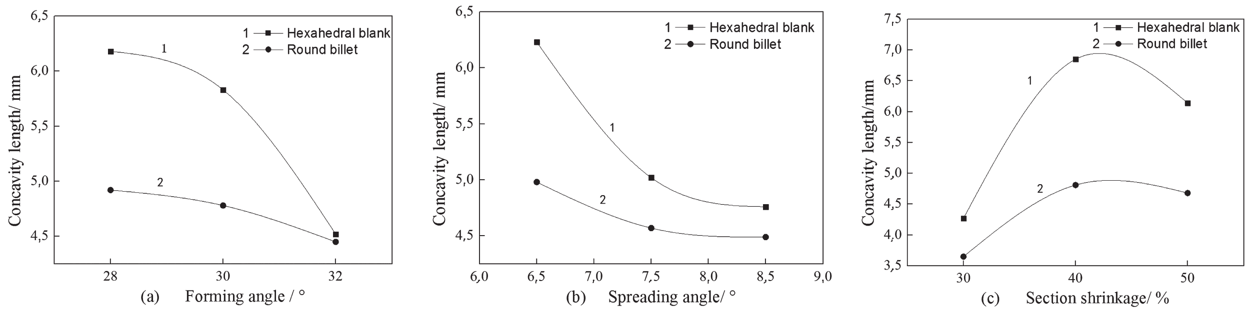
Figure 5 Comparison of the influence of various factors on the quality of rolling piece

COMPARISON OF CONCAVITY LENGTH OF HEXAHEDRAL BLANK ROLLING AND ROUND BILLET ROLLING

The hexahedral blank has a cross section dimension of D = 15 mm and a length of L = 30 mm. The round billet of the same volume and cross section dimension is used for rolling, the diameter of the round billet is about 13,641 mm. Select the 9 sets of conditions in Table 1 for finite element simulation.

The variation of concavity length in different parameters is as shown in Figure 6. Comparing the three graphs 6(a), 6(b), and 6(c), it can be seen that the length of the concavity of hexahedron blank is greater than that of round billet. It can be seen from the trend of curve in Figure 6(a) that the change trend of forming angle to the length of the concavity of hexahedral blank is the same as that of round billet. When the forming angle α is 28 °, the concavity length of round billet is 4,92 mm, which is 1,26 shorter than that of hexahedral blank. When the forming angle is increased to 32 °, the length of the concavity is reduced to 4,45 mm, which is reduced by 9,6 %. The reduction is smaller than that of hexahedral blank.

It can be seen from the trend of the curve in Figure 6(b) that the change trend of spreading angle to the len-



(a) Forming angle α, (b) Spreading angle β, (c) Section shrinkage Ψ

Figure 6 Comparison of the influence of various process parameters on the concavity length of the hexahedral blank and the round billet.

gth of the concavity of hexahedral blank is the same as that of round billet. When the spreading angle is 6,5 °, the length of the concavity is 4,98 mm, and when the spreading angle is increased to 8,5 °, the length of the concavity is reduced to 4,49 mm, which is reduced by 9,8 %. The reduction is smaller than that of hexahedral blank.

It can be seen from the trend of the curve in Figure 6(c) that the change trend of section shrinkage to the length of the concavity of hexahedral blank is the same as that of round billet, and the influence range is smaller than that of the hexahedral blank. This is because the metal flow rate of the hexahedral angular portion is faster than that of the core metal, which is larger than the concavity length of the same process parameters, and the forming angle, the spreading angle, the section shrinkage to the length of the concavity in the hexahedral blank. The effect is slightly larger than in the round billet.

CONCLUSION

Within the selected process parameters, the length of the concavity of the 42CrMo hexahedral blank decreases with the increase of the forming angle α, the range is about 26,8 %; it gradually decreases with the increase of the spreading angle β, but the decrease is slowly, about 23,6 %; when the section shrinkage Ψ varies between 30 % and 40 %, the length of the concavity increases with the increase of the section shrinkage Ψ; when the reduction of section shrinkage changes in the range of 40 %-50 %, the length of concavity decreases with the increase of section shrinkage.

The degree of influence of the section shrinkage Ψ, the spreading angle β and the forming angle α on the concavity length of the CWR of the 42CrMo hexahedral blank is reduced.

The simulation results show that the hexahedral blank rolling is feasible. The comparison with the round billet rolling shows that the overall trend of the influence on the length of concavity is the same. The influence of the forming angle, the spreading angle and the section shrinkage on the length of concavity in the hexahedral billet is slightly larger than that in the round billet.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 51975301) and Natural Science Foundation of Zhejiang (No. LZ17E050001).

REFERENCES

[1]. D. P. Li, G. Q. Li, Z. B. Bai, Application and new development of cross wedge rolling, Journal of Harbin Institute of Technology 32(2000)05, 97-99.

[2]. Pater Z, Bulzak T, Tomczak J, Cross wedge rolling of driving shaft from titanium alloy Ti6Al4V, Key Engineering Materials, Trans Tech Publications 687(2016), 125-132.

[3]. Z. H. Hu, K. S. Zhang, B. Y. Wang, Forming technology and Simulation of cross wedge rolling parts, Metallurgical Industry Press 187(2004), 223-256.

[4]. Q. H. Zhang, Finite element numerical simulation of rolling of shaft parts, Materials Science and Engineering 134(2010), 47-50.

[5]. J. Zen, C. G. Xu, W. W. Ren, X. S. Guo, The influence of process parameters on the length of concavity of cross wedge rolling under different end shapes, Journal of Plastic Engineering 24(2017), 111-117.

[6]. J. Wei, X. D. Shu, Research on key technology of forming shaft end by closed cross wedge rolling, Thermal Processing 45(2016), 140-144.

Note: The responsible translator for the English language is J.T. Wang, Ningbo, China