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The stress analysis and optimization of the staged combined concave die under the real working pressure

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ABSTRACT

According to the structure equivalent strength optimization theory, each concave die layer's size and inter layer interference of the flat end combined concave die were obtained by using the Lame formula. Then, the end angle and stage height were introduced into the computation model. According to the comparative analysis of the computation result, it can be found that the structure of combined concave die with both up and below steps is reasonable, and the stage height is 6mm, the end angle is 22° and the concave die with this structure was used to the forming simulation analysis. The finite element analysis software DEFORM-3D was used to simulate the process of volume forming of the part. The numbers of pressure of convex die were obtained at different simulation steps. The equivalent stress, radial stress and tangential stress distribution was obtained corresponding to different depressing magnitude of the convex die. From the analysis results of the volume molding simulation, It could be seen that during the whole process of extrusion the stress distribution of inner wall of the die was uneven. The node pressure and node coordinate of the inner wall at the finished time of the extraction, which was used for the stress analysis and optimization design again, and the force situation and optimized structure were obtained.

KEYWORDS

Staged combined concave die; Stage height; End angle; Finite element analysis.

INTRODUCTION

The traditional combined concave die is designed by using the Lame formula of the thick cylinder theory. The combined concave die designed with this design method is very similar. With development of the finite technology, the finite analysis method is very perfect and convenient in the design of extrusion die and is extensively applied, but most methods are for design and analysis of the extrusion die under the uniform internal pressure [1-5]. This paper selects the bulk forming software DEFORM-3D as the simulation platform to perform the dynamic finite element simulation for the combined concave die work process and validates feasibility of the extrusion process. The die stress distribution law inside the combined die is obtained for different rolling reductions of the terrace die by analyzing the stress on the interior of the combined concave die under different simulation steps. The analysis indicates that change of the stress on the internal wall of the terrace die is not uniform with change of rolling reduction of the terrace die during extrusion and the action position and size will also change. It is not suitable to analyze and optimize the stress on the concave die for the flat end surface or step combined concave die by using the uniform internal pressure.

Identification and finite element analysis of combined concave die parameterized structure

Taking three-layer cold extrusion pre-stress combined concave die as one example [6], the bearing internal pressure p is 1610MPa. The internal layer concave die is made of Cr12MoV and the permitted stress is [σ1]. The pre-stress ring is made of 5CrNiMo. The permitted stress is [σ2] and [σ3]. The elastic modulus is E. The Poisson ratio is γ. Different parameters are shown as the table 1. The Lame formula is used for optimization to get the size of different layers and inter-layer over of the concave die according to the structural equal strength optimization theory, shown as the table 2.

Table 1 List of known parameters of three-layer combined concave die

Parameters	P(MPa)	$[\sigma_1]$(MPa)	$[\sigma_2]$(MPa)	$[\sigma_3]$(MPa)	d_1(mm)	H(mm)	γ	E(MPa)
values	1610	2550	1210	1210	40	35	0.3	2.07E5

Table 2 Optimization results of Lame equation

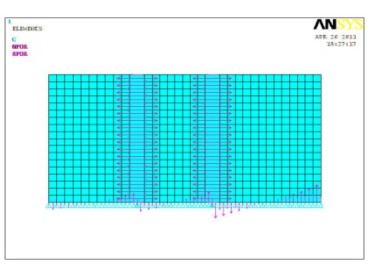
Parameters	Q_1	Q_2	Q_3	d_2	d_3	d_4	a	dr2	dr3	dr2′
Results	0.478	0.694	0.694	83.632	120.450	173.476	4.337	0.424	0.365	0.253

The parameters are described as follows: Q_1, Q_2 and Q_3 respectively indicate the ratio of internal diameter to external diameter of the internal layer, intermediate layer and external layer in three-layer combined concave die. d_2, d_3 and d_4 respectively indicate the external diameter of three-layer combined concave die. a is the ratio of the maximum external diameter to internal diameter of three-layer combined concave die. dr2 is the shrink range between the internal layer and middle layer. dr3 is the shrink range between the middle layer and external layer. dr2' is the correction value of dr2 in case of cold pressing assembly from outside to inside. dr2' is used in this paper for computing.

The generic finite element software ANSYS is used to establish the parameterized symmetric finite element model with end surface inclination α and step height h11 based on the above parameters. The surface-surface contact pair between the internal and intermediate layer and between the intermediate layer and external layer is respectively established. The augmented Lagrange method is used to impose the contact and coordination conditions [7], shown as the figure 1.

When two end surfaces to analyze are the step inclined end surface, to make the analysis results symmetric, the shift is constrained in y direction at three key points on the down end surface. The inclination of the end surface varies within 0~35°. The step is 0-10mm high. The inclination of the end surface obtained by finite element analysis is 22°. When the step is 6mm high, the stress of the internal layer concave die should reach the minimum. This structure is selected as the dimension of the combined concave die with the up and down step inclined end surface. The structure schematic is shown as the figure 2. Its stress state is compared with it of the routine flat end surface combined concave die, shown as the table 3.

Under the joint action of the end surface inclination and step height, the equivalent stress of the concave die is improved. With growth of the inclination, the radial stress of the internal layer concave die will also increase. On the whole, the step combined concave die is better than the routine flat end surface combined concave die.



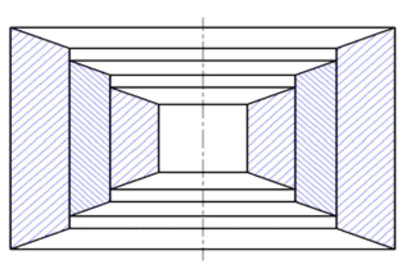


Figure 1 Boundary condition diagram of concave die under pre-stress state Figure 2 Structure

Table 3 Stress state comparison of combined concave die with step up and down end surface and concave die with flat end surface

	Internal layer			Intermediate layer	External layer
	seqv	Sx	Sz	seqv	seqv
Flat end surface combined concave die	2233	-1605	994.9	1069	1095
Combined concave die with step up and down end surface	1634	-1724	271	844	1039
Comparison and analysis	Decrease	Increase	Decrease	Decrease	Decrease

CHANGE OF POSITIVE PRESSURE ON THE INTERNAL WALL OF INTERNAL LAYER OF CONCAVE DIE IN COLD EXTRUSION FORMING SIMULATION

DEFORM-3D software is a finite element system based on the process simulation system provided by America Scientific Forming Technology Corporation, which can realize simulation analysis for modeling, forming, heat conduction and forming device features in an integrated environment.

The die stress is analyzed in DEFORM-3D forming simulation. The combined concave die is set as the elastic die. The terrace die is set as the rigid model. The extrusion material is set as the isotropic plastic model [8-9]. The extrusion material is the rigid plastic body. The total stroke of the terrace die without bouncing is 3.5mm, the step is set as 0.08 mm (the step should be less than 1/3 of the minimal cell length). The simulation step number is set as 60. Each step is stored one time. Enough constraint conditions are imposed according to the actual condition. The equivalent stress, radial stress and tangential stress of the combined concave die under different rolling reductions of the terrace die by analyzing the stress on the die in different simulation steps.

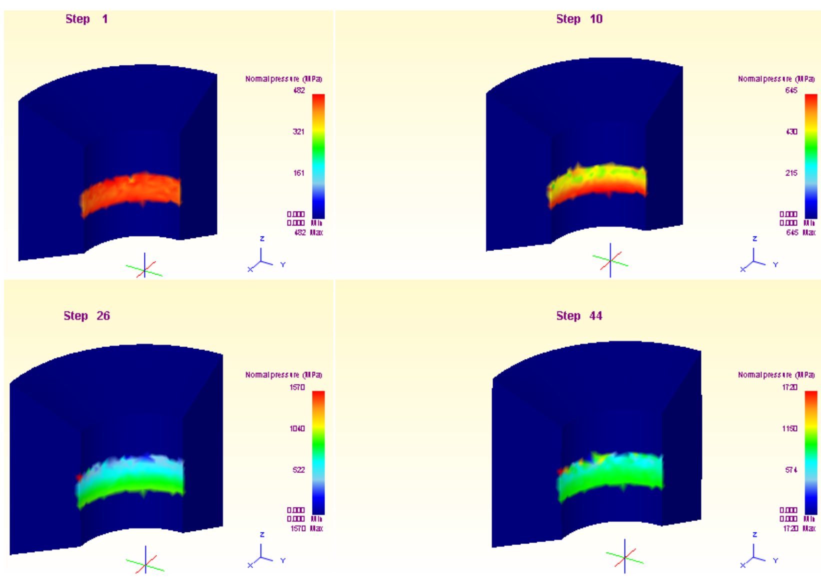


Figure 3 Change of the positive pressure on internal wall of the step combined concave die under 0.08, 0.8, 2.08 and 3.5mm rolling reduction

The figure 3 indicates that the pressure size and action position will also change with change of the contact between the work part and concave die and the positive pressure is not uniform for each simulation. The pressure and coordinate of the nodes on the internal wall of the internal die of the terrace die under 0.08mm, 0.8mm, 2.08mm and 3.5mm rolling reduction is extracted to draw the distribution law of the positive pressure on the internal surface of the internal die on the height of the concave die during extrusion, shown as the figure 4. It indicates that the pressure distribution on the internal wall of the concave die is very non-uniform and the action position also changes during extrusion, so it is not proper to analyze and optimize the stress on the combined concave die by using uniform pressure and a new idea is required for optimization.

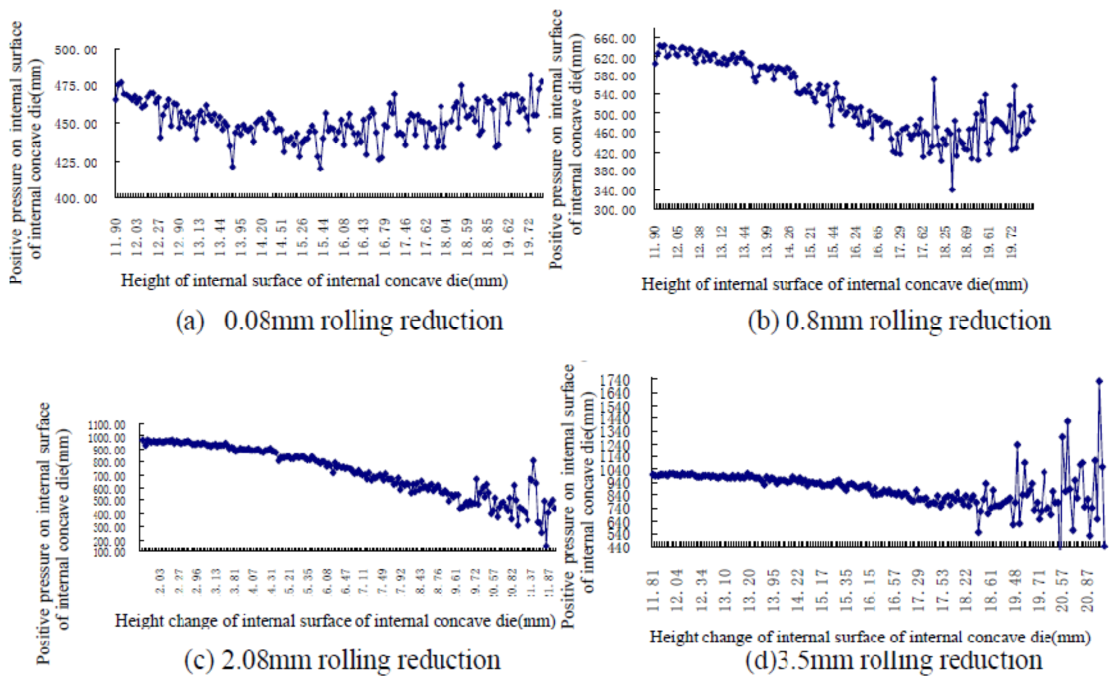


Figure 4 Distribution law of side pressure on the interface surface of internal die at the concave die height during extrusion

OPTIMIZED DESIGN OF STEP COMBINED CONCAVE DIE BASED ON ANSYS

To accurately load non-uniform node loading force in ANSYS analysis, the nodes on the internal surface of the internal die is divided into the nodes which are consistent with nodes in forming simulation. This implementation method is to establish the hard point. After the hard points are divided into the grids, they will become the nodes. To create the hard points, some requirements are proposed for grid cells. 4-node plane182 cell is selected.

Mathematic model for optimization of combined concave die

The optimized design is a technology to find the optimized design scheme. The mathematic model of the optimized model is the mathematic description of the optimized design engineering problem and includes design variants, constraint conditions and target function [10-12].

The optimized mathematic model is:

Design variant $X=[d_2,d_3,d_4,\text{dr1},\text{dr2},\text{a},\text{h11}]^T$, where in dr1 and dr2 are the shrink range for processing and manufacturing. a is the inclination of L1, L2 and L3 end surface of the concave die. h11 is the height of the step 1 and 2.

Constraint conditions: the main stress on different layers of the concave die is less than their permitted stress, namely $SEQV \le [\sigma]$;

Optimization target: the pull stress is permitted on the internal wall of the concave wall. The stress on different layers should be maximized under same bearing side stress.

$$objfun = \text{Max}\left\{\left|\frac{SEQV_i-[\sigma]_i}{[\sigma]_i}\right|\right\}$$ (i=1,2,3), i indicates i^th concave die.

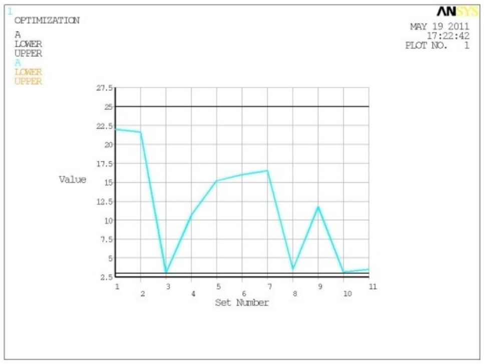
Optimization results

The figure 5-8 display change law of the diameter, shrink range, step height and end surface inclination of different layers of three-layer combined concave die with iteration time under actual internal work pressure. The x coordinate indicates the iteration time and y coordinate indicates the values of the optimization variant. After multiple optimization and iteration, the target function is optimized in the step 11. The table 4 indicates the optimization results of the combined concave die under the actual internal pressure.

From the table 4 and figure 5-6, compared to the size prior to optimization, the size of the internal layer of the concave die nearly has no change. The pre-tightening ring of the intermediate layer reduces and the size of the outer pre-tightening ring decreases little.

Table 4 Optimization results of combined concave die under actual internal work pressure

Outer diameter of different layers (mm)			Shrink range (mm)		End surface inclination (degree)	Step height (mm)	Maximum equivalent stress (MPa)		
d2	d3	d4	drl	dr2	A	H11	SEQV1	SEQV2	SEQV3
83.477	108.61	170.29	0.353	0.451	3.4943	9.2125	1695.8	629.90	1014.2



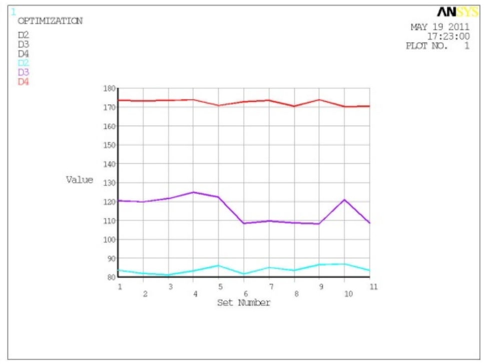
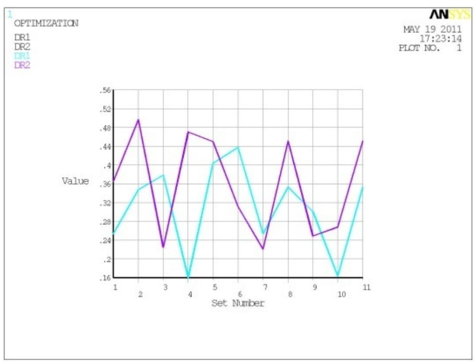


Figure 5 End surface inclination (A) Figure 6 Outer diameter of internal layer, intermediate layer and external layer (D2,D3,D4)



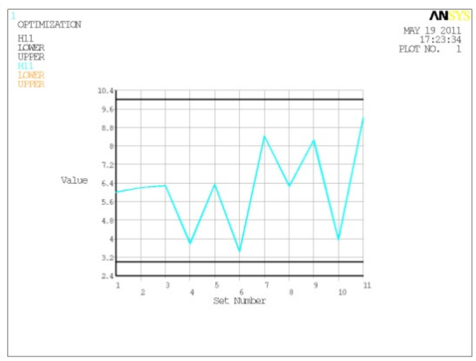


Figure 7 DR1 of intenral layer and intermediate layer and DR2 of intermediate layer and external layer Figure 8 step height

After optimization, the equivalent stress distribution law of the step combined concave die under the work state is shown as the figure 9. The maximum equivalent stress of different layers of step combined concave die does not approach yield stress of the materials, especially the maximum equivalent stress of the internal layer and intermediate is far lower than the yield limit of the selected materials, so it leads to material waste.

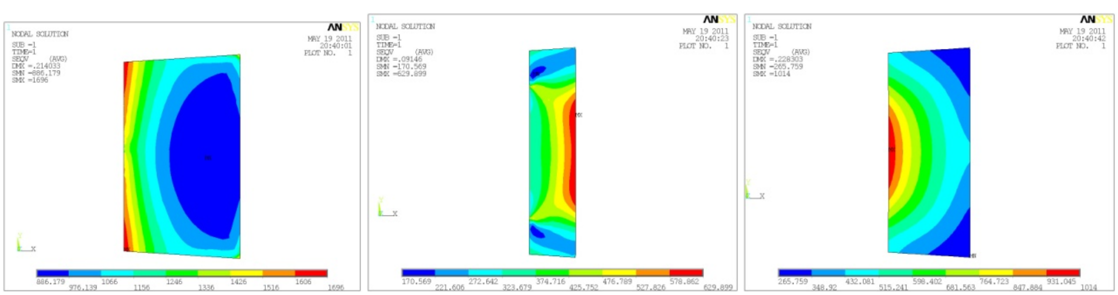


Figure 9 Equivalent stress diagram of step combined concave die under work state

The figure 10 shows the equivalent stress diagram of step combined concave die under work state. The figure shows that the maximum equivalent stress of different layers of the combined concave die is less than the permitted stress of the die material on different layers. The assembled combined concave die is not destructed. It indicates that the optimized variant value is reliable.

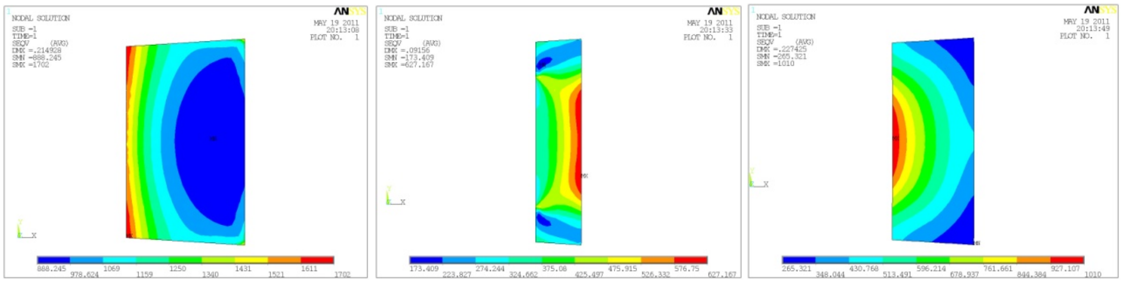


Figure 10 Equivalent stress diagram of step combined concave die under pre-stress state

CONCLUSIONS

This paper regards the non-uniform loading force on the internal wall of the concave die as the loading force for the concave die analysis based on the analysis results of DEFORM-3D at the final step of extrusion process simulation. The large analysis software ANSYS is used to analyze the stress of the combined concave die. Two types of finite element software are combined to provide new basis for combined concave die design under non-uniform internal pressure.

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REFERENCES

[1] Xie Jianxin, Li Jingyuan, Liu Jingan. Initial Design of Flat Extrusion Cylinder for 80MN Extruder. Forging Technology, 1999,24(3):48~51.

[2] Liu Quankun, Tao Hongzhi, Wang Leigang. Analysis on Strength of Porcelain Extrusion Concave Die. China Machinery Engineering, 1997, 8(6):37~39.

[3] Li Yan, Liu Quankun, Wang Leigang. Analysis on Distribution Law of Distortion and Stress of Multi-Layer Combined Round Extrusion Cylinder. Journal of Hefei University of Industry (Natural Science Version), 2002,25(6):1154~1158.

[4] Gao Hanhua. Application of Finite Analysis in Combined Concave Die Design. Light IndustryMachinery, 2006,24(2):93~95,

[5] Zhang Min. Finite Element Analysis and Combined Concave Die Optimization of Support Shaft Extrusion Die. Shangdong University. 2007.

[6] Hong Shenze. Extrusion Process and Mold Design. Beijing: Machinery Industry Press, 1996.

[7] Ye Xianlei. Application Instance of ANSYS Engineering Analysis Software. Beijing: Tsinghua University Press, 2003.

[8] Edited by Wang Ping, Hou Muying. Machinery Optimization Design. China Geology University Press, 1998.

[9] P.Groche, T.Rathmann. Development of a technological processor for 3D-FEA of rotary swaging processes . ICFG Workshop, May 23-27, 2004.