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Forming Process of Inlet Valve 85Cr18Mo2V by Electrical Upsetting Forming

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ABSTRACT

Experimental studies were carried on the inlet valve 85Cr18Mo2V work pieces which have head cracks with electric upsetting by the means of OM, SEM and EDS. By numerical simulation of the forming process of intake valve of 85Cr18Mo2V, the optimized parameters of electric upsetting forming were obtained. The simulation result shows that the optimized electric upsetting process can guarantee the quality of the inlet valve: defects such as surface cracks, folding disappeared, the internal organization of valve were even and micro crack disappeared.

INTRODUCTION

Valve is one of the vulnerable parts of diesel engine. Under the influence of high temperature gas corrosion and mechanical load, the strength, corrosion resistance and wear resistance of the valve material will be reduced, which will cause the failure of the valve [1-3]. At present, the diesel engine valve manufacturing process basically adopts electric upsetting. A machinery factory uses special martensitic stainless steel 85Cr18Mo2V to produce intake valve of diesel engine. During electric upsetting forming process, the surface of intake valve blank cracks, which results in economic losses.

Combining theoretical analysis, numerical simulation and experimental study on electric upsetting forming process of diesel engine inlet valve, electric upsetting forming process and quality of the intake valve have been improved to provide theoretical guidance for the actual production.

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EXPERIMENTAL METHODS

Failure Samples

During the actual production process of a machinery factory, the blank in electric upsetting appears as shown in Figure 1.1 (A), (B) surface cracks. Electric upsetting process parameters upsetting the thick cylinder velocity V1=20mm/s, anvil cylinder velocity V2=2mm/s and initial spacing a=20mm, bar heating temperature T=1200℃.

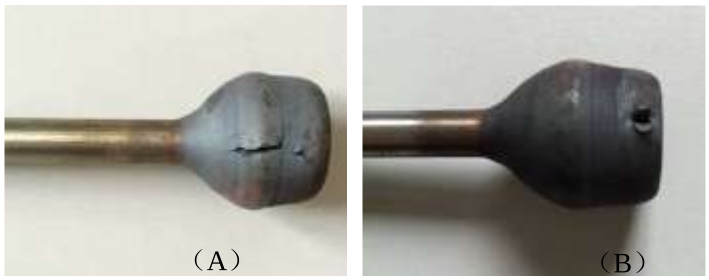


Figure 1. Inlet valve cracks of electrical upsetting.

Preparation of Samples

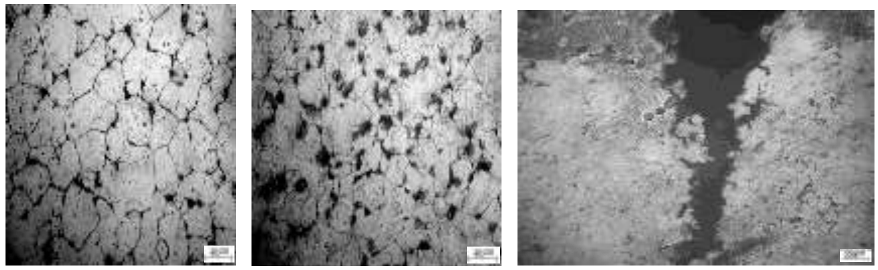
For "garlic" end of sample A, after coarse grinding, fine grinding, polishing, and selecting aqua regia as corrosive agent, with a cotton swab dipped in aqua regia gently wiping the surface of the sample, sample surface was darkened and gloss lost. After cleaning and drying metallographic specimen was made. The specimen A was cut along the vertical direction of the crack, and the section passes through a series of steps, and was made into the metallographic sample, and the optical microscope was used to observe the microstructure.

The specimen B was divided into two halves along the crack surface, and was immersed in alcohol solution. The ultrasonic cleaning was adopted. The fracture morphology and microstructure were observed by JSM-6490LA scanning electron microscope.

RESULTS AND ANALYSIS

Analysis of Organization and Structure

Figure 2 (a) is the microstructure of for sample A "garlic" end. It can be seen, grain is rough and uneven; there is melting, burning phenomenon at grain boundary. It is probably caused by large upsetting current and too high temperature of billet. From Figure 2 (b), there is a large number of inclusions on the grain boundary and there is obvious segregation of impurity elements.

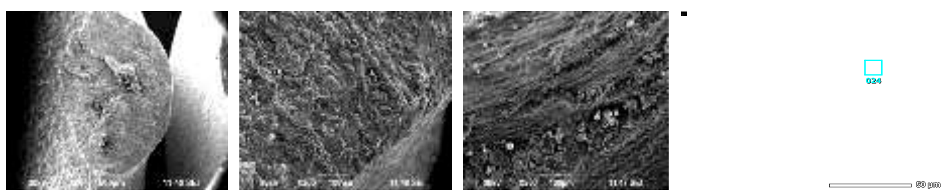


（a）microstructure of the end （b）inclusions on the grain boundary （c）morphology of cracks

Figure 1.2. Microstructure of the inlet valve cracks.

Fig. 2 (c) is morphology of crack of sample A, It can be seen visible crack is formed by the surface of the billet and propagates along grain boundaries irregularly and serious intergranular corrosion occurs. It is due to high temperature of the blank in the upsetting process, which leads to low grain boundary strength and cracks along the grain boundary 2.2 morphology and EDS

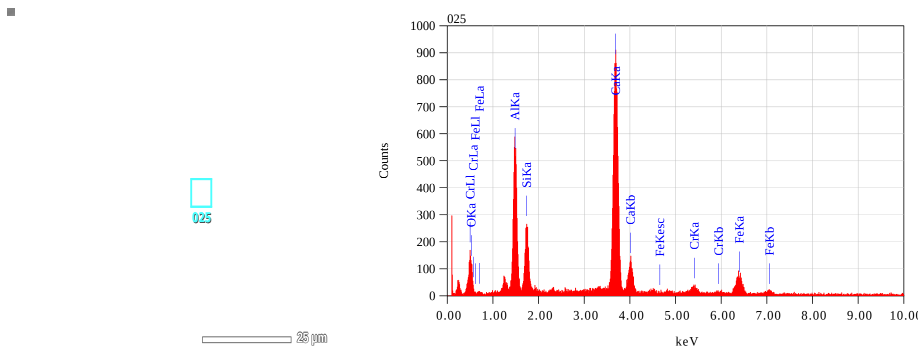
Figure 3 (a) is the crack morphology for sample B. It can be seen there is no obvious macroscopic plastic deformation at cracking fracture and fracture is relatively flush and has steps of the radial, which develops to herringbone pattern. It can be determined it is brittle fracture. From Figure 3 (b), it can be seen that the crack source is on the surface of the billet, and the crack expands from the exterior to interior.



（a）scanning of cracks（b）source of cracks（c）expanding route（d）inclusions

Figure 3. Macroscopic morphology of cracks.

The scanning energy spectrum analysis of the inclusion on the grain boundary is shown in Figure 4. From Figure 4 (b), it can be seen that the inclusions are mainly Ca and Al non-metallic inclusion, which reduces the metal binding force, and destroys the continuity of the organization. In high temperature upsetting process, plastic deformation ability of alumina inclusions have great differences from the substrate. Under the action of the external stress, binding site of inclusion and matrix is prone to stress concentration and initiation of micro cracks. The micro cracks continue polymerizing and growing under external forces, and finally macroscopic cracks form, which lead to cracking of the blank.



(a) microstructure of inclusion at boundary (b) EDS

Figure 4. Energy spectrum of inclusions on the end face.

NUMERICAL SIMULATION OF ELECTRICAL UPSETTING

Boundry Condition

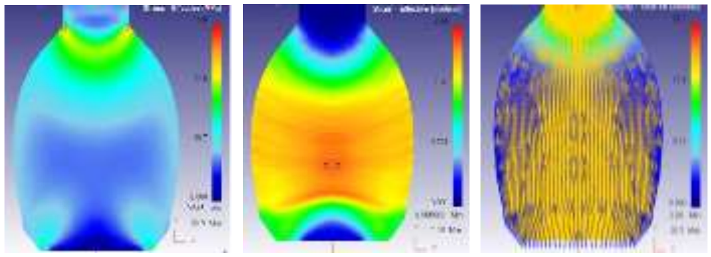
Taking into account the original bar and electric upsetting blank in the shape of symmetrical structure, this paper takes the 1/2 as the research object. Anvil, upsetting rough cylinder and the clamping electrode are set as a rigid body, the ambient temperature is 25℃, contact heat transfer coefficient is 1.1 w / mm^2℃ between bar and anvil and between clamp electrode, the friction coefficient between rod material and anvil,, between the cylinder and the clamping electrode is 0.2. Original size of the bar: length is 167mm and diameter is 11.5mm.

Parameters

TABLE 1. THE SIMULATION SCHEME ONE OF ELECTRICAL UPSETTING.

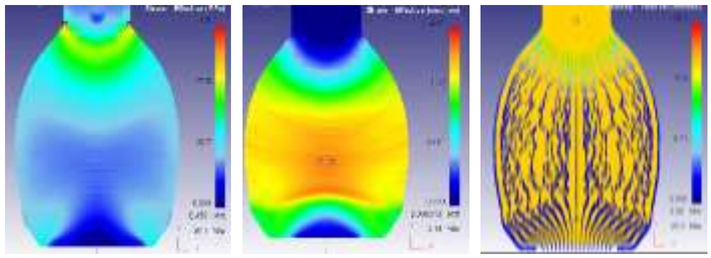
No	Cylinder speed（mm/s）	anvil speed of（mm/s）	temperature（℃）	Initial spacing（mm）
1	20	2	1200	20
2	18	2	1200	20
3	15	2	1200	20
4	18	2	1150	20
5	18	2	1100	20

Simulation Results



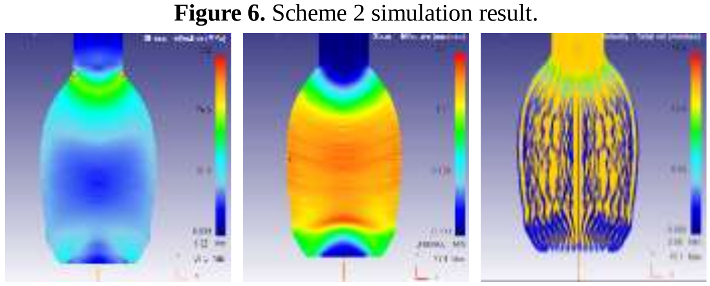
（a）Equivilent stress （b）Equivilent strain（c）flow of metal

Figure 5. Scheme 1 simulation result.



（a）Equivilent stress （b）Equivilent strain（c）flow of metal

Figure 6. Scheme 2 simulation result.

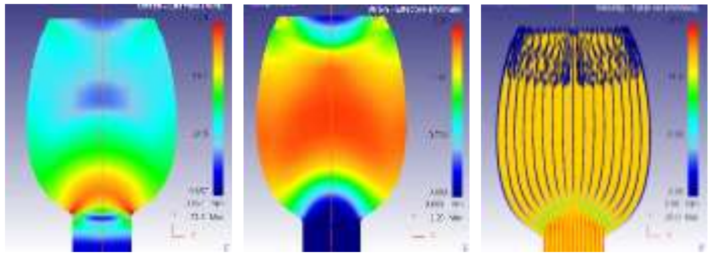


（a）Equivilent stress （b）Equivilent strain（c）flow of metal

Figure 7. Scheme 3 simulation result.

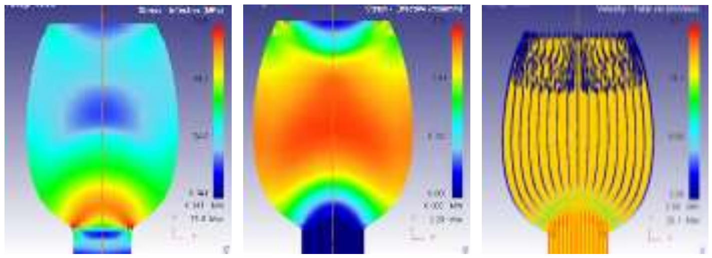
From blank upsetting simulation map, high stress area of the electric upsetting deformation always concentrated in the neck region at the junction of the rod part and "garlic", in an angle of 45 degrees the stress is the maximum. On the contact surface of the clamping electrode with the bar, due to the role of clamping force and friction force and a certain stress occur, equivalent stress close to anvil cylinder should be the minimum. Main strains concentrate in the central part of the "garlic", which is the large deformation zone. Strains become smaller near anvil cylinder regional and equivalent strains remain minimal near clamping electrode area.

With the same other parameters and reducing the upsetting cylinder speed, upsetting speed and deformation amount reduce. From table 1, it can see, forming the shape of garlic is the best when upsetting cylinder speed is 18mm/s, which can meet the requirements of the subsequent forging. When upsetting cylinder speed is 20mm/s and 15mm/s, the billet length diameter ratio is 1.32 and 1.63, forming the shape does not meet the technical requirements.



（a）Equivilent stress （b）Equivilent strain （c）flow of metal

Figure 8. Scheme 4 simulation result.



（a）Equivilent stress （b）Equivilent strain （c）flow of metal

Figure 9. Scheme 5 simulation result.

When other parameters are constant, the temperature of the billet is reduced. From table 2, the shape is the best when the ratio of the length to diameter of the billet is 1.20. Comprehensive simulation results shows that, when upsetting cylinder speed V1=18mm/s, anvil cylinder speed V2=2mm/s, heating temperature T=1100℃, initial spacing a=20mm, electric upsetting quality is the best and can meet the process requirements

TABLE 2. SIMULATION RESULTS OF ELECTRICAL UPSETTING ON DIFFERENT PROCESS PARAMETERS.

No	cylinder speed （mm/s）	anvil speed （mm/s）	temperature（℃）	Initial pacing （mm）	Length diameter ratio θ
1	20	2	1200	20	1.32
2	18	2	1200	20	1.21
3	15	2	1200	20	1.63
4	18	2	1150	20	1.31
5	18	2	1100	20	1.20

VERIFYING EXPERIMENTS

In order to test the correctness of numerical simulation results, electric upsetting test of billet were carried out. The parameters are as follows: upsetting cylinder speed V1=18mm/s, anvil speed V2=2 mm / s, the initial distance a=20mm and heating temperature T=1100℃.

Macroscopic Inspection

Shape and dimension inspection of valve electric upsetting is good. There is no crack, folding, distortion and other defects, and the temperature is normal by means of thermometer.

Analysis of Section of Blank

Cut the electric upsetting after the inlet valve blank along the axial direction in 8 positions, as shown in Figure 10 and select metallographic observation point. The microstructure of blank is observed by metallographic microscope, and grain size is measured using line transect method. Microstructure is as shown in figure 11.

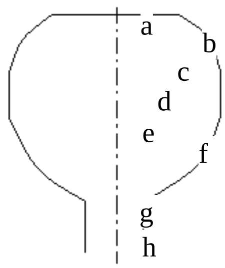
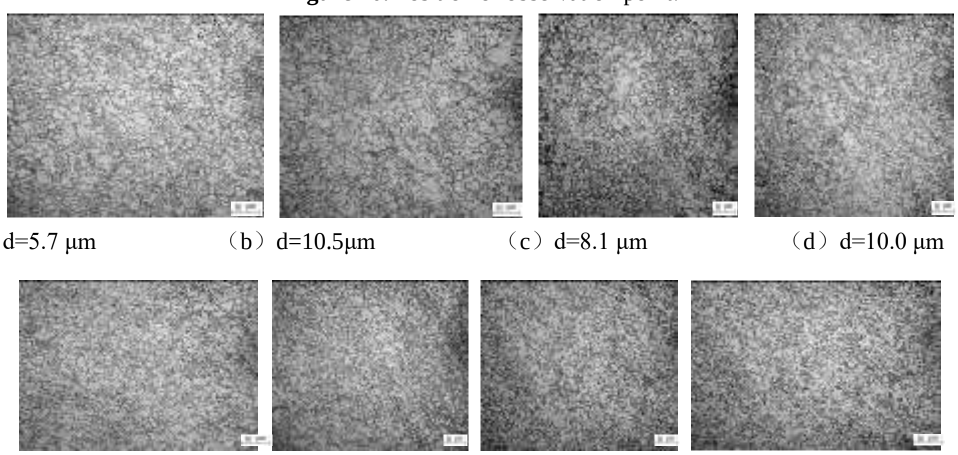


Figure 10. Position of observation point.



（a）d=5.7 μm （b）d=10.5μm （c）d=8.1 μm （d）d=10.0 μm

（e）d=6.6μm （f）d=5.2μm （g）d=5.1μm （h）d=6.7μm

Figure 11. Metallographic structure in different positions.

From Figure 11 it can be seen that the grain size of the various parts of the forming billet is uniform and fine and there is no defects such as micro cracks.

Macro and microstructure analysis results showed that the formability of the inlet valve is better under the selected parameters of electrical upsetting process which can obtain high-quality air valve roughcast which are consistent with the simulation results.

CONCLUSIONS

(1) Cracks of the specimen come into being from the surface of the billet and extend along the grain boundaries. The microstructure of end of billet is not uniform and coarse. There is a large amount of non-metallic inclusion of Ca and Al on the grain boundary, which leads to the decrease of the grain boundary binding

force. During the upsetting process, because heating current of the billet is too large and the temperature is too high grain boundary melt or burn.

(2) During electric upsetting process, the stress reaches the maximum on the direction of 45 degrees of the blank neck and equivalent stress is minimal near anvil cylinder. The deformation of the metal is uneven due to different friction during the process. The inhomogeneous deformation between blank face and the middle region of will generate additional stress. When additional stress reaches to the material allowable stress, cracks occur on the surface of the "garlic”.

(3) By simulating optimal parameters of electrical upsetting process are as follows: upsetting cylinder speed V1=18mm/s, anvil speed V2=2 mm / s, initial spacing a=20mm and heating temperature T= 1100℃.

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