Extending Service Life Of H13 Hot Extrusion Dies For Aluminum Alloy By Transverse Forging Technology

Abstract: With good medium temperature performance, US steel brand H13 is widely used as a high carbon and chromium hot work die steel. Because of the high cost of H13 raw material, long processing cycle of the dies, high requirements of operational performance, therefore, it has been an important research subject to extend the service life of H13 die for both the die manufacturer and its user. It’s found that experimented transverse forging technology to forge H13 hot extrusion dies for aluminum alloy, and succeeded in extending its service life of 1-1.5 times by changing fiber direction and adopting new heat treatment process.

The manufacturing quality of the HOT extrusion dies is the key to achieve the extrusion process, improve product quality, extend the service life of the dies and reduce costs. And the forging is an important step to achieve the required shapes in the whole manufacturing process of the dies. Through forging, normalizing, tempering and spheroidizing post forging, the internal metal organization structure and carbide distribution can be effectively improved, and the defect of chemical composition segregation generated in smelting can also be avoided, which lays a necessary foundation for the subsequent manufacturing process. Meanwhile, The Parameters IN forging process is easy to be operated and controlled. So the blank forging of the die and the heat treatment post forging is especially important in the whole production process of the dies.

This paper mainly presents the blank forging technology of H13 hot extrusion dies for aluminum alloy.

The design of deformation methods and deformation degree of H13 blank forgings of hot extrusion dies for aluminum alloy.

Drawing and upsetting process is the main methods of deformation. Carbide distribution can be effectively improved through drawing, and the fiber orientation can be effectively reduced through upsetting, thus to increase the forging mechanical properties in transverse direction. Deformation degree (forging ratio) has direct impact on the refinement and distribution of the internal carbide of the forging.

Along with the increasing of the times of drawing and upsetting, the non-uniformity of carbide will be gradually reduced. There will be little influence to continue drawing and upsetting when the non-uniformity level of carbide is reduced to a certain degree. Comprehensively considered the working condition of H13 hot extrusion dies for aluminum alloy and the forging material, rational design of the deformation methods and deformation degree (forging ratio) can meet the operation requirements of the die and extend its service life.

The following factors should be taken into consideration when designing the deformation method and deformation degree (forging ratio) of forging blank of the dies.

1. The size of the die and the complexity of the die shapes,
2. The working area of the die (surface part or center part of the forging),

3. The work performance requirements of the dies,
4. The raw material, smelting method and delivery state.

The previous forging technology of H13 hot extrusion die for aluminum alloy

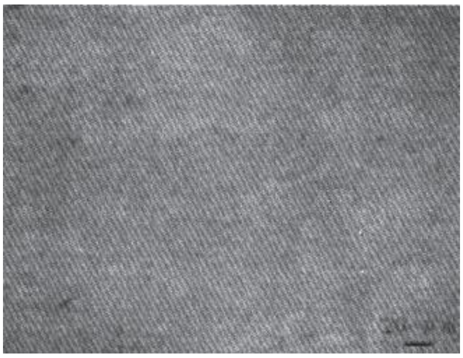
The raw material we choose is H13 ESR ingot, delivery state to be forged round billet with annealing.

1. Deformation design
Drawing and upsetting in the axial direction, the specific procedures include
(1). Upsetting in Axial direction
(2). Drawing in axial direction
(3). Upsetting in axial direction again
(4). Trimming into shape

2. Forging ratio design
Upsetting forging ratio ⩾ 2 for both times
Drawing forging ratio : 2.0 - 2.5

3. The metallographic organization after normalizing, tempering and spheroidizing by axial drawing and upsetting forging technology.

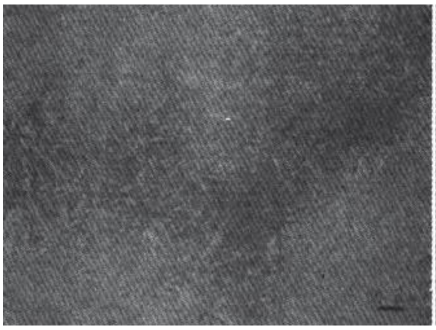
Image 1. Drawing and upsetting in axial direction for **small size** die
Metallographic organization after normalizing, tempering and spheroidizing
(Test standard NADCA207)



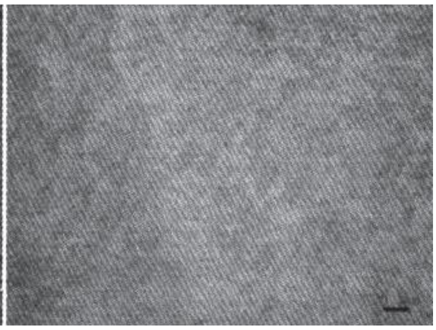
Size of die Φ340mm, sampling location : die core
Matrix : annealing pearlite organization level B2
After corrosion 500X

Image 2. Drawing and upsetting in axial direction for **large size** die
Metallographic organization after normalizing, tempering and spheroidizing

(Test standard NADCA207)



Size of die Φ980mm, sampling location : die core
Matrix : annealing pearlite organization level D3
After corrosion 500X



Size of die Φ 800mm, sampling location : die core
Matrix : annealing pearlite organization level D1
After corrosion 500X

The new experimental forging technology of H13 hot extrusion die for aluminum alloy

1. Deformation design

Drawing and upsetting in transverse direction, the specific procedures include

(1). Upsetting in axial direction
(2). Drawing in transverse direction to change the fiber direction
(3). Upsetting in axial direction
(4). Trimming into shape

2. Forging ratio design

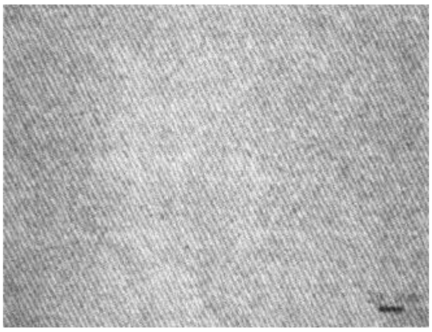
Upsetting forging ratio : Step 1⩾2, Step 2⩾2.5
Drawing forging ratio : 2.5 - 3.5

3. Comparison of mechanical properties

	Forging technology	R_m(Mpa) 520℃	$Rp_{0.2}$ (Mpa) 520℃	A (%) 520℃	A_{ku} (J) 23℃	HRC 23℃
Die dia. Φ340mm	Upsetting in axial direction	1145	1040	5.0	9.0	40.1
	Forge in transverse direction	1206	1098	8.0	12.5	43.6
Die dia. Φ800mm	Upsetting in axial direction	1120	1020	4.5	7.0	41
	Forge in transverse direction	1180	1067	5.5	8.0	46.3
Die dia. Φ980mm	Upsetting in axial direction	1010	920	8.0	7.0	40
	Forge in transverse direction	1070	988	10.0	7.0	44

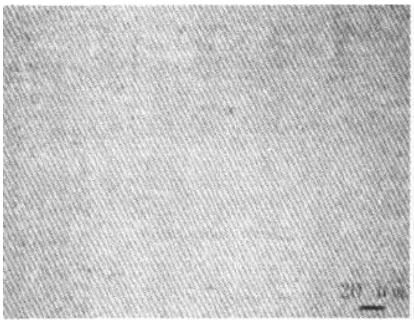
4. The metallogrphic Organization after normalizing, tempering and spheroidizing by transverse drawing and upsetting forging technology.

Image 3. Drawing and upsetting in transverse direction for **small size** die
Metallographic organization after normalizing, tempering and spheroidizing
(Test standard NADCA207)

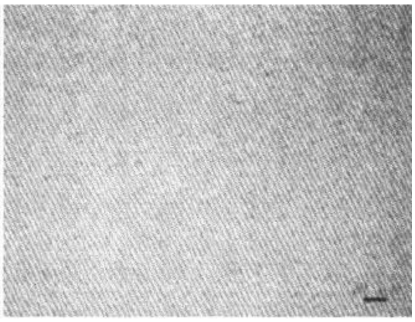


Size of die Φ340mm, sampling location : die core
Matrix : annealing pearlite organization level A3
After corrosion 500X

Image 4. Drawing and upsetting in transverse direction for **large size** die
Metallographic organization after normalizing, tempering and spheroidizing
(Test standard NADCA207)



Size of die Φ980mm, sampling location : die core
Matrix : annealing pearlite organization level B1
After corrosion 500X



Size of die Φ 800mm, sampling location : die core
Matrix : annealing pearlite organization level A2
After corrosion 500X

The comparison of two kinds of forging technologies

Experimental results show that there's no obvious difference on the metallographic organization after spheroidizing between axial forging technology and transverse forging technology for small size H13 hot extrusion dies for aluminum alloy. Axial forging technology can also refine the internal carbide of the blank, make its distribution even, comprehensive mechanical properties of the die is also good, and meet requirements. And there's no need to change thefiber direction during die process of blank forging, it's easy to operate and save energy. But for large size die, the axial forging technology can't meet its working requirements well because of its large size, complexity of its shape and force, MORE smelting defects and etc.

The transverse forging technology has helped to break the carbide in the center of the blank, make the carbide small, distributed evenly, improved the organization structure and composition segregation in the center of the forging effectively, and is suitable for large size H13 hot extrusion dies for aluminum alloy with central areas stressed. The uniformity in both longitudinal and transverse direction are improved due to the change of fiber direction and elimination of metal direction. The internal fiber flow distribution inside the forgings is in accord with the working force requirements of hot extrusion dies for aluminum alloy.

The feedback from the users over the past two years proved that the service life of spec 071 die of 12500 T extrusion machine (mainly for the production of aviation parts) is extended by at least 1 - 1.5 times by the transverse forging technology.

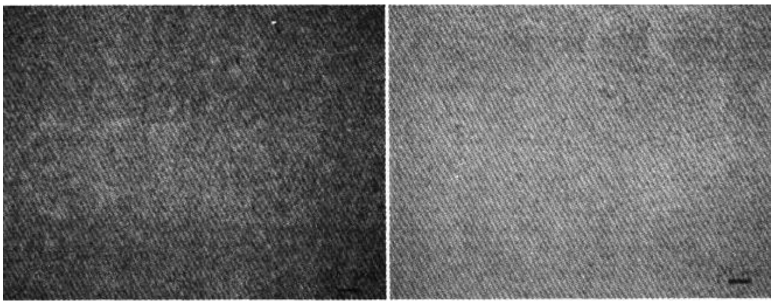
At present, we are experimenting comparatively on the chemical analysis, metallographic structure after QT, mechanical performance in high temperature and the influence on the service life of the H13 material from Japan and several domestic big steel mill. Below is a comparison on H13 chemical analysis, micro structure after normalizing, QT and spheroidizing, the mechanical performance in high temperature and the influence on the service life is being tested now.

Blank size : dia. Φ800mm thickness 240mm
Forging technology : transverse forging
Sampling location : die core

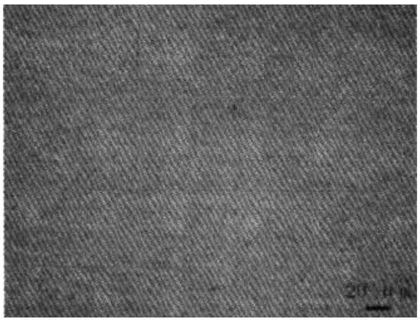
Table 1. Comparison on the chemical analysis

	C	Si	Mn	Cr	Mo	V	P	S
Standard analysis GB/T1299	0.32~0.45	0.80~1.20	0.20~0.50	4.75~5.50	1.10~1.75	0.80~1.20	≤0.030	≤0.030
Japan steel KDA1M	0.41	0.41	0.42	5.15	1.52	0.60	0.006	0.002
Qi steel H13	0.43	0.95	0.37	5.33	1.42	1.09	0.006	0.007
Bao steel H13	0.41	0.82	0.36	5.36	1.29	0.93	0.010	0.006

Image 5. Transverse forging technology
Metallographic organization after normalizing, tempering and spheroidizing
(Test standard NADCA207)

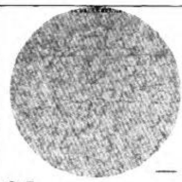
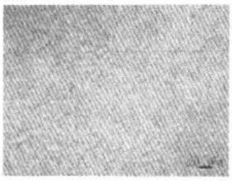
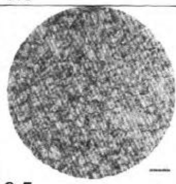
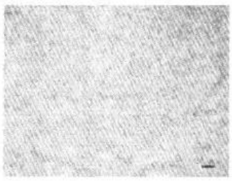
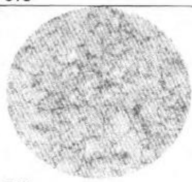


Japan Steel Qi STEEL
Matrix : annealing pearlite organization level B1, Matrix : annealing pearlite organization level A2



Qi Steel
Matrix : annealing pearlite organization level B1

Table 2. Metallographic structure of the die after QT by transverse forging technology

	Hardened Structure	GrainSize
Japan SteelKDA1M		 9.5
Qi SteelH13		 9.5
Bao SteelH13		 8.0

Through the comparing of chemical composition, we find there is slight difference between H13 Japan steel and domestic steel, the purity degree of the Japanese steel is higher than the domestic one. But through transverse forging process, there isn't not much difference on the micro structure of the blank. Proper forging process, forging ratio and reasonable heat treatment process can make up for the smelting deficiency to a certain extent.

The matters need attention for transverse forging methods,

1. When drawing in transverse direction to change the fiber direction, there will be metal outflows in the center of the forging blank. If the inhomogeneous deformation occurred to the outflow metal, there will be annular uneven carbide in 1/2 radius of the die blank, so in the second upsetting (last deformation process), the forging ratio must be enough. By comprehensively consideration of the height-diameter ratio of the blank and the working condition of the die, 3.0 is more suitable for second upsetting ratio.
2. The upper anvil (or hammer head) and lower anvil should be pre-heated before forging to prevent cracking on the edges an Corners due to the fast cooling in the first upsetting process.
3. If ESR ingot is used for forging, then the forging ratio need to be increased, and at least two times of transverse forging in vertical direction (cross direction) are need to change the fiber direction, in order to break the carbide in the center of the blank effectively.

4. In the transverse drawing process to change fiber direction and the last heating and upsetting process, final forging temperature, reduction, deformation degree and speed of deformation must be strictly controlled every time, otherwise, cracking is easily occurred in the circumference edges of the end faces and excircle surface of the forgings.

We, ALTA SPECIAL STEEL CO.,LTD have a core advantage on the H13, 1.2344, SKD61 tool steels, with vast supply experience to the aluminum dies, profiles industry. Currently, our the MAX dia. Up to 500mm.

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