RESEARCH ON A NEW FORGING TECHNIQUE
—SHORT-HOLLOW-RAPID DIE FORGING†

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Abstract  A new forging technique—short-hollow-rapid die forging, used in Ti-Al alloys was studied. Compared with conventional method, the new method can improve the crystalline structure properties of the forged piece, reduce the average forging pressure by 20% to 30%, lessen the thickness deviation by 5 mm, and prolong the service life of the dies by 2 to 4 times.

Key words  rapid die forging; Ti-Al alloy; hollow

There are three problems in Ti-Al alloy forging: (1) Crystalline structure defects; (2) High resistance of deformation; (3) Deep scratches on the dies caused by the forged piece. The new short-hollow-rapid die forging technique was successfully used in TC9, TC11, and Ti679 Ti-Al alloy die forging, and solved all these problems.

1 THE PRINCIPLES OF SHORT-HOLLOW-RAPID DIE FORGING

1.1 The Principle of Short Dies

According to the relations between the forging pressure and the press-down shortages (see Fig. 1), when the press-down shortages are less than its critical point value, a little change of the press-down shortages will cause a continuous increase of flash and a sharp rising of forging pressure. Hence, the thickness deviation or remained press-down shortage always exists in conventional forged pieces.

To reduce the thickness deviation, we shortened dies according the following formula:

\[ h = H - \Delta h \]  (1)

where \( h \) — the height of the die space,
\( H \) — the height of the forged pieces,
\( \Delta h \) — the critical point value of press-down shortage (the shortened value of dies).

When we used the shortened dies to forge, the thickness deviation of the forged pieces can be calculated as follows:

\[ \Delta s = \Delta H - \Delta h \]  (2)

where \( \Delta s \) — the thickness deviation of forged pieces,
\( \Delta H \) — press-down shortage of shortened-die forging.

The change of average pressure with the thickness deviation can be seen in Fig. 2.

1.2 The Principle of Using Hollow Round Blanks

Solid round blanks are generally used in conventional die forging. This kind of blanks

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Synopsis of the author  Zen Sumin, professor, born in 1932, specializing in forging technology.

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often result in dead metal zone and uneven crystalline structure. Fig. 3 shows the deformation zones of a solid round blank. In order to improve the quality of forged pieces, hollow round blanks should be used as far as possible. Hollow round blanks can be made by piercing and ring rolling. By using hollow blanks, we can eliminate almost all the dead metal zones, and increase the deformation in the center of blanks. The metal in the dies will flow in two different directions, hence, avoid whirling flow and cross flow. The average pressure required in a round blank die forging can be expressed as

$$p = K \cdot \sigma \cdot (1 + 0.17a/h)$$  \hspace{1cm} (3)$$

where $p$—average pressure, $K$—amendment, $\sigma$—yield strength of the blanks under the die forging temperatures, $a/h$—the ratio of the blanks’ width to its height.

By using hollow blanks, we can reduce the value of $a/h$, so we can reduce the average pressure $p$, and improve the crystalline structure properties of forged pieces.

1.3 The Principle of Rapid Forging

The resistance of deformation in die forging depends on the critical temperature of forging. The higher the temperature is, the less the average pressure. Fig. 4 shows the relations between the temperature and the average pressure in Ti-Al alloy forging (Take 2Al-4V for example). From Fig. 4 we concluded that at certain heating temperatures, blank delivering and pressure exerting should be carried out as quickly as possible to keep higher forging temperature. The rapid die forging was then developed.

1.4 Service Life of the Forging Dies

The service life of forging dies can be estimated with formula (4), which is suitable for the die forging of Ti-Al alloys, high temperature alloys.

$$N = \kappa \frac{a}{b} \left( \frac{\sigma}{\rho \cdot c} \right)^2$$  \hspace{1cm} (4)$$

where $N$—the number of service times, $k$—experience factor, $a$—alloy factor, $b$—shape factor, $\sigma$—yield strength at working temperatures, $\rho$—average pressure, $c$—stress concentration factor.

From formula (4), we can see that the life will increase with the increase of yield strength and the decrease of average pressure. The short-hollow-rapid die forging can reduce the average pressure, so it can increase the service life of dies. The life can be prolonged 3 to 5 times as long as that of conventional forging dies.

2 SHORT-HOLLOW-RAPID DIE FORGING TESTS AND ITS RESULTS

2.1 Rapid Forging Test

The test was carried out with a 6000 t hydraulic press. Because of the quick delivering and rapid forging, the critical forging temperature increased by 50 °C, and the average pressure decreased by 23%. The test result is shown in Table 1.

2.2 Short-Rapid Forging Test

The test was carried out with a 6000 t hydraulic press. The forging die was shortened by 3mm. The result showed that the average pressure was decreased by about 33% (see Table 2).

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<tr>
<th>Table 1 Rapid forging test result</th>
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<td>blank delivering times (s)</td>
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<td>pressure exerting times (s)</td>
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<td>heating temperatures (°C)</td>
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<td>average pressure (MPa)</td>
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<td>thickness deviation (mm)</td>
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<td>shortened size (mm)</td>
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