Heat Checking of High Pressure Die Casting Dies - Effects, Causes and Solutions

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Abstract: Heat checking is the main failure type of high pressure die casting (HPDC) dies, which have significant impact on the production, efficiency, cost, and other aspects of the new energy vehicle industry. This article discusses the impact of heat checking on die-casting production, the causes of heat checking, and targeted prevention and control of heat checking from several perspectives, attempting to propose more effective solutions for enterprises.

Keywords: Heat checking; HPDC; casting; die steel

1 The Influence of Heat checking on Die Casting production

HPDC Dies

The impact of heat checking on die-casting production is profound and diver When heat checking occurs on the dies, it will cause imprints at the corresponding positions of the casting. As the degree of heat checking increases and the cracks become deeper, the imprints on the casting will gradually become burrs. When the cracks become more severe and the burrs become unacceptable, it often declares the final life of the die.

Casting

Heat checking brings burrs, particles, and excess flesh to castings, corresponding to cracks, slag, and flesh on the dies. At this point, in order to ensure the delivery quality of castings, it is necessary to arrange deburring or even additional processing procedures. How to do deburring more economically and effectively is not only related to the customer's equipment conditions, but also to the cracking characteristics.

Die casting production

When the problem of burrs on castings becomes unacceptable, it is necessary to request a shutdown for die repair, which will obviously cause delays in delivery. In the situation of extremely tight delivery time, the severely cracked dies cannot be taken off the machine due to production capacity maintenance, and there is no window for welding repair/maintenance work. Only by deploying backup dies to replace the old dies can delivery be guaranteed. On the one hand, before the preparation of the mold is in place, the delivery of castings must bear multiple pressures such as deburring costs, yield/delivery time reductions, etc; On the other hand, the cost of die preparation itself is also high, and both customers and suppliers bear losses.

In order to increase production capacity, many die-casting factories invest heavily to shorten the cycle time, such as improving the pouring arrangement, adding die cooling/warming machines, adopting 3D printing inserts, and so on. If a production capacity bottleneck is formed in the deburring step at this time, the effect of the initial investment cannot be realized. Therefore, it becomes more practical to correctly solve the heat checking problem corresponding to burrs.

2 Cause of heat checking

The temperature gradient provides conditions for the inconsistent expansion and contraction at both ends of the gradient field, and the contraction determines the location of heat checking, which occurs at the cold end of the gradient field. the hot end of the gradient field expands while the cold end contracts. The hot end tends to "pull back" the contracted cold end to the length before contraction, which generates tensile stress at the cold end (while the corresponding hot end receives compressive stress). This tensile stress repeatedly occurs with the repeated punching of the die and accumulates back to cause surface cracks on the die, which originate from the repeated temperature gradients and are also known as thermal fatigue.

3 Factors affecting heat checking

Furthermore, we will explore the causes of more practical forms of heat checking, namely how different forms of thermal cracking such as dense thermal cracking, sparse thermal cracking, and local deep cracking are formed. As shown in formula 1, N is the shots before heat checking initiation, S is the high-temperature creep strength of the material, proportional to the die temper-back resistance and room temperature hardness, and has about 80% ratio, D is the material plasticity, proportional to the die elongation and Charpy-V impact energy, and has about 20% ratio, R is the creep scale, proportional to the die temperature and thermal stress

$$N = \frac{\mathrm{S} \times \mathrm{D}}{\mathrm{R}} \tag{1}$$

Assuming R remains constant and external conditions such as die temperature and thermal stress are unified, there are four possible scenarios:

1. S is low, and D is high. Due to the high weight of S, the initiation time of heat checking is advanced, and the appearance of heat checking is early. Due to the high D, the crack propagation distance is short, so the heat checking presents a dense form, and it is easy to develop into slag dropping after increasing the die shots.

2. S is low, D is low, the initiation time of heat checking is advanced, and heat checking appears early. Due to the low D, the crack propagation distance is long, so the crack presents a sparse and "large grid" shape, and it is easy to develop into chipping after increasing the die shots.

3. S is high, and D is high, the initiation time of heat checking is delayed, and the appearance of heat checking is late. Due to the high D, the crack propagation distance is short, so the thermal cracking also presents a dense form. After increasing the die shots, it will also develop into slag, but the degree is lighter later.

4. S is high, and D is low. Due to the high weight of S, the initiation time of heat checking will still be delayed, and the appearance of heat checking will be delayed. Due to the low D, the crack propagation distance is long, so the crack also presents a sparse and "large grid" shape. After increasing the die shots, it is easy to develop into chipping, and the degree is more severe.

4 Heat checking response plan

Understanding the formation mechanism of different heat checking forms is essential to better generate response plans for different situations.

Firstly, from the perspective of mold materials, it is always correct to improve toughness without damaging other properties under any circumstances. High toughness can improve D, delay the initiation of heat checking, and inhibit crack propagation, avoiding the development of heat checking into large chippings.

If it is possible to improve toughness or not reduce toughness while increasing hardness, it is a more ideal situation, which is equivalent to simultaneously improving S and D. To achieve such effects, high toughness reserve mold steel materials such as EX55 are needed. Due to their metallurgical properties and excellent heat treatment processes, this type of material is more likely to achieve high toughness at high hardness.

The performance of die steel belongs to the basic preparation for dealing with heat checking, and on this basis, it also requires the support of supporting heat treatment equipment and technology. The hardness scheme that adapts to the specific structural characteristics of the die is the most important and the core direction of subsequent work.