Research on Performance Optimization Method of Cold Work Mold Material

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Abstract: The performance and heat treatment process of cold-working die steel have a decisive influence on the service life of the die. The properties of cold work die steel mainly include wear resistance, toughness, strength, fatigue resistance and bite resistance. The performance of heat treatment process mainly includes hardenability, hardening capacity, tempering resistance, overheating sensitivity, oxidation decarburization tendency, quenching deformation and cracking tendency, etc. The performance and heat treatment research progress of typical cold-working die steel and new cold-working die steel are described in order to improve the service life of the die.

1. Introduction

Cold working die is a kind of die for deformation and pressure processing of materials at normal temperature. The actual working condition is under heavy load and requires high surface quality. High alloy or high carbon steel is mostly used, such as carbon tool steel, alloy tool steel, high speed tool steel, powder high speed tool steel and powder high alloy die steel. Compared with hot die steel, cold die steel has high carbon content, good hardenability, strong wear resistance and hardness, and wide application range. Cold-working die steel needs to bear strong impact force, friction force, bending stress and compressive stress when working. Wear is the main failure mode of cold-working die steel. At the same time, there are premature failures due to fracture and edge collapse. The purpose of prolonging the service life of cold-working die steel can be achieved by studying the optimization method of microstructure and properties.

2. Performance Characteristics of Cold Work Die Steel

Cold-working die steels use a wide range of cold-working die materials, ranging from various carbon tool steels, alloy tool steels, high-speed tool steels to powder high-speed tool steels and powder high-alloy die steels. However, only 20 kinds are commonly used. At present, Cr12, Cr12MoV and Cr12Mo1V1 are widely used cold work die steels. Cr12 has insufficient strength and toughness and wear resistance. The content of alloy elements in Cr12MoV is low and the wear resistance is low. Cr12Mo1V1 has good wear resistance, certain toughness and red hardness, and is widely used. New types of steel include LD(7Cr7Mo2V2Si) steel, GM(9CrW3Mo2V2) steel and ER5(Cr8MoWV3Si) steel. Compared with Cr12 die steel, carbide segregation of this kind of steel is improved, with higher toughness and wear resistance. Representative grades and performance characteristics of different types of cold-working die steel are shown in Table 1.

Table 1 Performance Characteristics Of Cold Work Die Steel

Name	Steel category	Shop sign	Performance characteristics
Cold work die steel with low hardenability Cold work die steel with low deformation Slightly deformed cold working die steel High strength	Carbon tool steel Low alloy tool steel High-alloy steel Low alloy hypereutectoid steel High-speed steel Medium carbon high alloy steel Spring steel, die steel	T10A, Cr2, T12A, V, MnSi, T7A, T8A, 9Cr2, CrW5. CrWMn, 9Mn2V, 9Mn2, MnCrWV, 9CrWMn, SiMnMo. Cr12MoV, Cr6WV, Cr12, Cr4W2MoV, Cr2Mn2SiWMoV. W18Cr4V, W6Mo5Cr4V2. 7Cr7Mo2V2Si(LD), (9Cr6W3Mo2V2)GM, CG2, 65Nb, 6W6Mo5Cr4V.	The alloy has low content of alloy elements, good processability, sufficient toughness and fatigue resistance after quenching, and low hardenability, tempering resistance and wear resistance.The alloy contains a little more elements, has better hardenability and hardening capacity, and is easy to control the quenching

cold working die steel High strength and toughness cold work die steel Impact resistant cold work die steel Low alloy air quenching die steel Flame hardened die steel Matrix steel Powder metallurgy die steel	High carbon and high chromium profile steel, medium alloy air quenched die steel High-speed steel Non-segregation powder high speed steel	9SiCr, 5CrW2Si, 6CrW2Si, 60Si2Mn, 5CrNiMo, 5CrMnMo 5SiMnMoV. Cr12Mo1V1, Cr5Mo1V. 7CrSiMnMoV,SX4(Cr8),Japan HMD5, HMD1, G05 steel. 65Cr4W3Mo2VNb, 6Cr4Mo3Ni2WV, 5Cr4Mo3SiMnVAl, 6Cr4Mo3Ni2WV. YG15, YG20, YG25.	deformation degree of parts. Toughness and tempering resistance are still low. It has high quenching hardenability and moderate tempering resistance, high wear resistance and small volume change after quenching. Deformation resistance and impact resistance are limited. It has high thermal stability except for Cr2Mn2SiWMoV steel. It has high strength, high tempering resistance and high wear resistance. The toughness is poor, the consumption of alloy elements is large, the manufacturing process performance is poor, and the deformation after quenching and tempering is difficult to control. High strength, high toughness and high impact fatigue resistance, but the weakness is low compressive strength and poor thermal stability. It is difficult to control after quenching deformation. It has excellent impact fatigue resistance and low wear resistance and compressive strength. It has good hardenability, dimensional stability, good strength and toughness, and certain wear resistance, which can reduce quenching deformation and cracking of mold parts. Shorten mold manufacturing cycle, simplify heat treatment process and save energy. Special cold-working die steel for reducing the manufacturing cost of the die and meeting the requirements of flame quenching. The toughness is higher and the tempering resistance stability is better. Reduce quenching temperature, quenching hardness or carbon content in high speed steel to improve its toughness. The strength and toughness, grindability, isotropy and heat treatment process are all better than those of ordinary high speed steel and have a longer service life.

3. Study on Performance Optimization of Cold Work Die Steel

3.1 Common Performance Optimization Methods

The common methods for optimizing the properties of cold-working die steel include pre-heat treatment, surface heat treatment and tempering treatment. In the pre-heat treatment stage, common annealing, normalizing, quenching and tempering, ultra-fine treatment, afterheat quenching after forging and tempering treatment are mainly used to improve the service life of cold work die steel. Surface heat treatment is a surface strengthening treatment method such as coating treatment, nitriding, carbonitriding, multi-element co-nitriding, boronizing, physical vapor deposition (PVD), chemical vapor deposition (CVD) and the like according to the working environment and requirements of cold-working die steel to improve the wear resistance, bite resistance, impact resistance, thermal stability and the like of the steel. After quenching, the microstructure of cold-working die steel is unstable. Tempering is required to eliminate quenching stress, prevent cracking and obtain stable microstructure and properties.

3.2 Study on Performance Optimization of Typical Cold Work Die Steel

Wang Jing et al. studied the influence of surface morphology on the friction and wear properties of Cr12MoV steel. by studying the variation trend of corrosion time, corrosion pit size and depth, it is concluded that reasonable design of the surface morphology of the die can effectively reduce the wear amount in sheet metal forming process [2]. Taking the mechanical properties of Cr12MoV forged cold-working die steel as the research objective, Wang Xigang analyzed the influence of different Al content on the strength and toughness of Cr12MoV forged cold-working die steel. The results show that when Al content is 1.5%, the highest hardness is 289 HBW [3] at 870℃, 760℃ and 1000℃ respectively.

Sun Maoyin and others took Cr12Mo1V1 as the research object, and analyzed the influence of different forging processes on its hardness and impact toughness. The results show that the peak value of air cooling after forging is 887 HV at 1100℃, and the tempering impact toughness at 650℃ decreases with the increase of forging temperature. The amount of martensite transformation decreases and the amount of retained austenite increases. When the forging temperature is 1100~1160℃, the forging blade can obtain better structure and properties [4].

Yang Chaofan and others mainly studied the microstructure change of LD steel after laser surface phase transformation strengthening and its effect on material properties [5]. Cai Ying and others studied the microstructure and properties of Cr5Mo1V cold work die steel after annealing at 860℃×2 h+740℃×5 h and tempering at 520℃×2 h under different heat treatment processes [6]. Ding Ruihua takes Cr12 as the research object. When quenching is 1000℃, tempering is 550℃, the yield strength is 750 MPa, the tensile strength is 1050 MPa, the elongation after fracture is 13.6%, and the impact work is 63 J. At this time, the comprehensive mechanical properties of die steel are the best [7].

3.3 Performance Optimization of New Type Cold Work Die Steel

The performance optimization of the new cold-working die steel mainly includes: Liu Rui et al. added 0.1wt% rare earth La and 0.5wt% graphene powder on the basis of Cr12MoV to prepare the new cold-working die steel required for the test. the research shows that the carbide in the steel changes from coarse network structure to fine particle dispersion and distribution in the matrix by using 800W laser output power for local heat treatment [8]. A new type of cold work die steel GYCRF developed by Lin Peng et al. is based on the cold work die material DC53(Cr8Mo2SiV) steel, the content of C and Cr is appropriately reduced, and a small amount of Nb is added to improve carbide segregation. While ensuring strength and wear resistance, the purpose of refining carbide and improving impact toughness is achieved [9]. Based on the fracture mechanics test of DC53, Zhang Yuming et al. analyzed and studied the distribution law of stress intensity factor at the crack front of standard compact tensile CT specimens containing penetrating cracks, calculated the crack propagation life, and studied its fracture mechanics properties [10].

The research progress of SDC99 is rich. Luo Yanyan and others used unbalanced magnetron sputtering technology to prepare CrTiAlN coating on the surface of SDC99 cold work die steel. The effect of Ti target current on the friction and wear properties of CrTiAlN coating was also studied. The coating thickness was 4.25μm; When the nanohardness is 26.08 GPa and the Ti target current is

4 A, the toughness of the coating and the binding force with the substrate are the best [11]. Zhou Longmei et al. performed cryogenic treatment on SDC99, studied the precipitation behavior of carbides before and after tempering, and studied the effect of cryogenic treatment on SDC99 steel on atomic scale [12]. Wang Peiying and others simulated the quenching and cryogenic treatment process of C-ring made of Cr8Mo2SiV (SDC99) by finite element method, and studied the influence mechanism of thermal strain and tissue strain on the deformation behavior of parts [13]. Sun pengpeng et al. studied the tempering characteristics of a new type of cold work die steel 7Cr5Mo2V and found that the tempering stability increased and dissolution was slow due to Cr and Mo replacing about 57.3at% Fe in the alloy cementite precipitated before secondary hardening [14]. Xie Chen and others studied the hardness, impact toughness, friction and wear properties, phase composition and microstructure of SDC99 after different cryogenic treatment processes. The results show that 1030℃ quenching +210℃×2 h tempering+(196℃ × 24 h) cryogenic treatment +210℃ ×2 h tempering can improve the comprehensive service performance [15].

4. Conclusion

The main ways to optimize the performance of cold-working die steel are: optimizing the performance of cold-working die steel through the change of heat treatment process parameters; On the basis of the original materials, the properties are improved by laser cladding coating, cryogenic treatment, etc. New materials for cold work die steel are developed by adjusting element content. The research and optimization of cold-working die steel performance is of great significance to die life prediction, safety design of related parts and optimization of cold working process parameters.

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