Effect of isothermal annealing on Spheroidization of carbides in GCr15 steel

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Abstract. The spheroidizing effect of GCr15 steel was studied and the microstructure was analyzed by SEM under different isothermal annealing. The results show that: the carbide particles become smaller and smaller which is easy to form and grow into lamellar carbide with the increase of the temperature, and when the heating temperature is increased to 800 °C; The carbide particles can grow into spherical shape independently, and even some of the particles begin to grow up with the increasing of the heating time; The optimum process of GCr15 steel is heating temperature 780 °C, heating time 5h, isothermal temperature of 700 °C, isothermal time 3h.

1. Introduction

GCr15 alloy steel has less content of high hardness, good abrasion resistance, excellent mechanical properties and other characteristics have been widely used in bearing manufacturing, die production and defense industry and other fields [1], but in use, often due to lack of toughness of steel and reduce the service life of the parts, to get high performance needs this heat treatment [2]. In order to make the bearing steel have high strength and toughness [3], it is necessary to obtain the tempered martensite and its microstructure with fine carbide particles. Therefore, the number of control, carbide size, morphology and distribution of bearing steel is the key to high quality, high performance, multi variety and direction for the austenitizing temperature based on different isothermal annealing process in the holding time, the process parameters of isothermal temperature and time on the number of spheroidal carbide particles and to find the optimal distribution, for the industrial production of spheroidization process and provide a theoretical basis.

2. Test materials and methods

2.1. Experimental material

The materials used in the test were taken from the GCr15 steel of a factory, and the main chemical composition was shown in Table 1.
Table 1 chemical composition of GCr15 steel

| alloying element | C  | Si  | Mn  | Cr  | S   | P   |
|------------------|----|-----|-----|-----|-----|-----|
| content %        | 0.9| 0.17| 0.36| 1.45| 0.01| 0.011|

2.2. Experimental method

The experiment was carried out in a box type resistance furnace, the sample was processed into a small cylinder of 25x10, and the experiments were carried out at different heating temperatures. The process parameters of sample 1-9, are shown in Table 2, of which 100°C /h heating rate rose to austenitizing temperature, cooling speed to 50 °C /h to isothermal temperature, and then to 50 °C /h to 650 °C out of furnace cooling air cooling. By using TESAN scanning electron microscope and energy spectrum with microstructure analysis.

Table 2 heat treatment process parameters

| Sample number | heating temperature /°C | warming-up time /h | Isothermal temperature /°C | isothermal /h |
|---------------|--------------------------|--------------------|-----------------------------|--------------|
| 1#            | 760                      | 4                  | 700                         | 3            |
| 2#            | 780                      | 4                  | 700                         | 3            |
| 3#            | 800                      | 4                  | 700                         | 3            |
| 4#            | 780                      | 5                  | 700                         | 3            |
| 5#            | 780                      | 6                  | 700                         | 3            |
| 6#            | 780                      | 5                  | 680                         | 3            |
| 7#            | 780                      | 5                  | 720                         | 3            |
| 8#            | 780                      | 5                  | 700                         | 2            |
| 9#            | 780                      | 5                  | 700                         | 4            |

3. Test results and analysis

3.1. Effect of different heating temperature on Microstructure of carbide

Figure 1 is observed with scanning electron microscope in the No. 1, No. 2, the microstructure of three different austenitizing temperature 3 GCr15 samples.

![Fig. 1](image_url)

It can be seen from the figure there are different spheroidizing effect at different temperatures, different morphologies of carbides for three in proportion.(a) and (c) carbide particles in large, there is a small part of a small particle diameter, but mainly to large diameter particles. On the contrary (b) diagram mainly to small granular carbides, only a small part of the large diameter carbide. In the three picture, the carbides have different degrees of spheroidization, some of the large particles can reach 1 m in diameter, the smallest particle diameter of up to 0.2 M. (c) phase (b), compared to some of the growth of carbide particles, the effect is not good. It can be seen from the (b) diagram that a large
number of carbide particles are small and dispersed, and the spheroidization effect is obviously better than (a) and (c).

3.2. Effect of different isothermal time on Microstructure of carbide
Figure 2 is observed with scanning electron microscope in the No. 2, No. 4, the microstructure of three different heating time 5 GCr15 samples.

![Fig. 2](image)

It can be seen from the figure with the heating time. The carbide morphology, size and number are significantly changed. (a) the austenitizing time is short, there are some undissolved carbide particles in the matrix to form a carbon rich region, and in the subsequent isothermal process as a nucleation center to form a uniform spherical structure. (b) in the austenitizing time, carbide particles dissolve without excessive nucleation centers in the isothermal process followed, only through the carbon depleted zone of ferrite and cementite separate spherical growth, such nucleation speed naturally ratio (a) formation of finer particles in the figure. With the extension of the heating time the carbide is dissolved and some small particles even disappear. When time is too long, the carbon concentration in austenite becomes uniform, and then it becomes a flaky pearlite.

3.3. Effect of different isothermal temperature on Microstructure of carbide
Figure 3 is observed with scanning electron microscope in the No. 6, No. 4, three different isothermal temperature on Microstructure of GCr15 specimen No. 7.

![Fig. 3](image)
Three figure can be seen in a large number of granular carbides, which is due to the carbide particles in this stage is a spontaneous process, the flake pearlite transformation high surface can the pelleted to reduce the energy. (b) and (a) than the isothermal temperature, carbon atom diffusion and nucleation driven, showing a more uniform dispersion of carbide particles. With the increase of temperature, the carbide particles dissolved residue, non -spontaneous nucleation decreases, in rich and poor carbon zones at the same time from nucleation. You can see a graph of some particles began to grow, the formation of lamellar pearlite.

3.4. Effect of different isothermal temperature and time on Microstructure of carbide
Figure 4 is the microstructure of the samples with different isothermal temperatures observed by SEM in No. 4, No. 9, GCr15. Through the experiment of heating temperature, heating time and isothermal temperature, it can be seen from the (b) that most of the large granular carbides have been dissolved and the size is small. This is because the activation energy and the driving force are suitable, the precipitated carbon atom can be more spontaneous nucleation, the non spontaneous nucleation of carbide particles is also small, so the effect is good. As time went on, some small particles of carbide began to approach the large particles and were swallowed up by large particles. This was because the activation energy and the driving force were too high, and the carbides began to melt and merge.

![Fig.4](image)

3.5. Effect of heating temperature and heating time on the particle size of carbides
As can be seen from Figure 5, the particle size of the large granular carbides in GCr15 decreases gradually with the increase of annealing time. When the 5h is heated, some of the carbide is dissolved, the original large irregular carbides are dissolved, and the remaining particles become smooth. When heating 6h after some carbide particles began to melt back up, the ball is not the best effect. The heating temperature is too high, the spread of nuclear carbon spacing is too large it is not good to make the ball effect is not good, the excess carbides aggregate to grow at the grain boundaries. When the heating temperature is too low, the diffusion coefficient of carbon is small, and the spheroidizing effect is not good, so the heating temperature is 720 °C, and the heating time is 5h.
3.6. Effects of isothermal temperature and isothermal time on the particle size of carbides

As can be seen from Figure 6 in the temperature is 720°C with the holding time, the grain diameter GCr15 carbides decreases gradually, this is because with the increase of isothermal time, carbon precipitation gradually increased, the activation energy and the nucleation driving force increases, the carbide grain diameter decreases. And 700 °C, 680 °C degrees of carbide grains is gradually decreased, then the grain began to grow up, this is because some carbide particles began to melt and merge and grow up. The isothermal time is longer, the stored energy is higher, the size will increase. So the best temperature is 700 °C, the isothermal time was 3h.

4. Conclusion

(1) The isothermal temperature at 760 °C -800 °C change, with the increase of temperature of carbide particles become fine and dispersed when the heating temperature rises to 800 °C when the uniform degree of austenite is too high, easy to nucleate and grow into flake carbide spheroidizing effect is not good.

(2) When the isothermal heating time is extended from 4H to 5h, the carbide particles can grow into spherical shape independently. When the time increases to 6h, the particle size of the carbide is not changed, and even some of the particles begin to melt

(3) The best process of GCr15 steel is heating temperature of 780 °C, heating time 5h, isothermal temperature of 700 °C, isothermal time 3h.

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