Correlation and Calculation of Metal Material Properties and Energy Consumption of Casting Products

Yirun Wang[1a*], Jun Zhang[1b] and Kai Liu[1c]

[1]Xi'an Traffic Engineering Institute, Shaanxi, Xi 'an 710300, China

[a] Email: gxweixingjian@sina.com

[*]corresponding author

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Abstract: By analyzing the characteristics of metal materials and the energy consumption of casting products, this paper summarizes the effects of different metal materials on the energy consumption of products, and proposes the calculation methods of metal material characteristics and energy consumption of casting products, including the benchmark method and the correction coefficient method. It provides some reference for the research on the relationship between the characteristics of metal materials and the energy consumption of casting products and the calculation methods.

1. Introduction

Foundry industry is one of the important industrial types in China, with a high energy consumption rate in the production process, which has 70% of the energy consumption rate of the melting process. Due to the differences in the material of the castings, there are different production processes. This requires a correct understanding and understanding of the effects of material properties on the energy consumption of the casting during the production process. This is an important basis for the calculation of energy consumption, and it is also one of the important ways for casting manufacturers to strengthen energy consumption calculation.

2. Metal Material Properties and Energy Consumption of Casting Products.

Foundry enterprises are one of the important types of Chinese enterprises. There are about 30,000 foundry enterprises in China, which is much higher than the number of founding enterprises in other countries in the world. The production process of foundry enterprises is a high-emission and high-energy industry, and research on its energy consumption is of great significance. Common products in the foundry industry include cast iron parts, aluminum alloy castings, and steel castings. In order to effectively reduce the production cost of enterprises and achieve the effect of energy saving and emission reduction, it is required to select reasonable production equipment, advanced production technology and optimized production methods in the production process. The assessment of energy consumption plays an important role in it [1].

The energy consumption per unit product of a casting refers to the ratio of the energy consumed by the casting to the qualified output in a statistical period. In actual use, energy consumption is affected by many factors, including geometric size, melting method, casting weight, and metal materials. This requires the enterprise to be able to calculate the energy consumption of the casting unit product in the process of energy consumption assessment, and use scientific calculation methods to judge the energy consumption of the enterprise. The difference in metal material properties affects the energy consumption of casting products and its calculation method to some extent [2].

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Table 1 Energy consumption of various industrial furnaces

Category	Annual energy consumption (standard coal / 10,000 tons)	Percentage of total industrial furnace energy consumption (%)
Melting furnace	4258.86	26.32
Petrochemical furnace	610.00	3.77
Heating furnace	695.73	4.30
Heat treatment furnace	229.49	1.42
Drying furnace	93.78	0.58
Burning furnace	5688.66	35.16
Chemical furnace	3498.19	21.62
Sintering furnace	592.40	3.66
Calciner	193.34	1.20
Others	318.20	1.97

The types of firing furnaces in China's industry include bricks, refractory materials, firing furnaces, cement, lime, grinding wheels and the like. There are two types of heat treatment furnaces, namely metal treatment furnace and metal heat treatment furnace.

Table 2 Energy consumption data of some industrial furnaces

Category	Unit	Lowest value	Highest value	Average	Foreign average
Steelmaking electric furnace	Tons of standard coal / ton of steel	0.27	0.522	0.311	United States 0.230
Cupola	Tons of standard coal / ton of iron	0.097	2.400	0.132	0.120
Steelmaking open -hearth	Tons of standard coal / ton of steel	0.106	0.409	0.174	United States 0.121
Steelmaking blast furnace	Tons of standard coal / ton of iron	0.469	0.707	0.529	Japan 0.440
Aluminum melting furnace	Tons of standard coal / ton of products	0.260	0.630	0.420	/

As can be seen from Table 2, from the average value analysis, the advanced level energy consumption of China's major industrial furnaces is very close to the foreign advanced value, and the average energy consumption is not large, but the energy consumption shows obvious advanced and backward differences. There is a big difference between advanced technology and backward technology. It can be seen that the energy saving of industrial furnaces in China's forging industry still has a large room for improvement, and it is required to strengthen the improvement of backward technologies. The energy-saving development of China's forging industry has a lot of room for improvement.

3. The Effect of Different Metal Materials on Product Energy Consumption

Due to the different materials in the metal, the casting production process also has certain differences. For example, the alloy cast iron KmTBCr26 and the gray cast HT250, which are often used in the production of castings, require an effective heat treatment at a low temperature after the casting of the gray cast, and a heating temperature of 600 ° C or less is set [3].

Alloy cast iron requires effective high temperature heat treatment after casting. First, it was heated to 980 °C, and heat-treated, the thickness was set to 25.4 mm, and the holding time was set to 15 min. After the end of the heat preservation, quenching and 220 °C tempering treatment were adopted. It can be seen that compared with the gray cast iron heat treatment method, the alloy cast iron treatment method requires higher temperature and more complicated treatment process, and thus the energy consumption thereof also increases.

For some high-strength and high-temperature resistant steel castings for locomotives, it is required to be subjected to secondary heat treatment after casting, so it has more energy consumption than ordinary steel castings [4].

Due to the difference in the content of alloying elements in the metal material, the melting temperature of the casting also has a certain difference. For example, in the steel casting series, ZG30MnSi grade low alloy steel castings have a melting process temperature of 1600 to 1620 °C, and the total content of alloying elements is less than or equal to 2%. The 1Cr19Ni10 grade high-alloy steel castings have a melting temperature of 1 650 °C, indicating the difference in melting temperature. Through a large number of practical operating experience in the factory, in the electric furnace smelting process, the power consumption per ton of high-alloy steel castings is about 280 kW • h higher than that of low-alloy steel castings. It can be seen that as the total content of steel castings increases, the smelting energy consumption also increases. The relationship between the energy consumption of casting products and the alloy composition of metal materials is shown in Figure 1.

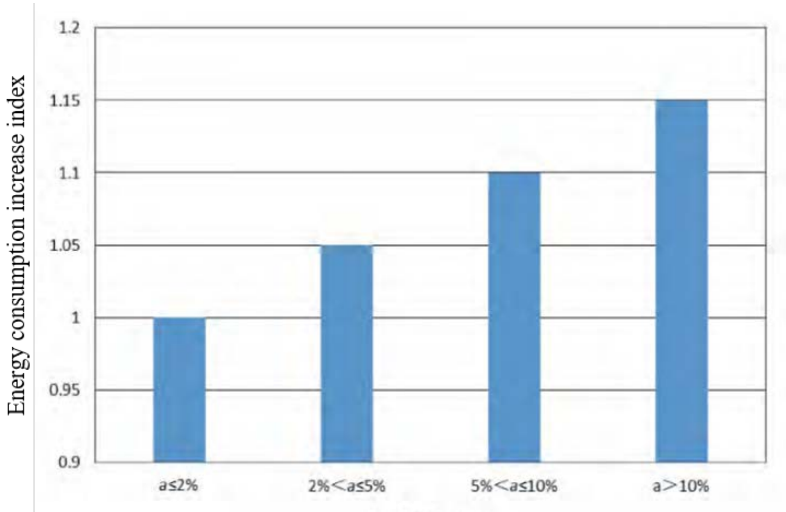

Fig.1 Relationship between energy consumption of casting products and alloy composition of metal materials

The Sr metamorphism method and the Na metamorphism method are respectively subjected to the corresponding metamorphism treatment, and the actual energy consumption in the specific implementation process has certain differences. Through a lot of practice, the Sr metamorphism process is double the energy consumption in the Na metamorphosis process.

Some steel casting products have special uses. For example, the common 00Cr19Ni10 grade castings require sufficient refining before the pouring operation to control the molten steel and alloying elements within certain limits. Furnace refining is one of the most important methods currently used. The operation mode of the electric arc furnace and the induction electric furnace is generally adopted, thereby also increasing the energy consumption per unit product of the steel casting.

4. Calculation of Metal Material Properties and Energy Consumption of Casting Products.

4.1 The benchmark method.

In the application of the benchmark method, the production situation of different enterprises is placed on the same benchmark condition for comparative calculation. The benchmark is set to the general process flow of the casting product, and the selected baseline data is the energy consumption per unit of product. If a special metal material is used, the increase in energy consumption due to changes in the processing steps is reflected in the baseline data. This calculation method is relatively simple but requires the enterprise to have a sound energy statistics base and energy measurement basis, which can meet the conditions of calculation and application.

4.2 The correction coefficient method.

In the process of calculating the energy consumption by using the correction coefficient method, the correction coefficient is used, and the weight of the casting product, the composition of the metal material, the pouring method, the production process flow, the geometric size, the melting method and the like can be corrected accordingly. The comparable casting yield, the actual production, is multiplied by the value of the corresponding correction factor. The specific energy consumption of a casting is expressed as the ratio between the comprehensive energy consumption of the casting production and the comparable production of the casting during the calculation cycle.

This approach can be applied to different processes and to the manufacturing process of product metals. However, it is difficult to select multiple process parameters. It is required to collect statistical data for many years and effectively combine it with on-site testing. After calculation and summary, the final empirical value is obtained [5].

For example, in the process of applying the correction factor method to the energy consumption of cast iron parts, it is required to combine the relevant correction factors to obtain the yield of comparable cast iron parts. The calculation formula is:

$$N_{kz} = K_1 \times K_2 \times K_3 \times K_4 \times N \tag{1}$$

In this formula, the actual output of cast iron parts is expressed by N, the weight correction coefficient of cast iron parts is expressed by K_2, the correction coefficient of smelting method of cast iron parts is represented by K_4, the output of comparable cast iron parts is represented by K_{kz}, the correction factor of complexity of cast iron parts is represented by K_1, the correction factor of the cast iron material category is expressed by K_3.

For the calculation of the energy consumption per unit of cast iron products, it can be concluded that:

$$U_{kc} = U_q / U_{bz} \tag{2}$$

In this formula, the cast iron parts can be expressed in U_{bz}, the cast iron parts can be expressed in terms of unit energy consumption in U_{kc}, the unit is kgce/t, and the comprehensive energy consumption of cast iron parts is expressed in U_q, the unit is kgce.

4.3 Centralized melting furnace energy consumption calculation method

It is required to calculate under the conditions of continuous production to calculate the chemical reaction heat of the metal material. Metal material smelting is carried out in an atmospheric environment. When a metal material is in contact with a gas such as N_2, CO_2, H_2, O_2, H_2O, CO, or C_mH_m in the atmosphere, various chemical reactions, including decomposition, diffusion, compounding, and dissolution, are generated.

Natural gas is one of the commonly used fuels in the smelting process. It has a calorific value of 33440-41800 kJ/m^3. The main components include methane, ethane, hydrogen and carbon monoxide. It has a volume fraction of methane above 98%.

For example, in the aluminum alloy smelting process, Al_2O_3-based oxidation slag is produced, and the yield is as high as 80-90%. Therefore, the calculation of the heat generated by the oxidation of aluminum is the main study. The specific reaction process is as follows:

$$AL(Liquid) + \frac{3}{4} O_2(Gas) = \frac{1}{2} Al_2O_3(Solid) \tag{3}$$

$\Delta G_0 = -194426 + 38.80T$

In the formula, the standard state Gibbs free energy is represented by ΔG0, and the unit is J.

The reaction heat calculation process of the oxidation reaction uses Raction-web to obtain the calculation result as shown in Fig. 2 below.

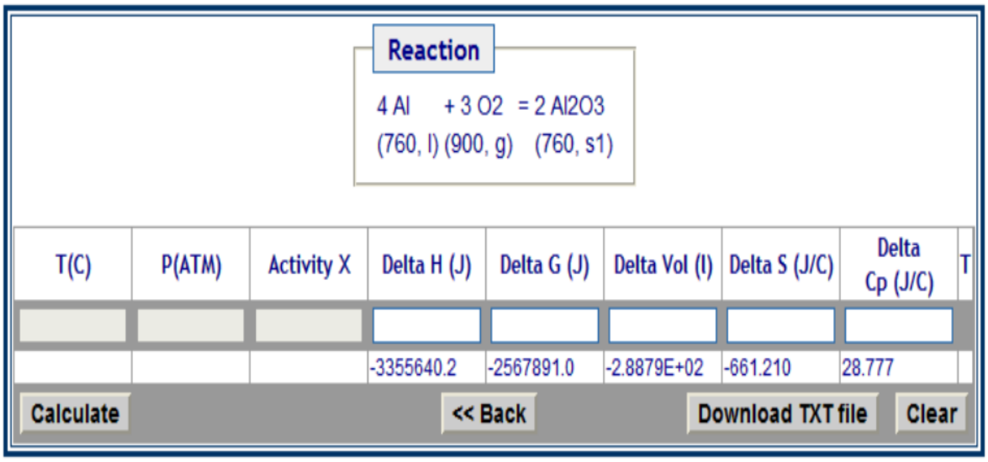

Figure 2 Reaction heat calculation results of oxidation reaction

From this figure, it can be seen that 1 mol of Al element generates Al_2O_3 after oxidation reaction, releasing 839 kJ of heat. The unit of kJ/mol is replaced with kJ/kg for ease of calculation. It is available that 1 kg of Al_2O_3 is capable of releasing 31,074 kJ/kg of heat. G represents the furnace production capacity, and the calculation can be obtained as G=3.15t/h=3150kg/h. Combining it with on-site data collection, it is possible to obtain a slag amount of 500kg/8t concentrated melting furnace. In this process, it should be able to see that Al accounts for about 30%. In the study, it is assumed that the remaining part is all Al_2O_3, and δ represents the oxidation rate of the metal, and δ=2.3% is obtained.

By substituting these values into the calculation formula, it is possible to obtain the oxidation heat release amount of the Al element by $Q_{\text{chemical exotherm}}$ when the aluminum alloy is melted, and it is obtained:

$$Q_{chemical\ exotherm} = G\delta q_y = \frac{2251317kJ}{h} \tag{4}$$

5. Conclusion.

In terms of the unit energy consumption of the casting, the composition characteristics of the metal material have an important influence. In order to improve the production efficiency of the foundry, it is required to strengthen the calculation of production energy consumption. The actual calculation of the unit's comprehensive energy consumption can be calculated by the correction factor method, which can obtain relatively scientific and reasonable calculation values. Under the continuous development and application of new casting processes, new technologies and new materials, it is required to strengthen the effective research on the casting production process and summarize the actual production process data. It is used as an important basis for adjusting the correction factor, and fully analyzes the energy consumption benchmark. Therefore, it is necessary to fully strengthen the effective analysis of the foundry industry and improve the energy utilization rate in the casting production process to meet the current environmental protection concept.

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