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Research Article

Development and Application of an Ultrahigh-Temperature Steam Generator

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A device which could produce high-temperature steam quickly was designed. The overall structure of the heating device and the heating pipe of key components were introduced mainly, and the working process of the heating device was analyzed and discussed. This high-temperature steam device with high heating efficiency, produces steam fast and could realize precise temperature control. This device could expand application research of polymer materials and composite materials and provide key guide parameters in the process of technical research.

1. Introduction

The forming process of polymer materials mainly includes injection molding, extrusion molding, blow molding, rotational molding, and other molding processes [1–3]. However, temperature control is an important condition and key parameter in the formation of all macromolecule materials [4–6]. Steam generator is a mechanical device that uses heat energy to heat water into hot water or steam. It can output stable and continuous high-temperature and high-pressure steam when working. It can be widely used in the temperature conditions of the polymer material forming process [7]. With the development of new materials and composites, higher requirements are put forward, for precise temperature control and rapid response. However, it is difficult for the traditional steam generator to provide such rigorous process conditions [8–10].

The heat conversion efficiency of the steam generator with electromagnetic induction heating technology is over 95%, with fast heating speed and uniform heating, it has unique advantages in environmental protection, service life, and safety performance. Its development directly affects the realization of the goal of building a resource-saving and environment-friendly society in our country [11, 12]. Hubei University for Nationalities and Ningbo GMF Environmental Protection Equipment Technology Co., Ltd. jointly tackle the key problems. On the basis of the fast steam generator (which can produce steam at 200°C), an ultrahigh-temperature electromagnetic heating device was developed (a high-frequency induction steam generator, no. 201510083719.0; an electromagnetic heating steam generator, no. 201510089798.6; an ultrahigh-temperature steam generator, no. 201610077236.4; an electromagnetic heating high-temperature steam generator, patent no. ZL201520308276.6). The device adopts electromagnetic induction heating mode and can produce high-temperature steam above 500 C. The temperature control precision is ±5°C.

2. Structural Design of Ultrahigh-Temperature Steam Generator

2.1. Overall Structure of Ultrahigh-Temperature Electromagnetic Heating Device. The structure of the ultrahigh-temperature electromagnetic heating device is shown in Figure 1. It mainly consists of the steam generator and the

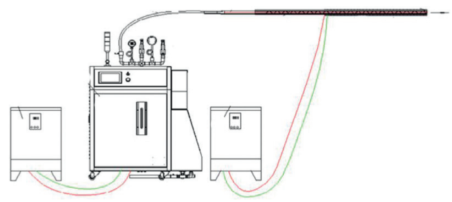

Figure 1: Ultrahigh-temperature electromagnetic heating device machine structure.

high-temperature tube reheating part. Its power is 50 kW and 20 kW. Under the action of the control system, the super high-temperature steam can be produced by two-stage heating. The steam generator device is mainly composed of four parts: water supply module, electromagnetic induction heating module, power supply module, and detection control and protection module. The water supply module supplies water to the steam generator. The power supply is responsible for the power supply of the electromagnetic heating device. The electromagnetic induction heating module consists of coils, insulation materials, heating pipes, etc [13]. The detection control and protection module is composed of flow meter, safety valve, pressure gauge, thermometer, PLC, and other modules. It ensures that the liquid level relay feedback controls the opening and closing of the pump, adjusts the water supply of the water supply system, and controls the heating system and safety protection system through the outlet steam pressure and temperature feedback [14, 15].

2.2. The Secondary Heating Heat Pipe. One of the core components of the high-temperature steam generator is a high-temperature tube which can realize secondary heating. The high temperature tube for secondary heating of ultrahigh-temperature steam generator is made of No. 25 steel. The reason is that No. 25 steel has good magnetic and thermal conductivity. The heat treatment standard temperature is above 600°C [15]. In order to increase the heat transfer rate, the front steam is heated by a sandwich structure with two tube walls. The outer wall thickness is 4 mm and the inner wall thickness is 3 mm. The design principles of the pipe thickness are that 4 mm outer wall thickness improves the heat dissipation capability of the outer wall and the 3 mm inner wall thickness can improve heat transfer efficiency and thermal conductivity. In order to prolong the journey of steam in the interlayer, increase heating time and achieve heating effect, and a stainless steel wire with diameter of 3 mm is wound in the interlayer and spirally wound, and the pitch is about 120 mm, which can makes the heating more uniform during heating process. In order to reduce heat loss and improve the efficiency of heat energy utilization, heat-resistant insulation material is wrapped outside the steel pipe, and then the inductance coil is evenly and tightly wound on the insulation material. The coil cover length is about 1500 mm. The winding density of the coil gradually becomes thinner from the outlet to the back, and the inductance is controlled at about 130H. The high-temperature heating tube is shown in Figure 2.

3. Ultrahigh-Temperature Steam Generator Operation Method and Test

The appearance of the ultrahigh-temperature steam generator is shown in Figure 3. Its working process is as follows:

(1) Firstly, turn on the 50 kW steam generator, set parameters, and control the water in the inner tank to be heated to about 180°C.

(2) Then, turn on the 20 kW controller and reheat the high-temperature heating tube to obtain high-temperature steam. It should be noted that the upper power limit of the secondary heating controller is 20 kW and the lower power limit is 5 kW. When the maximum temperature is about to be set, the control module automatically adjusts the working power to achieve accurate temperature control.

Ultrahigh-temperature electromagnetic heating device can complete all functional operations on touch screen. Tests show that, with the increase of temperature, the water vapor in the outlet decreases continuously. When the secondary heating is opened, it takes about one minute to heat the steam temperature at the outlet from 160 to 500°C. The measured temperature curve of the outlet is shown in Figure 4.

In order to verify the heating effect of this device on the processing of polymer materials, we selected a small piece of waste plastics, mainly composed of polyethylene and PE, as a sample for pyrolysis test. As shown in Figure 5, the PE sample was placed 5 mm away from the outlet of the high-temperature device, and the change of PE sample was observed and the corresponding temperature was recorded. The recorded experimental data show that the heating rate has a great influence on the pyrolysis process. The samples begin to melt at 130°C, begin to decompose at 240°C, rapidly decompose at 400°C, and slowly decompose at 530°C, and basically complete pyrolysis. The experimental results show

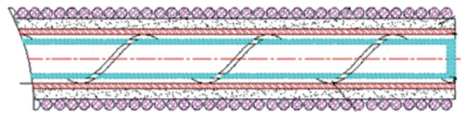

Figure 2: High-temperature heating pipe.

Figure 3: Ultrahigh-temperature steam generator appearance.

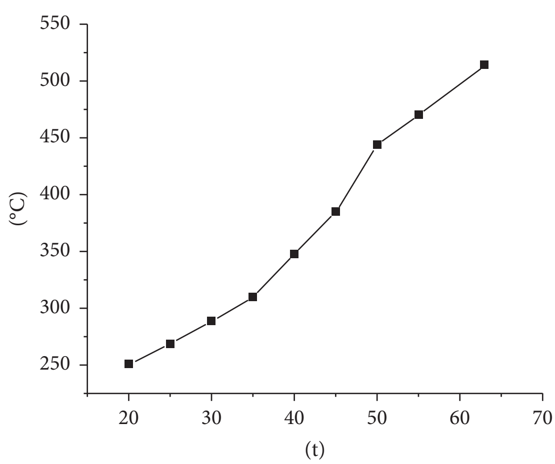

Figure 4: Measure the temperature of the outlet curve.

Figure 5: Experiments of PE heat decomposition.

that the device can be used for heating pyrolysis of polymer materials.

4. Conclusions

Ultrahigh-temperature electromagnetic heating device designed by electromagnetic induction heating technology runs stably. Its application in the heating system of polymer material forming process can meet the basic requirements of temperature control in plastic industry. It can significantly improve the efficiency of rolling molding, save energy consumption, and improve the quality and accuracy of products. It is helpful to explore the application technology of polymer materials and composites in special industries and to study new materials.

Data Availability

The data used to support the findings of the study are available at https://figshare.com/s/d5c50e34db550714a3fb.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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