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The Application of Electron-Beam Welding in Pellet Mold Preparation

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Abstract: This paper provides insight into the application of electron-beam welding in pellet mold preparation, highlighting the importance of the combination of electron-beam welding and pellet mold preparation in the fields of microstructure joining and micro- and nanostructure preparation. Precise material joining and microstructure fabrication can be achieved by the precise control of electron-beam welding and the shape adjustment of pellet molds. These applications hold significant potential in the modern industrial field, providing robust support for the development of new materials and the growth of the petrochemical industry. This paper asserts that in the future, the ongoing development of electron-beam welding and pelletizing template technology will unlock new possibilities in the field of petrochemicals, fostering progress in science and technology.

Keywords: Electron-beam welding; Pellet mold; Microstructure

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1. Introduction

Electron-beam welding plays a key role in the development of the petrochemical industry. This technology has unique advantages, such as high focal energy density, precise welding control, and low heat input, making it popular in several fields. Pellet molds are also a key technology in the petrochemical industry that helps to improve the efficiency of petroleum product manufacture and has a broad application prospect. Exploring the potential applications of combining electron-beam welding with pellet mold preparation in the petrochemical field poses several challenges [1]. The objective of this paper is to study the application of electron-beam welding on pellet mold welding in order to determine its feasibility in the petrochemical industry. This study is expected to bring new development ideas to the petrochemical industry and promote the application of electron-beam welding technology in this field.

2. Electron-beam welding

2.1. Working principle of electron-beam welding

Electron-beam welding is a highly sophisticated welding technique that functions on the basis of a high-speed electron beam [2]. In this welding method, an electron gun is used to generate a stream of high-speed electrons that emit energy through a hot cathode. These high-speed electrons are guided by an electric field and condensed into a fine stream of beams containing a huge amount of energy, which is then shot at the welding spot. The high-energy electron beam is focused on the weld seam of the workpiece and is extremely penetrating. Technicians can precisely control the energy of the electron beam to ensure that the heat generated during the welding process is highly concentrated minimizing its impact on the surrounding material [3]. The energy of the electron beam is converted into heat at the welding point, resulting in instantaneous melting or fusion of the workpiece material. The principle of electron-beam welding has several features. Firstly, the electron beam has a very high energy density, which can generate high temperatures at the welding point, realizing rapid melting and fusion of materials. Secondly, because the focus of electron-beam welding is extremely precise, its heat input is very low, so it does not have a thermal impact on the surrounding material, reducing the probability of deformation and stress. Thirdly, by adjusting the energy of the electron beam, the welding depth can be precisely controlled to adapt to different types of materials. Lastly, electron-beam welding can be integrated with computerized control systems to further automate the welding process [4].

2.2. Electron-beam welding parameters

The quality of electron-beam welding is closely related to the control of welding parameters. In the electron-beam welding process, several parameters need to be carefully controlled to ensure the welding quality. The first parameter is the electron beam energy density. This is an important parameter in welding, and the energy density of the electron beam directly affects the depth of the weld. By adjusting the current of the electron beam, the energy density can be precisely controlled to adapt to the welding requirements of different materials [5]. The second parameter is the focal diameter. The focal diameter is the size of the focal point of the electron beam. By adjusting the focal diameter, the width of the weld can be controlled. Smaller focal diameters are usually used for fine welds, while larger focal diameters are used for wider weld areas. The fourth parameter is the welding speed. The welding speed is the speed at which the electron beam moves during the welding process. It is closely related to energy density and weld depth. High welding speeds reduce heat input and are suitable in certain situations, while lower speeds will be needed to create deeper welds [6]. Lastly, the environment plays an important role in electron-beam welding. Inert gases, such as argon, are used to protect the weld area from oxidation and impurities. The parameters of electron-beam welding are shown in **Table 1**.

Table 1. Parameters of electron-beam welding

<table>
<tr><th rowspan="2">Type of joint</th><th rowspan="2">Welding position</th><th rowspan="2">Plate thickness，(mm)</th><th colspan="2">First layer of the weld channel</th><th colspan="2">Welding passes for the remaining layers</th></tr>
<tr><th>Diameter of welding rod (mm)</th><th>Welding current (A)</th><th>Diameter of welding electrode (mm)</th><th>Welding current (A)</th></tr>
<tr><td>Straight edge buttressing</td><td>Flat welding</td><td>4–5</td><td>3.2</td><td>90–120</td><td rowspan="2">4</td><td rowspan="2">160–180</td></tr>
<tr><td rowspan="3">Single-sided V-butt</td><td rowspan="3">Flat welding</td><td rowspan="3">> 6</td><td>4</td><td>160–180</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">160–180</td><td>4</td><td>160–180</td></tr>
<tr><td>5</td><td>200–240</td></tr>
<tr><td rowspan="2">X-butt</td><td rowspan="2">Flat welding</td><td rowspan="2">> 12</td><td rowspan="2">4</td><td rowspan="2">160–180</td><td>4</td><td>160–180</td></tr>
<tr><td>5</td><td>200–260</td></tr>
</table>

3. Introduction to pellet molds

3.1. Definition of pellet mold

A pellet mold is a tool used to prepare granular materials. It is a template with specific shaped holes or grooves that determine the shape and size of the granular material. These holes or grooves can be spherical, cylindrical, conical, etc., depending on the desired shape of the granules [7]. Pellet molds are widely used for the preparation of granular materials in petrochemical processes. These molds have a key role in refining, chemical production, and petroleum processing. The main function of pellet molds is to convert powdered or granular raw materials into uniform granular materials. This is important for a variety of processes in the petrochemical industry, such as the production of granular catalysts, granulation of powdered additives, and coating of granular materials [8]. Through granulation, the flow, storage, and transportation of raw materials can be improved, along with the homogeneity and stability of the product. Secondly, pellet molds usually include a template aperture plate. These plates are used to control the size and shape of the pellets. The selection and design of the template apertures are critical in the pelletizing process because they directly affect the physical properties of the final product. Finally, the preparation of pellet molds usually involves complex processes that include steps such as mixing raw materials, pelletizing, drying, and cooling. These processes require precise control parameters such as temperature, humidity, flow rate, etc. to ensure the quality of the final product. In the petrochemical industry, the wide range of applications of granular products requires continuous improvement and optimization of the pellet mold manufacturing process to meet different process requirements and product specifications [9].

3.2. Pellet mold preparation methods

Pellet molds can be prepared by various methods depending on the shape and material properties of the desired product. The first method is photolithography. This is a common micro- and nano-fabrication method for preparing molds with tiny holes or patterns. In this method, a photosensitive material is coated on a substrate, and then a mask and UV light irradiation are used to chemically react the photosensitive material to form the desired pattern. The unwanted parts are removed by chemical etching or corrosion, leaving the template. The second method is the electron beam etching method. This method is similar to photolithography but an electron beam is used to expose the photosensitive material. This method allows for the preparation of smaller-sized holes, as well as more complex mold patterns. The next method is the electrochemical etching method. In this method, the substrate is immersed in an electrolyte, and holes or grooves are formed in the substrate through an electrochemical reaction, in which the size and shape of the holes can be controlled precisely. The last method is the mold method. Pellet molds are prepared using molds that have the desired shape of the holes or grooves. The material is heated and injected into the molds, then cooled and hardened, resulting in the desired template. Each preparation method has its unique advantages, which can be utilized for different purposes. In the pharmaceutical industry, choosing the right method of preparing pellet molds is crucial to ensuring the consistency of drug particles [10].

3.3. The role of pellet molds in the petrochemical industry

Pellet molds play an important role in the petrochemical industry, especially in the preparation of catalysts [11]. Catalysts play a central role in petroleum refining and chemical production. By using pellet molds, the catalyst feedstock can be converted into homogeneous particles, which ensures uniform distribution during the reaction and thus improves the reaction efficiency. This step is essential for petrochemical processes such as cracking, hydrogenation, and catalytic reforming. Secondly, pellet molds also play an important role in the application of additives. In the petrochemical industry, additives such as antioxidants, adsorbents, etc. are usually required in a powdered or liquid form. Through granulation, these additives can be more easily mixed with the substrate, improving handling and homogeneity while reducing dust generation, which is critical for ensuring both process stability and product quality. Finally, pellet molds also help to improve the handling of powders. In the petrochemical industry, it is often necessary to handle powdered feedstocks, such as drying, cooling, and sieving of pellets. The application of pellet molds improves the flow and handling properties of powders, which increases productivity and reduces possible problems in production [12].

4. Combination of electron-beam welding in pellet mold welding

When electron beam welding is applied in fusion with pellet molding technology, they present excellent potential in the field of joining microstructures [13]. This combination provides new opportunities to realize precise connections, especially for microstructures.

4.1. Precise joining of microstructures

In the petrochemical industry, the combination of electron-beam welding in pellet mold preparation plays a key role, especially in the precise joining of microstructures. This combination allows fine work and enables highly precise and controllable joining at a microscopic scale. First, this combination provides an important tool for the petrochemical field in the preparation of microstructures. For example, precise connections of microstructures are needed in the fabrication of microreactors or microsensors to ensure their efficient operation in petrochemical applications. The synergistic application of electron-beam welding in pellet mold manufacture helps to prepare fine micro-components needed in petrochemical processes. Secondly, this combination can potentially be used for device preparation in the field of nanotechnology. Nanoscale devices are required in the petrochemical industry for precise monitoring and control. The integration of electron-beam welding in pellet mold production helps in the preparation of high-precision nanosensors, nanocatalysts, etc., to support microscopic operations in petrochemical processes. Furthermore, this combined technology offers flexibility in customizing microstructure connections. This is important to meet the specific needs of different petrochemical processes, such as customized interconnections for microsensor networks. Finally, this technology also plays a role in the encapsulation of tiny structures. In the petrochemical sector, some microstructures need to operate in harsh environments and therefore require effective encapsulation to protect them from the external environment. The integration of electron-beam welding in pellet mold production provides a reliable encapsulation method to ensure the reliable operation of microstructures in unfavorable industrial environments [14].

4.2. Micro- and nanostructure preparation

In the petrochemical field, the integration of electron-beam welding in pellet mold production provides a precise and controlled method for the preparation of micro- and nanostructures [15]. This technology combination can be applied to the preparation of microscale and nanoscale devices. By combining electron-beam welding and pellet mold technology, microparticles and nanostructures can be effectively connected and assembled to prepare microscale and nanoscale devices, such as microreactors, nanosensors, and nano-optical elements. These devices have a wide range of applications in the petrochemical field, such as catalytic reactions, fine analysis, and chemical sensing. Second, this combination of techniques can be used to precisely control the preparation of nanopores. Electron-beam welding can be utilized to join and close templates with nanoscale pores, which is useful in preparing micro and nanostructures with specific pore sizes and shapes, such as nanofilters, nanoreactors, and separators. These structures are used in the petrochemical industry for controlling the transfer and separation of substances. Besides, this combination of technologies can support the synthesis of nanoparticles. The synthesis of nanoparticles can be achieved through the combined use of electron-beam welding and pellet mold technologies to prepare nanoparticles with specific shapes and properties. These nanoparticles can be used in petrochemical applications such as drug delivery, catalytic reactions, and material modification. Finally, this combination of technologies helps to achieve precise joining of micro and nanostructures. Through the integration of electron-beam welding in pellet mold production, it is possible to ensure the precise assembly of micro and nanostructured substances. This is critical for applications in petrochemicals that require precise control of structure and properties, such as integrated circuit preparation and production of nanomaterials in microelectronics [16].

4.3. Precise joining of micro- and nanostructures

Precision is crucial in the field of preparing and joining structures at the micro- and nanoscale. The preparation of micro- and nanostructures requires confining chemical reactions and structural connections to the tiny scale to ensure a high degree of precision and control. This task involves using electron-beam welding technology, enabling targeted heating and fusion of metals or insulators at the nanoscale to create tiny reaction cavities or channels. Pellet molds also play a key role in controlling the size and shape of the reaction cavities to ensure that they conform exactly to the design specifications. Secondly, the preparation of micro- and nanostructures requires ensuring that catalysts or reactants are precisely dispersed in tiny spaces. The application of electron-beam welding allows precise positioning of the catalyst or reactants, while the pellet mold ensures uniform distribution. This highly precise catalyst positioning and dispersion is essential for improving reaction efficiency and selectivity. Moreover, the structure must be hermetically sealed and stable in the preparation of micro- and nanostructures to avoid reactant leakage or external interference. Electron-beam welding can be used to join and seal the components of the micro- and nanostructures to ensure superior hermeticity, especially in high-pressure, high-temperature, or chemically aggressive environments. Finally, the precise fusion of micro- and nanostructures requires corresponding testing and validation steps to ensure that the structure performs as expected, including a thorough evaluation of key parameters such as reaction rate, selectivity, and product distribution. With the synergistic application of electron-beam welding in pellet mold production, precise control and a high degree of reproducibility can be achieved, thus facilitating accurate performance testing.

5. Conclusion

The application of electron-beam welding in pellet mold production and the combination of the two in the areas of microstructure joining, drug delivery system preparation, micro- and nanostructure preparation, and biomedical device manufacturing were explored in this paper. The integration of electron-beam welding in pellet mold production allows precise drug carrier preparation, customized device manufacturing, precise joining of micron- and nanoscale structures, and high-quality manufacturing of biomedical devices. The emergence of these applications not only enriches research in related fields, but also brings great opportunities for pharmaceutical manufacturing. These technologies will continue to evolve in the future, offering the possibility of solving even more complex problems.

Disclosure statement

The authors declare no conflict of interest.

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