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Advanced molding and processing technology at home and abroad

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Abstract. With the development of industrialization technology, the variety of plastic products has increased and the product application fields have become more and more extensive. People also have higher and higher requests for the quality of plastic products. The traditional molding process has been difficult to meet the requirements of the recent high standards, which promotes the continuous innovation of plastic molding technology, and advanced molding technologies are emerging. This paper introduces several advanced technologies of molding processing at home and abroad and provide an outlook of the development prospects of technology in this field.

1. Introduction

With the development of industrialization technology, the variety of plastic products has increased and the product application fields have become more and more extensive. People also have higher and higher requests for the quality of plastic products. This undoubtedly puts higher demands on technical personnel. The traditional molding process has been difficult to meet the requirements of the recent high standards, which promotes the continuous innovation of plastic molding technology, and advanced molding technologies are also emerging. In this paper, several advanced technologies were introduced for molding and processing at home and abroad.

2. Electromagnetic dynamic processing technology

Polymer electromagnetic dynamic forming processing technology is a new type of polymer molding processing technology invented by Professor Jinping Qu from South China University of Technology in the 1980s. Prof. Jinping Qu began with the method of energy conversion and introduced the mechanical vibration field induced by the electromagnetic field into the whole process of polymer plastic extrusion. He proposed new concepts and principles such as polymer dynamic plasticating extrusion, direct electromagnetic energy transformation, and mechanical structure integration. And he invented and successfully developed the plastics electromagnetic dynamic plasticating extrusion equipment. This new type of extrusion equipment fundamentally overcomes a series of shortcomings such as large size, high energy consumption, large noise, and difficult to improve product quality. This equipment integrates mechanical, electronic, electromagnetic technologies. It uses a direct electromagnetic energy conversion method to introduce the vibration field induced by the electromagnetic field into the entire process of polymer plasticating extrusion and transform the traditional steady molding into a controllable cyclical dynamic molding. Compared with the traditional screw plastic extruder, the new equipment has the following significant advantages:

1：The energy consumption of the new equipment is reduced by 30% - 50%. Because the new equipment utilizes advanced and efficient energy conversion methods, and it eliminates the intermediate links of energy transfer of traditional equipment, so that the effective use of energy is greatly improved.

2：The volume and quality of the new equipment are reduced by 60%. The new equipment adopts a new mechanical structure that integrates machine, electricity and magnetism, which makes the structure of the whole machine compact, thereby greatly reducing the volume and quality.

3：The cost of machinery manufacturing for new equipment is reduced by 50%. The new equipment has a simple structure, no large length-to-diameter ratio of the screw, barrel, and no complicated transmission system, thus manufacturing costs were significantly reduced.

4：The noise of the new equipment dropped below 77dB. The new equipment adopts advanced energy conversion methods and advanced mechanical structures, thereby significantly reducing noise.

5：The new equipment has a good effect of plasticizing and mixing, and the quality of its extruded products is high. The new equipment adopts a planetary suspension moving body and vibration field to strengthen the mixing and plastification of plastics, and it introduces the vibration field into the entire extrusion system, and various unstable disturbance factors are modulated, which greatly improves the plasticization quality and improves the stability of the extruding process, while allowing the polymer to be self-reinforcing, significantly increases the quality of the extruded product.

6：The new equipment has a wide adaptability to plastics, and it can adapt to the processing of most different types of thermoplastic plastics without replacing machine parts. The use of highly efficient mixing and plasticizing units enhances the effect of the vibration field on plastic extrusion.

On the basis of plastics electrodynamic plasticating extrusion equipment, Qu Jinping introduced the electromagnetic-induced mechanical vibration force field into the entire process of polymer plasticization metering, injection molding and holding, and he also invented a method and device for electromagnetic polymer dynamic injection molding and developed a successful plastics dynamic injection molding machine. The working principle of the electromagnetic dynamic injection molding machine is to use the electromagnetic winding to generate the vibration field and apply the vibration to the injection screw so that the screw superimposes a pulsation on the basis of the original uniform motion, and then the vibration field is controlled to be introduced into the entire process of the plastic melting, plasticizing, injection and pressure maintenance. Compared with the traditional screw reciprocating injection molding machine, this new device has the following significant advantages:

1：The energy consumption of this new device is reduced by more than 50%.

2：The volume and quality of this new device have been reduced by more than 30%.

3：The noise of this new device dropped below 78dB, and it has no oil pollution, greatly optimized the work environment of workers, and improved labour productivity.

4：This new type of equipment has a high quality of molded products and has wide adaptability to materials. Because the plasticizing effect is good under the vibration field, the fluidity has been improved, the injection pressure is reduced, and the clamping force is reduced. This not only reduces the mold clamping mechanism, but also reduces the internal stress of the product to improve the product quality and improve the product size accuracy.

In summary, plastics electromagnetic dynamic plasticating extruder and plastics electromagnetic dynamic plasticating injection molding machine are the latest technological achievements in the field of polymer molding processing, representing the latest research progress of extrusion molding and injection molding technology, respectively. A major breakthrough in the processing industry is at the leading international level.

3. Gas-assisted injection molding technology

Gas-assisted injection molding is one of the most important developments in injection molding technology since the introduction of reciprocating screw injection molding machines. It produces a hollow cross section through the high-pressure gas inside the injection-molded part and uses the gas to keep the pressure, reduces the residual internal stress of the product, eliminates the surface sink marks of the product, reduces the use of materials, and shows the complete filling process that is unmatched by traditional injection molding. The process of gas-assisted injection mainly includes three stages: the initial stage is melt injection, and the plastic melt is injected into the cavity, which is the same as conventional injection molding, but the melt only fills 60% -95% of the cavity. The injection volume varies from product to product. The second stage is gas injection. The high pressure inert gas is injected into the melt core. The melt front continues to flow forward under the pressure of the gas until it fills the entire cavity. Melt flow distance significantly shortened and melt injection pressure can be greatly reduced during gas-assisted injection molding. Gas can enter the part through the gas injection element from the main flow path or directly from the cavity. Because gas has the characteristic of always choosing the minimum resistance (high temperature, low viscosity) in the direction of penetration, it is necessary to design gas passages in the mold. The third stage is to maintain the pressure of the gas, so that the part is cooled under the condition of maintaining the gas pressure, and the isotropic pressure transmission characteristics of the gas is further utilized to uniformly press outward inside the workpiece and supplement the volumetric shrinkage caused by the melt cooling solidification through the gas expansion(secondary penetration), ensuring that the outer surface of the product is in close contact with the mold wall.

Gas-assisted injection molding technology can be traced back to 1971, when Americans tried injection molding to create thick hollow heels but ended in failure. Later in 1983, the British derived "Cinpres" to control the internal pressure forming process from the structural foaming manufacturing room decoration materials, namely the gas-assisted injection molding process. The process was quickly accepted by the people as a new process after it was exhibited at the 1986 German International Plastics Machinery Exhibition, and it was called the future technology of the plastics processing industry.

Gas-assisted technology has made injection molding possible for many parts that could not be injection-molded with traditional techniques. It has been widely used in almost all plastic parts of automobiles, home appliances, furniture, electronics, daily necessities, office automation equipment, and building materials. and as a challenging new process opens up entirely new applications for plastic molding. At present, gas-assisted technology is particularly suitable for injection molding products in the following fields:

Tubular, rod-shaped injection products: such as handles, hooks, chair armrests, shower heads, etc. The use of a hollow structure can significantly save raw materials and shorten the cooling time and production cycle without affecting the function and performance of the product.

Large flat injection molding products: such as automotive dashboards, interior grilles, commercial machine enclosures, and parabolic health antennas. By providing a built-in air passage in the product, the rigidity and surface quality of the product can be significantly improved, warpage and surface depression can be reduced, and the clamping force can be greatly reduced, so that a larger manufacture can be formed on a smaller machine.

Thick and thin-walled in one-body complex injection molding products: such as product shells of televisions, computer, printers, and internal support and exterior trims. This kind of products cannot be molded once by traditional injection molding process. The use of gas-assisted technology can increase the freedom of mold design and facilitate the integration of accessories. For example, the number of the internal support and external trim parts for Panasonic 29-inch TV shells, which are from conventional injection molding, has reduced from 17 to 8, which can significantly reduce the assembly time.

Gas-assisted equipment and processes are easy to mate with traditional injection molding. Gas-assisted injection molding equipment mainly consists of nitrogen preparation and recovery devices and air pressure control units. After the nitrogen from the preparation device is pressurized, it passes through the control unit and enters the mold. After the pressure maintaining phase is over, the high-pressure nitrogen gas held in the gas-assisted product will also be recovered by the control unit and recycled. The function of gas injection and recovery on the mold is achieved by an air inlet element called a gas needle. The injection molding machine is connected to the gas pressure control unit through a displacement sensor connected to the screw stroke to control the melt-gas injection conversion time.

The gas-assisted technology successfully produced thick-walled and partial-wall products by hollowing out the thick walls, and the products have excellent surface appearance, low internal stress, light weight, and high strength. Therefore, gas-assisted injection molding is an extension of traditional injection molding technology. It is a breakthrough in traditional structural foam molding. It is a novel and advanced plastic molding technology and has huge technical advantages. It can be expected that gas-assisted injection technology will become a new industrial technology that are widely used in plastics processing field in the 21st century.

4. Water assisted injection molding technology

Similar with the gas-assisted injection process, water-assisted injection molding can be used to produce hollow parts with complex shapes and large diameters, which has a good aesthetic effect. In water-assisted injection molding, the temperature at which water is used depends on the part and the material, typically between 10-80°C, and replaces the melt in the absence of water evaporation. Compared with gas-assisted injection, the wall thickness and cooling time of plastic parts in this process can be reduced by 75%.

Water-assisted molding is limited in its application due to its difficulty in adapting to high temperatures, the use of pressurized water, and the fear of air bubble effects. However, the German Institute of Plastics Processing (IKV) in Aachen has overcome these shortcomings. Their new technology can use water injection molding rod or tubular hollow parts, one or more hydraulic pumps to inject water into the melt, through the replacement of the material into the mold or the center of the melt has begun to fill the cavity. Injected in such a way that the water does not evaporate, the front of the water acts like a displacement plunger on the melting core of the part, and the transition from the front of the water to the melt solidifies a very plastic film. It is like a high viscosity core that further drives the polymer melt. The water then flows through the already formed hollow body and finally the water is pressed out of the part by means of compressed air. Through a storage tank, the water can be recycled. Compared with gas, water provides better cooling effect, so that the cooling and circulation time can be shortened much more. The injection is so fast that the polymer melt does not have hydrolytic degradation.

5. Microcellular foam injection molding technology

Microcellular foam (MCF) refers to a foam having a pore diameter of 0.1 to 10.0 μm, a micropore density of 10^9 to 10^{15} pores/cm^3, and a density reduction of 20 to 40%. MCFs based on thermoplastics are called thermoplastic microcellular foams, and MCFs based on thermosets are called thermoset microcellular foams. At present, there are many researches on thermoplastic microcellular foams, common types are styrene resin (PS, SAN), polyvinyl chloride (PVC), polyethylene (PE), polybutadiene (PB), polypropylene (PP), polycarbonate (PC), Polyester (PBT, PET), etc. The experimental results show that microcellular foams have better mechanical properties than ordinary foams. Compared with non-foamed plastics, microcellular foams are distinguished by their excellent impact toughness (which can be up to 5 times that of solid plastics). High rigidity (which can be up to 3 to 5 times the solid plastic), high fatigue life (which can be up to 5 times greater than solid plastic), high stability, low dielectric constant and thermal conductivity. Most properties of thermoplastic MCF have exceeded the corresponding physical engineering plastics. With a higher price/performance ratio, it has great application prospects.

Microcellular foam molding and application is based on the concept and preparation method of microcellular foam proposed by the Massachusetts Institute of Technology (MIT) in the 1990s. There are two main design ideas:

(1) When the size of the foam pores in the foam is smaller than the defects in the material, the presence of the foam pores will not reduce the strength of the material.

(2) Due to the presence of micropores, the original crack tip in the material is passivated, which helps to prevent cracks from expanding under stress, thereby improving the mechanical properties of the plastic.

Microcellular foam injection molding technology is different from traditional plastic foaming technology in that it does not require chemical foaming agents, nor does it use hydrocarbon-based physical catalysts, foaming agents, and other related reactive components. The microcellular foam injection molding technology known for the gas chamber foaming method utilizes the state of the gas supercritical fluid to generate tiny pores of uniform distribution and uniform size throughout the polymer (according to different materials and applications of the polymer, the foam is usually 5-10 μm in size). The rational use of microcellular foam injection molding technology can expand the product structure, increase production efficiency, reduce production costs, and make plastics more widely used in the national economy and people's livelihood.

The products produced by this technology have the following characteristics: (1) it can reduce the weight, sometimes up to 50%; (2) it can shorten the production cycle, and can be shortened by 50% compared with ordinary foam molding methods; (3) it can save energy, due to the reduction of material viscosity and the weight during product processing the amount of material to be plasticized has been greatly reduced , thus reducing energy consumption by 36%.

The disadvantage of this technique is that the surface of the product is not perfect, but it can be compensated by the pre-melting technology to obtain a product with a smooth surface and foamed core.

Today's microcellular foam injection molding technology has the potential to reduce waste by saving materials, shortening production cycles and improving dimensional stability and precision, thereby greatly reducing overall production costs and has great potential. Although more understanding of the applicability of microcellular foam injection molding technology is needed, the benefits brought by this technology are obvious to all.

6. Blow molding technology

Blow molding is a method of forming a hollow part by inserting a softened or molten thermoplastic parison into the inner cavity of a cold metal mold and inflating the parison against the wall of the cavity until it reaches the plastic. The parison retains the shape of the metal mold, and then it demolds and trims the formed part to remove flash or trim. Although most polymers can be molded by various blow molding methods, the proportion of PE is large. Blow molding technology has become a unique process that produces very complex, irregularly shaped hollow parts. Due to the relatively low inflation pressure (0.2 to 1.0 MPa), cast aluminum molds can be used, which is less expensive than conventional injection molding.

Blow molding is an important and fast-growing plastics molding method, and it has entered the industrial parts market that was considered unlikely 10 years ago, such as automotive parts (dashboards, etc.), home appliance parts, building parts and medical applications. The blow-molding equipment has a low price (which is about 1/3 to 1/2 of injection molding), low energy consumption (in the injection molding, the pressure in the mold cavity is generally lower than 1Mpa), and the adaptability is strong (the complex structure and double arm parts can be formed), which make up for the lack of injection molding, molded industrial parts have a high degree of integrity, good overall performance, high added value, and low cost.

Extrusion blow molding is one of the main molding methods for hollow plastic parts production. It is suitable for PE, PP, PVC, thermoplastic engineering plastics, thermoplastic elastomers and other polymers and various blends, mainly used for molding packaging containers, storage tanks and vats , industrial parts such as the automotive industry as well. Like other plastic hollow molding the main advantages of extrusion blowing molding are low product cost, simple process, and high efficiency, but its outstanding disadvantage is that the wall thickness and uniformity of the product are not easy to control.

The various properties and dimensions of extrusion blow molded articles are closely related to the thermomechanical process experienced by plastics at various stages of the blow molding process, including parison molding, parison inflation, and product cooling. Professor Huang Hanxiong of the Department of Industrial Equipment and Control Engineering at South China University of Technology has used different methods to study the three-stage mechanism of plastic extrusion blow molding. His research has important significance for the optimization of process and mold structure and improvement of production efficiency.

7. Conclusion

Today is an era of synthetic materials represented by plastics. Plastic products are everywhere, and it can be said that we are surviving in the "plastic world". With the development of science and technology, plastic molding and processing technology will continue to be more sophisticated, automated, energy-saving, and unmanned, which will further improve the performance of various products, reduce manufacturing costs, and expand its application area.

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