RESEARCH ARTICLE

Application of computer simulation in the optimization of plastics processing technology

Morton Veblen, Benjamin Ferdinand

(Department of Civil and Environmental Engineering, Western University, Evanston, USA)

Abstract: The application of proportional integral derivative (PID) and computer aided engineering (CAE) in the optimization and control of plastic processing technology is reviewed. PID method can be used to adjust and optimize the processing technology by stages, so as to obtain the processing technology with good dynamic and steady-state characteristics, and then improve the quality of plastic products. The CAE method is mainly used in the processing of thin-walled products. Through the scientific selection of materials, the rational design of the structure and the effective optimization of the process, the probability and extent of defects in plastic products can be reduced. In the process of process optimization, the use of computer simulation is a highly efficient, reliable and scientific method due to the huge workload.

Keywords: Plastic products; proportional integral differential method; computer aided engineering technology; process optimization; processing defect

Polymer materials have excellent dimensional stability, weather resistance, chemical corrosion resistance, etc. Some specialty polymer materials also have excellent dielectric properties, optical properties, flame retardancy, etc.[1–5]. For example, conjugated polymer materials have excellent electrical conductivity, polyurethanes and phenolic resins have excellent thermal insulation properties, and ultrahigh molecular weight polyethylenes are used in body armor because of their high strength. Due to the simple processing and low cost of polymer materials, they are widely used in civil, military, medical, aerospace and other equipment. In addition, in recent years, with the rise of technologies such as spraying and three-dimensional printing, the application of polymer materials has been further promoted[6–10]. At present, in the production and life, the most widely used polymer materials are thermoplastic polymer materials, such as polypropylene, polyethylene, polyvinyl chloride and so on. The main processing methods of these polymer materials are injection molding.

Injection molding is the use of injection molding machine to heat polymer raw materials to its melting point above, and then inject polymer melt into the mold, after the polymer melt cooling molding can be obtained products. During the processing, the material preheating temperature, melt temperature, injection pressure, injection time, packing time, packing pressure, cooling temperature and other factors have an unpredictable impact on the quality of products[11–15]. In traditional machining methods, only a large number of parallel experiments and operation experience can confirm the processing parameters, not only the process is cumbersome, but also the processing cost is high. Computer simulation is needed and developed rapidly, which makes up for the shortage of traditional methods. Computer simulation technology includes molecular design, engineering design and manufacturing. The commonly used software are Moldflow, MATLAB, etc. The commonly used methods are density functional theory, Monte Carlo method, fuzzy proportional integral differentiation (PID) method and so on. Combining with molecular mechanics, quantum mechanics, rheology

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and so on, it can meet the requirements of macro-processing and molding of polymer materials, and is widely used in the development of new materials, molecular design and simulation, product model design, product structure and performance optimization, auxiliary control of the whole process of material processing and so on[16–20]. This paper mainly introduces the influence of various processing parameters on the quality of plastic products during the injection molding process of thermoplastic polymer materials, and discusses the application of computer simulation technology in this field.

1. Optimization and regulation of processing technology by PID method

In the injection molding process of thermoplastic polymer materials, the temperature of the cylinder is too low, the polymer melt cannot flow sufficiently, and the internal stress cannot be released in time, causing defects such as bubbles, micropores, cracks and warpage of the plastic products; however, If the temperature is too high, the polymer melt is easily decomposed or scorched, and rapidly shrinks upon cooling, resulting in an unsatisfactory product size and warpage deformation. Using computer simulation technology, the injection molding process parameters can be simulated, adjusted and optimized to prevent overshoot and oscillation in actual production, and the best processing technology can be obtained to improve the quality of plastic products. PID is a common method. Wang Pingjiang *et al*.[21] simulated the barrel heating process of Huazhong 8 NC all-electric injection molding machine by using fuzzy PID method and a variety of computer simulation techniques. It is found that when the final temperature of the barrel is 190.00 C and the heating time is 800 s, the heating process is more stable, and there is no scouring phenomenon. After the heating, the temperature of the barrel can be stabilized at 190.00 C and no temperature oscillation occurs within 2 200 s. In actual production, even if the barrel structure is different and different materials have different thermodynamic characteristics, and there are environmental factors, the simulation results are only ±1.50 ° C. The temperature of the control cylinder was 190.00 ° C, and the polypropylene product produced did not show any obvious defects. Because the influence of barrel temperature on different polymer materials and even the same raw material from different producing areas is different, many computer simulation methods can be used to optimize the process more accurately and improve the reliability and authenticity of the simulation results.

Tao Ximeng *et al*.[22] also simulated the barrel temperature of the injection molding machine. The barrel of the injection molding machine was divided into 3-6 heating sections with different set temperatures by using piecewise fuzzy PID method. The simulation results show that the simulation error of piecewise fuzzy PID method is as low as 0.19 C when the barrel temperature is set to 280.00 C, while the steady-state error of ordinary PID control is as high as 5.80 C. When the temperature is set to 380.00 C, the simulation error of piecewise fuzzy PID method is only 1.13 C. This shows that the piecewise fuzzy PID method has more accurate dynamic and steady-state characteristics, and can be used in many kinds of polymer injection molding. In the actual production, it is often necessary to mix raw materials for processing. Zhou Xien *et al*.[23] designed a kind of fuzzy PID method with self-adaptive characteristics, which can be used to simulate the barrel temperature of mixed-color material processing. The results show that the fuzzy PID method with adaptive characteristics is excellent in stability. When the set temperature is 160 ° C, the overshoot phenomenon in the heating process is lower than 20 ° C, the temperature response time is less than 150 s, and the temperature is kept. There is no turbulence in the temperature during the process, which fully meets the requirements of the injection molding process for the mixing of mixed materials in actual production. In addition to the properties of the raw materials themselves, the injection molding machine barrel structure and artificial factors are two other major factors affecting the accuracy of temperature control. Luo Fan *et al*[24] designed a self-tuning fuzzy PID method for these factors. It is found that the temperature overshoot, heating time and steady state error of any heating section are reduced by 1.00 ° C, 8 min, 0.10 ° C, respectively, compared with the conventional fuzzy PID method. This shows that the designed self-tuning fuzzy PID method has very important guiding significance in the control of plastic injection molding process.

In addition to the barrel temperature, injection pressure, injection rate, holding pressure and holding time during injection molding also have a significant effect on the quality of plastic products. Higher injection pressure and injection rate will accelerate the flow rate of polymer melt, so that polymer melt can not release internal stress in time, resulting in defects in plastic products; too low injection pressure and injection rate may lead to insufficient filling in the injection process, thereby affecting the quality of plastic products. Therefore, the appropriate packing pressure and holding time can ensure the dimensional accuracy of plastic products[25]. The electro-hydraulic system of injection molding machine is a system to control injection pressure and packing pressure. Peng Hua[26] simulated the electro-hydraulic system of MA900 injection molding machine by fuzzy PID method. It was found that when the injection pressure was 6 MPa and divided into 5 stages, the pressure of 1 s and 5 stages were 2,4,6,4,2 MPa respectively, the insufficient pressure in the injection process could be effectively avoided and the process overshoot could be avoided. The optimized injection process is applied to the actual production of disc plastic products. The quality error of the products can be controlled to 0.04 g and so on[27]. The injection rate of plastic injection molding is simulated by fuzzy PID method and traditional PID method respectively. The results show that when the injection rate is 1.0~2.5 m/s, the overshoot of the traditional PID method is serious, and there is obvious oscillation after reaching the steady state. In contrast, the response process of the fuzzy PID method does not have an overshoot phenomenon, and there is no oscillation after reaching the steady state. In addition, the heating process, sol and gelling process also affect the quality of plastic products to some extent[28]. Cui Zhenhua[29] used the predictive compensation fuzzy PID method to simulate the related processes of the injection molding equipment and the injection system. The results show that the dynamic characteristics and steady-state characteristics of the proposed compensated fuzzy PID method are superior to the traditional PID method, and the best injection curve and molding process in the injection molding process are obtained through computer simulation.

In summary, the PID method has a fast response rate and excellent dynamic and steady-state characteristics for the process control, and can optimize the processing technology to find the best processing technology and reduce the dimensional error of plastic products. To avoid quality defects; moreover, the PID method can be used to obtain overshoot phenomenon and less oscillating processing technology, which can guide the actual production.

2. Application of Computer Aided Engineering (CAE) technology in process optimization

The PID method regulates and optimizes the machining process, while the CAE technology performs detailed simulation of the machining process to further optimize the machining process. There are many factors affecting the quality of plastic products, and manual screening is a heavy workload. Using CAE technology can greatly simplify the process optimization, improve efficiency and reduce costs. Moreover, the accuracy of CAE technology is much higher than manual screening, and it is often used to optimize the processing technology of thin-walled plastic products. Polypropylene has excellent flowability, and the shrinkage of polypropylene products is usually low because of its crystallization characteristics. In addition, polypropylene has excellent dimensional stability, weatherability, chemical stability and mechanical properties, and is often used in the production of thin-walled products. Pan Xiu Shi *et al*[30] used polypropylene as raw material to process the motor cover plate with a wall thickness of 2 mm, and used CAE technology to simulate the cooling system and injection molding process of the product processing, and obtained an optimized processing technology. When applied to actual production, the dimensional shrinkage of the polypropylene thin-wall engine cover is only 1.0%~2.5%. Shen Honglei *et al*.[31] used CAE technology to simulate the processing parameters of washing machine panels made of polyolefin or polyester. It has been found that the needle valve nozzle can meet the requirements of holding pressure and holding time at different parts of the product at the same time, and can prepare products with less warpage deformation and fewer weld lines. In addition, in the process of simulating the processing technology by CAE technology, each process can be optimized to guide the actual production. Most of the auto parts are polypropylene thin-walled products, such as the car rear-view mirror cover, which is a relatively common plastic thin-walled product. Shen Xiaowei[32] analyzed the shape, structure and size of the rearview mirror cover of the automobile, and used CAE technology to simulate and optimize the processing technology of the plastic products, and processed the products. The results show that CAE technology is an effective means to improve the processing efficiency and processing accuracy of thin-walled products. The automotive interior is also a thin-walled polypropylene product, which will be warped and deformed due to improper process selection during processing. Fan Yabo[33] used CAE technology to simulate the machining process of automotive interior trim panels and established a mapping model between process parameters, warpage deformation and shrinkage index. By optimizing the injection temperature, injection rate, mold temperature, holding pressure and holding time, and optimizing the process for product production, the warpage deformation of plastic products is reduced from 5.828 mm to 5.306 mm. The trace index decreased from 3.906% to 3.221%. In recent years, the development of automobile lightweight is becoming more and more prosperous, so the processing technology of full-plastic body is also increasingly demanding. Qinliu *et al*.[34] take polyethylene / ultra-light fiber composite foam material as raw material, simulate the structure of full-plastic automobile body by CAE technology, design the model structure and select the molding method, and process the full-plastic automobile body by rotational molding technology. Through the optimization of the temperature and the simplification of the processing, the optimal processing technology is obtained, so that the heating time is reduced from 20 min before the optimization to 12 min, and the temperature distribution error is only 5%~10%. After the actual production, a polyethylene plastic body product with dimensional stability and mechanical properties meeting the requirements of use is obtained. In addition to polyolefins, acrylonitrile-butadiene-styrene terpolymers (ABS) are also commonly used for injection molding of thin-walled articles. Zhang Youhong[35] combined with the thermodynamic characteristics of ABS, using CAE technology to simulate and optimize the injection molding process of ABS mobile phone casing. It is found that the warpage deformation of the product can be reduced to 0.297 mm when the barrel temperature is 230 degrees. Wang Wei[36] used ABS as raw material to prepare 0.500 mm thick plastic blade. The CAE technology was used to simulate the machining process. It was found that compared with the traditional process optimization process, the optimization cycle of CAE technology was shorter, the machining error was smaller, and the product quality was higher. Yin Xiaoding[37] used CAE technology to optimize the processing technology of ABS control panel, thus designed a reasonable pouring system and cooling system. When the dimension of the product is 170.00 mm *90.60 mm *46.64 mm and the thickness is 2.20 mm, the shrinkage rate of the product prepared by the optimized process is as low as 0.5%. Wang Lei *et al*.[38] The production process of ABS telephone shell was optimized by CAE technology. Through optimization and Simulation of pouring system, cooling system and molding process, the ABS telephone shell with wall thickness of 2.00 mm and surface roughness of 0.8 micron was prepared. The product accuracy grade is 4. Compared with the traditional optimization process, the production cycle optimized by CAE technology is shorter, the production cost is lower, and the optimized process precision is higher. The products with fewer defects can be obtained when used in the production of plastic products.

3. Conclusion

Adopting PID method to adjust and optimize the processing technology can effectively improve the dynamic and steady-state characteristics of each process in the process, and produce the products with the required quality. CAE technology is mainly used to optimize the process of thin-walled products. The optimized process is applied to the processing of products. The products with high dimensional accuracy, low warpage deformation and shrinkage index, and less weld lines can be obtained. In the process of process optimization, because most of the process parameters have a significant impact on the quality of products, the process can be effectively simplified by computer simulation, and the reliability and scientificity of computer simulation are proved by examples, which not only improves the production efficiency, reduces the production cost, but also reduces the production cost. With the optimized processing technology, the processing quality of the products can also be effectively improved.

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