At this stage, the varieties and specifications of aluminum profiles continue to increase, and the scope of application continues to expand. The extrusion forming process is the key technology to realize the production of aluminum profiles, and its technological level determines the quality of the profile products and the service life of the mold. However, in actual production, the quality of the die is difficult to guarantee, and it takes multiple die trials and die repairs to produce qualified products. The numerical simulation technology is used to simulate the actual extrusion process, which can track and describe the flow behavior of the metal in real time, reveal the real flow law of the metal, predict the possible defects of the profile during the extrusion process, and adjust the mold structure and process parameters in time. It can not only improve the quality of extruded profiles, but also reduce production costs and shorten the mold production cycle. Based on this, this paper established an extrusion die optimization design model integrating finite element simulation technology and artificial intelligence algorithm. The prediction models were established with the mean square deviation of the section velocity, the maximum extrusion force and the maximum temperature of the section, respectively, and the optimal design of the structure was realized by using the particle swarm algorithm. The experimental results show that the model in this paper can realize the function well, which verifies the validity of the model.

1. Introduction

Due to the advantages of light weight, high strength, good corrosion resistance, good electrical and thermal conductivity, beautiful appearance, good sealing, easy recovery, etc., aluminum table residual profile products have been widely used in petrochemical, machinery manufacturing, household appliances, vehicles, ships, aircraft, communications, and other fields [1]. In recent years, the demand for aluminum has been increasing year by year. All countries in the world also focus on aluminum alloy (AA) and its production and LK, and its development speed is much higher than other metal materials. At present, there are more than 1000 large enterprises engaged in aluminum extrusion (AEx) in China, and the annual consumption of more than 400,000 sets of molds [2]. For AEx, the design of die structure and process parameters is an important link to ensure product quality and reduce the cutting when put into production.

Although China’s aluminum profile processing industry is developing rapidly, the design of the determination of process parameters still relies on analogy and design experience. The die quality is difficult to ensure. It needs many die tests and repairs to produce qualified products [3]. This production mode leads to the problems of low production efficiency and poor product quality in Aluminum processing enterprises in China, and there is still a big gap between China and the world’s leading aluminum producers [4]. Therefore, improving the traditional mold design method,
using scientific theory to guide production practice, improving mold development speed, saving development cost and improving product quality has become an urgent demand for the development of aluminum profile industry [5]. AA profile extrusion process is a metal material forming process that puts AA ingot into the die cavity of special extrusion die and forces AA to extrude from the die hole under the strong pressure and certain speed of extruder, so as to obtain AA profile with required shape and certain mechanical properties [6]. Its forming principle is shown in Figure 1.

According to the stress of the metal in the extrusion cylinder and mold cavity, the different strain state, metal flow direction, lubrication state, extrusion temperature, extrusion speed and the structure of the equipment, the type or structure of the mold and the shape and number of the blank, the shape or number of the product, extrusion forming can be divided into different types. AEx forming process has the following characteristics [7]. In the process of extrusion forming, the extruded metal material can obtain more intense and uniform triaxial compressive stress state in the deformation zone than that of rolling or forging, so that the plasticity of the processed metal can be fully played [8]. Extrusion method can not only production profile is a simple type tubes, rods, and wire products, but also can produce other pressure processing method is difficult to produce changes in cross section and shape complex profiles and pipes, such as phase variable cross section profiles, with special-shaped whole wall material and shape of the strengthening rib extremely complex and variable cross section pipe material, porous pipes and hollow profile [9]. The products produced by extrusion are of high precision and good surface quality. This not only greatly reduces the total workload and simplifies the follow-up process but also improves the comprehensive utilization rate and yield of extruded metal materials [10].

If the extrusion ratio is too large or too small, the uniformity of metal flow will deteriorate. Excessive flow of metal also increases the inhomogeneity of metal flow. During extrusion forming, the more uniform the temperature on the cross section of the ingot, the more uniform the material flow during extrusion [11]. Based on this, this paper gives an innovation concept of extrusion optimization model.

The motive of our paper is described as: this paper introduces an extrusion die optimization design model integrating finite element simulation technology and artificial intelligence algorithm. The prediction models were established with the mean square deviation of the section velocity, the maximum extrusion force and the maximum temperature of the section, respectively, and the optimal design of the structure was realized by using the particle swarm algorithm.

The remaining paper is assembled as follows. Section 1 introduced the paper. Section 2 thoroughly explain all the work related to our research. In section 3, establish the evaluation model to analyze the artificial intelligence extrusion. Section 4 explains the experiments with experimental results. Section 5 concludes the paper.

2. Related Work

In this portion, firstly all the existing problems of AEx technology is well-explained. Earlier scholar used numerical and experimental research methods for AEx. After this, explain all the method used in flow of numerical simulation. Last section of this portion, describes the research method for extrusion of AA profiles and discuss the results.

2.1. Research Status and Existing Problems of AEx Technology

In recent years, numerical simulation and experimental research methods have been used by many scholars to systematically study the AEx process, and great progress has been made. It mainly includes the research on the influence of structure parameters and process parameters of AEx die on extrusion process, the research on the optimization design method of extrusion die and the research on the extrusion process of complex large section aluminum. Extrusion die is the key equipment of AEx forming, its design and manufacture is reasonable to achieve high efficiency, high quality, low consumption of one of the important guarantees.

Fang et al. studied the influence of the guide chamber series on the metal flow, temperature distribution and extrusion pressure in the whole extrusion process by taking the extrusion die with double die holes as an example, carried out experimental verification [12]. Donati et al. took AA6082 AA profile as an example and studied the influence of welding chamber height and guide plate shape on weld quality by experimental method [13]. Wu et al. used Super Forge software to study the metal flow law in the extrusion process of rectangular hollow pipe. Through comparative analysis results, it was found that the main factors affecting the end face flattening of rectangular hollow pipe extruded parts were the shape and size of shunt hole and the path shape of shunt hole entrance to work belt [14]. Mehta et al. conducted a simulation analysis of twelve different die structures of shaped profiles by using the finite volume method, found that the profiles produced by diversion die had better surface quality [15]. Extrusion process parameters mainly include extrusion ratio, extrusion speed and extrusion temperature, mainly related to equipment capacity, extrusion method, alloy type, product specifications and other factors. Bastani et al. used Hyper Xtrude analysis software based on ALE algorithm to study the influence of extrusion process parameters on material flow and temperature distribution in the extrusion process [16]. Yan et al.
2.2. Methods to Describe Fluid Motion in Numerical Simulation. AA at high temperature can be regarded as a viscous incompressible non-Newtonian fluid. At present, the methods to describe fluid motion mainly include Lagrange description method, Euler description method.

In Lagrange method [19, 20], the calculation grid is fixed on the object and moves with the object, that is, the grid points and material points always coincide in the deformation process, so there is no relative motion between material points and grid points. In 2003, Yan used the Lagrangian description method to numerically analyze the double die hole extrusion process, compared it with the single die hole extrusion process. It was found that when using the double die hole die for extrusion production, there are two opposite eddy current fields in the deformation body, which offset each other, which is conducive to improving the quality of profile products [21]. However, when the Lagrange method is used to analyze the extrusion problem with large deformation, the element is prone to produce distortion, which requires frequent mesh redrawing, resulting in large volume loss and seriously affecting the calculation accuracy. At the same time, because the self-contact problem of material element is difficult to solve, the rigid symmetry plane is needed to simulate the shunt welding process of hollow profiles.

In Euler's description, we do not treat a single particle as the object, but study the functional relationship of fluid velocity, acceleration or thermodynamic parameters with time at some points in space [22, 23]. Euler grid is fixed, avoiding the redivision of the grid, especially suitable for large deformation process. Zhou et al. [24] studied the extrusion forming of AA door and window profiles by using Euler description method, obtained the distribution of physical field quantities such as equivalent strain, temperature and speed at each stage and the variation of die load/stroke curve during the whole forming process. However, when Euler method is used to simulate the extrusion process of aluminum profile, it is necessary to use complex mathematical mapping to describe the movement of free surface and grid the area that material may flow through, which occupies a lot of computer memory, especially when analyzing thin-wall, hollow, and complex section profiles, the calculation time is unacceptable.

2.3. Research Method for Extrusion Process of AA Profiles. Numerical simulation method has been widely used in flow analysis, temperature field simulation, die strength calculation, friction and lubrication analysis of AEx process. Numerical simulation methods are mainly divided into finite element method, finite difference method and finite volume method. Finite difference method is the earliest method used in computer numerical simulation [25]. In this method, the solution domain is divided into a differential grid and the continuous solution domain is replaced by a finite number of nodes. This method is an approximate numerical solution which directly transforms the differential problem into an algebraic problem, but the processing of irregular area is more complicated. The basic idea of finite element method is model discretization and piecewise interpolation. The target solution domain representing continuous medium is discretized into finite element body, and the infinite degrees of freedom are transformed into finite degrees of freedom [26]. For each unit, a function determined by the relevant node quantity is selected to approximate describe its field variables, and the relationship between each physical quantity is established according to certain principles. By integrating the relations established by each unit, the whole problem can be solved and calculated. Finite volume method [27] is also called control volume. In the process of material flow, the governing equations such as mass conservation equation, momentum conservation equation and energy conservation equation must be satisfied.

3. Establishment of Evaluation Model
As an intelligent computing method in the process of development, industrial intelligence technology corresponds to information processing system in biotechnology. In recent years, many scholars at home and abroad in the use of artificial intelligence algorithms of extrusion die structure and process parameters optimization design has made great progress, but most of the current research is aimed at simple solid or symmetry hollow profile of single objective optimization, for asymmetric hollow profile extrusion die rarely make the news research of multiobjective optimization problem. Based on this, this chapter intends to use artificial intelligence algorithm to carry out multiobjective optimization design of shunt combined die respectively, establish the optimization design method for hollow profile extrusion die, so as to provide a reasonable guiding scheme for the design of enterprise extrusion die.

3.1. Basic Principle of Response Surface Method. Response surface method is a statistical method to find the optimal value within a certain range and is often used to solve problems related to nonlinear data processing. Through rational use of response surface method, we can obtain the
significance of variables through the influence of each factor on variables, and also analyze each variable according to the interaction between multiple factors, so as to optimize the response surface. Response surface includes experimental design, modeling, response surface analysis, polynomial function fitting, contour drawing, finding the optimal model and so on. Based on the response value of each factor level, the predicted optimal response value and the corresponding experimental conditions can be found. The response surface method considers the random error of the test. At the same time, the response surface method fits the complex unknown function relationship in a small area with a simple primary or quadratic polynomial model, which is simple and easy to calculate. It is an effective means to solve practical problems. The prediction model obtained is continuous. Compared with the orthogonal experiment, its advantage is that it can continuously analyze all levels of the experiment in the process of optimizing the experimental conditions, while the orthogonal experiment can only analyze isolated experimental points. The detailed flow of response surface method is shown in Figure 2.

The range of factors in response surface design is required to be the optimal range. If the selected experimental range is not appropriate, the response surface analysis will not get good optimization results. Therefore, a reasonable experimental range should be determined through theoretical analysis or a large number of literature before using the response surface method. Through the experiment of advance the reasonable range, response surface design, it is concluded that the different conditions of the experimental data, and response surface analysis was carried out on the experimental data, the fitting equation is obtained by nonlinear fitting method, usually there is interaction between different affecting factors were for quadratic polynomial, a more complex relationship can be used in a higher times polynomial. The response surface cloud image and optimal value can be obtained by fitting the equation. The optimal value obtained at this time is only an optimal result predicted by response surface analysis, which needs to be further verified by experiments. If the experimental result is close to the predicted result, it indicates that the response surface analysis result is good. If it is inconsistent with the experimental result, it needs to improve the factor range for reanalysis.

3.2. Basic Principle of Particle Swarm Optimization.

Particle swarm optimization algorithm is inspired by the foraging behavior of birds. Usually, birds gather, disperse and change their flight trajectory in the process of foraging. However, individuals in the population maintain a certain distance in the process of flight. Therefore, when PSO algorithm simulates the foraging behavior of birds, the flight space of birds can be likened to the search space of the algorithm, and the particles of the population are abstracted from each bird, without mass and size. On the whole, the solving process of optimization problem is like the foraging process of birds. PSO algorithm has been widely concerned by scholars because of its simplicity, few parameters and easy implementation.

PSO is a population-based search algorithm whose basic principles are similar to the foraging behavior of birds. In order to put it simply, suppose a group of birds are looking for food in the air. Although they know how far it is to the food, they can only change their flight path by looking for the bird closest to the food, so that they can find the food faster. In particle swarm optimization algorithm, particles are used to represent individuals in a flock, and fitness value is used to measure the distance between particles and the optimal position. The flow chart of particle swarm optimization algorithm is shown in Figure 3.

Therefore, the definition and process of particle swarm optimization algorithm are described as follows. Assuming that the population size is N and the dimension of its search space is D. In PSO, each particle in the population \( i (1 \leq i \leq 1) \) represents a potential solution, that is, a feasible solution to the problem. Each particle has a velocity and position vector that represents the current state of the particle, namely \( V_i = [v_{i1}, v_{i2}, \ldots, v_{id}] \) and \( X_i = [x_{i1}, x_{i2}, \ldots, x_{id}] \). In the process of population search, PSO will record the historical best position of particles \( P_{best} = [p_{11}, p_{12}, \ldots, p_{id}] \) and the global best position of particles \( G_{best} = [g_{11}, g_{12}, \ldots, g_{id}] \). At each iteration, the velocity and position of particles will be updated, and the update mechanism is shown in formula.

\[
V_{ij}^{t+1} = V_{ij} + c_1 r_1 (p_{best} - X_{ij}) + c_2 r_2 (G_{best} - X_{ij}) X_{ij}^{t+1} = X_{ij}^{t+1} + V_{ij}^{t+1},
\]

(1)

where, \( c_1 \) and \( c_2 \) are called learning factors, which can also be called acceleration constants, representing the learning weights from \( P_{best} \) and \( G_{best} \), respectively. \( r_1 \) and \( r_2 \) are random numbers from 0 to 1. \( t \) is the current iteration. Formula (1) contains three parts. The first part, called inertia, represents a memory of the current updating particle’s speed. The second part is called “self-cognition,” which represents the particle’s memory of its best position in history and the possibility that the particle is close to its best position in history. The third part is called “social cognition,” which reflects the cooperation and information sharing among particles, indicating that particles tend to approach the global optimal position.

Topological structure represents the connection mode between particles in PSO algorithm, and the accuracy and convergence speed of the algorithm will be different due to the different connection mode between particles. Therefore, only by fully learning the characteristics of some common topological structures in the PSO algorithm can we choose a more reasonable topological structure for the algorithm and improve the performance of the algorithm.

(1) Annular structure: it is first generated and is most common in the research of PSO algorithm. Simply put, in this structure, all the particles are connected end to end to form a ring. Each particle has two adjacent particles and exchange information with them, so that information sharing can be realized among particles to ensure the diversity of the population.
(2) Star structure: it has a central particle, and all other particles are connected with the central particle. In a population, information transfer occurs only between the central particle and other particles, and there is no direct communication between particles other than the central particle. Through analysis and research, this structure can improve the information transfer speed between particles and accelerate the convergence speed, which is suitable for the optimization of PSO multimode function.

(3) Von-Neumann structure: compared with ring structure and star structure, this structure is more complex. Its particles are in the form of three-dimensional grid existence, a particle and up, down, left, right four directions of the nearest particles connected together to form a three-dimensional network structure. The algorithm with this structure can not only get sufficient search in each region, but also promote the information exchange between particles and reduce the risk of falling into local optimization.

(4) Four types of topologies: as the name suggests, the structure divides the particles into four equal groups, with the particles in each group exchanging information through pairs of connections, and then exchanging information through the connections
between groups. In this structure, particles can transmit information in a minimum range and be effectively utilized, and then the whole population can share information through information transmission between groups, thus improving efficiency. Shapes of all types of topologies are shown in Figure 4.

(5) Pyramid structure: this structure is a more complex topology. The structure is connected in a hierarchical form, with the outermost particles being each vertex, connected to the four particles in the middle layer, and then connected to the bottom particles in turn. In this structure, the connection mode of particles is more complex. It is precisely because of this complexity that there are more paths for information transmission between particles, and information can be shared more comprehensively. The schematic diagram of the five topologies is shown in Figure 4. The pyramid topology is more complex in its structure rather than others. This topology is used for both software and hardware construction. Here, it is much important for constructing extrusion aluminum alloy model.

The five topological structures mentioned above are applicable to different algorithms due to their different ways of formation. Through our research on particle swarm optimization algorithm, it is found that the ring structure is the most used topological structure among many related PSO improved algorithms.

3.3. Improved Particle Swarm Optimization. In many cases, the direct reason for the slow convergence of the algorithm is that the population cannot effectively maintain the diversity of its search space in the iterative process. If there are forces between the particles, the particles will not gather together in the process of updating because of the guidance of the global optimal particles, so that the diversity of the particles in the search space can be effectively maintained. Through an in-depth research and analysis of PSO algorithm and related improved algorithms, this paper has a new attempt on algorithm update strategy. This paper mainly introduces the idea of two-group model, the measurement of force, the model of ion group optimization algorithm.

The most direct aspect of force between particles in a swarm is to think of each particle as an ion with a unit positive charge or a unit negative charge. In addition, the population is automatically divided into two subgroups due to the different charge of particles. In the process of renewal, the particles are not only affected by attractive or repulsive forces, but also by the optimal particles in the subgroup. Therefore, the speed of the algorithm will be updated according to formulas (2) and (3), and the position update method is shown in formula (4).

\[
V_{i}^{t+1} = c \cdot r \cdot (g_{best}^- - X_i^t) + \alpha \cdot \sum_{j=(N/2)+1}^{N} (X_j^t - X_i^t) - \beta \cdot \sum_{j=1}^{N/2} (X_j^t - X_i^t),
\]

\[
V_{i}^{t+1} = c \cdot r \cdot (g_{best}^+ - X_i^t) + \alpha \cdot \sum_{j=(N/2)+1}^{N} (X_j^t - X_i^t) - \beta \cdot \sum_{j=1}^{N/2} (X_j^t - X_i^t),
\]

where \(g_{best}^-\) is the global optimal position of the subgroup where the particle with positive charge is located, and \(g_{best}^+\) is the global optimal position of the subgroup where the particle with negative charge is located. \(X_j^t\) is an example for the particle currently being updated, that is, a particle with the same or different charge as the particle currently being updated. \(c\) is the weight of the optimal particle in the learning group, \(\alpha\) and \(\beta\) are the weight of the attractive and repulsive forces. The particle velocity update formula consists of three parts. In the first part, the “social cognition” particle will learn from the subgroup with the opposite charge to itself, namely \(g_{best}^- (g_{best}^+)\) as the learning example, the particle will move towards the globally optimal position in the subgroup with the opposite charge to themselves. The second part is called the attractive part, where particles are attracted to particles with different charges and therefore move towards them. The third part is the repulsive part, in which the particle and the particle with the same electrode repel each other, so there is a reverse guiding effect on the particle trajectory.

The size of the attractive or repulsive force between particles will be different depending on the distance between them. In multidimensional space, Euclidean distance is chosen in this paper to calculate the distance between particles, and the size of the force is measured according to its distance \(d = \sqrt{(x_i - x_j)^2}\) is defined as the Euclidean distance between particles.

\[
d = \sqrt{(x_i - x_j)^2},
\]

where, \(x_i\) and \(x_j\) are two particles in the population. Obviously, when \(x_i = x_j\), the Euclidean distance is zero. Assuming that the particle is in a two-dimensional search space, let \(x_i = (x_{i1}, x_{i2})\), \(x_j = (x_{j1}, x_{j2})\), then the Euclidean distance is

\[
d = \sqrt{(x_{i1} - x_{j1})^2 + (x_{i2} - x_{j2})^2},
\]

The calculation method of three-dimensional or even multidimensional is similar to formulas (4) and (5). If the force between particles is defined as \(f\), let \(f = e^{-d}\). According to the decreasing property of this formula, the smaller the distance between particles, the larger the force is. Otherwise, the smaller the force is.
4. Experiments and Results

In this section, taking a multi cavity wall panel profile as an example, the experimental scheme is determined by box Behnken design method with the help of numerical simulation software Hyper Xtrue. Using the response surface method, the second-order response surface model of design variables and evaluation indexes is established, and the shape of shunting hole of extrusion die is optimized combined with particle swarm optimization algorithm.

4.1. Initial Mold Design Scheme. The studied in this section has four cavities, with a cross-sectional area of 2624 mm², a wall thickness of 4 mm, and the maximum width of the entire profile section of 268 mm. Due to the complex cross section shape and large width thickness, it is difficult to ensure that all parts of the metal on the cross section of the profile extrude the die hole at the same speed and required thickness. Figure 5 shows the three-dimensional structure of the hollow material.

Figure 5 shows the three-dimensional model of the upper formwork, with an outer diameter of 500 mm and a height of 135 mm. The upper die is provided with two shunt holes, which are slightly outward inclined to promote metal flow and welding. In addition, in order to balance the metal flow, the middle part of the shunt hole is offset to the extrusion center for a certain distance, so that the width b of the middle part of the shunt hole is less than the width e of the edge part. First of all, SDV of metal velocity mean square deviation on the section at the exit of the die is taken as the first optimization objective to ensure that each particle on the section flows out of the die hole at the same speed. As the second optimization objective selected in this section, extrusion pressure F is the key parameter of selecting extrusion equipment and making process specification in extrusion production. In the extrusion production, increasing the extrusion temperature can effectively reduce the deformation resistance of AA, to improve the production efficiency, but too high temperature is easy to lead to the extrusion products coarse crystal ring, pockmarked surface and other defects. The mesh quantity of the whole model is about 40 months, in which the workpiece material is AA6063 gold, and the mold material is H13 die steel. For each set of design schemes, the 3D model was reconstructed, and HyperXtrude software was used for numerical calculation, and the corresponding sectional velocity mean square was obtained. The specific process parameters used in the simulation are shown in Table 1.

In order to obtain the optimal shunt hole structure, combined with the actual production experience, the specific value range of each variable is shown in Table 2.

4.2. Fitting of Response Surface Model. The response surface method, also known as regression design, takes the regression method as a function estimation tool, approximates the relationship between the factors in the multi factor test and the test results (response value) with polynomials, functions the relationship between the factors and the test results, and can carry out surface analysis on the function in turn to quantitatively analyze the influence of various factors and their interaction on the response value. In this section, the second-order response surface equation is selected to predict the response values under different design variable combinations, and its expression is

\[ y = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_i^2 x_i^2 + \sum_{p < i}^{n} \beta_{pi} x_p x_i + \varepsilon, \]

(5)
where, $x_i$ is design variable, $\varepsilon$ is residual error, $\beta_{0i}, \beta_i, \beta_{ii}, \beta_{pi}$ are all undetermined coefficients. The above three response surface models can be used to predict the velocity mean square error (SDV), maximum extrusion force ($F$) and maximum temperature of profile section under different combinations of design variables. Figure 6 respectively show the comparison between the actual value and the predicted value of different optimization objectives. It can be seen that the predicted value is basically consistent with the simulated result, indicating that the prediction result of the regression model is relatively accurate.

In order to evaluate the reliability of the experimental results and the confidence of the mathematical model, the experimental results need to be tested: one is the variance test, which tests the significance of the influence of various factors and evaluates the reliability of the experimental results; The second is the significance test of the regression equation to test the reliability of the mathematical model. Table 3 shows the analysis results of coefficient of variation of cross section velocity mean square deviation response model of die exit material.

**Table 1: Process parameters used 1 simulation.**

| Diameter | Length | Extrusion ratio | Temperature | Coefficient | Extrusion speed |
|----------|--------|-----------------|-------------|-------------|----------------|
| 280      | 560    | 23.5            | 485         | 3000        | 1              |

**Table 2: Process parameters used 2 simulation.**

| Design parameters | Value range |
|-------------------|-------------|
| Middle part of the shunt hole | 40–90       |
| Circumscribed circle straight | 310–400     |
| Tap hole high     | 90–150      |

**Figure 5:** The three-dimensional structure of the hollow material.

**Figure 6:** Comparison between predicted value and real value.
In order to more intuitively reflect the relationship between design variables and optimization objectives, this section analyzes the influence of shunt hole shape on velocity mean square error, extrusion pressure and maximum temperature of profile section with the help of three-dimensional response surface. Figure 7 shows the response surface diagram of the interaction between the width of the middle part of the shunt hole and the diameter of the outer circle at the outlet of the shunt hole and the mean square error of the cross section velocity at the outlet of the mold when the height of the shunt hole is 120mm. It can be seen from the figure that with the increase of the width of the middle part of the shunt hole, the velocity mean square error of the section decreases first and then increases.

This is because the change of the width of the middle part of the shunt hole changes the distribution state of the flow resistance in the shunt hole. When the width of the middle part of the shunt hole is 40in Ill, the flow resistance of the center part of the profile is much larger than the profile edge part, so the flow velocity of the profile center part is much smaller than the profile edge part.

5. Conclusion

In this paper, the flow law and deformation mechanism of the material in the mold cavity are systematically studied, and the influence law of the mold structure parameters and process parameters on the extrusion forming process is obtained. Based on the finite volume method of steady-state extrusion process, an automatic optimization system of extrusion die shunt hole was developed. An optimal design model of extrusion die integrating finite element simulation technology and artificial intelligence algorithm was established. Taking a special-shaped hollow profile as an example, the extrusion die structure of the profile was optimized to obtain uniform profile section velocity distribution, minimum die stress and die stress deformation. Taking a multi cavity wall panel profile as an example, the shunting hole shape is selected as the design variable. Combined with the response surface method, the prediction models aiming at the mean square deviation of profile section speed, the maximum extrusion force and the maximum temperature of profile section are established respectively. The optimal design of the shunting hole structure of the extrusion die is realized by PSO algorithm. It makes the profile section velocity distribution more uniform. The sinking bridge structure can improve the flow rate of materials at the bottom of the bridge and the weld quality of profiles.

In the previous study, steady-state extrusion process was the main process. In the future study, the unsteady process at the initial stage of extrusion will be numerically simulated. In this paper, the variation law of the macroscopic physical field such as velocity, temperature and die force during AEx is studied. In the future research, the microstructure of materials during extrusion forming will be analyzed. Due to the limitation of experimental conditions, most of the research in this paper is carried out based on numerical simulation method. In the future research, more in-depth experimental research will be carried out on the deformation mechanism, internal structure of aluminum profile and weld quality of AEx process with the help of the recently purchased 800 tons extruder.

Data Availability

The datasets used during the current study are available from the corresponding author on reasonable request.
Conflicts of Interest
The authors declare no conflicts of interest.

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