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Research of Modeless NC Casting

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ABSTRACT: *With the globalization of the market and the intensifying competition in the manufacturing industry, the rate of product replacement has continued to accelerate. Shorter new product development, research and production cycles have grown up to be an an inevitable trend in the manufacturing industry, and the market has increasingly demanded personalized products. increase. As a rapid casting forming technology, modeless casting has changed the modeling and core making methods in traditional casting, eliminated the mold manufacturing link, saved product development time, and has the characteristics of digitalization, precision, flexibility, and greenness. This paper studies the technical principle, working time and working efficiency of modeless CNC castings, to provide a reference for the promotion of technology of modeless CNC castings.*

KEYWORDS: *modeless; numerical control; manufacturing technology*

1.Moldless manufacturing technology

1.1 Moldless Manufacturing of Casting Moulds Based on the Discrete Stacking Principle

The mold-less manufacturing of molds based on the principle of discrete stacking uses the rapid prototype of the discrete-stacking forming principle and the technique and method of making molds called RP mold manufacturing technology [1]. The use of RP technology to directly produce molds for pouring, such as coated sand molds, resin sand molds, etc. are called direct RP mold manufacturing, and can also be used to make vanishing patterns. The RP direct casting mold manufacturing technology based on the principle of discrete stacking has made some progress in recent years. With this method, various processes such as the production of wax molds, foam plastic molds, and wooden molds in the customary precision casting process are omitted. Major changes. At present, the typical direct CAD manufacturing mold processes mainly include PCM (Patternless Casting Modeling) moldless manufacturing process, SLS (Selective Laser Sintering) selective laser

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sintering process, 3D-P (3-Dimensional Printing) three-dimensional printing process Direct shell casting process (DSPC) and German GS (Generissand) process. Each process has its equipment to achieve it.

1.2 Moldless Casting Technology Based on Cutting

Due to the rapid development of numerical control technology, the rapid processing and manufacturing technology based on the removal principle has been rapidly applied in the machinery industry and has been commonly used in metal parts processing and mold manufacturing. At present, numerical control technology also applies to mold manufacturing. It is a major change in the traditional foundry industry. The processing technology is driven by a CAD model to directly drive a special tool to quickly cut the sand blank, and finally obtain poured sand mold or core [2]. In this process, traditional casting patterns are not necessary, and not only is the production speed fast and the accuracy is high, but the shape of the processed model has limitations. Sometimes the manufacturing of sand cores with extremely complex thin-walled core structures requires separate mold manufacturing.

Since 2006, the Advanced Manufacturing Technology Research Center of the General Research Institute of Machinery Science has researched the mold manufacturing technology based on the cutting principle, and successfully produced the SMM series forming machine with a machining accuracy of ± 0.1mm [3]. At present, it has been able to complete the processing and manufacture of various types of foundry sand molds such as water glass sand, resin sand, and coated sand. At present, the maximum size of a single block that can be processed is 2000mm x 1000mm x 300mm. Using digital moldless casting precision forming machine processing, the processing time is only 52 hours, if using traditional technology, it takes at least 30-50 days, sometimes even 100 days.

2. Theoretical analysis of digital moldless mold processing efficiency

The moldless NC forming technology is based on the principle of material removal. According to its principle, the entire forming time is determined by the preparation time, roughing time and finishing time:

$$T_{t2}= T_{p2}+ T_r+ T_f \tag{1}$$

Tt2 is the time used for mold cutting; Tp2 is the preparation time for mold cutting; Tr is the time for rough machining; Tf is the time for finishing. Tp2 is mainly the generation of the machining program of the model, the installation of the sand blank and the cutter, and the milling time of the sand blank. In the actual production process, Tp2 is generally about 1 hour.

The main goal of roughing is to pursue the material removal rate per unit time and prepare the geometric contour of the workpiece for finishing. The time of rough machining is composed of cutting time and idle time of lifting knife, that is:

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$$T_r = T_{rc} + T_{r0} \quad (2)$$

In the formula, Trc is the roughing time of the mold; Tr0 is the roughing idle stroke time of the mold. The roughing process is to cut the sand blank into a roughly cast shape. In this process, a certain margin must be left to be removed by subsequent finishing, so as to ensure the high quality of the finished mold surface. So it's cutting time is:

$$T_{rc} = \frac{V - A \times S}{pvd} \quad (3)$$

Where Trc is the cutting time of roughing; V is the volume removed; S is the surface area of the model; A is the margin to be left for roughing; p tool step; v tool feed rate; d is the cutting depth of the tool.

Due to the need of cutting, the process of raising the knife and vacantly inevitably occurs during the CNC cutting process. The total idling time is made up of n times of knife lifting idling time.

$$T_{r0} = \sum_{i=1}^{n} t_{r0}(i) \quad (4)$$

Among them, T_{r0} is the idling time for roughing; $t_{r0}(i)$ is the idling time for the i-th lifting; n is the number of lifting. So the roughing time is:

$$T_{rc} = \frac{V - A \times S}{pvd} + \sum_{i=1}^{n} t_{r0}(i) \quad (5)$$

The finishing time is composed of the cutting time and the feed time of the knife, that is

$$T_f = T_{fc} + T_{f0} \quad (6)$$

Where Tfc is the time for finishing the mold; Tf0 is the time for the idle stroke for the finishing of the mold

The finishing strategy depends on the contact point between the tool and the workpiece, and the contact point between the tool and the workpiece changes with the surface slope of the machining surface and the effective radius of the tool. The finishing time is:

$$T_{fc} = \sum_{i=1}^{M} \frac{l_i}{v_i} \quad (7)$$

Where l_i is the processing path length of each layer, v_i is the processing rate of each layer, and M is the total number of processing layers for finishing.

$$T_{f0} = \sum_{i=1}^{m} t_{f0}(i) \quad (8)$$

In the formula, $t_{f0}(i)$ is the time for the i-th emptying operation; m is the number of times for the emptying operation. So its exact time is

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$$T_f = \sum_{i=1}^{M} \frac{l_i}{v_i} + \sum_{i=1}^{m} t_{f0}(i) \tag{9}$$

To evaluate the efficiency of non-membrane NC castings, it is hoped that the model can be judged directly without being refined. Therefore, it is extremely important to establish an evaluation value about the model volume, surface area, height, removal volume and complexity to judge the processing method.

Assume processing evaluation time k

$$K = k_1 V + k_2 S + k_3 H + k_4\ \overline{V} + k_5 \lambda \tag{10}$$

Where V is the model volume; S is the model surface area; H is the model height; V is the removal volume; λ is the model complexity coefficient and λ is the lift time of the model processing, which is related to the mold cutting process. The method of oblique downward feeding is very small in the entire finishing process, so only the amount of tool lift during rough machining needs to be considered. To define.

Let the number of unconnected cavities be w, and the height range of the i-th unconnected cavity isHxi~Hyi. According to the cutting process, we can know that:

$$\lambda = \sum_{i=1}^{w} [\frac{\frac{H_{yi}-H_{xi}}{2} - \frac{v_{run}^2}{a} dx}{v_{run}} + 2\frac{v_{run}}{a}] \frac{H_{yi}-H_{xi}}{d} \tag{11}$$

In the formula, $v_{run}$is the speed of lifting the knife; a is the acceleration of the knife; H_{yi} is the bottom height of the unconnected cavity; H_{xi} is the top height of the unconnected cavity; d is the cutting depth of each layer of the tool.

k_1 is the model volume weight coefficient. The model is formed by removing the irrelevant blanks layer by layer. It has nothing to do with the model volume, so k_1 = 0.

k_2 is the model surface area weight coefficient. During the finishing process, the tool is cut along the contour of the outer surface, and the cutting time is proportional to the model's finishing depth and feed rate.

$$k_2 = \frac{1}{dF_1} \tag{12}$$

k_3 is the height weighting factor when the model is formed. The height has little effect on the milling process and can be ignored, so k_3 = 0.

k_4 is the volume weight coefficient removed, the model cuts off the excess volume forming, the forming process is inversely proportional to the feed amount fz of the roughing tool, the depth d of the roughing, and the feed rate F of the roughing.

$$k_4 = \frac{1}{Fdfz} \tag{13}$$

k_5 is the weight coefficient of model lifting. In the cutting principle, lifting is a

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necessary process, so the weight is k_5=1.

The processing process involves preparation and post-processing time, so the efficiency evaluation value T of the processing process.

$$T = \frac{1}{3600}K + aT1 \quad (14)$$

A low evaluation value indicates high processing efficiency. The model contains relatively thick areas, and the forming method of mold cutting should be preferentially used.

3.Development of moldless CNC molding machine

The forming machine is mainly based on the load-bearing form, the number of movements, and the nature of the movement (linear or curvilinear movement) required for the CNC machining of the mold. ,repair. The mold CNC machining forming machine realizes the forming motion (linear motion, circular motion, spiral motion, or curved trajectory) of the workpiece surface by the main movement (completed by the tool) and feed movement (relative movement of the tool and the workpiece) when processing the workpiece. motion). And these movements of the forming machine must be completed by the corresponding execution parts (such as main moving parts, linear or circumferential feed parts) and some necessary auxiliary movements (such as indexing, clamping, cooling and lubrication). The mold CNC machining forming machine is a typical mechanical control integrated system, which mainly includes 3 subsystems:

(1) Data processing system. The CAD model data of the part is input and the model is processed to obtain the mold CAD model of the part. CAM-assisted machining design for the mold to generate machining codes that the forming machine can recognize.

(2) Control drive system. Read the CAM machining code of the part mold, and generate control instructions and cutting motion instructions according to the process requirements. Driven by the instructions, the tool system and the motion mechanism are driven to complete the specified operations.

(3) Structural ontology system. It mainly includes auxiliary systems such as racks, motion systems, and chip removal. It is the execution mechanism of the process. It provides a controllable processing environment for the forming machine and the basic structure of cutting and movement. It also completes the overall functional requirements under the control information Actions.

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4. Conclusion

In short, light weight, precision, efficiency, and cleanliness will be important development directions of casting technology. Therefore, it is required that casting molding manufacturing be lighter, thinner, more precise, stronger, tougher, low cost, short process, and quality. High direction development. Since moldless mold manufacturing technology requires no pattern, short manufacturing time, integrated modeling, no draft angle, and can produce molds with free curved surfaces (curves) and CAD / CAE / CAM integration, it realizes the casting process. The important way of automation, flexibility, and agility. The rapid digital manufacturing method of moldless casting mold is a technology suitable for the production of single-piece, small-batch, diverse varieties of castings and molds, and has broad application prospects.

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