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Application of Machining Equipment with Feedback Detection Function in Polyhedron Precision Processing Control

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ABSTRACT: This research first describes the existing problems of high labor intensity, low productivity, product quality with no guarantee and high scrap rate in modern grinding equipment, and introduces the operating principle of grinding equipment. On this basis, this paper introduces a polyhedron precision machining equipment with feedback detection function. This equipment is strong in locking torque, has high positioning accuracy, low manufacturing cost, and can pinpoint the turning position of blanks to be machined accurately. It has passed through the design verification of feedback detection function, and solves the technical problems of low positioning accuracy of polyhedron work pieces grinding and processing, high manufacturing cost and unable to meet the requirements of high-precision polyhedron machining in the current technology.

KEYWORDS: Machining equipment; Feedback detection function; Precision processing control.

INTRODUCTION

In the field of manufacturing technology, simple traditional manufacturing technology has seen a development history of thousands of years. Especially in the past three hundred years, the development of machinery manufacturing technology is in the ascendant, and emerges the trend of compound technology, especially composite materials and compound machining, which have lead the trend of the world, played a leading role, and are worthy of attention and reflection. Among the technologies, precision compound machining technology has become an important focus of development for its great advantage of compound of various precision machining abilities. The early polyhedron grinding process is generally performed manually, not only is labor-intensive, low in productivity, also has no guarantee of the product quality and has high scrap rate. While the existing polyhedron grinding apparatus generally sets a clamping mechanism at one end of the shaft for clamping the polyhedron, and abrades the polyhedron with the surface of rotating wheel under it. After the completion of one surface of the polyhedron, the polyhedron is turned to convert the processed surface. This turning process is generally performed by mechanical transmission for automatic conversion, and the positioning of polyhedron turning is realized through the self-locking force between worm and gear. But there is clearance between worm and gear, and it will increase resulted from abrasion with long time using. So the positioning accuracy of polyhedron processing surface turning is low, and cannot ensure the processing quality of polyhedron.

As for parts with end faces of regular polygon, the commonly used machining methods are milling and planning of each surface. When using milling machine to process parts with end faces of regular polygon, indexing mechanism is applied, involving indexing precision, intermittent transmission and other factors that affect the machining accuracy. Due to these factors, it is difficult to improve the processing efficiency [1]. Based on hypocycloid principle, the numerical control machine can process the parts with end faces of regular polygon. The processing is a continuous turnery process. Compared with the conventional milling method, this method can increase the processing efficiency, as well as improve the precision, and it can also be used for batch processing of bolt head of hexagonal nut and square nut, and connecting shaft in regular polygon [2-3]. In recent years, many scholars have made study on this method. For instance, Professor Wu Yanming made improvement of CA6140 type lathe, and carried out processing experiments of regular polygon parts [4]. According to hypocycloid parametric equation and using Matlab, Dong Limin analyzed turning radius of cutting tools, the impact of center distance between cutter and work piece on the machined parts [5]. However, the previous research provides no specific implementing method, and does not consider the angle motion of machined regular polygon. Therefore, this paper proposes a polyhedron precision machining equipment with feedback detection function. This equipment is strong in locking torque, has high positioning accuracy, low manufacturing cost, and can pinpoint the turning position of blanks to be machined accurately. It solves the technical problems of low positioning accuracy of polyhedron work pieces grinding and processing, high manufacturing cost in the current technology. This equipment is composed of processing platform, grinding plate and grinding head equipped on the platform. The grinding head is equipped with turning surface device, angling device and angular locking mechanism. The turning surface device is composed of case and some tubular dividing shafting rotatablely connected with the case. The front end of dividing shafting passes through the case and extends above the grinding plate. In the front end of the dividing shafting, a work holder containing polyhedron blank is fixed by a clamping mechanism. On the corresponding dividing shafting in the case sets an index plate with gears. On the case above the index plate sets conical pin which can be spliced among adjacent gears.

PRINCIPLE OF POLYHEDRON GRINDING AND CUTTING

As shown in Figure 1, a stands for the distance between the center of work and the center of cutter, L stands for the length of the point of the cutter to its rotating center. Assume that the work and cutter all rotate counterclockwise at the same time, and their angular velocity are ω and ωT respectively. A rectangular coordinate system xoy is established as shown in the figure. ox axis passes through the rotating center of cutter, meanwhile, suppose the initial position of the cutter is on the ox axis. According to the principle of relative motion, the trajectory of point of the cutter on the work can be calculated through kinematic inversion. Namely, suppose the work immobilizes, the cutter center rotates around the work center at the angular velocity of –ω, meanwhile, the cutter has autorotation velocity of ωT. After a period time of t, the cutter moves from o0A0 to o1A1, at this time, the positive angle between the cutter and x axis should be (ωT-ω)t. Therefore, the trajectory of the point of cutter on the work can be described by formula (1) as shown below.

$$\begin{aligned} x(\omega t) &= a\cos\omega t + L\cos(\omega_T - \omega)t \\ y(\omega t) &= -a\sin\omega t + L\sin(\omega_T - \omega)t \end{aligned} \tag{1}$$

For the convenience of description, the ratio of cutter's rotating speed and work's rotating speed is represented by ratio of angular velocity k:

$$k = \omega T / \omega \tag{2}$$

Meanwhile, introduce size factor γ:

$$\gamma = \left(a - L\right) / L \tag{3}$$

Only by adjusting parameters of k and γ appropriately, there obtains a trajectory approximate polyhedron on the work, and its edges equal with the ratio of angular velocity k. Figure 2 shows the trajectories when k=3, γ is 1/ 8, 1/ 4, 1/ 2 respectively. The center part of the trajectory is approximate a triangle, and the smaller γ is, the straighter the curve side of the triangle is. So long as the appropriate adjustment of parameters, the curve polyhedron can replace the regular polyhedron within a certain error range, thus to achieve the purpose of turnery.

ERROR ANALYSIS

The following is the analysis of machining error taking k = 3 as a case. As shown in Figure 3, the curve is the tool path when γ= 1/ 2, the arrows indicate the direction of the trajectory. A, B, C are three intersections of the trajectory of cutter point. D, E, F are the farthest three points away from center o. G is the intersection of trajectory and x axis, and H is the intersection of straight line BC with x axis. As can be seen from the figure, there is an error between the trajectory of cutter point curve triangle ABC and the ideal triangle ABC. According to the symmetry of the trajectory, it can be judged that the length of line HG is the maximum error. Next is the calculation of the coordinate of the key points in the trajectory, and the calculation of error [6].

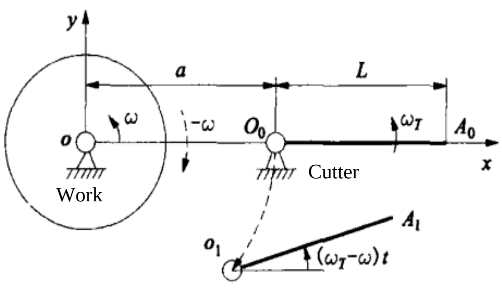

Figure 1. Schematic Diagram of Trajectory of Cutter Point.

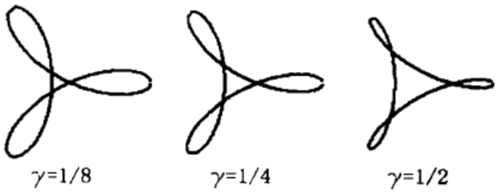

Figure 2. Various Trajectories of Cutter Point when k = 3.

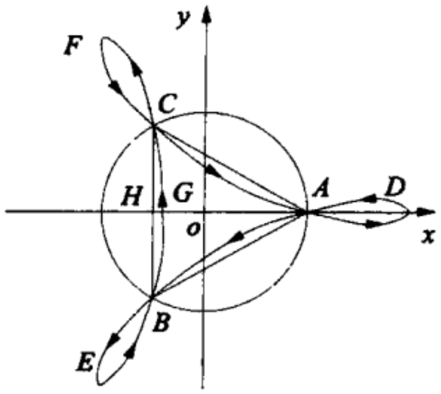

Figure 3. Schematic Diagram of Error Analysis.

Let $y(t)=0$, then the coordinate of intersection of the trajectory and x axis is calculated. Considering k = 3, based on formula (1), there is the following formula:

$$y(\omega t)=\sin\omega t(-a+2L\cos\omega t)=0 \tag{4}$$

The solution of formula (4) is :

$$\sin\omega t=0,\ or\ \cos\omega t=a/2L \tag{5}$$

namely,

$$\omega\text{t}=0 \text{ (corresponding point D)},\ \ \omega t=\pi \text{ (corresponding point G)} \tag{6}$$

$$\text{or } \omega t=\alpha,\ \ \omega t=2\pi-\alpha \text{ (corresponding point A)} \tag{7}$$

$$\alpha=\arccos(a/2L) \tag{8}$$

Since a and L are all greater than 0, there is 0<α< π/2.

Equation (6) and (7) are substituted into the formula (1), then the coordinate of point G and A can be obtained: $xG=L-a$, $xA=(a2-L2)/L$. So the coordinate of A is $A(\frac{a^2-L^2}{L},0)$.

Similarly, coordinate of intersections of B and C can be obtained as $B\left(-\frac{a^2-L^2}{2L},-\frac{\sqrt{3}}{2}\frac{a^2-L^2}{L}\right),C\left(-\frac{a^2-L^2}{2L},\frac{\sqrt{3}}{2}\frac{a^2-L^2}{L}\right)$.

When the diameter of work equals to the diameter of the circumscribed circle of triangle ABC, the triangle can be machined in the circular section. At this time, the diameter of work is

$$d = 2x_A = 2\frac{a^2 - L^2}{L} = 2L\gamma(2+\gamma) \tag{9}$$

The maximum error of curve triangle ABC and ideal triangle ABC e equals to the length of line FG. Namely

$$e = x_G - x_F = L - a + \frac{a^2 - L^2}{2L} = \frac{1}{2}\frac{(a-L)^2}{L} \tag{10}$$

Given equation (2), equation (10) can be rewritten as

$$e = L\gamma 2/2 \tag{11}$$

From equation (9) and equation (11), there is

$$e = \frac{\gamma}{4(2+\gamma)}d \tag{12}$$

From equation (12), it can be seen that the larger the diameter of work is, the larger the machining error is, and the smaller size factor is, the smaller the machining error is. As for a work with given diameter, the larger the length of cutter is, the machining error is, as shown in Figure 4. In order to reduce the machining error, the length of cutter must be increased. Obviously the increase of the cutter length means the increase of structure of machine tool and inertness, so the increase cannot be unlimited. When processing with the maximum length of the machine tool, the error still does not meet the requirements, it is essential for error compensation.

FEEDBACK DETECTION AND ANALYSIS OF ADVANTAGES

Design of Feedback Detection Function

This paper introduces a polyhedron precision machining equipment with feedback detection function. This equipment is strong in locking torque, has high positioning accuracy, low manufacturing cost, and can pinpoint the turning position of blanks to be machined accurately. It solves the technical problems of low positioning accuracy of polyhedron work pieces grinding and processing, high manufacturing cost and unable to meet the requirements of high-precision polyhedron machining in the current technology.

The above mentioned technical problems is mainly solved through this polyhedron precision machining equipment with feedback detection function. As shown in Figure 4, it includes processing platform, grinding plate and grinding head equipped on the platform. The grinding head is equipped with turning surface device, angling device which can adjust the pitch angle of rotation surface, and angular locking mechanism which can lock the angular mechanism. The turning surface device is composed of case and some tubular dividing shafting on the same horizontal plane rotatablely connected with the case, as shown in Figure 5. The front end of dividing shafting passes through the front wall of the case and extends above the grinding plate. In the front end of the dividing shafting, a work holder containing polyhedron blank is fixed by a clamping mechanism. On the corresponding dividing shafting in the case sets an index plate with gears. On the case above the index plate sets conical pin which can be spliced among adjacent gears. By setting a plurality of dividing shafting in the case, it is feasible to machine the polyhedron fixed on each dividing shafting at the same time, thus to improve production efficiency and reduce processing costs. Since the dividing shafting is located in the same horizontal plane, it can operate synchronous angle rotation driven by the angling device, and can realize synchronous surface turning through synchronizing wheel driven by a motor. Positioning for once, various works can be processed at the same time, which saves both time and efforts. The index plate with gears is set on the dividing shafting, and conical pin is set on the case in corresponding place above the index plate, which can slide in radial direction relative to the index plate, as shown in Figure 6. When turning the processing surface of the polyhedron, the dividing shafting rotates and the index plate rotates simultaneously. When the surface turning is finished, the conical pin slides to the index plate and plugs between the opposite two gears. Since the conical pin is matched with the clearance of gears, it locks the position of index plate, namely, it locks the position of dividing shafting and the processing surface of the polyhedron. It has greater locking torque compared with the original worm and gear, and simple in structure, low in manufacturing cost. Meanwhile, it eliminates back lash between gears, and can lock the polyhedral work piece to be machined precisely on the turning surface, as shown in Figure 7, which is high in positioning accuracy and meets the positioning requirement of surface turning of high-precision polyhedron. The above operation is completed with encoding because the existing automatic programming system makes the operation easier [7]. Finally the precision judgment of the processed surface is operated by on-line detecting of grinding roughness [8].

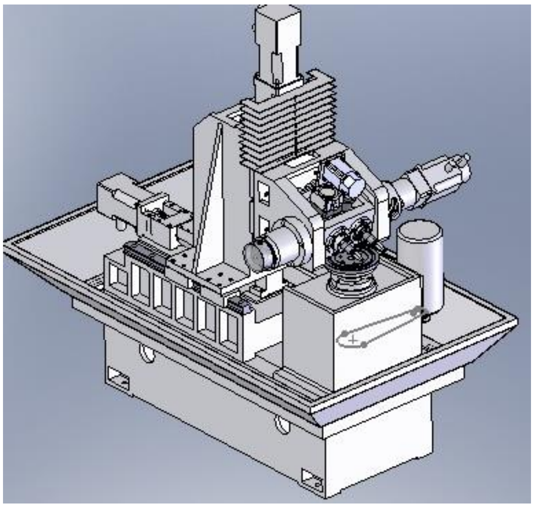

Figure 4. Diagram of polyhedron precision machining equipment.

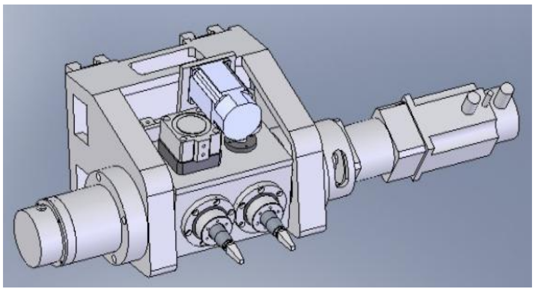

Figure 5. Structure of precision dividing head.

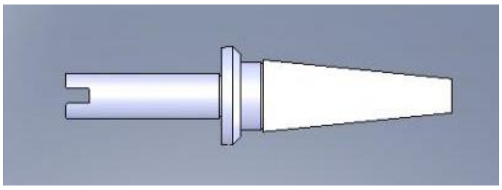

Figure 6. Conical Pin.

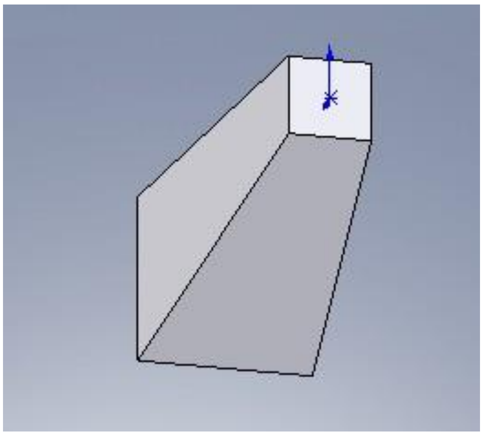

Figure 7. Positioning of turning surface.

Analysis of Advantages

The proposed polyhedron precision machining equipment with feedback detection function has the following advantages.

1. The index plate and its matched conical pin lock the rotating angle of the dividing shafting (namely turning angle of polyhedron blank), which is strong in locking torque, high in positioning accuracy, and low in manufacturing costs;

2. The design of multiple dividing shafting clamping and fixing polyhedron blank for simultaneous machining improves the production efficiency, and reduces production costs;

3. The angular locking mechanism is set by corrugated pipe and conical expansion mechanism, which improves the positioning accuracy of angular rotation and machining quality of polyhedron grinding;

4. The dividing shafting can replace its work piece fixing rod at any position, which is convenient and improves the machining efficiency;

5. The coding network can detect the position of polyhedron blank at all times, and provides feedback on the real-time detection information to the control system. The control system controls the servo motor to re-adjust the angular position of the case to achieve closed-loop control, which improves the accuracy of the angular position of the polyhedron, and then meets the machining requirements of high-precision polyhedron.

CONCLUSION

This paper first describes the existing problems of high labor intensity, low productivity, product quality with no guarantee and high scrap rate in modern grinding equipment, and introduces the operating principle of grinding equipment. On this basis, this paper introduces a polyhedron precision machining equipment with feedback detection function. This equipment is strong in locking torque, has high positioning accuracy, low manufacturing cost, and can pinpoint the turning position of blanks to be machined accurately. It solves the technical problems of low positioning accuracy of polyhedron work pieces grinding and processing, high manufacturing cost and unable to meet the requirements of high-precision polyhedron machining in the current technology. The proposition of this equipment breaks the limitations of existing technical equipment, and enables polyhedron precision machining control to reach a new milestone.

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