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The Research of Cycloid Rotational Processing Technology

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Abstract:- In order to make the cycloid rotational indexing technology be general, the paper do a lot of research on the method based on the principle analysis and experiments. By analyzing the influence of various cycloid parameters on the cycloid shape, and according to the surface features of machine parts, parts can be divided into three categories. General model is established on the basis of this, and on the premise of guarantee of approximation precision, processing and highest efficiency as the goal, design optimization algorithm about parameters. Through modeling analysis, find out the main factors affecting machining precision, and according to the theoretical analysis, the appropriate process improvement methods are put forward.

Keywords:- cycloid; rotational indexing; processing precision; processing technology

I. Introduction

Rotational indexing processing is a new kind of processing technology. This technology refers to the tool rotation knives and synchronous rotating at the same time. By changing the ratio of rotating speed of the work piece and tool to implement different work piece machining. For some complex processing surface, on the basis of the turning points in processing make point click run cycloid trajectory, namely the formation of cycloid rotational processing method. Cycloid rotational points processing method is a kind of high efficiency, high precision machining method. The implementation of processing method requires special high precision CNC machine with high performance. At present domestic cycloid rotational machine mostly imported. Domestic research on this technology has also been started from 2003[1], and the periodical results have been achieved, which was successful in the processing of automotive parts and polygon gear sets of the surface, end face straight groove parts[1-5]. Research and experiments show that the cycloid rotational processing method not only can accomplish more than a few parts processing, but also can be used in a wider application range. In order to promote the cycloid rotational processing technology, it is necessary to carry on the deeper and more extensive research.

In this paper, through the analysis of the cycloid parameters of the study, looking for cycloid parameters and shape the relationship between the trajectory. Based on this, the parts are classified. Foreach type of parts processing of a suitable processing model is set up. fAnd through the model analysis verify the feasibility and effectiveness.

II. The relation of mathematical principle and parameter of cycloid rotational indexing processing

Mathematical principle and the relationship of parameters of cycloid rotational indexing processing
Cycloid rotational indexing processing is an economic and efficient processing technology. For ordinary turning processing, the part is rotating and the cutting tool is not rotating; For milling ,the cutting tools is

rotating and parts did not turn. When using cycloid rotational indexing processing, Parts rotate, while the tool is rotated. According to the different ratio of rotating speed, you can process a variety of complex surface parts.

2.1 The mathematical model of cycloid

Cycloid divided into hypocycloid andepicycloid. Currently processing are realized based on the principle of cycloid generated. Therefore, this article only discuss hypocycloid parameter equation.

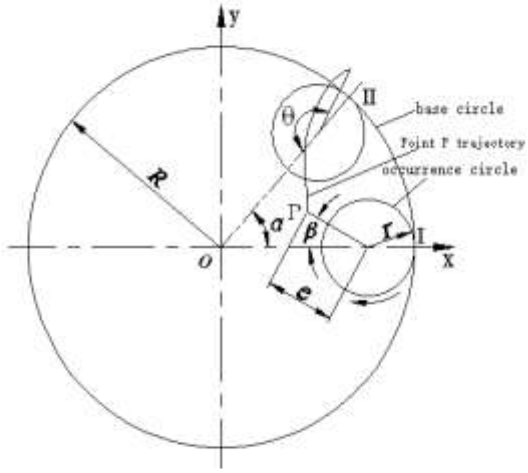


Fig.1 Formation of cycloid trajectory

As shown in Fig.1, R is the cycloid base circle radius, r is the occurrence circle radius. Occurrence circle from the horizontal position I do pure roll along the base circle. Circle occur as a disk rigid body on the rigid body round. Let a point P of the rigid body be used as the locus generating point. e is P and occurrence circle center distance. β is Cycloid initial Angle. When the occurrence circle rolling to the position II, θ is the circle rotation angle. α is the included angle between the position I and the position II. In the event of a circle rolling process, the trajectory available type which can be formed by the point Formula (1).

$$\begin{cases} x = (R-r)\cos\alpha + e\cos(\theta+\beta) \\ y = (R-r)\sin\alpha + e\sin(\theta+\beta) \end{cases}$$

In the formula $\theta = (1-\frac{R}{r})\alpha, \quad \alpha \geq 0^\circ$

2.2 The relationship between cycloid parameters and cycloid shape

From formula (1) we can know there are several kinds of parameters of the cycloid, R, r,α,θ,e and β. Where the initial angle only changes the position of the cycloid trajectory, and does not change the shape of the cycloid trajectory. This parameter is used to adjust the relative position of the cutter shaft and the parts in the circumferential direction in the actual machining process. Parameter is only affect the length of the cycloid trajectory. By the formula,θ has noeffect on the shape of cycloideither. Therefore only consider the influence of parameter R, r ande to change the cycloid shape.

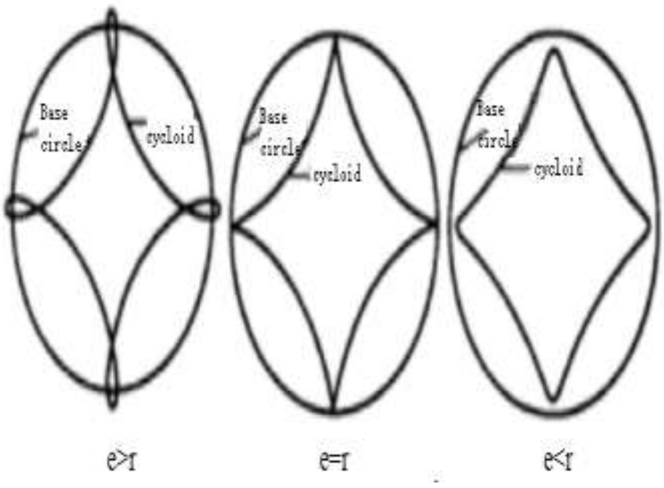


Fig.2 The transformation of trajectory when e changes

Accordingly, want to get the ideal trajectory shape, first to determine the proportion of R and R, and then by adjusting the size of the e value and R value, found a suitable trajectory shape. Depending on the shape of the workpiece and the characteristics of the cycloid, the workpiece can be divided into three types of parts even polygons, odd polygons and involute. Analysis of each category andestablish the model, then can through input parts parameters to get parts processing data, so as to achieve a range of generality.

2.3 Polygon parts processing

Under the condition of the premise of $r/R=1/2$, when $e\neq r$, cycloid trajectory become elliptic[3]. To use this kind of the cycloid machining parts, cycloid segment of anellipse trajectory must be approximated a straight line.experiments show that when the e be constant, make $r = e\pm L$, Two short axis of the ellipse equals while the long axis is different(The length of the L for elliptic short axis). As shown in Fig.3. In actual processing, considering the longer the long axis, cycloid approximation straight line accuracy is higher, so take $r = e + L$ for optimality.

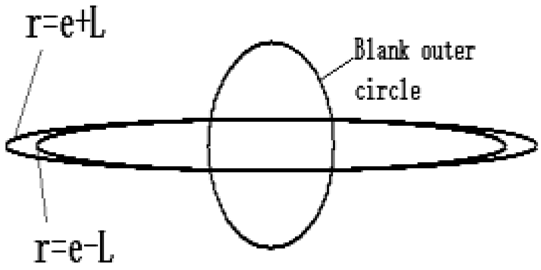


Fig.3 elliptical locus when $r = e + L$

According to these two kinds of cycloid trajectory characteristics, can simulate the straight flute machining tool path, as shown in Fig.4. From the diagram, the straight line in the middle is the orbit of cutting tool center, and oval is orbit of two endpoints for the blade.

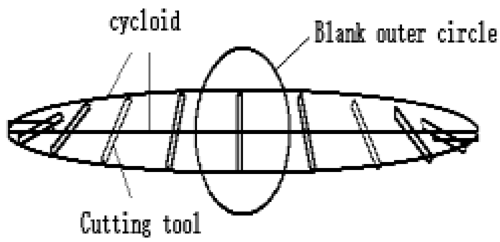


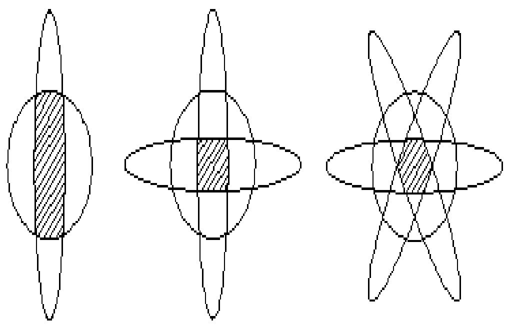
Fig.4 cutting tool path

At this point, the formula (1) turns into

$$\begin{cases} x = (2e + L)\cos\alpha \\ y = L\sin\alpha \end{cases}$$

Formula (2) is clearly a elliptical expressions. When L=0, (2) into a straight line. When L is constant and L≠0 , maximum of y is elliptical short axis length is constant too. The long axis length x of the ellipse increases with the increase ofe value. Therefore, the bigger thee value is, the more flat the ellipse is, the greater the intermediate sections round section tend to be more straight line, the higher approximation accuracy. namely in the maximum turning radius of the cutting tool machining of precision parts is the machine's highest accuracy. Therefore, in the process, as long as the cutting tool radius of gyration is equal to the machine maximum turning radius, can be processed in the following a variety of precision parts.

With using an ellipse to cut a circle, as shown in Fig.5 (a), remove the shadow parts can be processed from end face straight flute. If remove the outside part of the shadow, we can get two surfaces. When we use two mutual into 90°of ellipse to intercept the circle, can get tetrahedron or two straight flute, as shown in Fig.5 (b). When using three into 60°elliptic to intercept the circle, can get hexahedron or three straight flute, as shown in Fig.5 (c). By analogy, with n (n∈N)ellipses to cut circle can be 2n side form or n straight flute..



(b) **(c)**

Fig.5 The cycloid trajectory of polygon parts

According to the model, set δ is the machining accuracy, Rc is parts circle radius, can derive the calculation formula of accuracy δ is:

$$\delta = L - \frac{L}{2}\sqrt{\frac{(2e+L)^2 - R_c^2}{e^2 + eL}}$$

Assuming that the maximum turning radius e max of machine used is 43 mm, request processing square parts which side length is 14 mm and accuracy is 0.03 mm. According to the formula (2) put

L=14,e=emax into type (3). Then get a theoretical approximation precision δ=0.017mm, which fully meet the processing requirements.

If required in 20 mm diameter round rod processing accuracy of 0.02 mm width of 4 mm straight flute, can take the L=4mm, then the requirement of accuracy e is value of 33.8 mm. While take e =emax , theory of approximate accuracy is 0.012 mm.

2.4 Odd polygon parts processing

Due to the closer the r to R/2, the bigger Radius of Cycloid sections round sectionis, The higher the precision is. If m is the number ofedges of the odd polygon , It's optimal for taking the r/R = (m/2 + 0.5)/m. after selecting reasonable e value ideal of a polygon can be got. Because the r/R is not fixed, therefore also need the following specific analysis.

When the polygonedges number m=3, cycloid trajectory as shown in Fig.7, curvature of cycloid round part of the radius is small. It's not suitable for approximate straight line,and only suitable for approximate circular arc. Because the tooth set of slide block slot on the circumference of a circle is the average distribution, cycloid of m = 3 is suitable for the slider slot parts processing.

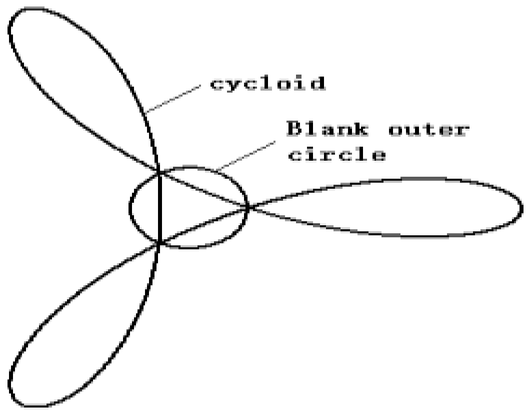
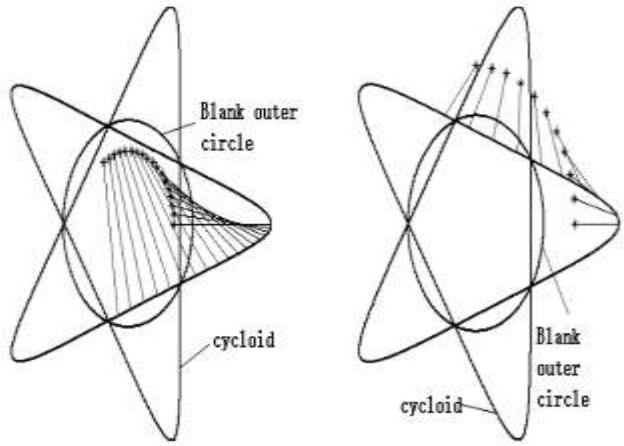


Fig.7 Trilateral cycloid trajectory

When simulating cycloid trajectory, we must also take into account the actual processing of the tip of a situation. M = 5, for example, Fig.8(a) is when R = 5r/3, the walking part of the route of the cutting tools, with "*" said tool rod circle orbit. Fig.8(b) is when R=5r/2, the walking part of the route of the cutting tools. Can be seen from the two pictures, Cutting tools and parts in Fig.8(a) round interference occurs, which obviously be not suitable for application in practical production, while the Fig.8 (b) at the right moment to cut the circle into a pentagon, which conform to the actual application. By analogy, heptagon and other odd polygon also must satisfy the R = m/R (m / 2-0.5). Therefore, (1) becomes:

$$\begin{cases} x = \dfrac{m+1}{m-1} r\cos\alpha + e\cos(\dfrac{m+1}{m-1}\alpha) \\ y = \dfrac{m+1}{m-1} r\sin\alpha + e\sin(\dfrac{m+1}{m-1}\alpha) \end{cases}$$

With m = 5,7,9...



(a) (b)

Fig.8 Point location of the schematic diagram

By formula (4) it can be seen that, according to the size of the parts, the number ofedges and the approximation precision, as long as applying optimization program to calculate r ande can be quickly work out the optimal solution of high accuracy of the odd polygon. Optimization process is shown in Fig.10, the specific steps are as follows: as shown in Fig.9, point A (XA, YA) and B (XB, YB) as the intersection of cycloid and circle, point C (XC, 0) is the halfway point of the cycloid AB, O as part of the circle, Polygon side length is L, center and the edge of the distance is H, set the approximation precision required for the δ y. First of all, sete and r an initial value, calculated |AB|. If |AB| > L, r increases a step △1, until |AB| = L. If |XA - XC| > △y and XA > XC, let e reduce a step △2; If |XA - XC| > delta y and XA < XC, let reduce a step △2, until |XA - XC| ≤ △y.

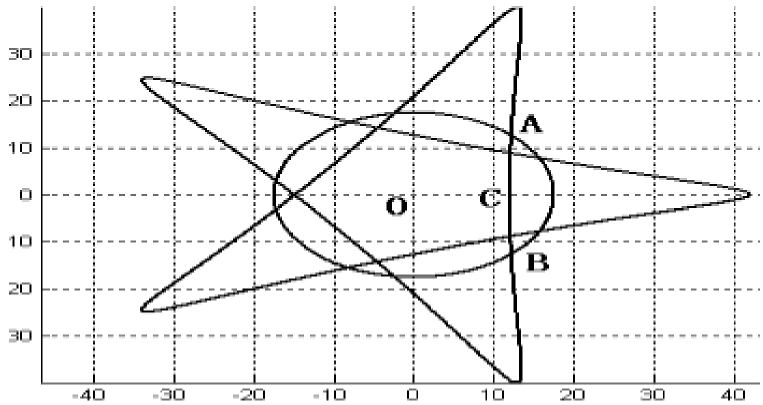


Fig.9 odd polygon cycloid trajectory

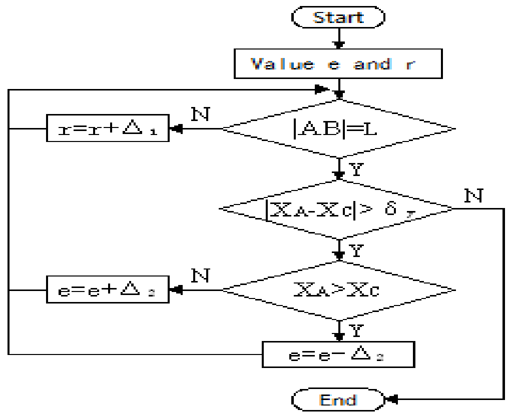


Fig.10 Optimization flow chart

Assuming that giving a 21 mm diameter round bar, request processing out of the circle radius to 10 mm, heptagon accuracy of 0.01 mm. Take M = 7 intoequation (4), and then according to the optimization flow chart inFig.10 get a best valuee = 12.5, r = 16.128, the approximate accuracy is 0.001 mm. Using the group parameter simulation tool processing route is shown in Fig.11.

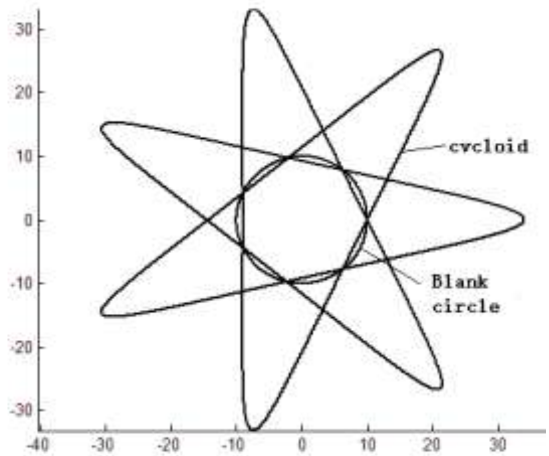


Fig.11 Running route simulation tools

2.5 Involute parts processing

With cycloid to approach involute processing parts, generally limited to inner gear parts, such as tooth set of classes. Studies have found that the diameter of less than 200 mm inner gear parts processing, in order to increase tool rod stiffness as much as possible, tool rod is as thick as possible. Due to e value of the main factors influencing the knife stem thickness, so the computation YiQu larger e value. Lots of experimental study show that r and e region when the r<e than r >e evalue is big, therefore in the processing of such parts when YiQu r <e. By a literature the r/r = k/z, which k is across a number of teeth, z as the number of teeth, k and z is relatively prime Numbers, and r/r ratio will affect the shape of the cycloid trajectory.

When r/r < 0.5, in the case of k/z = 13/36 cycloid shape as shown in Fig.12. The cycloid to approach involute, but each cycloid approximate length is shorter, so close to the whole article involute need number is more, unfavorable to processingefficiency. When k/z = 29/36, just cycloid to approach involute.

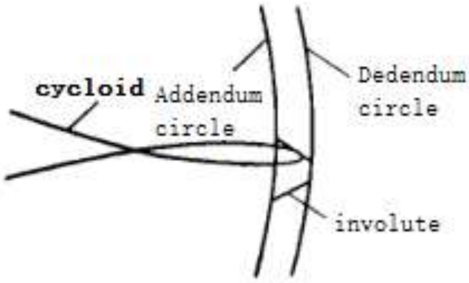


Fig.12 cycloid trajectory approaching involute

Due to a lower approximating the whole involute cycloidal approximation precision, therefore using the multiple involute cycloidal to form clusters, as shown in Fig.13.e value fixed in the machining process, so as long as the change in the simulation of r value and β can get different positions of the cycloid to approach involute.

By the relationship between the cycloid shape and parameter selection, to get a suitable cycloid to approach involute, relation to be fulfilled:

$$\begin{cases} \frac{r}{R} = \frac{k}{z} \\ r < e \\ \frac{1}{2} < \frac{k}{z} \le \frac{29}{36} \end{cases}$$

Therefore, (1) turns into:

$$\begin{cases} x = \frac{z-k}{k} r\cos\alpha + e\cos\left(\frac{z-k}{k}\alpha + \beta\right) \\ y = \frac{z-k}{k} r\sin\alpha - e\sin\left(\frac{z-k}{k}\alpha + \beta\right) \end{cases}$$

In the formula: $\frac{1}{2} < \frac{k}{z} \le \frac{29}{36} \qquad r < e$

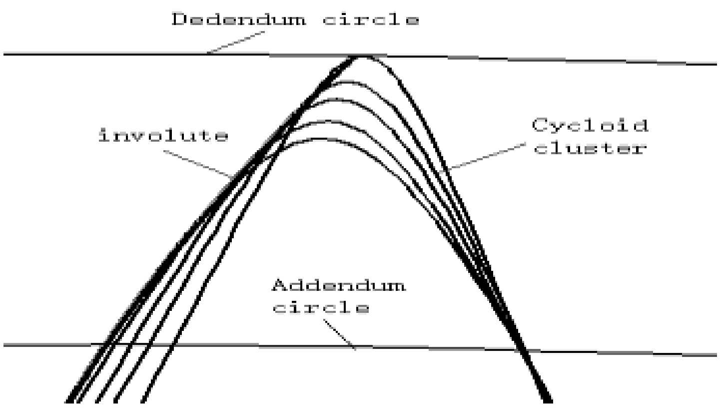


Fig.13 cycloid cluster approaching involute

Trans-number of teeth k and the number of teeth z is relatively prime numbers, According to the above constraints, as long as valuing a larger k , then select appropriate e value, can get the least line number to approaching involute.

According to the involute class model, set m=2.5, number of teeth z=36, dividing circle pressure Angle alpha=30°, addendum circle radius of Ra = 44 mm, dedendum circle radius Rf=46.75 mm, approximation accuracy of the δ=0.01 mm teeth, the machining accuracy is 0.02 mm, table 1 can be obtained by simulation and calculation of data, where n is the number of cycloid.

Tab.1 cycloid parameters

Number	k	n	e (mm)
1	19	12	25.4
2	23	11	30.5
3	25	9	33.1
4	29	6	38.2

By comparing the value n wo can know that under the condition of precision, article 4 of cycloid cluster number is the least, this means that the faster processingefficiency. So the fourth set of data is choosed and get the final parameter values of the resulting cycloid clusters:
r=[35.421,34.930,34.358,33.673,32.875,31.965];β=[-1.369,-1.466,-1.573,-1.689,-1.805,-1.904]

III. Conclusion

Through the analysis of the relationship between cycloid parameters and cycloid shape, learned in cycloid rotational indexing technology ,the ratio relationship between the base circle radius R, occurrence circle radius r and the value of e is the main factors influencing the cycloid shape.

According to the shape classification of machining parts, by adjusting the ratio relationship between the base circle radius R, occurrence circle radius r and the value of e,established the general processing model of three parts,and through the calculation, verified the feasibility of the model.

The establishment and application of general control model, not onlyenlarged the rotating machine processing range, in order to further promote the cycloid rotational indexing technology laid the foundation.

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