

Machining Error Analysis of Turbine Blades Surface Based on Matlab

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Abstract: The machining error analysis of turbine blade surface is an important link of the manufacturing process, this paper studied machining error analysis method of blade surface, and the machining error analysis system was developed based on this method by using MATLAB. Application example show that this system is able to analysis machining error of multiple blade surface data, and improve the efficiency of analysis.

Keywords : turbine blade, machining error, MATLAB

I. Introduction

Steam turbine is used to generate electricity in power plant, which occupies an important position in the development of national economy, and the turbine blade is one of the key parts of the turbine. The machining quality of the steam turbine blade is the guarantee of the stable and efficient operation of the turbine, and the machining error of the blade profile has a significant influence on the operating efficiency of the turbine.

At present, the common method of manufacturing error detection is to use the three coordinate measuring instrument to measure the output of the text or Excel text format, and the error analysis is carried out by the specific software. Therefore, this paper mainly studies the turbine blade based on MATLAB error analysis system, the system can simultaneously multi type point data were analyzed, and the output of the analysis results.

II. Data Preprocessing

The steam turbine blade can be defined into several groups of section line, each line can be divided into inner arc curve, the inlet edge arc and back arc curve and outlet circle four, blade surface machining quality but also through the maximum thickness, leaf length, inlet and outlet edge radius parameters characterization. Get the three coordinates measuring instrument data points contains data the whole profile of all types. Therefore, before the error analysis, we must extract the arc, the back arc, the arc and the arc of the steam.

1. Three Spline Interpolation

In computer aided design, for closed curves, the general use of B spline or Bezier spline curves to deal with, but these curves cannot point through the known point. Therefore, in this paper, an improved piecewise three spline is used to deal with the closed blade profile.

Suppose the measured value point data is $\overline{P}_1, \overline{P}_2, \dots, \overline{P}_n \in R^2$, (The measuring point is in the same vertical height, so the Z coordinate value is ignored), $\overline{P}(s), s \in [0, n]$ is the three spline curve in the interval $[i-1, i] (i = 1, 2, \dots, n)$. The three spline interpolation curve can be obtained by the following formula:

$$\begin{aligned} 4\overline{P}_1 + \overline{P}_2 + \overline{P}_n &= 3(\overline{P}_2 - \overline{P}_n) \\ \overline{P}_{i-1} + 4\overline{P}_i + \overline{P}_{i+1} &= 3(\overline{P}_{i+1} - \overline{P}_{i-1}), i = 1, 2, \dots, n-1 \\ \overline{P}_1 + \overline{P}_{n-1} + 4\overline{P}_n &= 3(\overline{P}_1 - \overline{P}_{n-1}) \end{aligned} \quad (1)$$

Among them, $\overline{P}_i = \frac{d\overline{P}}{ds}(i)$ is the undetermined constant, and \overline{P}_i is the known value point.

Simultaneous solution of the above equation (1) can be obtained \overline{P}_i , and bring it into (2) type, you can obtain the interpolation function $\overline{P}(s)$.

$$\overline{P}^i(t) = \overline{P}_{i-1} + \overline{P}_{i-1}t + (-\overline{P}_i - 2\overline{P}_{i-1} + 3\overline{P}_i - 3\overline{P}_{i-1})t^2 + (\overline{P}_i + \overline{P}_{i-1} - 2\overline{P}_i + 2\overline{P}_{i-1})t^3 \quad (2)$$

Among them, the variable $t = s - i + 1, t \in [0, 1]$. By using the above method, the data of the type value points can be used to synthesize the three spline curve $\bar{P}(s)$.

2. Offset Point Picking Up

The curve equation obtained by the fitting can be further processed, which can be separated from the inner arc, back arc, the arc and the arc of the steam. For the inlet and outlet of the arc, each has an approximate constant radius of curvature, so it can be separated by analyzing the curve of the radius of curvature of the curve.

$$\rho_i = \frac{(1 + y'^2)^{3/2}}{|y''|} \quad y = f_i(x_i) \quad (3)$$

Suppose the curve equation $y = f_i(x), x \in [x_{i-1}, x_i]$ of each segment, because of the two order continuity of the curve equation, the radius of curvature of every point can be calculated conveniently according to the formula (3) of the radius ρ_i of curvature:

- (1) In order to calculate the distance between each type of value point and other points of all types, and compare its size, assuming that the maximum of two points is A, B, then these two points will be the point of the arc and the arc of the steam. In order to calculate the exclusion point A, B out of all points to the straight line LAB distance, assuming that the maximum distance from the point of the line is C, then point C must be the point of the back arc. Take line segment AB of the midpoint of D, and calculate the exclusion point A, B, C and the rest of all points and the distance of point D. If the shortest distance is E, then the point E must be the point on the inner arc, as shown in Figure 1;
- (2) All data points are divided into two groups, the first group of A from the point of passing between the back arc point C to point B points, a total of M points, the second group from the A through the inner arc point E to point B points, a total of N-M points;
- (3) The first type value from the point of A (marked P1), followed by calculating the radius $\rho_i (i = 1, 2, \dots, m)$ difference between the radius of curvature of each point and every two adjacent points $\Delta\rho_i = \rho_{i+1} - \rho_i$, and compared with the set value increment ε between the size;
- (4) If $\Delta\rho_k > \varepsilon$, and $\rho_{k+1} > \rho_k > \rho_{k-1}$. Is that PK+1 does not belong to the inlet (outlet) point on the arc edge, and point to Pk as in (a) Ta point between the steam side arc and back arc;

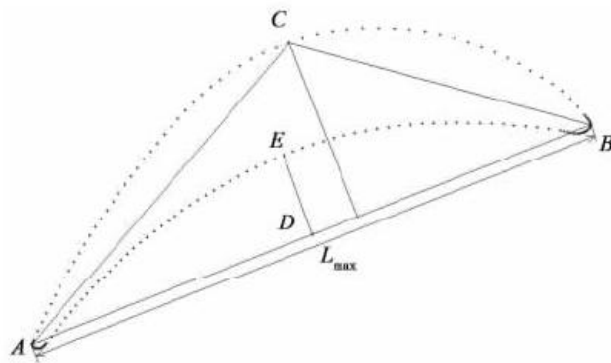


Fig. 1 selection the initial point

- (5) Similarly, the first type value points from point B to calculate, can get out of (into) Sa point between the steam side arc and back arc. The second point is still using the calculation method of type (2)-(4) can get into (out of) Tb point between the steam side arc and inner arc and (in) Sb point between the steam side arc and the inner arc;
- (6) Points of the point \underline{Ta} , \underline{Tb} and \underline{Sa} , \underline{Sb} between the point of the radius of the curvature of the average value, respectively is ρ_1, ρ_2 , if $\rho_1 > \rho_2$, then the point is that the point Ta and Tb belong to the point of the arc, the point between the point Sa and Sb is the point of the arc.

III. Calculation Of Characteristic Parameters

1. Inlet And Outlet Steam Radius

For the inlet edge of the arc, the cut point of Ta, Tb between the radius of curvature of the inlet edge belongs to the arc point on the minimum value[11], which is the inlet edge of the arc radius:

$$R_1 = \min \{ \rho_i \} (i = 1, 2, \dots, m) \quad (4)$$

So will the point Sa, Sb belong to the radius of curvature of edge point on arc minimum, namely the outlet edge radius of arc:

$$R_2 = \min \{ \rho_i \} (i = m + 1, m + 2, \dots, n) \quad (5)$$

2. Blade Chord

The blade chord is value of the distance between two type blade type line the longest distance is in the calculation of the distance \overline{AB} of ① .

3. Maximum Blade Section Thickness

Assuming that the points obtained in the back arc curves are C1,C2,...,CK, the points on the inner arc curve are E1,E2,...,El.Calculate the distance $\overline{C_i E_j} (i = 1, 2, \dots, k; j = 1, 2, \dots, l)$ between each two points on the back arc and the inner arc curve, the maximum thickness of the blade section can be expressed as

$$\max_{i \in [1, k]} \left\{ \min_{j \in [1, l]} (\overline{C_i E_j}) \right\}.$$

IV. Application Example

Based on the analysis of the error of each step of the above steps, this paper based on the MATLAB of the steam turbine blade surface error analysis software. In leaves of B400 Wuxi Dingyuan Precision Machinery Co. Ltd production as an example, through the three coordinate measuring instrument, measuring the height of the surface profile of Z=250 type system[12], the error results are shown in Table 1 the output of the measurement system will analyze import error.

Table 1 results of error analysis

	maximum section thickness of blade/mm	blade chord/mm	arc radius of inlet side/mm	arc radius of outlet side/mm
theoretical data	25.742	100.864	2.347	1.227
experimental data	25.910	100.108	2.483	1.309
Error percentage	0.65%	0.75%	5.80%	6.68%

V. Conclusion

- (1) To deal with the error analysis of the blade section type line, first of all, the data of the type value points are processed by the method of section three spline closed curve fitting;
- (2) The curvature radius comparison method is used to distinguish the arc, the back arc, the arc and the arc of the steam;
- (3) The results show that the machining error analysis software based on the turbine blade surface machining error analysis software can realize the analysis of the machining error, and can batch process, improve the analysis efficiency.

References

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