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Research on Optimization of NC Machining Parameters

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Abstract. The necessity and research development of the optimization of NC machining parameters is analyzed. Problems, probable solutions, development trend of the optimization research of NC machining parameters are reviewed. And some useful research directions are proposed.

Introduction

Manufacturing technology is the main power in promoting human history development and the process of civilization, it's the material foundation of economic and social development, it plays an important role in the national economy. With the development of computer technology and modern control theory, CNC machine tool has appeared. In recent years it has appeared in almost of the manufacturing filed due to its unique advantages. With the rapid development of CNC machine tool, it is being developed toward high efficiency, high speed, high precision, complex processing, five axis machine tool is this high-grade CNC machine tool. It can process most of the procedure of a work piece through one time clamping, which greatly increasing the production efficiency. It is the best way in processing impeller, rotor and crankshaft [1].

Technology of NC machining is the base and key of modern automatic, flexible and numeric machining technology. It is an important research subject in modern mechanical industry to improve the efficiency of numerical control process. The intent of this article is to present the way to improve productivity and reduce productive cost by setting up optimization system to achieve reasonable machining parameters [2]; In process of NC machining, especially in process of machining complex surfaces, the cutting conditions can change. However, cutting parameters are still chosen artificially and remain unchanged in present process of NC machining, which causes the decrease of NC machine productivity [3].

The machining process parameters optimization

The NC machining. According to the optimization of NC parameters of complex parts with great change in NC manufacturing, the method to discrete simulation is used in this paper. Shape of the work piece is subdivided into uniform meshes and the depth of each cell being machined by the milling cutter is calculated. The cutting depth of the cutter in corresponding cutter spacing is figured out with the cutter spacing files [4]. Then the process route is dispersed with the change of the cutting depth, and each process route segment is optimized according to steady parameters method. The continuous varying parameter optimization problem is transformed to discrete multi-parameter optimization problem and the corresponding model is constructed. Then the multi-parameter optimization problem is rapidly solved by decomposing it to many sub-problems. At last the math optimized model is established, and the optimized program is compiled which is operated in PC in order to determine the best cutting parameters in this route. In the machining process of the part there are several such routes, so the globally optimized parameters can be achieved by optimizing each route [5-6]. It is always the main components using five axis CNC machine tool, because its material, surface quality and precision requirements are generally high and tradition method will cause a great waste. Virtual machining technology can construct model of CNC machine tool, simulate work piece processing, verify NC code, and solve the processing problems, so it has a very good application prospect. In this paper, I will use CNC simulation software VERICUT and CAD/CAM software UG

NX6.0 through the establishment of virtual five axes machine tool and tool library, complete the engine impeller virtual machining.

The key technology. Geometry-dynamics modeling in five-axis numerical control milling with cutting parameters optimization is one of the key technologies to manufacturing the vital parts independently in national projects. It is also an effective way to improving the productivity and precision in manufacturing enterprises. However, some important questions remain as follows. In the stage of tool path generation and optimization, the commercial CAM software in general lack of the analysis of global approximation between the surface enveloped by tool motion and the design surface via fine-tuning of the discrete cutter locations. In the stage of selection and optimization of the cutting parameters, the effective modeling, simulations and the quantitative uncertainty analysis in five-axis machining process are absent. The cutting parameters optimization is traditionally developed based on the deterministic parameter model, thus the obtained nominal optimization results are not the real ones as expected in practical machining.

$$v_c = \frac{\pi n d_0}{60 \times 1000} \tag{1}$$

$$v_f = n \cdot f = n \cdot f_z \cdot Z \tag{2}$$

This paper aims to solving the problems given above arising from the studies and shop floor. The relationships of the contents of this paper are rational motion design of rigid point-fine-swept surface generation of tool spatial motion-tool path optimization-robust cutting parameters optimization. The tool path optimization and cutting parameters optimization in five-axis numerical control machining of complex surfaces are detailed to improve the productivity and precision from a geometry way as well as a dynamics way.

$$F_i = C_{F_i} a_p^{x_{F_i}} f^{y_{F_i}} v^{z_{F_i}} K_{F_i} \tag{3}$$

Processing movement design

The cutting tool is viewed as the rigid point-line from a respective of kinematics, and then the study of the cutting tool motion can be transformed into that of the rigid point-line. The mapping of the point-line rational motion to the hyper-plane curve in dual quaternion's space is constructed. The rational motion design of the rigid point-line is developed. In the frame of rigid point-line motion design, the problem of design of rational ruled surface is transformed into that of hyper-plane curve design in dual quaternion's space. The design and optimization of the cutting tool orientation curve, which is a sphere NURBS curve is viewed as the curve design and optimization in quaternion space. The experiment, optimization of cutting tool orientation curve in five-axis machining of blade structures, indicates that the overcuts in the machining are eliminated and the quality is improved after optimizing the tool orientation curve.

$$left = \min(m_1, m_2),\ \ borrom = \min\left(n_1 - \frac{R}{\nabla y}, n_2 - \frac{R}{\nabla y}\right) \tag{4}$$

$$right = \max(m_1, m_2),\ \ top = \max\left(n_2 + \frac{R}{\nabla y}, n_1 + \frac{R}{\nabla y}\right) \tag{5}$$

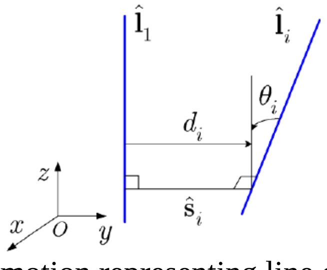

Fig. 1 Screw motion representing line displacement

The individual cutter locations are viewed as the discrete spatial point-lines and the continuous tool path is generated by using the rational motion method. The analytical swept surface of typical cutting tool used in five-axis motion is developed based on the double parameters envelope theory of sphere congruence. The problem of global tool path optimization is then transformed into that of the comparison of two surfaces, i.e. designed surface and the swept envelop surface. Optimization of five-axis tool path is modeled as fine tuning of initial cutter locations under the minimum zone criterion which requires to minimize the maximum geometrical deviation between the design surface and the envelop surface.

Table 1 The discrete point - line coordinates

px	py	pz
34.0628	2.3206	-0.6628
20.2133	-10.0726	0.2033
3.9795	-17.6729	-0.1776
-14.8317	-32.6353	0.6269
19.8372	-11.5360	0.6834
12.5479	-13.0996	0.1185
4.5728	-15.4883	-0.2732
-3.6213	-21.4639	-0.8878

The finite shell element model of work piece is developed, and the material removal process in milling is treated as the perturbation of the work piece geometry. The effect of material removal on the modal shapes of blade structure in high-speed machining is predicted by using the matrix perturbation theory, as a result the varying dynamics of work piece are obtained and the modal shape experiments are reduced.

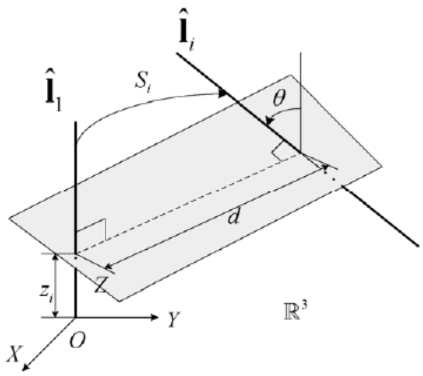

Fig. 2 A special case of line displacement.

The experiment results validate the theoretical predictions. Considering the uncertainties in work piece-tool, the interval finite element characteristic matrices of workpiece-tool are obtained using the interval arithmetic. Upper and lower bounds of dynamic responses of the tool are derived based on the interval arithmetic.

$$\begin{pmatrix}\mathbf{l}_1\\0\end{pmatrix}\cdot\mathbf{Q}_i=\begin{pmatrix}\mathbf{l}_1\\0\end{pmatrix}\cdot\begin{pmatrix}\mathbf{s}_1\sin\dfrac{\theta_i}{2}\\ \cos\dfrac{\theta_i}{2}\end{pmatrix}=0\quad(i=1,2,\cdots n)\tag{6}$$

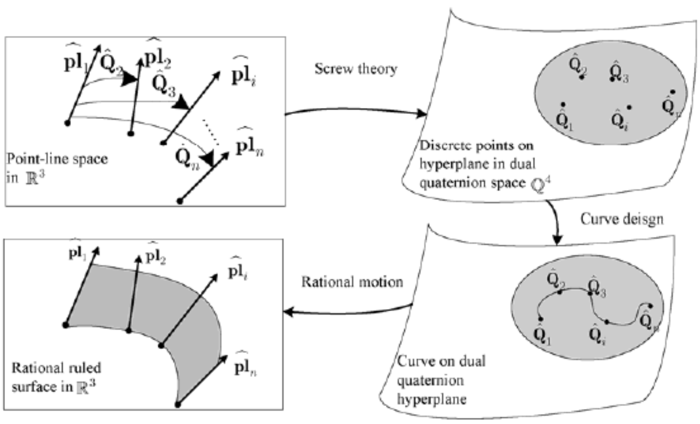

Fig. 3 Kinematic generation of ruled surface with rational motion method.

Based on the sensitivity analysis, considering the uncertain parameters in five-axis machining, the upper and lower bounds of chatter lobes and the dynamic responses of tool are obtained. The multi-object optimization problem with uncertain parameters is transformed into the single-object optimization one with deterministic parameters. In practical five-axis machining of blade structure, considering the uncertain parameters of modes of tool system, the robust optimization model is developed, in which the optimization object is to maximize the spindle speeds and minimize the tool vibration amplitudes, and the constrained condition is to keep the machining process un-chatter. Comparing with the deterministic model, the results of the robust model guarantee the stability of the milling process and improve the surface quality of the blade structure.

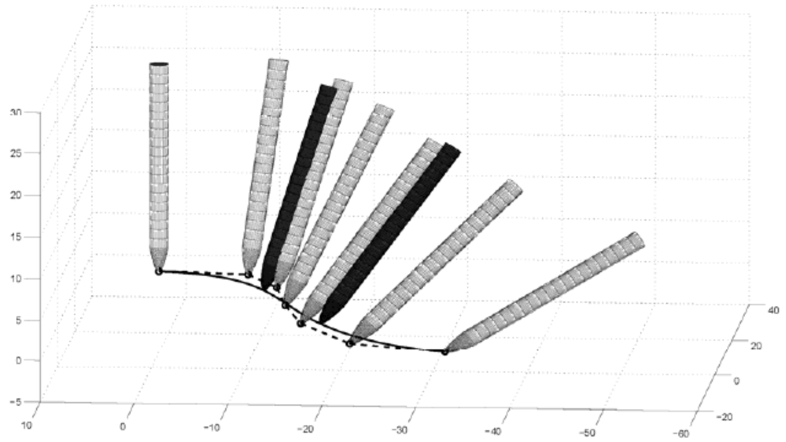

Fig. 4 Control structure of a point-line rational motion of degree 6

Summary

In this paper, the optimization of varying machining parameters for NC cutting operations is discussed. It can improve the efficiency effectively. Using the method a great deal of technologists could be released from the repeated handwork, and rationalization and standardization of cutting parameters will be realized, productivity of the machining center can be improved and well economy benefits should be obtained consequently.

References

[1] Xiong Y, Wu J, Deng C, et al. Machining process parameters optimization for heavy-duty CNC machine tools in sustainable manufacturing. International Journal of Advanced Manufacturing Technology, Vol. 18 (2013) No, 4, p. 1-10.

[2] Cai A J, Guo S H, Dong Z Y, et al. Cutting Parameter Optimization Technique for High Efficiency NC Machining. Advanced Materials Research, Vol. 211-212 (2011), No. 10, p. 167-171.

[3] Pradhan S K, Saini S K. Multi-Objective Optimization of CNC Turning Machining Parameters. Advanced Materials Research, Vol. 1016 (2014) No. 1016, p. 172-176.

[4] Saini S K, Pradhan S K. Optimization of Machining Parameters for CNC Turning of Different Materials. Applied Mechanics & Materials, Vol. 592-594 (2014) No. 592-594, p. 605-609.

[5] Zhao C L, Guan X S. Parameter Optimization of Thermal Error of NC Machine Based on Matlab. Advanced Materials Research, Vol. 657 (2013), p. 1224-1227.

[6] Zhang C, Zhou L, An L, et al. Optimization of NC machining parameters based on machining simulation[J]. China Mechanical Engineering, Vol. 18 (2007) No. 24, p. 2955-2954.