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RESEARCH ON TOOL PERFORMANCE EVALUATION AND PARAMETER MATCHING BASED ON SHAPE-PERFORMANCE APPLICATION THEORY

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Green manufacturing engineering is the mainstream of the development of the 21st century, so the dry cutting technology is gradually concerned by various scholars, because the technology does not use or trace use of cutting fluid and has a green environmental protection role. However, due to the lack of cutting fluid in the dry cutting process, resulting in higher cutting temperature, so that the tool wear speeds up, tool life and processing efficiency are reduced.

Key words: tool performance; shape-performance; titanium alloy; integrated design; cutting parameters.

Research purpose and significance

Titanium alloy is a kind of difficult to process materials, because of its good thermodynamic properties, high corrosion resistance, high strength to weight ratio and other capabilities and widely used in a number of mechanical manufacturing fields, the field of aerospace, but difficult to process materials with large cutting force, short tool life, high cutting temperature, poor machining surface characteristics, so in the process of titanium alloy cutting, The same will appear the speed of tool wear, tool life reduction, processing efficiency reduction and other problems. Therefore, in the process of dry cutting titanium alloy, in order to solve the problem of low tool life and low processing efficiency, it is necessary to optimize the design of tool shape parameters and tool parameters, improve tool life and efficiency, reduce tool wear speed.

Tool "Shape-Performance-Application" integrated design theory based on parameter matching and performance evaluation

Nowadays, there are a variety of tool design methods in common use, but there is no one fixed tool design method can be used to guide the design and development of all tools or a class of tools. Therefore, for the purpose of parameter matching and performance evaluation, the tool "Shape-Performance-Application" integrated design theory based on parameter matching and performance evaluation is proposed. This theory means that under the condition of specified workpiece parameters, it can predict the tool performance in the forward direction, evaluate the tool performance according to the predicted value, and match the parameters in the reverse direction by relying on the correlation relationship between the performance indicator, tool geometric parameter and tool operating parameter. According to this theory, an integrated tool design method based on the theory of "Shape-Performance-Application" is established. Through the establishment of this method, the design and development of all tools are realized.

Dry milling (side milling) of square block titanium alloy with integral carbide end milling cutter is studied. In order to improve the tool life and machining efficiency, the tool wear rate and material removal rate are taken as the performance indicators. The tool geometric parameters and tool operating parameters are designed for the end milling cutter. According to the integrated tool design method based on "Shape-Performance-Application" theory, the matching research of tool shape parameters and non-quantifiable parameters in tool use parameters is given priority. Among them, the unquantifiable parameters of the tool shape parameters include the tool type, tool material, tool structure and tool coating, and the tool operating parameters include machine tool parameters, tool installation, cutting mode and tool clamping. According to the shape of titanium alloy workpiece, material properties, physical and chemical properties and other parameters, and in order to save costs, reduce the waste of workpiece, the use of finite element method and analytical method to obtain the tool wear rate and material removal rate, so the tool type is end milling cutter, tool structure is integral, tool material is YG6 hard alloy, coating selection without coating, machine tool parameters, tool installation and tool clamping are not considered, and the cutting mode is dry side milling.

Comprehensive importance evaluation of tool parameters and cutting parameters

After the unquantifiable parameters of tool geometric parameters and tool operating parameters are obtained, the matching between quantifiable parameters is studied. Among them, quantifiable parameters include tool parameters and cutting parameters. In the process of tool design, the performance indicators will be selected according to the requirements, but it is difficult to meet the performance indicators at the same time. In order to solve the above problems, the correlation between parameters and performance indicators is essential, but there are many influencing parameters in the cutting process, such as tool parameters, cutting parameters and so on. Therefore, in order to speed up the research process and reduce the complexity of the correlation function, it is necessary to prioritize the comprehensive importance evaluation of each parameter to multiple performance indicators, so as to select several parameters with the highest comprehensive importance for subsequent research. Grey-fuzzy analytic hierarchy process is a method combining grey theory and fuzzy theory, which can solve the problem of inaccurate evaluation results caused by limited test times in cutting process, and the problem of unclear interaction mechanism and degree between parameters and performance indicators in cutting process. Analytic hierarchy process solves the problem of comprehensive evaluation of multiple performance indicators. According to the characteristics of dry milling titanium alloy with end milling cutter, the cutting parameters are selected as the rake angle, clearance angle and helix angle, and the cutting parameters are selected as the cutting speed, feed per tooth, cutting depth and cutting width. SPSS software is used to establish 7 factors 3 horizontal orthogonal test without considering the interaction between parameters. The tool wear rate and material removal rate corresponding to the combination of different tool parameters and cutting parameters are obtained by finite element method and analytical method. The comprehensive importance of tool parameters and cutting parameters is evaluated by using grey-fuzzy analytic hierarchy process, and the ranking is carried out according to the evaluation results. The results showed that clearance angle, helix angle, feed per tooth and cutting depth are the four parameters with the highest comprehensive importance, which are selected for the subsequent parameter combination optimization and evaluation.

Horizontal optimization of tool parameters and cutting parameters

The parameters of the highest comprehensive importance are studied to determine the range of tool parameters and cutting parameters. In the process of cutting, tool wear, cutting force, surface roughness and other performance indicator values change with the progress of cutting at any time. Therefore, according to the characteristics of dynamic change of performance indicators, the dynamic comprehensive evaluation method based on gain level excitation is selected to comprehensively evaluate each level of tool parameters and cutting parameters, and optimize the value range of tool parameters and cutting parameters. SPSS software is used to establish 4 factors and 5 horizontal orthogonal tests without considering the interaction between parameters. Finite element method and analytical method are used to obtain the tool wear rate and material removal rate of different tool parameters and cutting parameters combination at different stages. The dynamic comprehensive evaluation method based on gain level excitation is used to analyze and process the tool wear rate and material removal rate of each stage, and the total dynamic comprehensive evaluation value of each level of the same parameter is obtained. According to the evaluation value, the optimized value range of tool parameters and cutting parameters is obtained. The optimized results are as follows: clearance angle 8°-11°, helix angle 30°-33°, feed rate 0.15mm/z-0.25 mm/z, cutting depth 2mm-3mm.

Optimization design of end milling cutter based on Shape-Performance-Application theory and method

The last stage performance indicator values corresponding to the orthogonal test table in the last chapter are selected for analysis and research. The response surface method is used to analyze the interaction between the parameters. For the tool wear rate, the interaction between the clearance angle and feed per tooth is the most influential term, and the feed per tooth is the least influential term. For material removal rate, the independent term of feed per tooth, the independent term of cutting depth and the interaction term between feed per tooth and cutting depth are the most influential terms, while the interaction term between clearance angle and helix angle has the least influence. At the same time, response surface method is used to obtain the correlation function of tool wear rate and material removal rate with respect to tool parameters and cutting parameters. According to the integrated tool design method based on "Shape-Performance-Application" theory, the tool parameters and cutting parameters are optimized by using NSGA2 multi-objective genetic algorithm, and the results are derived in table form. The dry cutting tool performance evaluation system is established by using grey-fuzzy analytic hierarchy process and programming language, which includes single parameter evaluation function, multi-group parameter evaluation function and table parameter evaluation function. The data in the parameter optimization table is analyzed and processed through the table parameter evaluation function of the tool performance evaluation system, and the data with problems are deleted. The qualified parameter combination is selected and the tool performance is evaluated. The results show that the optimal tool parameter combination is 10.5° clearance angle, 31.5° helix angle, 0.15mm/z feed per tooth and 3mm cutting depth.