

High Efficiency Milling of Steam Turbine Blade

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The rotor blade, which is typically 60 inches in length, has a complex shape and needs to be made out by a material of low thermal conductivity to withstand temperatures above 600 degree Celsius. 12%Cr steel is a series of heat-resistant steel used as turbine blade material because of its high creep rupture properties as well as superior oxidation and corrosion resistance properties. In order to satisfy the accuracy requirement, it is usual to be machined on an over 4-axis machine tool using a small diameter ball end mill. To satisfy the requirements of surface roughness, it is necessary to lower the pick feed, which leads to an increase of cutting distance and time. In the material which is low thermal conductivity, as heat flow is hardly to diffuse, the tool wear easily progresses. As a result, it leads to deterioration of surface roughness in spite of long cutting time. Furthermore, low machinability due to this causes high temperature on the tool face and strong chemical affinity with most tool material, thereby leading to premature tool failure. Many investigations have been carried out on tool wear and machinability of stainless steel. All the work is contribute to improve the milling efficiency or accuracy, but it still has a limit due to a small pick feed value.

Conventional machining method of turbine blade, often use a small diameter, in the pick feed direction, the surface roughness definitely occurs. In general, hand finish is necessary. In order to satisfy the surface integrity, small pick feed value is selected, which caused the cutting distance to be longer. Due to this, tool wear is severe when milling stainless steel. It will shorten the tool life and affect the machining accuracy. Moreover, the removal rate is very low because it takes quite a long time to milling a piece of blade using ball end mill. For the end of improving the milling efficiency of steam turbine blade and retarding the tool wear, we propose a new method. The research will verify its validity both in theoretically and experimentally, and develop a new CAD/CAM for generating the tool path of the new method, furthermore, the machining mechanism of the proposed method is explained.

Chapter 2 will introduce the proposed tilt taper end mill method, and simulation the theoretical surface roughness in both pick feed and feed direction, in certain range, it satisfy the requirement of proposed method.

Chapter 3 will introduce the validity examination of tilt taper end mill. Considering the differences of conventional method and proposed method, model experiment is needed. In order to measure the surface property, the surface is plane. An important merit of taper end

mill is that can retard the tool wear, therefore, tool wear experiments is necessary. When doing the experiments, surface property such as surface roughness and surface profiles are be evaluated, using these factors to examine the validity. Tilt taper end mill owns the characteristics of ball end mill and square end mill, in order to prove the advantage of tilt taper end mill method, tool wear experiments of the three methods are carried out, the results will be discussed. Before performing it, cutting conditions selection are need. At first we selected pick feed of tilt taper end mill is 4mm, and then feed per tooth and cutting speed and axial depth of cut were selected according to the influence on surface roughness of each factor, cutting conditions of the other two methods are decided based on the cutting conditions of tilt taper end mill. Another, we selected cutting conditions of the three methods though examining the influence on surface roughness of each factor. Tool wear experiments were carried out according to the selected two cutting conditions. The results show that only taper end mill can complete the total removal amount under required surface roughness, and until completing the work, the machined surface keeps uniform with tool wear. Surface property of the other two methods were effected by tool wear easily, surface roughness value over the required value before completed the total work.

Chapter 4 will introduce the cutting force and cutting temperature of three cutting methods.

The low thermal conductivity of the material results in high cutting temperature, which is associated with deformation and friction at the tool-chip and tool-workpiece interface. The tool wear experiments had shown the validity of tilt taper end mill method, but it still cannot explain the mechanism. In this chapter, a device was designed for measuring the cutting force and cutting temperature. Though the experimental results, the waviness of cutting force using taper end mill can keep stead until complete the total work, and the milling process of taper end mill is discontinuous. Owing to this, the heat can be removed instantaneously so that the tool life can be extended, it is benefit for keep a good surface property. The results shows that cutting process of tilt taper end mill is discontinuous, the real cutting time only is about 10% of a cutting period, therefore it has enough time to cool off the heat generated by cutting. This will be benefit for retarding the tool wear to obtain a higher surface quality.

Chapter 5 will introduce the special CAD/CAM for tilt taper end mill. The surface of steam turbine blade is freeform surface, tool path is needed when milling it. Current commercial CAM is difficult to generate the tool path for the proposed method. Due to this, the objective of this chapter is to solve it and obtain a high accuracy surface, it will present an implementing work in automatic generation of 5-axis tool paths and NC code for the special taper end mill, and then verify the validity through modeling experiments of sphere. From the application example, it knew that the generated NC code could be successfully implemented in machining spherical surface, and relative error can be controlled within 0.15%.

Chapter 6 will summary the thesis and give a description of the future work.