Color Image Display On Cylindrical Surfaces By Vibration Cutting

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Solid surfaces with special optical micro-nano structures will show a unique structural color effect that changes with the observation angle. Due to the high efficiency and high precision of its micro-nano structure, vibration cutting technology has attracted wide attention in the field of structural color surface application in recent years. This paper presents an innovative approach to realize structural color image on cylindrical surface based on vibration cutting. Different from the generating principle of the planar structure color pattern, the mapping relationship between the dominant wavelength of diffractive light on the structured cylindrical surface and the incident angle and observation angle dependent on the position of the circular surface was established in this study, and the optimal design method of workpiece speed and tool feed speed in the process of cylindrical turning is obtained by using PVT command commonly used in machine tool.

1. Introduction

Due to the outstanding optical, tribological, mechanical and biological properties, the surface micro-nano structure has been widely studied and applied in the various fields [1]. Different from the production of pigment color, the structural color originates from the optical physical effects such as interference, scattering, diffraction, etc. The wavelength of the light wave affected by the micro-nano structure will change with the change of the incidence angle of light, thus resulting in the visual change of the structural color [2]. Compared with pigment color, structural color not only has the advantages of high stability and no pollution, but also has variable color and can be accurately regulated. In addition to the functional decoration, the structural color can be used not only for anti-counterfeiting [3], but also for sensing the bending state of PAWS [4].

During vibration cutting, vibration is applied to the cutting tool to accurately generate periodic micro-nano structures on the metal surface. This method can reduce cutting force, improve surface finish, suppress burrs and increase tool life, so it is applied to multiple materials difficult to process materials and brittle materials [5]. Recently, an effective method for rendering diffractive structural color image is proposed using elliptical vibration texturing [6]. It can precisely control the target color by coupling the cutting speed and frequency. However, these studies can only be processed on the plane surface, so this study proposed a method of using vibration machining to process color patterns on the cylinder surface, and provided a feasible scheme for rapid and economical -scale production of structural color components.

2. Principle and Simulation

2.1 Principle

Different from pigment colors that selectively absorb, reflect and project light with specific wavelengths, structural colors are generated by the scattering, diffraction or interference of visible light on the surface of some objects with specific micro and nano structure, and the corresponding wavelength of light will change with the change of incident angle and observation angle. As shown in Fig. 1, the relationship between the diffractive structural color and the observation and incidence angles is given by the classical grating diffraction theory.

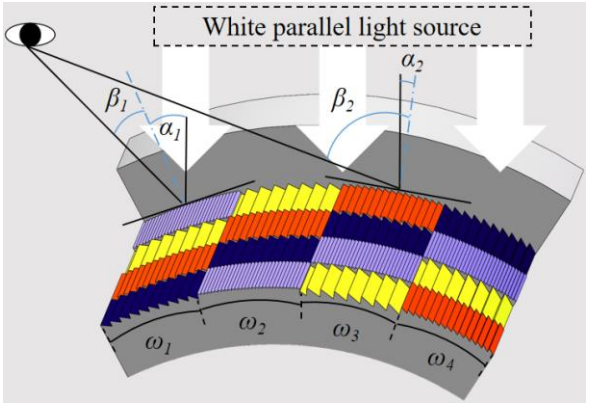

Fig. 1 Schematic of structural color on cylindrical surface

As shown in Fig. 2, the vibrating cutting device can provide a one-dimensional vibration in the Z direction at the micro and nano level. On the other hand, the rotation of the cylinder provides a nominal cutting speed, and at the same time, provides a feed speed for the tool along the axis of the cylinder in the Y direction.

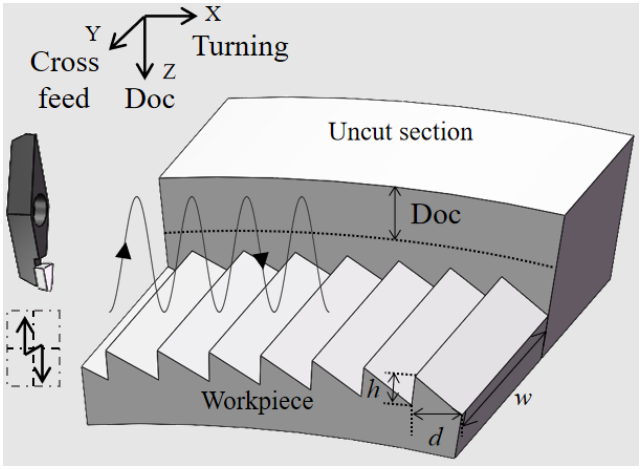

Fig. 2 Vibration cutting diagram

2.2 Pixel segmentation PVT algorithm for dynamic color image

A pixel segmentation PVT method with similar wavelength is proposed in this paper. When the pixel segments are too short or too long, the fitting effect will start to deteriorate. Therefore, the shortest pixel and the longest pixel segment should be bounded. When the wavelength of adjacent pixels approaches and is accumulated to exceed the number of the shortest pixel segment, but not exceed the number of the longest pixel segment, then the number of pixels with similar wavelengths in the segment is divided into segments. If the segment exceeds the number of the longest pixel segment, then the segment is divided into multiple segments for fitting. Because the principle of observing structural color optical patterns on the cylindrical surface is different from that of the plane, the cylindrical surface is composed of multiple structural color patterns, but only one pair of patterns can be observed at a time, so it is necessary to use the shortest number of pixels at the pattern conversion to fit the sudden change of speed.

After the algorithm optimization, the method of obtaining the optimal integer millisecond time needs to be changed accordingly. The method of the optimal integer millisecond time is to give a maximum time difference number for the interval between the minimum and the maximum time obtained by the original optimal integer time search method. When the interval is greater than the maximum time difference, it is necessary to shorten the interval to improve efficiency. That is, the time average of all pixels in this period is rounded down, and then half of the maximum time difference is added and subtracted to obtain a new time search interval. As shown in Fig. 3, after the optimization of the pixel segmentation algorithm, the pvt speed curve can not only fit the ground speed change caused by adjacent wavelength change, but also fit the speed gradient segment with similar wavelength without speed jitter.

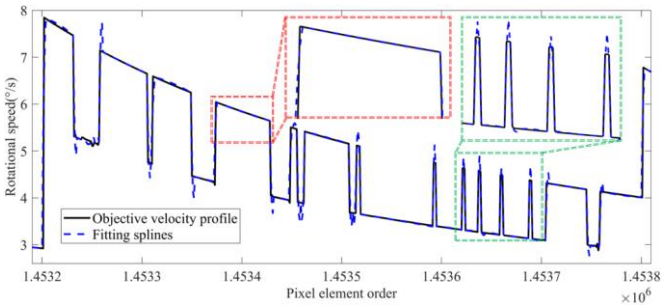

Fig. 3 Fitting results of the pixel segmentation PVT algorithm

3. Conclusions

In this paper, a method to realize color pattern on the surface of a cylinder is proposed. The grating spacing is controlled by adjusting the rotation speed of the rotation axis, and then the color of the pattern is adjusted. The mapping relationship between the dominant wavelength of diffractive light on the cylindrical surface and the incident angle and observation angle is discussed. The pixel segmentation PVT algorithm is used for dynamic color image. The color patterns of optical structures can be modulated by vibrating textures on surfaces such as cylinders, which provides the possibility of machining optical structure patterns on more complex surface.

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