3D Simulation of Regular Surface Texturing on Free Form Surfaces by Using Patterned Grinding Process

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Abstract— Surface texturing is a process of generating patterns on the surface of a workpiece to provide functionality or for aesthetic reasons. Grinding is one of the cheapest yet indispensable method used for surface texturing. In texturing by grinding process, the grinding wheel needs to have a particular shapes or patterns such as helical grooves on its peripheral surface. These patterns are then printed on the surface of workpiece upon grinding i.e. by the relative motion of the wheel and the workpiece. The pattern shapes depends on various factors such as grinding cutting speed, feed rate and geometry of the helical groove. Prediction of patterns on the freeform surface prior to texturing process by 3D simulation built over mathematical model is very crucial. If the textured patterns are predictable, various grinding parameters can be determined easily. This paper presents a 3D simulation environment for the prediction of patterns on freeform surfaces.

Keywords- 3D simulation; surface texturing; patterned grinding wheel; non-planar surface texturing

I. INTRODUCTION

Grinding wheels are commonly dressed to maximize the performance of grinding operation. During grinding, micro particles from machining debris enters into the pores on the wheel surface and prevents wheel loading which is essential for smooth grinding (improves surface finish) and cause vibration and leave burn marks on the workpiece. A common tool used for this purpose is single point diamond dresser. This diamond dresser can be used for making grooves on the active surface of workpiece along the circumference.

II. RESEARCH METHODOLOGY

In grinding, by the mechanism of wheel surface reproduction, patterns on the surface of wheel can be directly transferred to workpiece surface. The first step involves in the preparation of wheel. Grooves can be made on the surface of wheel by using standard single point diamond dresser.

A. Modeling of the round tip of diamond dresser

The diamond dresser used for making profile on the surface of the grinding wheel has round tip with radius 1 mm. As it is important to know the geometry of the tip prior to incorporating it in the wheel, the round tip is modelled by using equation (1) and is verified by using octave. The working height of the tool tip h is a combination of non-linear and linear portion of the tool

and it varies along the x-axis. The height h at any arbitrary point on the x-axis can be given by the following equation¹.

$$h = \frac{x_0}{\tan(\alpha/2)} - \frac{x}{\tan(\alpha/2)} + y_0 \quad (1)$$

Table 1. Parameters for making profile of round tip

Sr. #	Parameters	Values
1	r= radius of round tip	1mm
2	t= distance from tool tip to center of wheel	2mm
3	α = crest angle	70°

By putting parameters given in table (1) in equation (1), the following graph has been obtained which is the representation of the round tip of diamond dresser.

Fig. 1. Profile of the round tip of diamond dresser

B. Geometric Modelling of Grinding Wheel

The patterns on the active surface of grinding wheels can be printed directly to the surface being machined. Different profiles can be made to obtain different textures on the workpiece surface. In this experiment a single groove has been modeled using screw theory. Number of turns were set to 3 while pitch and crest angle were maintained at 2 and 45 degree respectively².

Fig. 2. A 3D simulation of grinding wheel having helical groove on its active surface.

The patterns are then transferred by the relative motion of the patterned grinding wheel and the freeform surface.

Fig. 3. Relative motion between grooved wheel and Non-Planar surface

III. NUMERICAL SIMULATION

Numerical simulation that is explicitly based on mathematical algorithm is developed in open source high-level interpreted language, GNU Octave. This program is used because of its command-line interface, which is more suitable for programming and its ability to solve non-linear computational problems efficiently. Flow chart of process is shown below.

Fig. 4. Swim Lane diagram for the texturing process

IV. RESULTS

The algorithm explained in figure (4) is then used to build mathematical model which formed the basis of developing 3D simulation software. A 3D simulation of textured freeform surface is shown in figure (5a) while verification of simulation results is shown in figure (5b).

Fig. 5. (a) A 3D simulated freeform surface having textures (b) Micrograph of real textured Non-Planar surface.

The results of 3D simulation are quite satisfactory and helps in the prediction of textures prior to the actual grinding machining process. In the development of above 3D textured surface, pitch was set to 2 mm and machining simulation was carried out for 30 minutes due to limited number of resources and absence of parallel processing facility. A series of experiments were carried out by varying the geometric parameters and changing the values of the variables to see the effect on output surface. The results have been found in complete agreement with 3D simulation results. It has been found that the ratio of cutting speed to feed rate is very important to determine the shape and length of textures. This ratio should be kept enough high to get textures because at a certain low ratio no vivid textures are generated. This property provides an evidence that this method is an accurate simulation of texturing process rather than stamping due to rolling of wheel.

V. CONCLUSION

A 3D simulation environment has been built that can be used to predict textures over any freeform surface. This tool will boost the productivity of texturing technology by helping us to choose texturing parameters for optimal texturing.

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