Development of a Grain Milling System by Use of Digital Data

Daijiro Uzuyama[1], Mamoru Kikuta[2] and Kenjiro Miura[3]

[1]Shizuoka University, f0930018@ipc.shizuoka.ac.jp
[2]Calsonic Kansei Corp., KIKUTA-M@ck-mail.com
[3]Shizuoka University, tmkmiur@ipc.shizuoka.ac.jp

ABSTRACT

The surfaces of automobile interior parts have geometrically microfabricated, which are called grain. The purpose of our research is to mill dies with grain by use of their digital data. We generate microfabricated geometry data from a CAD model of a die with displacement mapping. With these geometry data, the die with grain is manufactured by milling. Our proposed method does not need chemicals, elaborated human skills or long time experiences, and can easily control grain mapping and the depth of grain milling.

Keywords: grain milling system, displacement mapping.
DOI: 10.3722/cadaps.2010.291-296

1 INTRODUCTION

The surfaces of automobile interior parts, stationery products and home electric appliances have geometrically microfabricated, which are called "grain". This purpose is to have premium accents (making a good showing and tactile impression) and slip stopper. Especially it is important to have premium accents for the surfaces of automobile interior parts. Fig. 1 shows the example of automobile interior parts and grain. Therefore, it is necessary to make the pattern of the grain continuous and distortionless. To generate the grain to the surfaces of resin products, the grain is heretofore generated to the die of them by use of etching or electroforming technique. They are described at 1.1. In our research, we generate the grain by use of digital data in order to make the products high quality and to make the process simple.

1.1 Existing Methods

One of the existing methods to generate the grain to the die is electroforming technique. It is a process of synthesizing a metal object by controlling the electrodeposition of metal passing through an electrolytic solution onto a metal or metallized form. Therefore the repeatability of this method is good, this method is generally used to fabricate the die of luxury cars interior parts. The degree of accuracy is about 0.1 micrometer. However, this method needs long time and high cost to synthesize a metal object. The other existing method is etching. Etching is the process of using strong acid or mordant to cut into the unprotected parts of a metal surface to create a design in the metal. Though the processing time of this method is short, this is not accurate. In addition, this method is bad for the environment for chemical treatment. In this work, a natural grain texture and a geometrical texture are used, but there are researches on how to generate naturally looking texture and extend a small texture to cover large areas [1, 2].

(a) Automobile interior parts (b) Grain

Fig. 1: The example of automobile interior parts and grain.

1.2 Our Approach

Our Approach is to mill dies with grain by use of their digital data. Existing methods can't be used without specialist equipments and elaborated human skills. However, the method which is to mill by use of the digital data is able to be used by general processing machine. In existing methods, it is difficult to control size, pattern and position of grain. However, it may be palliative to easily control them in our approach. The grain milling system which is developed by us is composed of two parts. One part is to generate grain to shape models of dies with parametric surfaces by use of digital data of grain. The other part is to process dies by milling or laser machining with the digital data of dies with grain.

2 THE METHOD TO CREATE THE DIGITAL DATA

In this chapter, it is described how to create the digital data of dies with grain. The shape model created by CAD software generally has some parametric surfaces. However, it is difficult to render complicated and microscopical grain by their parametric surfaces. Therefore, creating the polygon mesh of their surfaces, then each vertex is displaced based on the image data of grain in order to render complicated and microscopical grain. This method which displace vertices is called "Displacement mapping" in computer graphics field.

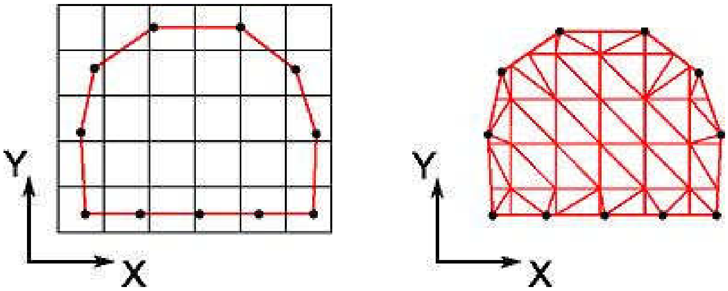
2.1 Polygon Mesh Generation

It is explained how to create the polygon mesh from parametric surfaces which is trimmed. At first, projecting the boundary lines that define trimming a surface to a plain surface (X-Y plane in this paper), We make a boundary polygon of the projected boundary lines. Then a 2D grid mesh is created which covers the polygon on the plane. As Fig. 2 (a) and examine whether each vertex of the grid mesh is inside the polygon. The positions of the inside vertices of the grid mesh and those of the boundary polygon are used to create triangle polygons as shown in Fig. 2 (b). In the next step, Calculating points at the intersection of parametric surfaces with the line from the vertex parallel to the Z axis, we create a 3D mesh by use of the 2D mesh which consists of only triangle polygons.

2.2 Texture Model Generation and Deformation

It is performed in the X-Y plane to correspond grain texture coordinates with vertices of the polygon mesh. Since the area of texture becomes smaller than that of the polygon mesh if the normal vector of the mesh is inclined with the Z axis, the grain texture is elongated in the regions not parallel with the X-Y plane called the standing wall. To solve the problem, it is necessary to shorten the texture in advance. First, a 2D grid mesh is created in the texture coordinate system. The unit length of this texture coordinate system is pixels distance. Second, changing the mesh to X-Y coordinate system, the mesh is translated to cover the target 2D mesh which is projected to X-Y plane. In this paper, this mesh is called a texture model. The example of a texture model is shown to Fig. 3 (a). Pink line is the 2D boundary line of target model, which is projected to X-Y plane. The texture model is deformed by use of the spring-mass model [1]. If both ends of a spring are inside the 2D boundary line, the natural length of the spring l can be represented as follows:

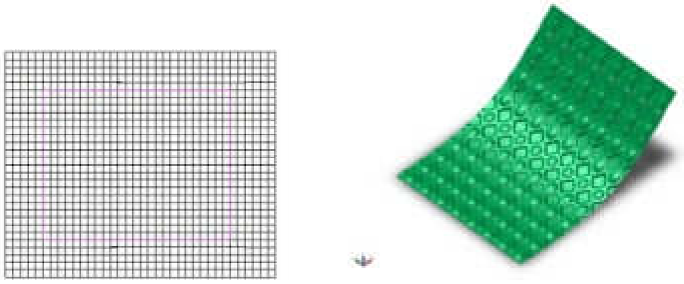
$$l = \frac{l_{2D}^2}{l_{3D}} \tag{2.1}$$



(a) 2D grid mesh (b) Triangle polygons generation

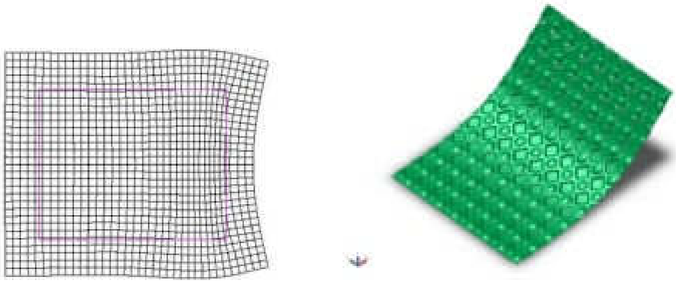
Fig 2: 2D mesh generation.

Where l_{2D} is length of the spring; l_{3D} is difference of two points which are projected both ends of a spring to surfaces of a target model. The natural length of the others springs is not changed. The shape of a deformed texture model is shown to Fig. 4 (a). The processing time is 480[s] on a 2.66[GHz] Core 2 Duo machine. The results of the generation of geometrical pattern grain with texture models are shown to Fig. 3 (a) and Fig. 4 (a) are illustrated to Fig. 3 (b) and Fig. 4 (b).



(a) Texture model (b) Grain generation

Fig. 3: The texture model of the target model and the result without the texture model deformation.



(a) Texture model (b) Grain generation

Fig. 4: The texture model of the target model and the result with the texture model generation.

2.3 Grain Generation

Grain is generated by use of Displacement mapping [2]. Displacement mapping is a method that displaces the vertices of target polygon mesh to normal direction with the texture which has concavo-convex information of the surface. The displaced surface $\vec{p}'(u,v)$ can be represented as follows and is shown to Fig. 5;

$$\vec{p}'(u,v) = \vec{p}(u,v) + d(u,v)\vec{n}(u,v) \tag{2.2}$$

Where $\vec{p}(u,v)$ is original surface; $d(u,v)$ is amount of displacement; $n(u,v)$ is the normal vector of original surface. The amount of displacement is given below. Calculating a point at the intersection of texture model with the line from the vertex parallel to the Z axis, the pixel value g at the point is converted into the amount of displacement d according to the following equation.

$$d = \frac{g}{255} d_{\max} \tag{2.3}$$

Where $d_{\max}$ is the maximum of amount of displacement; the texture is a 256 shades gray scale image.

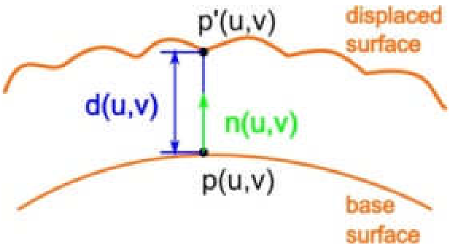


Fig. 5: Displacement mapping.

2.4 Consideration of Draft Angle

Grain of the products surface is generated to normal direction. Since the concavoconvex of dies engage with concavoconvex of products, products may get hunt when products are ejected from dies. To solve the problem, the amount of displacement of dies is changed according to draft angle. The more draft angle comes to $0°$, the more the amount of displacement becomes small. A reduction ratio of displacement r is calculated by use of a function of the draft angle which is arbitrarily defined. Then the reduction ratio r is multiply by the amount of displacement d which is obtained in 2.3. Using this value as a new amount of displacement, depth of grain is changed. An example of changing the depth of grain by use of this method is shown to Fig. 6.

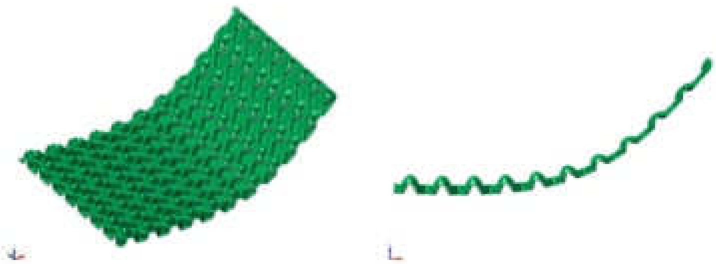


Fig. 6: The result with consideration of draft angle.

2.5 Results

The result of grain generation to a simple model which has trimmed surfaces is shown to Fig. 7. This result was obtained when the length per a pixel and grid interval were 50 [μm]. Fig. 7 will reveal that it is possible to generate grain to some trimmed surfaces. This result of STL file format requires about 350 megabytes of memory.

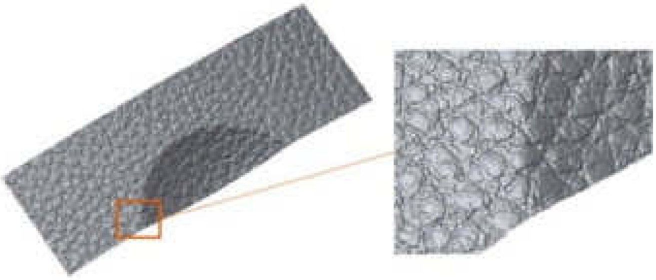


Fig. 7: The result of grain generation.

3 MILLING EXPERIMENT

We tried a milling experiment with the digital data which is generated by use of our method. Using CAM (Sescoi® WorKNC V19) which can be fed digital data and the 5-axis machining center (Makino Milling Machine Co. GF-6), 3-axis milling by the plane surfaces data with grain and 5-axis milling by the surfaces data with grain were tried. From the perspectives of processing time and accuracy, the 5-axis milling works, locking up an inclined axis, milling the injection molded die. A sample which is shown to Fig. 8 is obtained.

(a) Milled die (b) Injection molding product

Fig. 8: The die which are milled by 5-axis machining and the injection molding product.

3.1 Milling Condition

Since the target model is the automobile interior parts which have complex free form surfaces and the grain need to be generated toward normal direction of the surface, 5 axis milling is needed. It is necessary to investigate whether 5-axis milling has repeatability as well as 3-axis milling. Therefore, 5-axis milling is used by use of same tools, condition and tool path as 3-axis milling (Tab. 1).

No.	Process	Tool diameter [mm]	Remaining amount [mm]	Tolerance [mm]	Revolution [mm^{-1}]	Cutting speed [mm/min]	Pf [mm]
1	Rough-1	ϕ 1.0	0.03	0.005	50,000	1,000	0.037
2	Middle-1	ϕ 0.4	0.01	0.005	50,000	1,000	0.023
3	Middle-2	ϕ 0.2	0.01	0.005	50,000	1,000	0.016

4	Finishing-1	ϕ 0.1	0.005	0.001	50,000	750	0.025
5	Finishing-2	ϕ 0.1	0.005	0.001	50,000	750	0.025
6	Finishing-3	ϕ 0.1	0.000	0.001	50,000	750	0.025

Tab. 1: Milling condition.

3.2 Geometry Estimation

Geometries are estimated by use of the data processing software (INUS Technology Inc. RapidForm). Standard deviation which is outputted from this software is used as quantitative numerical value. Fig. 9 shows the result of estimation. Electroforming technique in this figure has the most reproducible method in existing methods. To compare repeatability, this method is shown. Fig. 9 shows that there are not difference of repeatability between 3-axis milling and 5-axis milling and though repeatability of them is inferior to the electroforming technique, there is not huge gap between electroforming technique and milling.

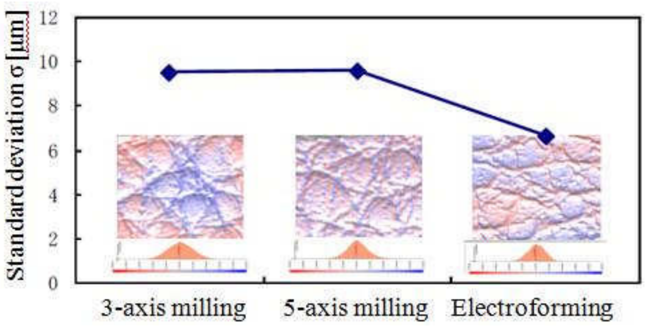


Fig. 9: Repeatability of some method.

4 CONCLUSIONS AND FUTURE WORK

In our research, aiming at the development of a grain milling system by use of digital data, we developed a method to generate grain by digital data of dies which have free-form surfaces. In addition, milling dies with grain, it was found that this system can go well. By using digital data, it becomes possible to generate data of dies with the draft angle and the strain of grain in mind. That is, grain is controlled actively. In the future, we are going to allow the system to create grain to complex model and respond to large area and large volumes of data. Lastly, the technique of 5-axis milling will be established.

REFERENCES

[1] Nakanishi, M.; Kobayashi, Y.; Shirai, K.: Creation of the wide-area texture which used texture synthesis, SICE Tohoku branch, No.246 meeting, 2008.

[2] Kamibata, J.; Ohtake, Y.; Suzuki, H.: Shibo design via texture synthesis, Proc. autumn meeting of Japan Society of Precision Engineering, 2009.

[3] Bourg, D. M.: Physics for Game Developers, O'Reilly Media, Inc., 2001.

[4] Cook, R. L.: Shade Trees, SIGGRAPH 84, 1984, 223-231.