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Fast Tool Servo Cutting Simulation Using CATIA API

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Abstract

The objective of this study was to predict the shape engraved by a high-speed transfer device called a fast tool servo (FTS) on a brass mold. We developed a simulation program using the CATIA library because in general grooving, an FTS generates a consistent waveform in the length dimension. We performed the cutting experiment at CoreOptix, using equipment from Moore Nanotech, and the SEM image of the actual pattern formed by the cutting process was compared with the shape predicted by the proposed program.

Key Words: Fast Tool Servo, CATIA API, Random Pattern, Micro Pattern, Grooving Simulation

1. Introduction

With the recent dramatic growth of the display industry, demand is rapidly increasing for the light diffusion film used on the rear panel of displays. The film, manufactured with sub-micron precision, is placed on the Back Light Unit (BLU) to evenly scatter light from the BLU, providing clear images with consistent brightness. The diffusion shapes of the film can be triangles, rectangles, pyramids, or pillars.

Thanks to developments in ultra-precision machinery and remarkable advances in related technologies that drastically reduce production time, roll mold processing based on diamond turning is gaining attention as a means for producing optical film for BLU applications. Diamond turning involves engraving a desired shape on a brass roll mold using a diamond tool; [1] the shape is later transferred to film.

The micro pattern machining on the surface of a wide mold is not easily simulated using conventional methods. A software simulates micro pattern grooving in 3D geometry, predicts the cutting force and optimizes the time factor in the roughing stage is developed and the prism, pyramid, rectangular and pillar patterns are simulated and compared with real pattern.[2]

If the same type of patterns are repeated moiré pattern appears on the screen reduce visual quality. A random pattern is proposed to minimize interfere pattern. In order to prevent moiré patterns on displays, studies are being conducted on processing methods using a Fast Tool Servo (FTS), a high-speed transfer device that acts as an additional axis in ultra-precision lathe-type machinery.[3] FTS eliminates repetition of the particular patterns that causes moiré artifact patterns, and provides random features while maintaining a basic, triangular shape.

In this paper, the Application Programming Interface (API) library of the CATIA software and Visual Basic (VB) was used to predict the shape to be processed, in order to simulate a shape randomly processed by the FTS.

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2. Simulation Program Structure

2.1 CATIA VBA Automation

The CATIA Visual Basic for Applications (VBA) used in this paper refers to sequences for the program, written in VB, to execute tasks using CATIA's internal commands, as shown in Fig. 1. It is widely used in various fields.

2.2 CATIA VBA Automation Algorithm

The internal algorithm of the program written in VB is shown in Fig. 2. The positions for assigning coordinates to CATIA are calculated with reference to the origin. Equation (1) expresses the distance on the roll mold travelled by the FTS tool vibrating at a constant frequency. Using Equation (1), the starting position of the phase is determined by applying a random position. Starting from the initial phase, the intended FTS waveform is drawn. Then the cross-section of the tool drawn according to the shape and size of the tool is swept to remove the FTS waveform from the mold, completing the FTS-cut shape.

$$CycleL = \frac{RPM \times Diameter \times \pi}{Hz \times 60} \quad (1)$$

Fig. 1 CATIA VBA Sequence

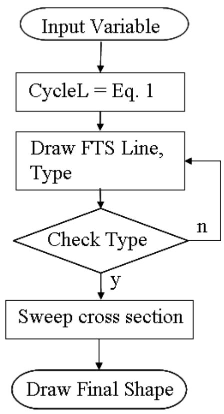


Fig. 2 Drawing Algorithm

2.3 Simulation of FTS-Processed Shape

The simulation program is shown in Fig. 3(a). The input values were pitch, depth, angle, amplitude, diameter, and RPM. Both FTS and non-FTS cutting were simulated, and a different FTS frequency was applied for each grooving. The initial screen of the program is shown in Fig. 3(a). We positioned the coordinates calculated using the algorithm of Fig. 2 and Equation (1) with reference to the origin and performed a simulation of the FTS-cut shape. In order to compensate for the errors that occur in the process, we applied a compensation constant in each line to randomly position the initial phase of grooving, making it similar to actual cutting.

3. Experimental Equipment

The FTS cutting experiment was conducted at CoreOptix Inc. We manufactured our own FTS tool (FTS400) and installed it on the ultra-precision machining system custom-ordered from Moore Nanotech, as shown in Fig. 4. The experiment was conducted on the roll mold shown in Fig. 5.

The roll mold used for the experiment was bronze-coated with a diameter of 300 mm and a length of 2000 mm. The roll mold was coated in a highly uniform matter, with a maximum 2% discrepancy within the 2000 mm length. The diamond tool used for cutting had a tool angle of 90°, as shown in Fig. 6.

When a rotating roll mold is cut with the FTS tool vibrating with a constant cycle, a waveform with a specific amplitude and frequency is generated. The waveform created by the tip of the FTS tool is shown in Fig. 7.

4. Experiment Comparison

4.1 Cutting Experiment

The experiment was performed at CoreOptix Inc. with the industry standard cutting conditions of Table 1.

Table 1 Industry Standard Cutting Conditions

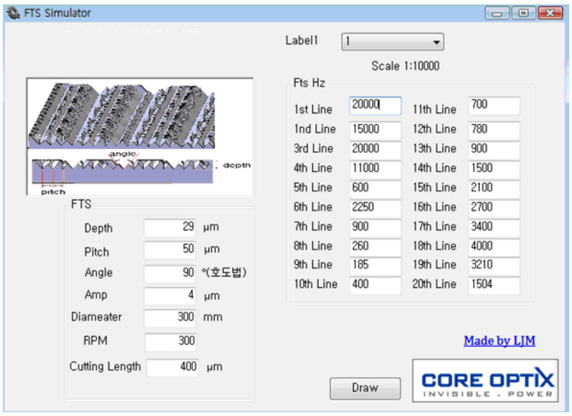
	Experiment 1	Experiment 2
RPM	200	300
Hz	20,000	20,000
Depth (μm)	0	28
Pitch (μm)	50	50
Amp. (μm)	7	6
Angle (°)	90	90

In order to eliminate the error caused by uneven coat thickness, the roll mold was first roughly machined to obtain a uniform surface. Then we performed two experiments with the two sets of conditions in Table 1. The result of Experiment 1 is shown in Fig. 8(a). Since the cutting depth was 0 μm, there was a clear distinction between the unprocessed areas and the cuts made by the vibrating FTS tool. The result of Experiment 2 is shown in Fig. 8(b). Each line cut at a depth of 28 μm has a different phase, forming randomly distributed V-grooves.

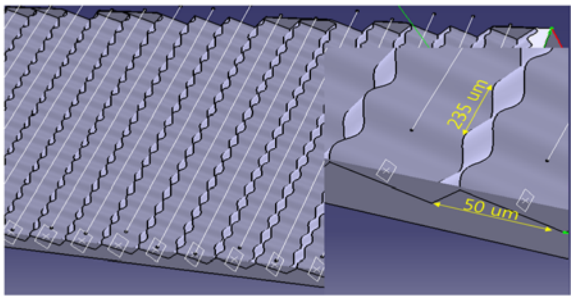
4.2 Comparison of Experiments

Production of micro-pattern film mostly involves engraving a pattern on the roll mold and transferring the pattern onto the film. Repetition of an identical pattern on the film is likely to cause moiré artifacts on the display. Therefore, an FTS tool is attached to the ultra-precision machining system to randomly distribute the patterns during cutting. Unlike conventional grooving, cutting with the FTS tool draws a waveform, and the cut shapes are randomly positioned within the frequency range, as shown in Fig. 9(a).

Figure 9(a) shows the scanning electron microscope (SEM) image of the mold cut with processing conditions typically used in the industry. The shape predicted by the FTS simulation program proposed in this study is shown in Fig. 9(b). Comparing the two images and the simulation results, we can conclude that the program developed by this study is capable of providing a preview of the micro-pattern prior to the actual cutting process.

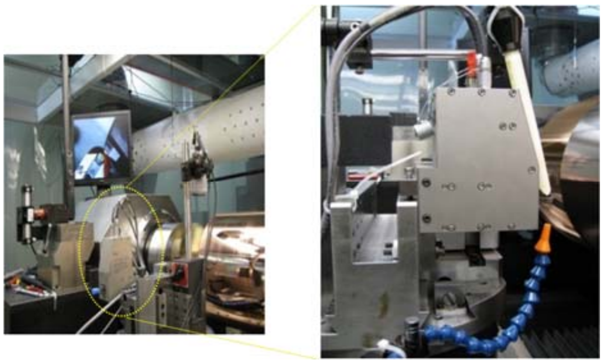


(a)



(b)

Fig. 3 Cutting Simulation using CATIA VBA



(a) (b)

Fig.4 (a) Ultra-Precision Machining System, (b) FTS Tool (FTS 400)

Fig. 5 Roll Mold

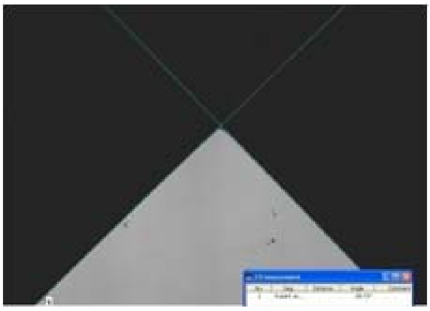


Fig. 6 Diamond Tool

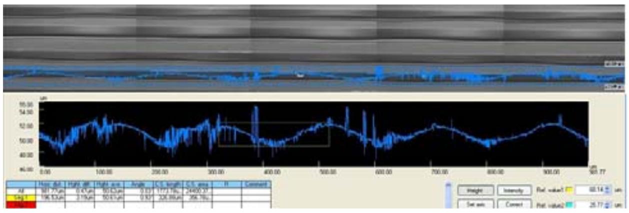
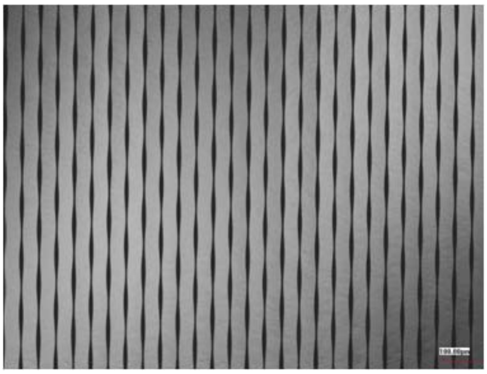
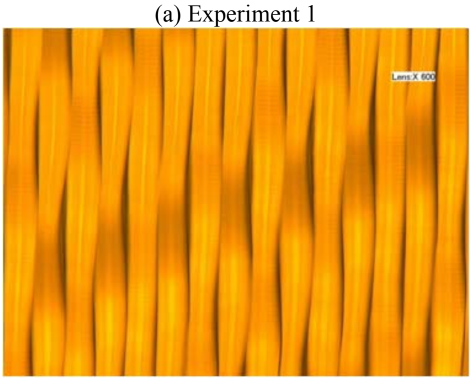


Fig. 7 FTS Waveform

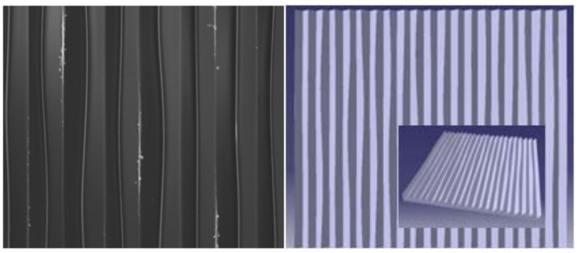


(a) Experiment 1



(b) Experiment 2

Fig. 8 Cutting Experiment



(a) (b)

Fig. 9 (a) SEM image of the processed mold (b) Shape predicted by the proposed program

5. Conclusion

In this study, we developed an algorithm and a program using CATIA VBA for simulating shapes produced by an FTS tool. With the conventional shape prediction method, it was difficult to not only predict the shapes randomly engraved by the FTS tool effectively, but to view and interpret predicted outcome. To resolve these problems, we used the CATIA library to allow an external program to activate it, automatically creating a processing area and providing various convenient functions.

The software implemented by this study enables simulation of engravings random patterns automatically, which is not supported by other programs. Since the program was developed using API of commercial software, it offers outstanding simulation capabilities, maximizes user-friendliness and is highly compatible with other analytical programs. The program developed by this study was presented to CoreOptix Inc., a micro-pattern processing company.

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