Title:
Modification Method of Drawn Design on Decorating Film/Shrink Film for Obtaining Distortion-Free Design

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Introduction:
Due to advancements in the production engineering of industrial products, there has been no appreciable difference in the performance of similar products. Appearance is considered an important factor for increasing the discrimination between products. Thus, the importance of decorative techniques in the manufacturing of products has increased in recent years. Decorative techniques can improve the appearance of products. Plastic is an important material in product design because it easily transforms, is very light, and has multifarious structural characteristics; however, it gives the customer the impression of a cheap product. Therefore, decorative techniques are also applied to plastic products. At present, film is predominantly used in decorating plastic products, particularly, decorating film and shrink film [1]. Decorating film is inserted into a mold, heated, and then unified with resin. Shrink film is wrapped around a product, heated, and then stuck onto the plastic products. However, the film could get deformed and the design image on the film could become distorted during the forming processes. The design that has been distorted in the forming processes will be different from the design that the designer requires. Therefore, there is a need to modify the distortion of the design on a film. However, no study on the modification of the distortion of the design on a film has been conducted till date.

The purpose of this study is to develop a method to modify the distortion of the design pattern that occurs because of film deformation during forming processes.

Design Modification Method:
In this chapter, an outline of the proposed method is explained. The modified design is made as follows.

(1) The lattice pattern film is made by printing the lattice pattern onto a film as shown in Fig. 1(a).. Two-dimensional coordinate value (x, y) of each lattice point is an original point.
(2) The lattice pattern film is laminated to an object. By measuring the two-dimensional coordinate values of the lattice points after the forming processes using a three-dimensional measuring instrument, the movement vector (v_x, v_y) of each point because of the shrinkage and expansion that takes place is calculated as shown in Fig. 1(b)..
(3) A backward vector of the movement vector $(-v_x, -v_y)$ is calculated, named as the modification vector. It is then given to each original point as shown in Fig. 1(c).. The acquired two-dimensional coordinate value is $(x - v_x, y - v_y)$.
(4) Similarly, all original points are given the obtained modification vector. These acquired points are the modified lattice points. Then an interval between points is acquired by linear interpolation and

drawn using OpenGL. This is the modified lattice pattern as shown in Fig. 1(d)..

The lattice points of the modified lattice pattern will move by the movement vector after laminating. Therefore, the modified lattice pattern becomes a distortion-free pattern after the forming processes.

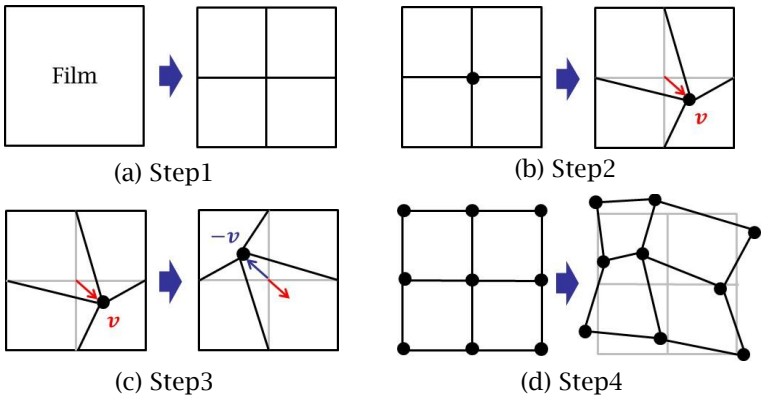

Fig. 1: Design Modification Method.

Fig. 2: Practice Condition: (a) Model A, (b) Model B, and (c) Original Lattice Pattern.

Experiment of Shrink Film:

Practice Condition

In order to verify the effectiveness of the suggestion technique with shrink film, an experiment was conducted by sticking the original lattice pattern design onto two types of evaluation models. The evaluation models and the original lattice pattern design are shown in Fig. 2. The original lattice pattern is 11 rows × 11 columns and the distance between the lattice points of the original design is 10 mm. In this experiment, shrink film was laminated by heating with a microwave oven at 100 degrees for one minute.

Results and Evaluation

Fig. 3. shows the modified designs of models A and B. The modified design of evaluation model A is enlarged outward (Fig. 3(a).), and the modified design of evaluation model B is shrunk inward (Fig. 3(b).). This is because modified vectors, which are considered as movement vectors, are given to each of the original lattice points.

Fig. 4(a). and Fig. 4(b). shows the original design and the modified design after stuck on evaluation model A. The distortion is removed generally but distortion of the points having a large movement vector has remained. Fig. 4(c). and Fig. 4(d). shows the original design and modified design after stuck on evaluation model B. The distortion has been largely modified. The modification accuracy

of evaluation model B is higher than that of evaluation model A. This is because evaluation model B has a more complex shape than evaluation model A, but the movement vector of each point of evaluation model B is smaller than that of evaluation model A. Therefore, after the laminating process, the distortion that remains is also smaller.

In order to evaluate the results quantitatively, the average error between each point of the original design and each point of the original design that is stuck to the model is calculated. Similarly, the average error between each point of the original design and each point of the modified design that is stuck to the model is calculated. Then, the average error of both x and y coordinates is calculated. Tab. 1. shows the average error of evaluation model A, and Tab. 2. shows the average error of evaluation model B. In both models A and B, the average error of x and y coordinates is less than half after using the modification method. Therefore, the effectiveness of the suggested technique was verified.

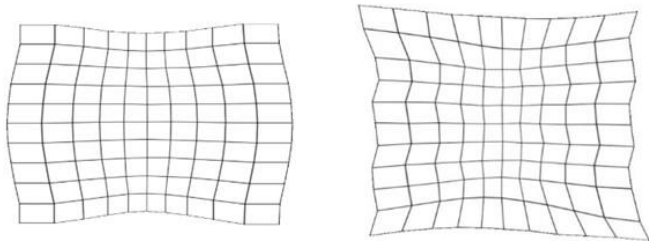

Fig. 3: Modified Design: (a) Model A and (b) Model B.

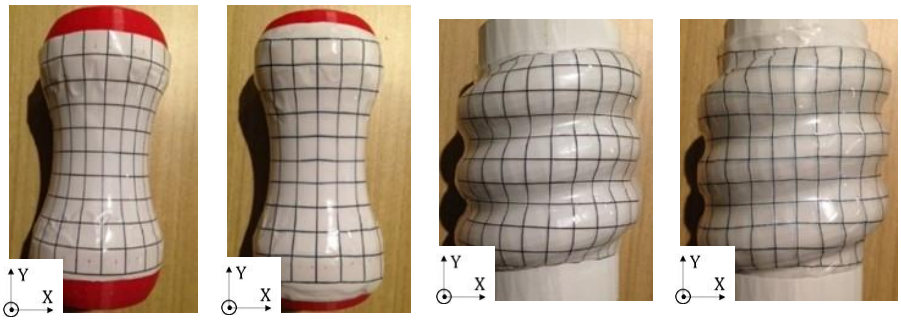

Fig. 4: Sticking Result: (a) Original Design of Model A, (b) Modified Design of Model B, (c) Original Design of Model B, and (d) Modified Design of Model B.

	Original Design [mm]	Modified Design [mm]
x	1.21	0.40
y	2.32	0.36

Tab. 1: Average Error of Model A.

	Original Design [mm]	Modified Design [mm]
x	2.97	1.41
y	0.65	0.26

Tab. 2: Average Error of Model B.

Experiment of Decorating Film:

Practice Condition

In order to verify the effectiveness of the suggested technique with decorating film, the evaluation experiment was conducted by sticking the original lattice pattern design to an evaluation model. The evaluation model and original lattice pattern design are shown in Fig. 5.. The original lattice pattern is 41 rows × 59 columns and the distance between the lattice points of the original design is 5 mm. In this experiment, decorating film was laminated with film insert molding method.

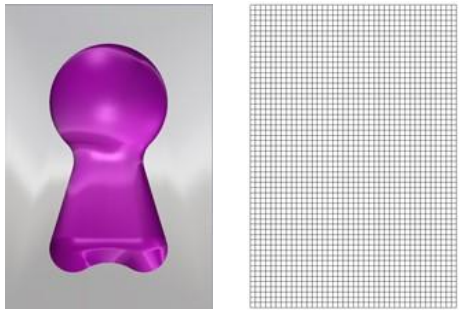

Fig. 5: Practice Condition: (a) Evaluation Model and (b) Original Lattice Pattern.

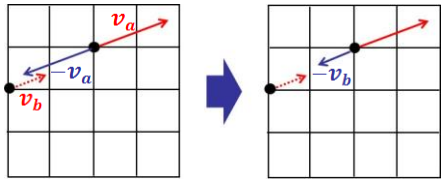

Fig. 6: Additional Modification Method.

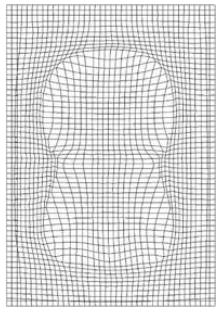

Fig. 7: Modified Design.

Additional Modification Method

Then, an additional modification is required. In this experiment, one lattice distance is set to 5 mm. However, at the region that film extend well, the size of the movement vector is bigger than one lattice. Therefore, the sum of the obtained modification vector and the movement vector of the nearest original point of the point after modified is calculated for every vector component *x* and *y*. When the size is more than 5 mm as shown in Fig. 6., the modification vector is modified to the obtained modification vector of the nearest original point of the point after modified.

Results and Evaluation

Fig. 7. shows the modified design according to the additional modification method. Fig. 8. Shows the sticking results of original design and modified design. In order to easily recognize the results, the range that there was specially large distortion was focused on. It can be seen that after corrected, lattice lines get closer to straight lines.

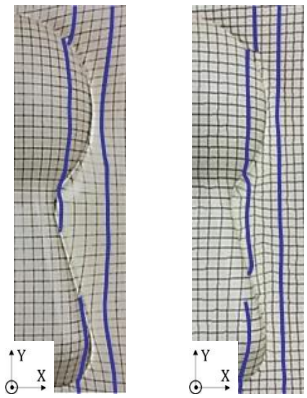

Fig. 8: Sticking Result and Assessment Scope: (a) Original Design and (b) Modified Design.

	Original Design [mm]	Modified Design [mm]
x	4.21	1.89
y	2.35	0.82

Tab. 3: Average Error at the Assessment Scope.

Finally, in order to evaluate the result quantitatively, the average error between each point of the original design and each point of the original design that is stuck to the model is calculated. Similarly, the average error between each point of the original design and each point of the modified design that is stuck to the model is calculated. Then, the average error of both x and y coordinates is calculated. For shorting a measurement time, the assessment scope is set to the range surrounded in blue lines in Fig. 8. Tab. 3. shows the average error in the assessment scope. The average error of both x and y coordinates is less than half after using the modification method. Therefore, the effectiveness of the suggested technique was verified.

Conclusions:

In recent years, film has been predominantly used in decorating plastic products. However, the film could get deformed and the design image on a film could become distorted during the forming processes. In this research, a method to modify the distortion of the design pattern that occurs because of film deformation during forming processes was proposed. The modified designs using shrink film and decorating film were made using this proposed method. The effectiveness of this method was confirmed through experiments. In the future, improvement in modification precision will be addressed.

References:

[1] Honma, S.: Second Processing Technique of Plastic, Kogyo Chosakai Publishing Co., Ltd., Japan, 2007.