Journal of Computational Design and Engineering 5 (2018) 435–441

Contents lists available at ScienceDirect

Journal of Computational Design and Engineering

journal homepage: www.elsevier.com/locate/jcde

Development of design system for crack patterns on cup surface based on KANSEI

Mai Misaka [a,*], Hideki Aoyama [b]

[a] Department of Integrated Design Engineering, Keio University, Yokohama, Japan
[b] Department of System Design Engineering, Keio University, Yokohama, Japan

ARTICLE INFO

Article history:
Received 29 September 2017
Accepted 29 December 2017
Available online 10 July 2018

Keywords:
Digital design
Crack patterns
KANSEI engineering
Neural network

ABSTRACT

With the development of manufacturing technology in recent years, as well as with the industrial product development, differentiation in the design aspect is becoming effective, not in terms of performance or quality. In addition, as consumers seek products that match their own sensibilities (KANSEI), designers are required to propose designs that highly conform to concept presented by client, while understanding the KANSEI of diversified consumers; therefore, their burden is increasing. To address these issues, the support of the development of computer-aided design has advanced; however, it is difficult to reflect human KANSEI or to generate a design that induces a natural impression through computers.

The purpose of this research is to develop a system that incorporates the KANSEI of users, and emits a pattern design that induces a natural impression using a computer. This work is focused on crack patterns that can be observed on pottery surfaces, and a method for generating crack patterns on a cup surface is suggested. In this study, a Bézier curved surface and fluctuation were employed in order to induce a natural impression. In addition, by using the neural network, the crack patterns were associated with user KANSEI. The neural network was composed of three layers, namely the input layer, the hidden layer, and the output layer; it adopted the sigmoid function as the transition function and the back propagation as the learning method. As a result, a system was constructed, in which a crack pattern that satisfied the input produces an output according to the desired impression of the user.

Finally, an evaluation questionnaire was distributed, and the usefulness of the system was confirmed.

1. Introduction

In the development of industrial products in recent years, it is becoming difficult to discriminate by performance or quality owning to advancement in manufacturing technology, and discrimination on the design aspect is considered effective. In addition, consumer values for products have changed; consumers are not satisfied with only the functions that are normally expected of products, and their present demands involve items that are comfortable and that fit into their own lifestyle. In other words, it may be said that the level of conformity between the product and the consumer KANSEI has become a decisive factor in the value of the product. For this reason, the designs of the products that are thought to greatly influence consumer sensitivity are considered more important than ever. However, designers face great challenges because various factors intertwine in a complicated manner, and the consumer preference has diversified. The designer is required to propose a design that presents high conformity to the demanded concept, while understanding the sensitivity of consumers and considering various conditions.

In order to solve such a problem, a support system pertaining to the development of computer-aided design has advanced. However, it is difficult to reflect the image and the KANSEI of a human in a computer, thus raising the problem that the exchange of the image and KANSEI among consumers, designers, and engineers may not be successful; therefore, it becomes difficult to generate a design that matches their KANSEI. In addition, the design generated by the computer is a regular shape and pattern, and it is difficult to create a design that gives a natural impression. In view of the above, there is a need to establish a method for accurately reflecting user KANSEI and easily developing a design proposal through which a natural impression would be generated by a computer. Kamahara, Aoyama, and Oya (2013) used polka dots as design targets, and associated patterns and impressions of patterns with the color, the size and the arrangement of polka using with neural networks. Then, when the weights of the KANSEI language related to polka dot patterns were fed as input, a system that created patterns that satisfied the input was constructed. Akiyama, Aoyama, and Oya (2014) focused on the wood grain pattern, in a

Peer review under responsibility of Society for Computational Design and Engineering.

* Corresponding author.
E-mail address: misaka@ddm.sd.keio.ac.jp (M. Misaka).

https://doi.org/10.1016/j.jcde.2017.12.008
2288-4300/© 2018 Society for Computational Design and Engineering. Publishing Services by Elsevier.

Fig. 1. Example of crack pattern on pottery (Kamano, 2016).

similar manner to Kamahara et al., using a neural network; they modeled the relationship between the impression on the wood grain pattern and its characteristic parameters, and they proposed a method to automatically create a pattern from the required impression. Studies are being conducted on creating patterns based on the KANSEI, as previously described; however, their number is still limited. Moreover, as these are limited to two-dimensional designs, various problems such as distortion will occur during the effort to apply the design to products.

In this work, the crack pattern seen in pottery products, such as those presented in Fig. 1 (Kamano, 2016), is the research object. Pottery products have long been popular as everyday items and art items, and the crack pattern that is seen on the surface is decorative. As it is impossible to modify the crack pattern once it enters, expert skills and knowledge are required for the application of the intended pattern.

Therefore, in this study, we propose a method for modeling the process of crack-pattern generation and of using a computer for the creation of a pattern that gives a natural impression to a three-dimensional cup-shaped surface. In addition, we aim to construct a system that will produce a crack pattern that satisfies the impression requested by the user by correlating the KANSEI of the user with the pattern parameter via the neural network.

2. Crack pattern generation method

2.1. Mechanism of crack generation

In this research, the generation process of actual crack patterns was modeled, and patterns were generated by computers. Therefore, the crack generation mechanism in actual pottery products will be explained. The schematic of the concept is shown in Fig. 2.

In general, pottery products consist of two layers, namely a base made of clay and a vitreous glaze that is applied on the base. We assume that at room temperature, there is a dimensional difference between the base and the glaze, as depicted in Fig. 2(a). During the firing process of the pottery production, the glaze melts at a high temperature and spreads on the base (Fig. 2(b)). During their cooling down to room temperature, both the base and the glaze shrink; however, the glaze tends to shrink more than the base because the thermal expansion coefficient of the glaze is higher than that of the base in general (Fig. 2(c)). As a result, the glaze is subject to tensile stress from the base, and a crack occurs at the part the yielding stress has been exceeded (Fig. 2(d)).

The aforementioned tensile stress is referred to as glaze stress. When the glaze has been thinly applied on an infinite flat base and their respective Young's modulus is the same, the glaze stress is calculated from Eq. (1).

$$\sigma_{gl} = E(T_0 - T')(\alpha_{gi} - \alpha_b)(1 - j)(1 - 3j + 6j) \quad (1)$$

Here, E is Young's modulus, T_0 is the temperature at which the glaze solidifies and glaze stress begins to occur, T' is the room temperature (20 °C), α_{gl} and α_b are the average coefficients of thermal expansion between T_0 and T' of the basis and the glaze, respectively, and j is the ratio of the thickness of 1/2 of the glaze to the thickness of the base. This equation was obtained by multiplying the equation of thermal stress with the correction term of the thickness that was calculated based on the measured value (The Ceramic Society of Japan, 2002).

2.2. Modeling of crack mechanism

To calculate the glaze stress from Eq. (1), the value of the glaze thickness is required. Typically, the glaze thickness is uneven; in this study, to model its unevenness, the shape of the base and glaze surfaces were modeled using a cubic Bézier curved surface. First, a three-dimensional cup shape was designed using a discrete point group. By applying the method of least squares to the group of points, we derived the control points of the cubic Bézier curved surface to construct the cup-shaped model and defined the base shape. The control point of the base shape was manipulated, and the shape of the glazed surface was defined by the cubic Bézier curved surface. Lattice points were formed on the base and the glaze surface. For both the base and the glaze, their respective Young's modulus, coefficient of thermal expansion, and thickness were attached to each lattice point as attribute data. Young's modulus was multiplied by random number at each lattice point to model the non-uniformity of the material. The thermal expansion coefficients of the base and the glaze were the same for all lattice points. The thickness of the base was fixed at 3 mm. The thickness of the glaze was considered as the distance from the Bézier curved surface of the base to each lattice point.

From these parameters, the glaze stress at each lattice point was calculated from Eq. (1), and the lattice point exceeding the yield point of the glaze was considered a cracking point. Then,

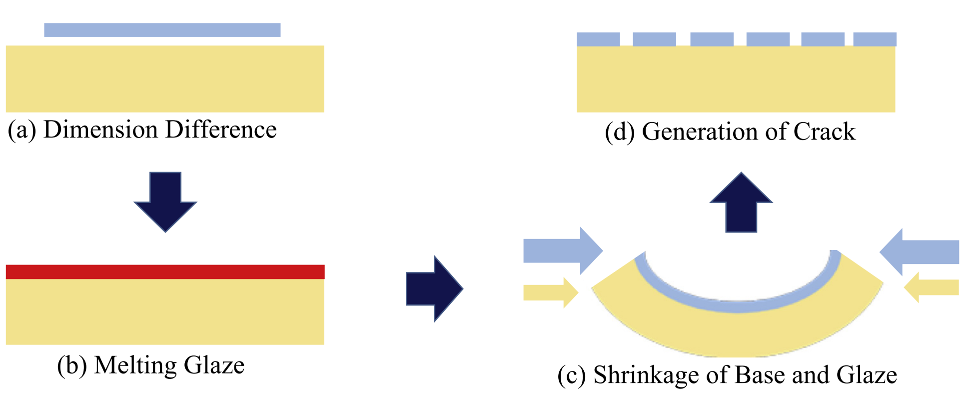

Fig. 2. Process of crack generation.