# Gripping Part of Products

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Computational method to optimize design of gripping part of products requires a grasping motion simulation using a computational model and an optimization method based on the simulation. A grasping motion simulation method based on finite element analysis has been developed for the virtual evaluation of gripping comfort. The validity of the grasping motion simulation was verified by comparing the contact pressure distribution generated on the palm of a hand using a finite element model with the measured result obtained via experiments on a human subject. Furthermore, an optimization method was introduced into the simulation to propose an easy method for obtaining a rough shape of the gripping part of a product that is comfortable to grip. An objective function during the optimization process was defined to minimize the contact pressure concentration level, and this was observed to have a negative correlation with the gripping comfort. The combined method allows an engineer to evaluate the gripping comfort of a product during the design process and aids in developing a shape that can provide better gripping comfort. Additionally, the combined method can also be used to reevaluate the gripping comfort of existing products.

Gripping comfort   Finite element analysis   Hand model   Grasping motion

Contact pressure   Topology optimization   Product design

# 1. Introduction

Kansei engineering [1] is an engineering method that considers the user's psychological feelings or needs. The development of a manufactured product based on this method is required to promote purchase intention by influencing users' emotional responses to the product. A product should be easy and comfortable to use to impress a user. Gripping comfort includes factors such as "good fit in hand" and "how comfortable the handle feels" [2] and is a crucial Kansei engineering value of manufactured products that is considered for products involving gripping in the hand (e.g., hair dryers, shavers, irons, or telephones). It is expected that improving the gripping comfort of the products can increase the value of the products and also stimulate user interest.

# 2. Computational Method to Optimize Design of Gripping Part of Products

Currently, when designing the gripping part of a product, the comfort evaluation is commonly conducted using human subjects in an experiment by using real-sized physical models (mockups). Based on the evaluation result, the designer then modifies the shape of the gripping part to obtain better gripping comfort. Subsequently, human

subject evaluation is performed again using modified mockups. After the process is repeated several times, a shape that is expected to exhibit optimal gripping comfort is finally selected as the final shape of the gripping part of the product. However, the method typically involves significant time and high cost in terms of creating mockups and performing multiple human subject experiments. Furthermore, it is difficult to select an optimal shape based on engineering knowledge because the evaluation result is subjective, qualitative, and susceptible to the conditions of the human subjects and surrounding environments during evaluation. Therefore, an evaluation based on physical parameters, such as contact pressure, is considered to provide more coherent results and decrease costs.

Some physical parameters (e.g., contact pressure and force) were utilized to predict gripping comfort. Kuijt-Evers et al. [3] investigated the relationships between the subjective comfort feeling and objective measurement results such as electromyography (EMG) signals and contact pressure during gripping of a saw. Lin and McGorry [4] observed that the normalized grip force is a significant factor that can be used to predict gripping discomfort when using a pneumatic nutrunner. Furthermore, Kong et al. [5] conducted a linear regression analysis to estimate gripping comfort from the measured gripping exertion force. We also proposed regression equations to predict gripping comfort from the contact pressure distribution on a palm or from finger joint angles while gripping an object in our previous study [6]. Therefore, by using a statistical method such as regression analysis, it is possible to estimate the gripping comfort if physical parameters generated during gripping (e.g., contact pressure) can be obtained.

Conversely, a numerical simulation method including finite element analysis (FEA) is widely utilized in the structural design of a manufactured product due to significant improvements in the performance of computers. By using FEA, it is possible to perform a virtual experiment in a shorter time, and this allows us to obtain results from many simulations considering the effects of many parameters, e.g., geometry, material characteristics, and applied load [7][8][9]. Therefore, the establishment of a grasping motion simulation method using a digital human-hand model (hand finite element model) allows us to simulate the grasping motion against various objects on a computer and quantitatively evaluate the gripping comfort based on physical parameters such as contact pressure. Furthermore, this will aid a designer in designing a product that is comfortable to grasp and reduce time and cost during the design process. Several studies on the development of a digital hand model and a grasping motion simulation are conducted to understand the human grasping behavior and to support the design of a product [10][11][12][13][14]. We also developed a finite element model of a hand and a grasping simulation method, and we investigated the effect of several parameters on the contact pressure distribution during gripping as recorded in a previous study [9]. However, the aforementioned studies did not establish a new method to quantitatively evaluate the gripping comfort based on physical parameters using grasping motion simulations and digital hand models.

Studies on tool handle design considering gripping comfort are also performed to design an optimal shape based on geometric parameters of a human hand. Sancho-Bru et al. [15] investigated the optimal tool diameter using a biomechanical model of a human hand. Eksioglu [16] proposed a criterion based on modified thumb crotch length (TCLm) to design hand-powered tools that provide comfort, safety, and high efficiency for the users. Garneau and Parkinson [17] reported a methodology to optimize the shape of a tool handle using hand anthropometry. Harih and Dolšak [18] offered a design method to develop tool handles using a digital human-hand model. Although several

studies examined optimizing the shape of the gripping part (handle), to the best of the authors' knowledge, there is a paucity of studies on an automatic method to obtain the optimal design of gripping part based on an evaluation using physical parameters. Development of a design method for the gripping part by using a grasping motion simulation and digital hand model can support manufacturers in designing a product that exhibits better gripping comfort under various gripping conditions.

Therefore, in the study, we developed a grasping motion simulation using a hand finite element model [9] to reproduce a typical grasping motion of a human volunteer obtained from an experiment [6] to evaluate the gripping comfort during grasping of a cylindrical object. The simulation method was validated by comparing the contact pressure distribution in the simulation result and experimental result to understand the capability of the method to quantitatively assess the gripping comfort based on the contact pressure. Additionally, we also introduced a topology optimization method into the simulation to propose a procedure to obtain a rough shape of gripping part that is expected to exhibit better gripping comfort.

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