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Analysis of "Thin" Mobile Phone Form Based on the Kansei Engineering

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Abstract: *This study aims to analyze the relationship between the form design parameters of mobile phones and their "Thin" perceptual images by using the evaluation method of Kansei Engineering. By summarizing the design principle of "Thin" mobile phone form, this study determines the semantic correspondence between the chamfer of mobile phone edge and the perception of "Thin - Thick." Designing an evaluation experiment obtains the subjective evaluation order of the experimental samples to analyze the correlation between the sample form design parameters and the perceptual evaluation of the "Thin" image. It concludes that the ranking of subjective assessment of mobile phone's "Thin" image is negatively correlated with the offset distance x of plane A and the offset distance Y of plane B, and strongly positively correlated with the value of conic polar diameter ρ. This study provides a theoretical basis for designing the "Thin" form of mobile phones, which can effectively offer a numerical and methodological reference for the design of objects with similar shapes.*

Keywords: *Perceptual Image; Modeling Analysis; Mobile Phone; Correlation Analysis*

1. Introduction

The great need to use mobile phones with one hand constantly reduces the thickness and size of mobile phones (Wu, 2018). Earlier components and batteries were bulky, and the thickness of the mobile phones could be easily diminished by reducing the size of the details. However, when component sizes have been reduced to the relative limits of the current technology, the phone's thickness cannot be significantly reduced, so phone manufacturers have to try to make the phones more "Thin " from other angles, such as visual and tactile perspectives.

Some of the phones' side edges are designed with symmetrically rounded corners or asymmetrically rounded corners that are cut inward to make the phones look and feel thinner. At present, scholars' research on mobile phone modeling design mainly adopts perceptual engineering methods to extract mobile phone modeling images (Erdem et al., 2020; Huang, 2014). At the object level, current studies mainly focus on exploring the innovative design of the mobile phones' CMF (Color, Material, Finishing) (Yaojun et al., 2018; Li et al., 2018; San et al., 2018), but relatively little research has been done on the form itself. "Thin" form design can deceive users' visual perception of thickness and effectively improve product image (Li, 2014), which is worthy of further research.

Kansei Engineering can establish the connection between users' perceptual image and product design elements (Qiao et al., 2016), suitable for studying mobile phone form. Therefore, this paper tries to explore the relationship between the design parameters of mobile phone form and the image of "Thin" from the perspective of Kansei Engineering to provide a reference for the design of the "Thin" mobile phone form.

2. Analysis of Mobile Phone Form

2.1 Design Principle of the "Thin" Mobile Phone Form

Increasing the length and width of the phone without changing the thickness parameters will make the phone appear thin. Rounding corners or cutting inward at the edge of the mobile phone will make the viewing angle smaller (Qiao et al., 2016) and the touch area lesser so that people can have the "thin" experience. In the design process, restricted by screen and hand width factors, making the mobile phone appear thin by arbitrarily lengthening or widening it is difficult. Therefore, the second method is easier

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to achieve the purpose of "thin" design.

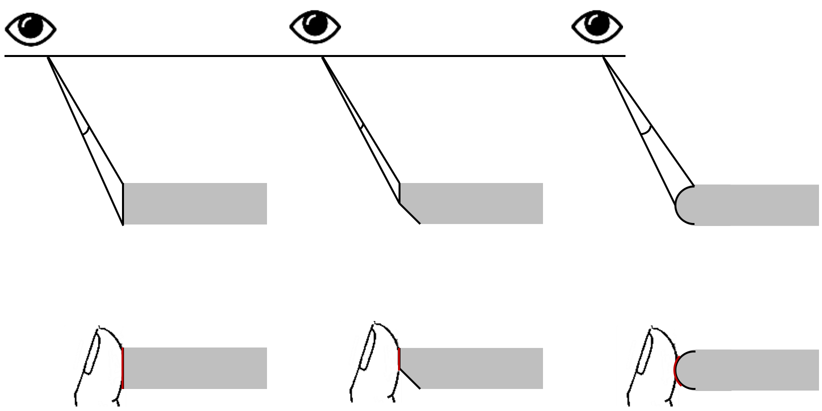

Figure 1 The Thin Feelings due to Different Viewing Angles and Touches

By cutting inward or rounding the corners symmetrically, the styling essentially affects the user's psychological experience in the visual and tactile channels rather than reducing the phone's thickness. Therefore, the research on the form design of "Thin" mobile phones can be realized by establishing the mapping relationship between the modeling technique and the user's perceptual image.

2.2 Summarization of "Thin" Mobile Phone Forms

By searching the appearance patent information through the keyword "mobile phone" on the SooPAT patent search website, 83,159 answers were obtained matching the results. When irrelevant words such as "phone shell" were removed, 34,671 answers were relevant. The standard wire-frame dimensions of the products could be acquired from the three-view drawings published by these patents. Random sampling analysis was conducted according to the proportion of 0.1%, and the top 15 mobile phone styles of the current season in sales volume were added to improve sample representativeness and reduce sampling error. Through analysis, mobile phone edge form features are mainly divided into three types. As shown in Figure 2, the edge of the A-type mobile phone is chamfered, and the edge shape in the side view is similar to the inverted trapezoid. The edge of the B-type mobile phone is symmetrically rounded, and the wedge shape of the side view is close to a regular semicircle. The C-type phone has a right-angle edge, and a side view edge is shaped like a rectangle.

In terms of the principle of form design, only A-type and B-type mobile phones embody the semantic words of "Thin."

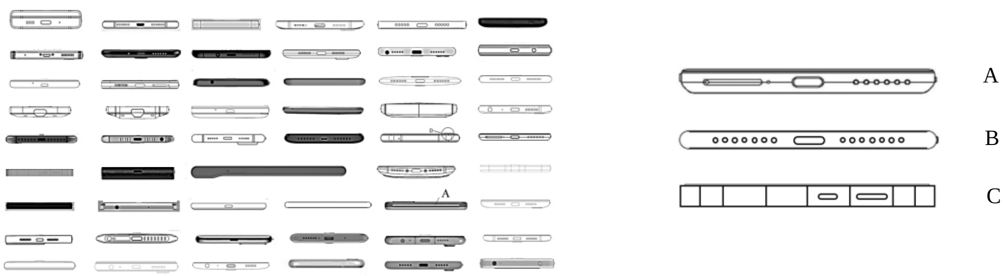

Figure 2 Typical Features of Mobile Phone Edge

2.3 Vocabulary Related to Perceptual Images

Visual and tactile stimuli leave an impression on the human brain and combine with local culture and living habits to form perceptual images to realize the elaboration of subjective judgment of design. Semantic difference quantifies subjective feelings based on the perceptual intention and divides image

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feelings into a single dimension. The perceptual image word of the object of this study is "Thin," and its antonym is "Thick. "

Subjects can be invited to rank different mobile phone forms according to their feeling and understanding of the words in the dimension ranging from "Thin - Thick "and the mobile phone form closest to the perceptual image of "Thin " can be obtained.

2.4 Key Elements of Form Design

Although there are various forms of mobile phones in the market, this study finds that the design of their edge forms has certain regularity. When the thickness is unchanged, the symmetrical fillet parameters of the edge of the B-type mobile phone are constant, but the chamfering parameters of the edge of the A-type mobile phone can be changed within a certain range. In parametric modeling software Unigraphics NX, the modeling of edge in-cut chamfer of type-A mobile phone is mainly affected by the following three parameters: bias distance of side A, i.e., x, bias distance of side B, i.e., y, and the Rho value on the elliptic curve, i.e., ρ ., which are shown in Figure 3.

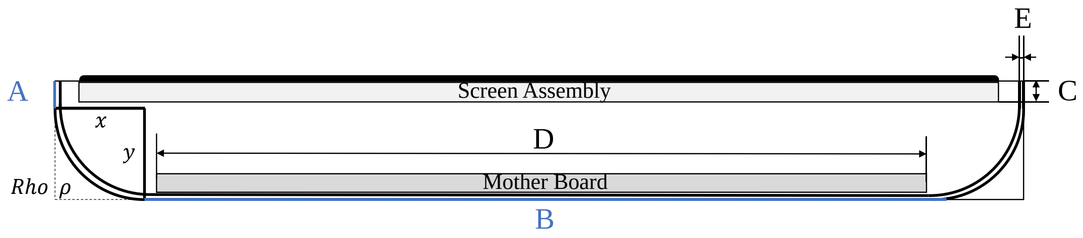

Figure 3 In-cut Chamfering Design Elements Diagram

The value of x is mainly affected by the width of the main board D and the wall thickness of the shell E, and the value of y is primarily influenced by the thickness of the screen assembly C. The conic polar diameter ρ is a variable in the polar coordinates of analytic geometry. In this environment, ρ can control the radian curvature of inward cutting chamfering, and its formula can be expressed as follows.

$$\rho = \frac{ep}{1 - e\cos\theta}$$

In the above formula, e represents the eccentricity, and p represents the distance from the focus to the directrix. ρ is always between zero and one. It is elliptic when less than 0.5, parabolic when equal to 0.5, and hyperbolic when greater than 0.5. The x, y,ρ values affect the visual and tactile perception of the edge shape of the A-type mobile phone when the phone's thickness remains unchanged. Therefore, the edge chamfering parameter of the A-type mobile phone corresponds to the semantic words of "Thin - Thick," as shown in Figure 4.

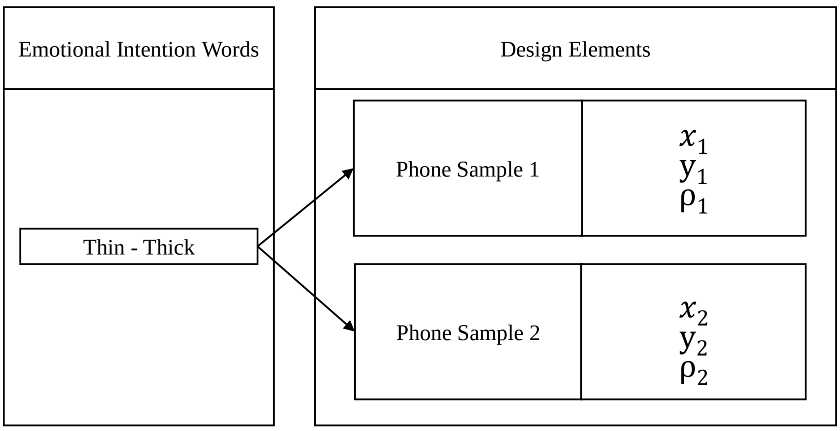

Figure 4 Mapping Model of "Thin" Image and Form Design Elements

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3. Experiment Process

3.1 Experimental Sample

The experiment selects iphone6s as the standard prototype. Its height is 138.3 mm, width 67.1 mm, thickness 7.1 mm, shell thickness E 0.95 mm, screen assembly thickness C 3.5 mm, and motherboard width D 52.2 mm. The digital 3D mobile phone model is constructed, and the values of x, y, and ρ of the edge chamfering of the 3D mobile phone model are recursively deduced as experimental samples.

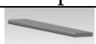
According to the wall thickness of shell and motherboard width, the range of x is attained, that is, 0mm<x<4.6mm. According to the thickness of screen assembly C, the range of y is attained, 0mm< y <6.5mm. Extreme ρ values will not produce successful production, so the ρ range is set between 0.1 and 0.9. To reduce the number of samples and reflect the difference caused by numerical changes, the three-factor three-level orthogonal method (Li, 2015) is adopted to recurse the model. The values of x, y, and ρ are divided into three equal parts and then input into the SPSS orthogonal experiment module to obtain nine groups of parameters. The standard prototype is taken as the 10th group of parameters to make experimental samples, and its morphological design parameters are shown in Table 1

In order to avoid the interference of color and material to the subjective evaluation of the subjects, the same color and material were used to generate ten samples by 3D printing technology.

3.2 Experimental Design

Twenty-five industrial designers with more than three years of working experience and graduate students majoring in industrial design are invited to rank the samples on the Table according to the semantic words "Thin - Thick". The samples most consistent with the image of "Thin" are arranged in sequence 1, and the samples most consistent with the image of "Thick" are arranged in sequence 10. The sorting results of samples are recorded, and the average rank of each sample is obtained. See Table 1 for the ten experimental samples. In this Table, the smaller the mean value, the closer the sample is to "Thin."

Table 1 Average Ordering of Form Design Parameters and "Thin" Image Evaluation of Ten Experimental Samples

Number	x	y	ρ	Sample	Sort average
1	1.53	2.16	0.26		4.64
2	3.06	4.33	0.26		1.6
3	4.6	6.5	0.26		2.04
4	3.06	6.5	0.53		4.6
5	1.53	4.33	0.53		6
6	4.6	2.16	0.53		6.56
7	3.06	2.16	0.78		9.52
8	4.6	4.33	0.78		7.8
9	1.53	6.5	0.78		9.4
10	3.5	3.5	0.53		2.84

3.3 Data Analysis

The consistency reliability coefficient Alpha is 0.664>0.5, indicating that the experimental results have good reliability. The sample order is a group of continuous numerical variables, and it is judged by a scatter plot that there is a linear relationship between the two variables and no abnormal value. Therefore, the Pearson correlation analysis method is adopted in this study to explore the correlation between x, y, ρ and the ordering results (Sun, 2007), which are shown in Table 2.

Table 2 Correlation Analysis between Sample Form Design Parameters and the Ranking Results of "Thin" Image Evaluation

		x	y	ρ
Sort	Pearson correlation coefficient	-.195**	-.162*	.821**
	Sig.(2-tailed)	.002	.010	.000

As can be seen from the above Table, the significance probability value between the ranking results

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and y is Sig<0.05, and there is a correlation mark of (*), indicating that the ranking results are significantly correlated with y. The significance probability value between the ranking results and x and ρ was Sig<0.01, and there was a correlation mark of (**), indicating that the correlation between the ranking results and x and ρ is very significant. The results are negatively correlated with x and y and positively correlated with ρ. The Pearson correlation coefficient is 0.821 which is close to 1.

4. Conclusion

This study explores the relationship between mobile phone form design parameters and the "Thin" image from the perspective of Kansei Engineering. According to the experimental results, it is found that the ranking of subjective evaluation of "Thin" image of mobile phone is negatively correlated with the bias distance of side A, i. e., x., and the bias distance of side B, i.e., y, and strongly positively correlated with the value of the polar radius, i.e., ρ. The value of ρ has a great influence on mobile phones' "Thin" image form. When designing the form of mobile phones or similar flat objects, the value of ρ can be appropriately increased to reflect the "Thin" perceptual image.

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