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IMPROVING PACKAGING ERGONOMICS THROUGH PUFF-ENHANCED SCREEN PRINTS

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Abstract: *Effective ergonomic packaging ensures efficient and intuitive product handling, providing easy access and a secure grip, thereby enhancing user experience. Achieving this involves optimizing packaging size, shape, and material. This study investigates the application of screen printing with puff-enhanced ink to improve packaging ergonomics. Puff-enhanced ink augments surface roughness, thereby enhancing tactile perception and grip security. This research utilized objective measurements and subjective evaluations to assess the impact of tactile properties on manual pulling force. Building on prior work where the mesh count of 120 l/cm was investigated, this study explores prints created using a screen with a mesh count of 63 l/cm. Three substrates were used: bulky paper, paperboard, and matte-coated kunstdruk paper, with the amount of added puff base varied between 0%, 10%, 20%, and 30%. The findings reveal that surfaces with increased roughness not only enhance grip and increase the manual pulling force but also suggest how different substrates and mesh counts impact the ergonomic properties of packaging. This contributes to a better understanding of the optimal conditions for effectively applying the puff base in the packaging industry.*

Key words: packaging, ergonomics, screen printing, puff base

1. INTRODUCTION

Tactile perception and interaction with objects are essential parts of our daily lives, shaping how we engage with the world. The skin on our palms is particularly sensitive, allowing us to feel textures and receive feedback from the things we touch (Striano & Bushnell, 2005). Touch is a primary way we communicate with our environment, helping us handle objects and assess their tactile qualities (Darden & Schwartz, 2015). Haptic perception refers to our ability to recognize the tactile features of different materials. People often use a rich vocabulary to describe how materials feel, which shows the complexity of our interactions (Meyer, 2001; Kawazu et al., 2000). However, Hollins has identified two main aspects of this perception: hardness (from hard to soft) and roughness (from smooth to rough) (Hollins, 1993). Friction between our skin and the surfaces of objects is crucial for safe handling, giving us confidence when we interact with various items (Veijgen, Masen & Van Der Heide, 2012; Veijgen, Van Der Heide & Masen, 2010; Derler & Gerhardt, 2012). However, there is still much to learn about slipperiness and its effects on grip safety (Bergmann Tiest, 2010). While some studies have looked at how the shape and surface of objects affect grip when lifting them (Kinoshita et al., 1997; Jenmalm, Goodwin & Johansson, 1998), they often overlook how materials can be improved and how psychological factors play a role. The challenges in measuring friction between skin and materials highlight the need for more research to understand what makes a grip feel secure (Derler et al., 2009; Bergmann Tiest, 2010). One innovative approach is screen printing with a puff base added to the ink. When the printed material is heated during the drying process, the puff base expands, creating a raised appearance on the surface of the print. This technique not only creates a three-dimensional effect but also enhances the texture of prints, potentially influencing how consumers interact with and perceive the products. By exploring these advancements, we can improve the tactile experiences and enhance the ergonomic properties of products intended for manual use, such as packaging. In the context of handling products, surface roughness plays an important role. Greater roughness can lead to a more secure grip, making it easier to handle and manipulate items effectively.

2. METHODS

The experimental phase of this research aims to test the hypothesis that incorporating a puff base in manual screen printing can enhance the ergonomic features of packaging. This study evaluates how the addition of a puff base in the ink affects comfort and manual pulling forces, with higher detected forces indicating samples with better ergonomic characteristics. The research involved an experiment followed by a survey. The experiment assessed the maximum pulling forces required to handle objects with printed samples, based on the premise that tactile properties influence comfort and usability. Fourteen participants (7 males and 7 females, ages 25 to 35) took part in the study. The experiments were conducted in a controlled environment with a temperature of 23±2°C and relative humidity of 50±2%. The methodology was informed by prior research conducted by Seo et al. (2008) and Bošnjaković et al. (2023).

2.1. Test samples

The test samples were created using manual screen printing on a Centropapir carousel machine (model no. S.6S4T.B). All prints were produced in black with water-based Teflex ink, incorporating Teflex's puff base at three different percentages: 0%, 10%, 20%, and 30%. Different percentages of puff base were used to create prints on various paper materials, leading to changes in characteristics like surface roughness. A screen mesh count of 63 l/cm was employed. After printing, the samples were dried at 133°C. The prints were applied to various substrates, including bulky paper (164-180 g/m²), matte-coated kunstdruk paper (257-300 g/m²), and paperboard (250 g/m²). Each print was rectangular (135 x 30 mm) with full coverage. In total, 12 distinct print variations were produced (Table 1). It's worth noting that the tactile characteristics of these exact prints on textile materials were analyzed in a previous study (Bošnjaković et al., 2022).

Table 1: Categorization of test samples

Test sample	Substrate	The added amount of puff base in the ink
vol-63-0	bulky paper (164-180 g/m^2)	0 %
vol-63-10	bulky paper (164-180 g/m^2)	10 %
vol-63-20	bulky paper (164-180 g/m^2)	20 %
vol-63-30	bulky paper (164-180 g/m^2)	30 %
pol-63-0	paperboard (250 g/m^2)	0 %
pol-63-10	paperboard (250 g/m^2)	10 %
pol-63-20	paperboard (250 g/m^2)	20 %
pol-63-30	paperboard (250 g/m^2)	30 %
kun-63-0	matte-coated kunstdruk paper (257-300 g/m^2)	0 %
kun-63-10	matte-coated kunstdruk paper (257-300 g/m^2)	10 %
kun-63-20	matte-coated kunstdruk paper (257-300 g/m^2)	20 %
kun-63-30	matte-coated kunstdruk paper (257-300 g/m^2)	30%

2. 2 Experimental apparatus, survey, and procedure

Participants entered the measurement room individually and received clear instructions. They could adjust their position in front of the experimental apparatus based on their dominant hand (Rowson & Yoxall, 2011; Peebles & Norris, 2003). The experimental setup (Figure 1) featured a Shimadzu Compact Tabletop Testing EZ-LX machine, equipped with a 2.5 kN measuring cell and operating at a speed of 0.1 mm/min. Maximum manual pulling force values were recorded in newtons (N) using TrapeziumX software. To measure the pulling force accurately, a tool coated with the printed samples was used.

Figure 1: Experimental apparatus and participant testing the samples

The tool's height was customized for each participant to ensure optimal comfort. Participants were instructed to grip the tool using their fingertips, with their thumb on one side and the other fingers securing the sample on the opposite side (both sides were coated with the same printed sample). Their task was to pull the coated tool downward with maximum force. The measurement ended as soon as they felt the sample slip through their fingers. After the pulling force measurements, participants completed a survey. everyone had the task of evaluating samples based on two criteria: pleasantness to the touch and ease of manual pulling, which reflects stability and grip security (1 - lowest grade, 10 - highest grade). To provide subjective feedback based on tactile perception, participants gently ran their fingertips over each sample, following established methodologies (Wongsriruksa et al., 2012; Bergmann Tiest, 2010; Srinivasan, Whitehouse & lamotte, 1990; Hollins et al., 2000; Chen & Ge, 2017). This survey facilitated the collection of subjective ratings and allowed participants a brief respite to rest their hands, muscles, and nerves. The same systematic approach was employed for each sample until all variations were evaluated.

3. RESULTS

Figure 2 presents the findings from the subjective tactile evaluations conducted on various test samples. The samples vol-63-20, kun-63-10, and kun-63-30 received the highest ratings for pleasantness to the touch. In terms of ease of manual pulling, the samples printed with vol-63-30, pol-63-30, and kun-63-30, each containing a puff base composition of 30%, achieved the most favorable ratings.

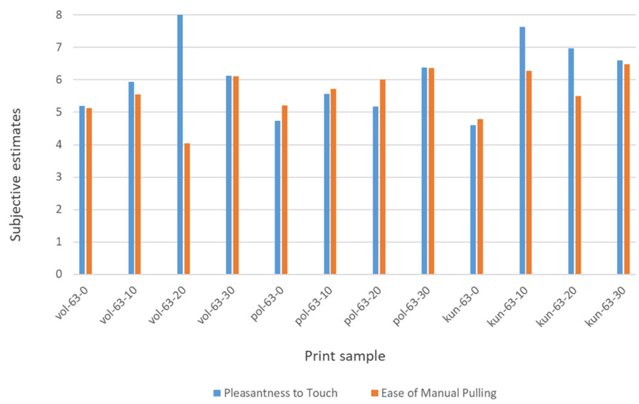

Figure 2: Graphic representation of the results of subjective estimates of printed samples by 14 participants

The mean values of manual pulling forces and standard deviations are given in Table 2. The normal distribution function was utilized to calculate the normal distribution based on the specified mean values of manual pulling forces and standard deviation (Figure 3).

Table 2: Mean values of manual pulling forces and standard deviations

Test sample	N	Mean	SD	Coefficient of variation
vol-63-0	14	68.883	29.073	0.422
vol-63-10	14	79.492	31.691	0.399
vol-63-20	14	72.847	27.983	0.384
vol-63-30	14	81.923	34.531	0.422
pol-63-0	14	62.674	26.213	0.418
pol-63-10	14	69.995	23.652	0.338
pol-63-20	14	72.473	29.599	0.408
pol-63-30	14	77.159	26.499	0.343
kun-63-0	14	67.729	29.154	0.430
kun-63-10	14	79.216	37.871	0.478
kun-63-20	14	75.503	31.361	0.415
kun-63-30	14	87.308	29.338	0.336

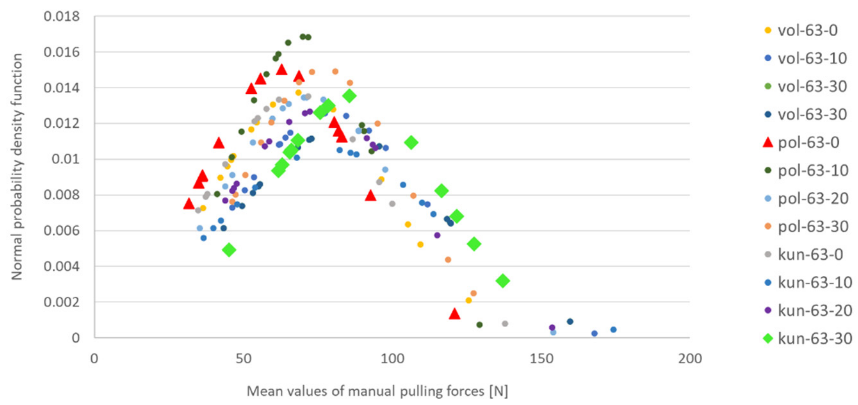

Figure 3: The normal distribution function for every printed sample

Figure 3 illustrates two key curves: one representing the manual pulling forces for the sample that exhibited the highest forces (marked by green rhombus symbols for sample kun-63-30), and the other showing the printed sample with the lowest forces (identified by red triangle symbols for sample pol-63-0). The standard deviations indicate a lack of significant deviations from normality. Notably, the curve for the kun-63-30 sample displays a clear rightward shift in the normal distribution, suggesting advantageous characteristics for manual pulling forces. A one-way repeated measures ANOVA was conducted to assess the effect of the printed sample on forces achieved by manual pulling. Mauchly's test of sphericity, which examines the assumption that the variances of the differences between all possible pairs of within-subject conditions are equal, was evaluated: $x^2(65)=101.220$, $p=.009$. Due to a violation of the sphericity assumption, the Greenhouse-Geisser correction was applied. The main effect of the printed sample was found to be statistically significant, $F(4.861, 63.196)=5.761$, $p<.001$, $\omega^2=0.038$ indicating a significant difference in forces achieved by manually pulling across the levels of printed samples. Post-hoc pairwise comparisons using Holm correction revealed significant differences between specific levels of printed samples. The results indicate that maximum manual pulling forces were significantly higher for samples with an added puff base compared to those without it. Comparing the maximum pulling force results on the same substrate, post hoc tests using Holm's method show a statistically significant difference in pulling forces between the sample pol-63-0 ($p=.027$) and the sample pol-63-30. Additionally, there is a statistically significant difference in pulling forces between the sample kun-63-0 ($p<.001$) and the sample kun-63-30. However, no statistically significant differences in pulling forces were observed between the samples on bulky paper.

4. CONCLUSION

Ergonomic packaging is designed to facilitate efficient, effective, and intuitive handling of products, ensuring a secure grip that enhances the user experience. This study explores the potential of screen printing with an added puff base to improve the grip properties of packaging materials. The puff base increases the roughness of the printed surface, which is essential for achieving a secure grip and effective manipulation. The research methodology involved an experimental setup followed by a survey to assess the maximum manual pulling forces of the printed samples. The results showed that varying combinations of printing parameters led to different subjective evaluations regarding pleasantness to the touch and ease of pulling. Ratings for pleasantness indicated a wide range, suggesting that the type of substrate significantly affects print characteristics. Furthermore, samples with a higher amount of added puff base generally received better ratings for ease of pulling. Differences in recorded pulling forces were also noted between samples containing a puff base and those without it. A comparison of maximum pulling forces on the same substrate revealed significant variations among certain samples, particularly between the pol-63-0 and pol-63-30 samples, as well as between the kun-63-0 and kun-63-30 samples. However, no notable differences were observed among samples printed on bulky paper. These findings imply that specific printing parameters can enhance pulling performance, while the type of paper substrate consistently influences the results. Further research may be warranted to delve deeper into these relationships. Nonetheless, the observed differences in pulling forces likely stem from several factors. The addition of the puff base enhances the roughness and texture of the printed surface, which in turn improves grip and friction. Additionally, the visual depth and texture created by the puff base may positively affect users' perception of grip, suggesting that incorporating this technique in screen printing could greatly enhance the handling of packaging products.

5. ACKNOWLEDGMENTS

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