

Tactile and mechanical investigation of screen printed specimens with puff effect

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ABSTRACT – REZUMAT

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The subject of this paper was the investigation of the tactile and mechanical characteristics of printed specimens achieved using the manual technique of screen printing. The specimens are printed using ink enriched with a puff base. The puff base gives the print a three-dimensional shape and surface characteristics. This paper aims to investigate whether such prints can be used to improve the ergonomic characteristics of a product that undergoes in-hand manipulation. To determine the possibility of using a screen printing technique with a puff effect for ergonomic purposes, two experiments were performed. The first experiment involved subjective investigation of the tactile properties of the prints which are important since the end-users are people. The second experiment involved laboratory testing of the resistance of prints to mechanical rubbing (colour rendering) which is important since the prints should be able to endure a lot of in-hand manipulation. The specimens were printed using the manual screen printing technique on four different textile substrates. Apart from the substrate, the amount of added puff substance in ink and the screen printing mesh count varied. After testing the mechanical resistance to rubbing, colour differences were calculated. Based on the results obtained, resistance to mechanical effect was confirmed, and it was determined which prints have the best resistance and tactile features. Further investigations will be focused on investigating the same type of printing on different materials, and discovering how can prints with puff effect contribute to in-hand object manipulation.

Keywords: Puff effect, screen printing, mechanical resistance

Investigarea tactilă și mecanică a probelor serigrafiate cu efect în relief

Subiectul acestei lucrări a fost investigarea caracteristicilor tactile și mecanice ale probelor imprimate prin tehnica manuală a serigrafiei. Probele sunt imprimate cu cerneală îmbogățită cu o bază în relief. Baza în relief conferă imprimării o formă tridimensională și caracteristici de suprafață. Scopul acestei lucrări este de a investiga dacă astfel de imprimări pot fi folosite pentru a îmbunătăți caracteristicile ergonomice ale unui produs, care este supus manipulării manuale. Pentru a determina posibilitatea utilizării unei tehnici de serigrafie cu efect în relief în scop ergonomic, au fost efectuate două experimente. Primul experiment a implicat investigarea subiectivă a proprietăților tactile ale imprimărilor, ceea ce este important, deoarece utilizatorii finali sunt oamenii. Cel de-al doilea experiment a constat în testarea în laborator a rezistenței imprimărilor la frecare mecanică (stabilitatea culorii), un aspect important deoarece imprimările ar trebui să poată suporta suficientă manipulare manuală. Probele au fost imprimate folosind tehnica de serigrafie manuală pe patru substraturi textile diferite. În afară de substrat, cantitatea de substanță în relief adăugată în cerneală și numărul de plase de serigrafie au fost variate. După testarea rezistenței mecanice la frecare, s-au calculat diferențele de culoare. Pe baza rezultatelor obținute s-a confirmat rezistența la frecare mecanică și s-a determinat care imprimări au cele mai bune rezistențe și caracteristici tactile. Investigațiile ulterioare se vor concentra pe analiza aceluiași tip de imprimare pe diferite materiale și pe descoperirea modului în care imprimările cu efect în relief pot contribui la manipularea manuală a obiectelor.

Cuvinte-cheie: efect în relief, serigrafie, rezistență mecanică

INTRODUCTION

Screen printing is a printing technique that enables printing on almost all types of materials (paper, textiles, plastics, etc.), as well as printing on objects of different shapes, profiles and sizes [1]. In the printing process, the most important component is the printing plate, which is a combination of a screen and a stencil. Between the screen and the substrate is a stencil, which carries printed information. The stencil, by its shape, closes certain parts of the screen, preventing the ink to get through to the substrate while

other parts not covered by the stencil allow the ink to be transferred to the substrate. The elements that the stencil has closed are called non-printing elements, and those that are left open are called printing elements [2]. Using screen-printing thicker layers of ink can be printed (12 mm and more) which is one of the major advantages over other printing techniques. Also, a wide range of printing inks can be used including special additives [2–4]. The puff base is one of the first special additive and effect in the screen printing technique (figure 1). Ink with the addition of a

puff base expands when printed and warmed up adding to the raised, soft print effect. The puff base was modified by adding a heat-active swelling agent. The print has a rough texture visually; however, it feels soft and rubbery to the touch. The touch is reminiscent of velvet and plush. Usually, it is used to create interesting designs that provide texture.

With the addition of a puff base, the printing is standardly done and the print is placed through a drying tunnel. During the drying process, the ink reacts to heat and swells, creating a raised or 3D effect on the substrate [5].

In recent years, ergonomic design has encouraged a renewed interest in users, manufacturers and researchers. In the past, product design has always been emphasized in its function, and it was always considered in the direction of improving efficiency. The task of a product that undergoes in-hand manipulation was only to fulfil the primary function for which it was made and to suit most potential users. However, in recent years, approaches have changed and new important segments have been introduced that have received particular attention in design, such as the comfort and consistency of how a product is used considering the capabilities of a potential customer.

There were several reasons for the emergence of these new principles, one of them being the rise in upper extremity musculoskeletal disorders. These disorders are widespread in industries that use hand tools. Products subject to in-hand manipulation must be safe and easy to use and tend to reduce the load transferred to the upper limbs to avoid the risk of musculoskeletal injuries [6]. The surface in contact with the palm should not be so smooth as to be slippery, nor rough so much to be abrasive. The friction properties of the surfaces that come in contact with the palm are complex because the skin is highly elastic and oil-resistant. Varnished wooden surfaces give better subjective estimations than metal or plastic of similar smoothness. The rubber is similar to wood but becomes “sticky” during use [7]. Lewis, Carré, and Tomlinson [8] investigated the impact of friction between the fingers as well as the palms and objects of sports equipment, with the assumption that the surface of the product material can strongly influence

how well an athlete plays. Not only does it determine how well the equipment can be caught and manipulated, but it also accelerates a safer and more stable grip and performance. The interactions of the hand with a frisbee were also explored. Researchers believe that the basics of skin tribology can play a key role in the development of optimized sports equipment, but there are still gaps in understanding and modelling the surface texture of the product and how much it affects comfort [8]. Considering that screen printing can print ink in a thick layer, which gives a print of high coverage properties and has great resistance to external influences, there is a potential that screen printing can be used to improve the ergonomic characteristics of similar products undergo in-hand manipulation. Screen printing has already been explored and suggested to be used in the printing of Braille [9], and this paper will explore the possibility of using screen printing with the addition of puff base to increase the ergonomic qualities of products intended for in-hand manipulation. In this research, textile is used as a printing substrate since the screen printing technology with the addition of puff effect is usually done on textile. Textile is widely used in our daily life and its tactile design is significant [10].

METHODOLOGY

This research aims to test the hypothesis through experiments. The hypothesis is that the specimens printed with the manual screen printing technique with the addition of a puff base in the ink can be used to improve the ergonomic characteristics of products that undergo in-hand manipulation. The puff base adds new qualities to the printed colour. The print gets a third dimension and its tactile surface characteristics change in addition to the visual senses, it can be tactile experienced. The printed specimens were investigated subjectively, where, through the survey where respondents estimated the tactile characteristics of prints. The survey included 10 respondents, 5 males and 5 females. All respondents were between 25 and 35 years old. After the subjective study, an objective study was carried out to check the mechanical characteristics of the prints, namely the resistance to mechanical rubbing (colour rendering).



Fig. 1. Screen printing with puff effect

The resistance to mechanical influence study was carried out in a laboratory setting, similar to the research [11–13] and the 105-X12:2016 standard [14].

Materials and experimental apparatus

The samples were printed by the manual screen printing technique on a carousel machine manufactured by TSH Printer LTD GMBH, model no. S.6S4T.B. All prints are printed in black on water-based Teflex ink. Teflex manufacturer's puff base was added to the ink in three different percentages of 10%, 20% and 30%. In addition to the percentage of puff base, the size of the screen printing mesh count varied. The screen printing mesh count of 63 l/cm and 120 l/cm were used. Given the variations of the two factors mentioned, six different types of prints were obtained (table 1). The screen printing mesh is made of silk and is woven with the ordinary type of weaving. Synthetic rubber squeegee 75 shore was used. After printing, each print was dried at 133° C for 30 seconds. The prints are printed on different textile substrates. Mixed textile material (97% cotton, 3% cotton) with a weight of 10.01 g/m², 100% viscose with a weight of 2.10 g/m², 100% polyester with a weight of 1.66 g/m² and 100% cotton with the weight of 1.08 g/m² were used. Material characterization was done according to ISO1833 standard for material composition and ISO 3801 for fabric weight. Each material was printed with three identical 100% coverage print samples of 135 × 30 mm to conduct statistical analysis. The printing duration of each substrate was 5 seconds per print, which can be translated to a printing speed of 34 mm/s for each print.

Testeks ft411 Electronic Crockmeter instrument was used for testing colourfastness of printed specimen to dry rubbing. The device applies a constant vertical pressure (9 N +/- 10%) with a rubbing head diameter of 16 mm and a stroke of 104 mm in length according to ISO 105-X12:2016 [14]. A similar methodology was used in the research of Lilić, Kašiković and Miketić (2019) [15]. The rubbing head is coated with a cotton canvas in contact with the test specimen. The canvas needed to be changed from time to time due to the occurrence of dirt. The scanning, measurement, visual assessments and analysis of the test specimens were performed before and after

three cycles of fifty repetitions (50, 100 and 150). The samples were scanned using the Canon CanoScan 5600F at 600 spi in full colour for archiving and subsequent image analysis. The measurement of the CIE Lab colour coordinates was done using the HP 200 colourimeter instrument, illumination D65, 2° standard observer and d/8 measurement geometry.

Procedure

The first part of the experiment was the subjective estimation of the printed samples. The task of the respondents was to fill in the survey. By physically touching the printed specimens, they needed to select from the group of specimens consisting of 6 different types of prints for one material type, the print that best suits the given characteristic. Accordingly, their task was to select a print type that was the smoothest/roughest, aesthetically best/aesthetically worst, most pleasant to the touch/most unpleasant to the touch, and the firmest/softest. As there were 4 different substrates, the specimens were divided into 4 different groups, and the survey was divided into 4 different parts. Each part was focused on one type of substrate material and the characteristics evaluated were the same for all parts. The second part of the experiment was conducted through laboratory testing. The resistance of the specimens to mechanical rubbing was investigated. The CIE lab coordinates of specimens were first measured and scanned before testing, and then the samples were treated in 3 cycles with 50 repetitions each. Scanning and measurement were performed between each cycle. Colourimetric of the samples were taken using HP 200. The CIE lab values for each specimen were measured three times. From these, the mean values were calculated, which are further used for calculating the colour differences of the print specimens. Colour differences were calculated according to the CIE 2000 (ΔE_{00}) colour difference formula [16, 17]:

$$\Delta E_{00} = \sqrt{\frac{\Delta L'}{k_L S_L} + \frac{\Delta C'}{k_C S_C} + \frac{\Delta H'}{k_H S_H} + R_T \cdot \frac{\Delta C' \Delta H'}{S_C S_H}} \quad (1)$$

where $\Delta L' = L'_1 - L'_2$ is a difference in lightness value, $\Delta C = C'_1 - C'_2$ is a difference in chromatic value, $\Delta H = 2\sqrt{C'_1 C'_2} \sin \frac{\Delta h'}{2}$ is a difference in hue value and parametric weighting factors $k_L = k_C = k_H = 1$.

Differences that were calculated were the difference in the colour of the print before rubbing and after 50 repetitions, the difference in the colour of the print before rubbing and after 100 repetitions and the difference in the colour of the print before rubbing and after 150 repetitions. Also, the differences in the colour of the prints between the 50th and 100th repetition, between the 50th and 150th repetition and between the 100th and 150th repetition were calculated. The colour differences were compared by the type of substrate and by print type. Colour difference values can be translated to human perception

Table 1

CATEGORIZATION OF PRINTED SPECIMENS		
Print type specimen name	Screen printing mesh count (l/cm)	Added puff base amount in the ink (%)
Print type 1	63	10
Print type 2	63	20
Print type 3	63	30
Print type 4	120	10
Print type 5	120	20
Print type 6	120	30

reference as ΔE_{00} lower than 0.2 – the difference is not perceivable, ΔE_{00} between 0.2 and 1 – the difference is noticeable, ΔE_{00} between 1 and 3 – the difference can be seen, ΔE_{00} between 3 and 6 – the difference is easy to see and ΔE_{00} over 6 – obvious difference [14, 15] used in this paper.

RESULTS AND DISCUSSION

Figure 2 shows the results of tactile estimations of prints given in a survey. Based on the mean values of the results obtained, it was discovered that the print combination of amount off puff base and the screen printing mesh count named type 1 (accordingly to table 1), regardless of the substrate on which it was printed, was chosen as the aesthetically best print. As the aesthetically worst print, print type 6 was selected, regardless of the substrate. Print type 1 for mixed textile material was selected as the firmest print. Print type 2 was selected as the firmest print on polyester and for viscose and cotton, it was print type 3. On the mixed textile material (cotton and elastin), viscose and polyester, print type 4 was selected as the softest, while for cotton, print type 6 was selected. For the most pleasant to the touch characteristic for mixed textile material, viscose and polyester type 4 were rated as the best. For cotton, it was the print type 1. The print type that was rated as the most unpleasant to the touch, regardless of the substrate, was specimen named type 6. The roughest specimen for polyester was type 2, while for the other materials it was the print type 6. The smoothest type of print is type 1, regardless of the material of the substrate.

Colour differences values calculated as a result of the mechanical rubbing experiment are shown graphically in figure 3, while the appearance of printing specimens (a group of printed samples printed on substrate viscose) and their change during testing cycles are shown in figure 4. It was often the case that printed specimens in the first rubbing cycle received a darker colour, and by the further process of rubbing the print began to lighten increasingly resembling the original colour. Some printed specimens began to lighten after the 50th repetition and some after the 100th. Therefore, as shown graphically in figure 3. after more rubbing, rather than increase, the colour differences were reduced. For example, colour differences calculated between samples before testing and after 150 repetitions are lower than it was calculated after 100 repetitions for the mixed textile substrate (97% cotton and 3% elastin) in the combination of print type 2.

The print type printed on mixed textile material with the lowest colour difference was 1 ($\Delta E = 0.70$) and the print type with the highest colour difference was 6 ($\Delta E = 2.64$). The print type that was printed on viscose with the lowest colour difference was 1 ($\Delta E = 1.09$) and the print type with the highest colour difference was 2 ($\Delta E = 7.52$). The print type printed on polyester with the lowest colour difference was 3 ($\Delta E = 1.57$) and the print type with the highest colour difference was 4 ($\Delta E = 3.46$). The print type printed on cotton with the lowest colour difference was 1 ($\Delta E = 1.19$) and the print type with the highest colour difference was 2 ($\Delta E = 3.09$). Print type 1 was the most durable print type for mixed textile, viscose, and

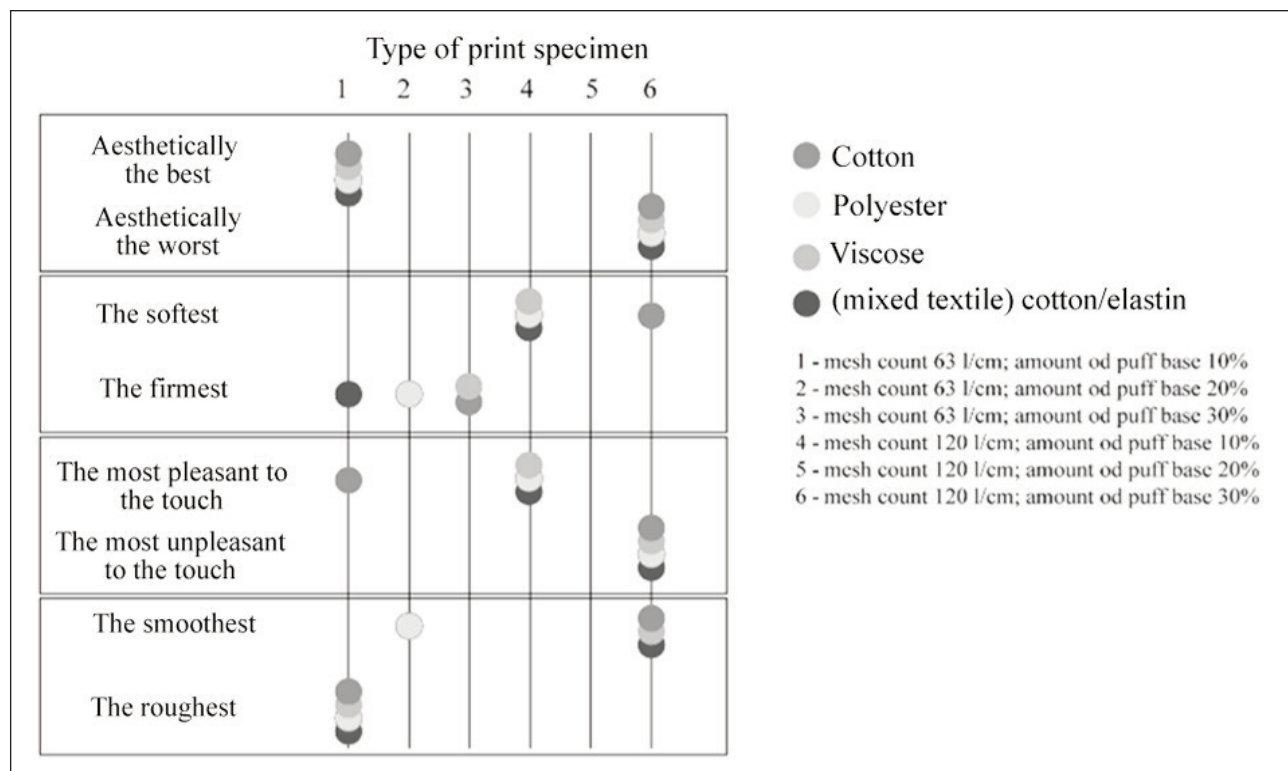


Fig. 2. Graphical presentation of subjective estimation results

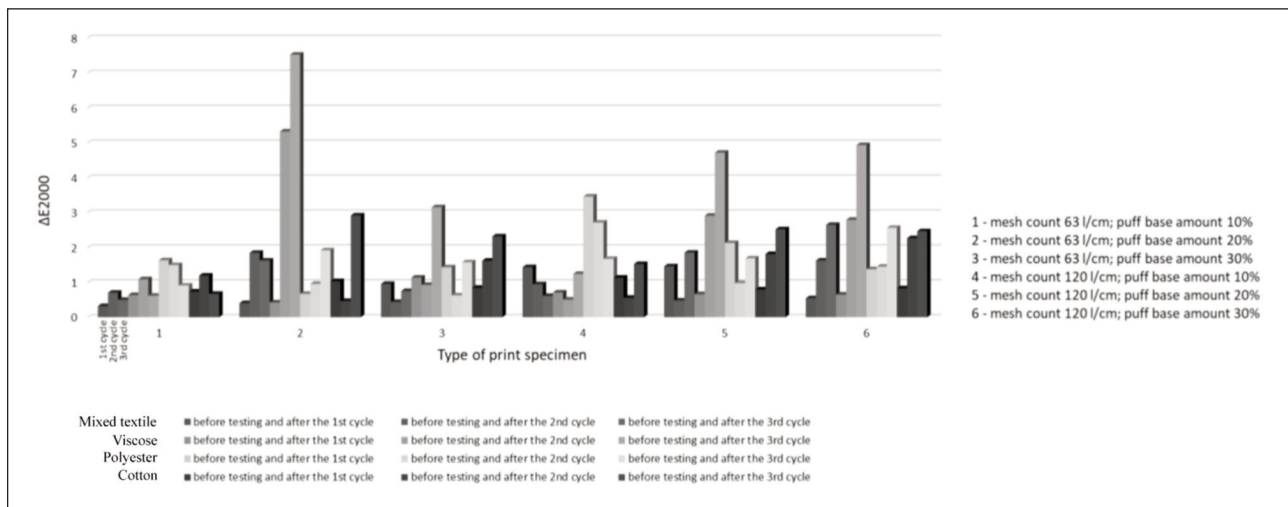


Fig. 3. Graphical representation of colour difference results

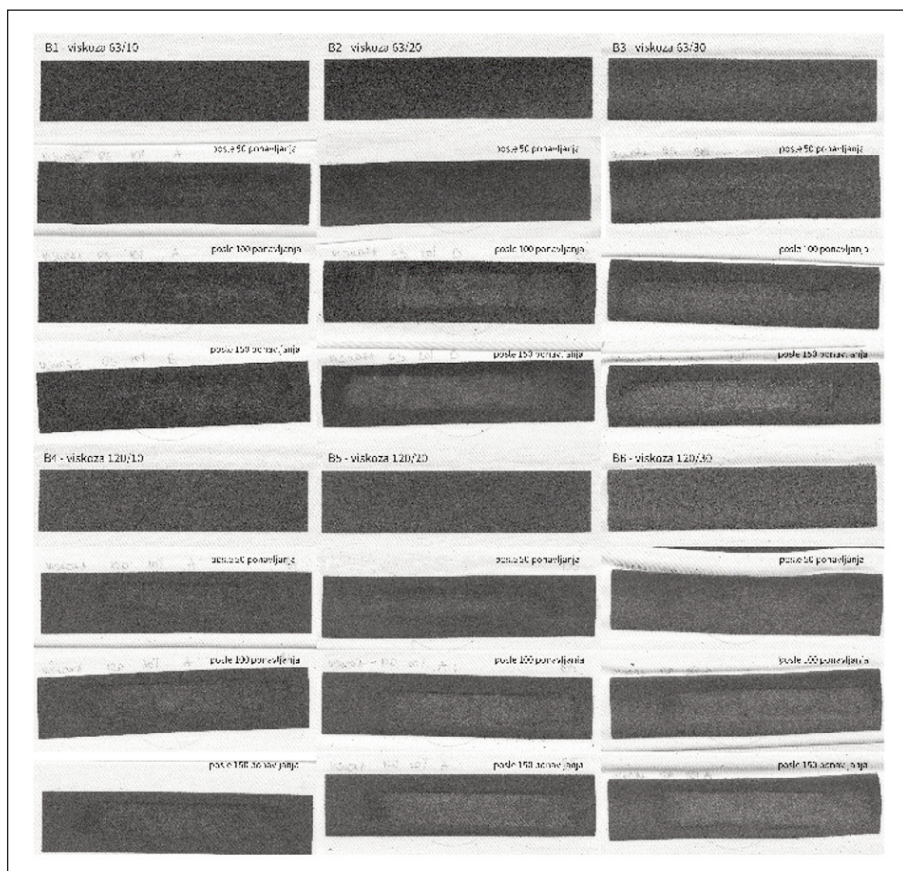


Fig. 4. The appearance of the specimens during testing on substrate viscoselts

mechanical rubbing printed on all four materials. These types of print have the same screen printing mesh count of 120 l/cm and the unfavourable combination was a screen printing mesh count of 120 l/cm and 30% amount of the puff base added in the ink. Similar results of the influence of mesh count on mechanical rubbing have been obtained in the research of Vladić et al. [11]. The most durable material appeared to be mixed material and the material with the least durable print was viscose.

CONCLUSION

Based on the obtained results, it can be concluded that there are valid reasons for introducing screen printing techniques in the process of enhancing the ergonomics characteristics of products. The usability of screen printed samples with the addition

cotton substrates. Print type 3 was the most durable print type for polyester. A print type 2 was the least durable print type for the substrates made of viscose and cotton. For polyester, the least durable print type was 4. Print type 6 was the least durable print for the mixed textile material. Based on all the results, print types 1, 2, and 3 provided the most resistant print to mechanical rubbing printed on all four materials. These prints have the same characteristic as the screen printing mesh count (63 l/cm). Print types 4, 5, and 6 provided the least resistant print type to

of a puff base in the ink was examined through subjective as well as objective investigation. As a result of subjective research, these prints proved to be highly well received by respondents. Every investigated tactile feature can be achieved in a proper printing combination of substrates and print type (the combination of the amount of puff base in the ink and screen printing mesh count). Besides the tactile feature, in order for these prints to be used for the improvement of the ergonomics characteristics of the products, they need to fulfil certain mechanical characteristics, such as resistance to rubbing. The results

of the mechanical testing show that the prints are very resistant. Observing altogether subjective and objective results it can be concluded that print types achieved in the combination of screen printing mesh count of 63 l/cm or 120 l/cm and 10% of the added amount of puff base in the ink, regardless of the substrate, gave the best results is this research. Further research will include an investigation of the screen

printing technique with added puff special effect printed on a wider range of substrates, and an investigation of its impact on in-hand manipulation.

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