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The Relief Effects of Thermoplastic Structured-Shrunken Yarns on Woven Fabrics

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ABSTRACT

This study aims to investigate the relief effects on woven fabrics by using heat-sensitive thermoplastic-shrink yarns and different yarn types together. The purpose of examining the relief effects is to create innovative surfaces and increase aesthetic value in the design of woven fabrics with yarns that gain permanent shape by shrinking with heat treatments. In line with the purpose, first of all, thermoplastic yarns and the studies carried out in this context, the fabrics produced were examined. The information gained was evaluated within the scope of woven fabric design, and relief effect woven fabrics were designed within the scope of a theme. Before the production process of the main fabric designs, preliminary research fabrics were woven for the selection of the appropriate yarn type, weaving structure, and knitting that will create the relief effects in the designs in the most accurate way. With the data obtained from the preliminary research, yarn, woven, and woven fabric structures were determined for fabrics and main designs and production calculations were made. After weaving production, all fabrics were heat-treated to create permanent relief effects after being removed from the loom. The relief effects seen in all fabrics after heat treatment were evaluated in terms of both structural and theme-related appearance by relating the type of yarn used in the production of fabrics, weaving, and woven structure.

Evaluations were also made according to the numerical and visual data determined during the design and production process. The preliminary research results and the descriptions of the main fabrics are discussed under the relevant sections, and their contributions to the design and production process are stated in the conclusion section. In the production process of the fabrics, dobby weaving techniques were used in the preliminary research fabrics, and jacquard weaving techniques were used in the production of the main fabrics. Single-layer, self-connecting double-layer, and double-layer bag structures were used as woven fabric structures. The yarns used are thermoplastic yarns that are heat sensitive and cotton and polyester yarns that do not heat sensitive. In the design and application works considered as interior textiles; in addition to thermoplastic yarns, the effects of non-thermoplastic yarns in terms of relief were also observed in terms of aesthetic quality and structure. In addition to the use of thermoplastic yarns with non-thermoplastic yarns, the desired aesthetic relief effects have been achieved with the combination of weaving structures, weave, and yarn density selected depending on the designs revealed in line with the themes of the fabrics.

It is thought that the study will contribute to the development of innovative perspectives in terms of function and aesthetics in creating relief effects in woven fabric design with the use of thermoplastic and non-thermoplastic materials, and weaving techniques.

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1. INTRODUCTION

From past to present, textiles have different usage areas and visuality depending on the changing structures of societies such as belief, ethnicity, geography, socio-economic status. Textiles are produced with three basic techniques: weaving, knitting, and non-woven surfaces. Among these techniques, weaving is the most commonly used production technique in textiles.

In both the functionality and visual appearance of textiles, the elements such as raw materials, color, weave, technique, and finishing processes are the main factors in creating difference and innovation. The physical and chemical properties of the yarns used in woven fabrics have important effects on the usage function and visual appearance. These effects may differ according to the raw material of the yarns. Many properties of the yarns, such as twisting properties, fineness and thickness, color, being transparent and opaque, make significant contributions to the visuality of the fabrics. They can give different visuals of aesthetic quality to fabrics. These different visual effects also contribute to the diversification of usage areas. For example, weaving fabric samples that created relief effects by using twisted yarns in different directions were exemplified in detail by Ann Richards [1]. In the first fabric, Z twisted yarn in the warp and weft, in the second fabric Z twisted yarn in the warp, S twisted yarn in the weft, in the third fabric S twisted yarn in the weft and warp, and the last fabric S twisted yarn in the warp and Z twisted in the weft was used (Figure 1).

Depending on the raw material of the yarns, chemical properties such as felting, shrinking, and dyeing are also effective in the usage function and visual appearance of woven fabrics. "Increasing raw material demand due to industrial development and the industrial revolution brought along the efforts of developing alternative raw materials and thus produced man-made fiber" [2]. The discovery and development of man-made fibers and their reactions as a result of the applied finishing processes have provided functional and visual diversity in the design and production of woven fabrics. For instance, shibori is the most known technique for both dimensional and visual appearance on woven fabrics. In Figure 2, a three-dimensional and colorful shibori-weaving by Brachmann is seen.

One of the important properties of man-made fibers is that they are sensitive to heat. This property of man-made fibers is called thermoplastic property and is also referred to as thermoplastic fibers and yarns in the sources. In other words, these yarns are the yarns that change their shape after heat treatment and have the potential to maintain these forms. Thermoplastic yarns are also called heat-sensitive or shrink-yarns in the textile industry. In this study, this yarn is referred to as a thermoplastic shrink yarn depending on the applications made. The reason for the use of this term is to differentiate "the finishing process, such as the bleaching, felting, or shrinking effect of the fiber depending on the elastane property" [4]. Another reason; it is to describe the relief effect that occurs as a result of 'finishing processes such as bleaching, felting, shrinking applied after weaving, depending on the elastane feature of the yarn' [4].

Figure 1. Different twisted yarns' effects on woven fabrics [1].

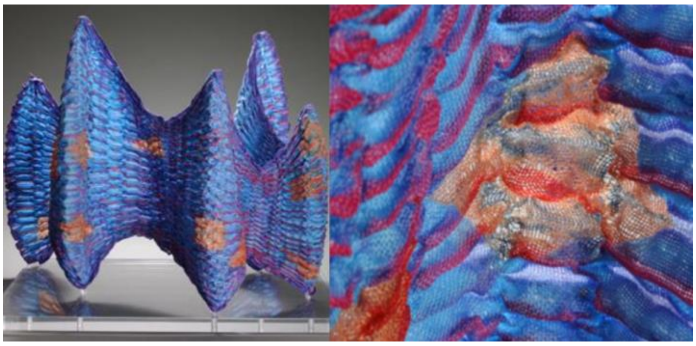

Figure 2. 'Folded Currents', Heat treatment and shibori-woven technique, Holly Brackmann, 2008 [3].

The use of thermoplastic-shrinkable yarns in the design and production of woven fabrics has provided permanent relief effects on the fabrics. Such relief effects have brought woven fabrics to different visual appearances with an innovative perspective. Due to their raw material, the thermoplastic structured- shrunken yarns can be melted at different temperatures and can maintain their permanence when the dry heat is removed. The reasons for the use of thermoplastic yarns in the design and production of woven fabrics; the infinite diversification of the material and technique, the possibility of an unlimited design, is an innovative material, low cost, functionality, and performance can be improved. In the 1960s, textile materials and techniques have become used as an art form. Especially in the 1970s, the Japanese designers reinterpreted fabrics produced from thermoplastic yarns. These fabrics can be considered as the best examples of the combination of traditional techniques and technology in the cooperation of arts and crafts concepts. Reiko Sudo, who has made great efforts in weaving fabrics with relief and volume effects using thermoplastic yarns, has also signed many innovative designs with Nuno Corporations [Figure 3].

Figure 3. ‘Jellyfish’ fabric with thermoplastic yarn by Reiko Sudo, 1994 [5].

Figure 4. ‘Pleats Please’ pleated fabrics by Issey Miyake, 2012 [6].

Structures with many different relief effects, natural or artificial; take place at every point of life, and with the formation of modern design consciousness, the idea of simple, effective, functional design shapes aesthetics and tastes [7]. The reflections of this situation are also seen in the design and production of woven fabrics in textiles. “Design and manufacture of woven fabrics with relief effects with thermoplastic yarns reached the highest level with the search for alternative surfaces and forms in the 1980s” [5]. In 1981, the Japanese designers provided to highlight man-made fibers by forming thermoplastic fibers with textile techniques and technology. Moreover, they brought an aesthetic approach with innovative surfaces. “In general, they have concentrated on fabric design rather than form in their collections and integrated the fabrics with minimal garment forms providing to express their high technology and aesthetic properties” [5]. By the end of the 20th Century, “thermoplastic structured fibers such as acetate, triacetate, polyamide, polyester, polypropylene, polyurethane elastomer” [8] brought fabrics to very different dimensions in terms of functionality and visuals combined with technology and art.

In the 21st century, fabrics made from thermoplastic yarns have been redesigned with a creative and innovative perspective. In the production of these new designs, fiber, yarn, weaving techniques, and finishing processes were used together. This different approach brought the industry and art cooperation to the highest point in weaving design. One of these creative and innovative approaches is relief effects. Relief effects also have an outstanding place in the design of woven fabrics in terms of aesthetics and technique. Because relief effects carry woven fabrics to an innovative and distinctive visuality. “Relief is defined as embossing of surface and divided into four groups as low and high relief, either inwards or outwards” [9]. Another definition of relief is as follows, apart from the definition that is identified with the art of sculpture in plastic arts: "Relief is the method of creating figures on the surface by leaving some parts hollow and some parts embossed" [10]. The relief effect is also the effect of light on embossed surfaces. It is the shadow effect that reveals deeply. The higher the voluminous areas on the woven fabric surface, the greater the depth of light and shadow, and the greater the relief effects [2].

Within the scope of art and design, relief is characterized as a form of texture and surface formation, especially in architecture and sculpture. Relief in the design of woven fabrics; ~~it~~ is expressed as voluminous and fluffy surfaces created by the combination of yarn, weave, density, and weaving techniques. In relief effect woven fabrics, light is an important factor in the perception of fluffy and voluminous effects. Light-dependent shadow effects can change the perception of relief effects. In this change, the use of yarn type, weave, density and weaving technique parameters is also important depending on the design. Depending on these parameters, the greater the difference between the indentation and protrusion in the created relief, the greater the depth of light and shadow. The smaller the difference between indentation and protrusion, the less depth of light and shadow. These increases and decreases will cause different relief effects on the surface of woven fabrics. On the other hand, depending on the aforementioned parameters, the flexibility and softness of the fabric are of great importance in the formation of the relief effect.

To create a relief effect in woven fabrics, woven structures are the most used among the parameters mentioned above. These woven structures are multi-layered, reinforced, pile, pleated, pique structures. Also the weave in woven fabric structures reveals effects such as relief, contrast, volume, vibration, opacity, and shine [11]. Structural features of yarns such as twisting direction, short and long fibers are also important in creating a relief effect. At the same time, properties such as heat shrinkage and shrinkage processes, which depend on the chemical properties of the raw material of the yarns, are also effective issues in creating a relief effect in woven fabrics.

In woven fabrics, the heat sensitivity feature of the thread creates the embossed effect with thermoplastic threads. In addition to thermoplastic threads, different types of threads should be used in fabrics. When heat treatment is applied to fabrics in which thermoplastic yarns are used, bulky relief effects occur on the surface depending on the design of the fabric and the production parameters used. These voluminous relief effects create different visual aesthetic qualities on the fabric surface. Elsasser was explained detailed the physical and chemical properties of the yarns are affecting the design in terms of relief and volume in her book named ‘Textiles: Concepts and Principles’ [12].

In the light of all pieces of information, the study aims to examine the relief effects to be obtained by using thermoplastic yarn in the design and production of woven fabrics in terms of aesthetic visual effects that will occur in connection with creativity. The main reason why thermoplastic yarns are preferred to create a relief effect is that they can take permanent shape with heat. During the research phase of the subject, sectoral studies and publications on this subject were examined and read. In all accessible sources, it has been observed that the effects such as volume and relief obtained by applying heat treatment to fabrics woven with thermoplastic yarns are not examined in detail in terms of aesthetic visuality concerning design and creativity. In the available resources, studies on the use of elastane yarn and felt to add volume to the fabric with the use of different materials have been reached. Regarding thermoplastic yarns, it has been seen that fabrics with finishing processes such as pleating and embossing and double-layered woven fabrics are mentioned. A detailed scientific study has not been found about the relief, volume, and sizing that occur depending on the structure and weave of the fabric with the use of heat-sensitive thermoplastic yarns in woven fabrics.

For this reason, it is thought that the study will guide those who will work in the field of aesthetic visual effects created by heat-sensitive thermoplastic yarns in the design of woven fabrics.

2. MATERIAL AND METHOD

Within the scope of this study, 7 preliminary research fabrics and 12 main fabrics were designed and produced to investigate the effects of thermoplastic yarns and relief in woven fabrics. Before the main fabric designs and production, seven preliminary research fabrics were designed and produced to observe the different relief effects of the thermoplastic yarn depending on the weave, woven technique, density, and material variables. After the heat treatment results of the preliminary research fabrics were evaluated, the main fabrics were designed and produced.

Pre-research fabrics were produced on a 55 cm wide, metal, ~~a~~ handloom with 24 heald shafts. The main material used in fabrics is threads of thermoplastic structure. The thermoplastic yarn was used only as weft yarn. The yarns used in the weft are 300-denier polyester shrink yarn, Nm 40/2 cotton yarn, Nm 25/2 cotton yarn, Nm 30 polyester boucle yarn, Nm 50/2 polyester yarn. Nm 50/2 polyester yarn, which is not likely to shrink during heat treatment, was used as a warp thread. Plain, 2/2 twill, 2/2 weft ribs were used as the weave. Material and production information of these samples are given in Table 1. In the tabulation of the standard and variable values used in the study, the work of Acar, Meriç and Kurtuldu structurally was taken as a reference. [4]. The comparison of the appearance of these samples before and after heat treatment in terms of relief effect is given under the title of ‘Evaluation of Relief Effects of Preliminary Research Fabrics’.

In the face-to-face meeting with Küçükerler Tekstil Ticaret Sanayi, it was learned that these yarns are heat-treated with dry hot air between 155-165^{0}C. For this reason, all fabrics were kept in 160°C, dry hot air for 3 minutes from a distance of 10 cm, to shrink them and take their permanent shape.

These patterns were prepared in the computer-aided weaving program and woven on 2400 platinum Somet Staubli Jacquard Loom with three weft yarn groups. In the 12 woven fabrics, 300-denier thermoplastic structured-shrunken yarn, 300 denier polyester non-shrunken yarn, Nm 4 micro polyester chenille yarn, and 1800 denier polyester air texturized yarn were used as weft yarns. As the warp yarn, 150-denier polyester non-shrunken yarn was used.

After evaluating the results of the preliminary research fabrics in terms of relief effects, the design and production of the main fabrics were started. 12 main fabrics were designed. In the main fabrics, 150 denier polyester yarn in the warp, 300 denier polyester yarn in the weft, 300 denier polyester thermoplastic yarn, Nm 4 micro polyester chenille yarn, 1800-denier polyester air-textured yarn were used. Thermoplastic structured yarns; It is only used as weft yarn because it has very thin filaments is less twisted, and has low breaking strength. The main fabrics were woven in a double-layer bag structure on a 2400 platinum Somet-Staubli jacquard loom. The weave of the fabrics was fixed as a plain weave.

The reason why thermoplastic structured-shrunken yarns are used only in weft is that they are not suitable for use as a warp yarn due to their very fine structure and low twist due to their rupture quickly [2]. Due to the results of pre-research fabric samples, the weave is fixed as a plain weave in main fabrics which are designed and prepared for production. The production criteria of the main fabrics are given in Table 2. In the tabulation of the standard and variable values used in the study, the work of Acar, Meriç, and Kurtuldu structurally was taken as a reference. [4]. The comparison of the appearance of these fabrics before and after heat treatment in terms of relief effect is given under the title of ‘Design and Production Process of Main Fabrics’.

Table 1. Technical information of the pre-research fabric samples

STANDARTS	Weaving technique	Dobby weaving
	Warp yarn	Nm 50/2 polyester non-shrunken yarn
	Warp density	16 threads/cm
	Fabric length	10 cm
	Heat treatment details	160^0C dry heat air, 3' from 10 cm length for each fabric
VARIABLES	Fabric structure	Single-layer (Sample 1,2,3) Double-layer (Sample 4,5,6,7)
	Reed number and change	80/2 (Sample 1,2,3) 100/2 (Sample 4,5,6,7)
	Weft yarns	300-denier polyester shrunken yarn (Sample 1), 300-denier polyester shrunken yarn, Nm 40/2 cotton yarn (Sample 2) 300-denier polyester shrunken yarn, Nm 30 polyester bouclé yarn (Sample 3) 300-denier polyester shrunken yarn, Nm 50/2 polyester yarn (Sample 4) 300-denier polyester shrunken yarn, Nm 25/2 cotton yarn (Sample 5, 6, 7)
	Warp density	16 threads/cm (Sample 1,2,3) 20 threads/cm (Sample 4,5,6,7)
	Total weft density	12 threads/cm (Sample 1) 8 threads/cm (Sample 2,3) 20 threads/cm (Sample 4,5,6,7)
	Weaving structure	1/1 plain weave (Sample 1,4,5,6,7) 2/2 weft ribs (Sample 2) 2/2 twill weave (S direction) (Sample 3)
	Fabric width on the loom	20 cm (Sample 1,2,3) 18 cm (Sample 4,5,6,7)
	Warp yarn arrangement	Only shrunken yarn (Sample 1) 10 cotton yarn, 2x (4 shrunken yarn, 4 cotton yarn) (Sample 2) 16 bouclé yarn, 10 shrunken yarn (Sample 3) 10x(1 polyester yarn, 1 shrunken yarn), 8 polyester (Sample 4) 10x(1 cotton yarn, 1 shrunken yarn), 8 polyester (Sample 5) 20x(1 cotton yarn, 1 shrunken yarn), 2 cotton yarn (Sample 6) 20x(1 cotton yarn, 1 shrunken yarn) (Sample 7)

Table 2. Technical information of the main woven fabrics

STANDARTS	Weaving technique	Jacquard weaving
	Weaving machine	Somet Staubli Jacquard Loom (2400 hooks)
	Warp yarn	150-denier polyester non-shrunken yarn
	Warp density	66 threads/cm
	Reed number and change	11/6
	Weaving structure	Ground: 1/1 plain Structure: double-layer bag-structure Border weave: 3/3 ribs
	Fabric width on the loom	170 cm
	Fabric length on the loom	50 cm
	Heat treatment detail	Monforts Ram Toptex/ Monfortex 8000, 155^0C, 16m/min (Group 1) Monforts Ram Toptex/ Monfortex 8000, 165^0C and 14m/min (Group 2) Monforts Ram Toptex/ Monfortex 8000, 155^0C, 16m/min (Group 3)
VARIABLES	Weft yarn groups	Group 1 (Bankiz 1, Kanyon 1, Tsunami 1, Mistral 1) 300-denier polyester shrunken yarn, Nm 4 micro polyester chenille yarn Group 2 (Bankiz 2, Kanyon 2, Tsunami 2, Mistral 2) 300-denier polyester shrunken yarn, 300-denier polyester yarn, Nm 4 micro polyester chenille yarn Group 3 (Bankiz 3, Kanyon 3, Tsunami 3, Mistral 3) 300-denier polyester shrunken yarn, 1800-denier polyester air texturized yarn
	Total weft density	20 threads/cm (Group 1) 21 threads/cm (Group 2) 20 threads/cm (Group 3)
	Fabric quality	1/1 (Group 1) 4/1 (Group 2) 1/1 (Group 3)

3. RESULTS AND DISCUSSION

3.1. Evaluation of Relief Effects of Preliminary Research Fabrics

As a first step, the width and length shrinkage of seven fabrics woven for experimental purposes was observed after weaving and heat treatment. After the weaving process was finished and the fabric was taken off from the loom, it was observed that the fabrics had shrinkage only in the width. After heat treatment was applied to the fabrics, it was determined that there was shrinkage in both width and length. Changes in the dimensions of these samples are given in Table 3. The appearances of the pre-research fabrics before and after the heat treatment are given in Figures 5-11.

If we evaluate the changes after heat treatment, it has been observed that the samples woven in double-layer structure shrunk more than the samples woven in a single-layer structure (Figure 5). Added at the end of the paragraph above the table.

Sample 1, which is given before and after the heat treatment appearances in Figure 5, was woven in a single-layer fabric structure with a plain weave. As a weft yarn, only thermoplastic structured-shrunken 300-denier polyester yarn was used.

It was observed that this sample shrank unevenly as a result of the heat treatment and a clear and regular relief effect could not be obtained (Figure 5-B). The first is the one-to-one binding of the weft and warp threads due to the plain weave used. Therefore, weaving has a dense structure. The second is the use of a second non-thermoplastic yarn in the weft.

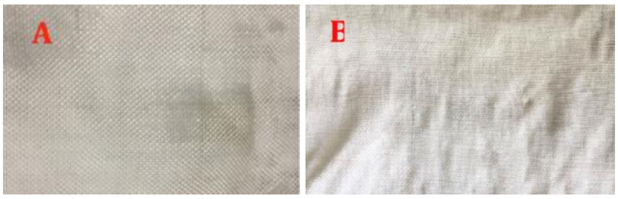

Figure 5. A) Appearance of Sample 1 before heat treatment, B) Appearance of Sample 1 after heat treatment [2].

Sample 2, which is given before and after heat treatment appearances in Figure 6, was woven in a single layer structure with a 2/2 weft ribs. As a weft yarn, thermoplastic structured shrunken 300-denier polyester yarn and Nm 40/2 cotton yarn were used. A high relief effect was observed on the fabric after heat treatment. Despite the single-ply fabric structure, it was concluded that the relief effect on the fabric is due to the use of 2/2 ribs as weave and cotton yarn and thermoplastic polyester yarn as weft yarn.

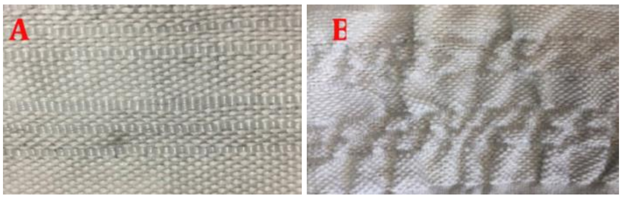

Figure 6. A) Appearance of Sample 2 before heat treatment, B) Appearance of Sample 2 after heat treatment [2].

Sample 3, which is given before and after heat treatment appearances in Figure 7, was woven in a single-layer structure with a 2/2 twill weave. As a weft yarn, thermoplastic structured- shrunken 300-denier polyester and Nm 30 polyester air texturized yarns were used. Despite the single-ply woven structure of the fabric, the use of air-textured and thermoplastic shrinking yarn as weft yarn and 2/2 twill as weave has created high relief effects on the fabric after heat treatment.

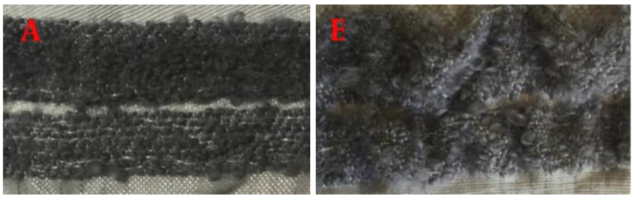

Figure 7. A) Appearance of Sample 3 before heat treatment, B) Appearance of Sample 3 after heat treatment [2].

Sample 4, whose views before and after heat treatment were given in Figure 8, were woven in plain weave. Single and double woven structures were used together in the fabric. The weft yarns used are 300-denier polyester yarn and Nm 50/2 polyester yarn with a thermoplastic structure.

Table 3. Dimensional changes of pre-research fabric samples

Pre-reseach fabric samples' numbers	Fabric witdh on the loom	Fabric width before heat treatment	Fabric width after heat treatment*
Sample 1	20 cm	19,5 cm	15 cm
Sample 2	20 cm	19,5 cm	16 cm
Sample 3	20 cm	19,5 cm	17 cm
Sample 4	18 cm	17 cm	14,5 cm
Sample 5	18 cm	17 cm	14,5 cm
Sample 6	18 cm	17 cm	14,5 cm
Sample 7	18 cm	17 cm	14,5 cm

** 160^{0}C heat treatment, 3' from 10 cm length for each fabric*

After the fabric is heat-setted, it is seen that the areas where thermoplastic structured-shrunken yarn and polyester yarn are used are straight, but the areas where only polyester yarn is used have a wavy appearance. Another reason for this appearance is the use of single and double-layered structures on the fabric surface with unit repetitions. It is thought that both the fabric structure and the yarn arrangement affect on the formation of high relief effects in the single-ply parts by pulling the thermoplastic shrinking yarn in the double-ply parts by heat treatment.

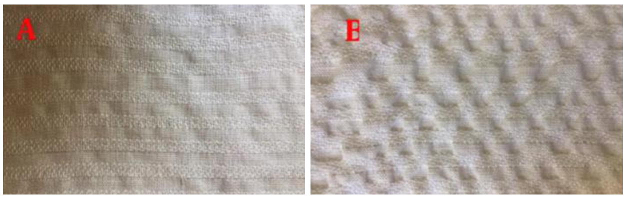

Figure 8. A) Appearance of Sample 4 before heat treatment, B) Appearance of Sample 4 after heat treatment [2].

Sample 5, which is given before and after heat treatment appearances in Figure 9 was woven in both single and double-layer structures with plain weave. Sample 5, whose views before and after heat treatment are given in Figure 9, was also woven as plain weave. Depending on the design of the fabric, single and double woven structures were used together. As a weft yarn, thermoplastic structured- shrunken 300 denier polyester yarn and 25/2 cotton yarn were used. The difference of Sample 5, woven in the same weaving structure with Sample 4, is the use of cotton yarns instead of polyester as weft yarn. When the appearance of the fabric is examined; although the thermoplastic shrink yarn shrunk after the heat treatment and created a relief effect on the fabric, the expected relief effect did not occur due to the thick and hard structure of the cotton yarn. The relief effect is minimal.

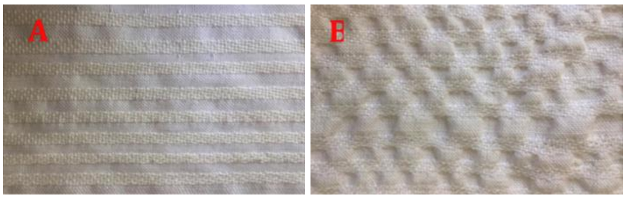

Figure 9. A) Appearance of Sample 5 before heat treatment, B) Appearance of Sample 5 after heat treatment [2].

Sample 6, which is given before and after heat treatment appearances in Figure 10, was woven in double-layer and bag structure with plain weave. As a weft yarn, thermoplastic structured- shrunken 300-denier polyester yarn and Nm 25/2 cotton yarn were used. The use of a double-layer bag structure in the fabric gave the fabric a relief effect with a wavy appearance after heat treatment. The combination of double layer and bag structure in the fabric gave the fabric a wavy appearance and a relief effect after heat treatment. Plain weave has negatively affected the degree of relief despite the double-layered structures. A much lower, irregular relief effect occurred than expected.

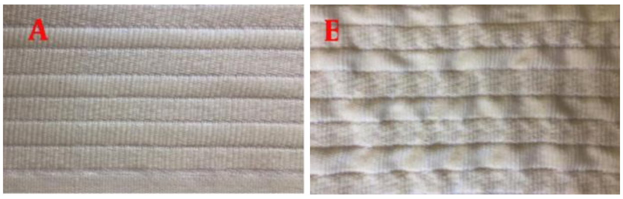

Figure 10. A) Appearance of Sample 6 before heat treatment, B) Appearance of Sample 6 after heat treatment [2].

Sample 7, which is given before and after heat treatment appearances in Figure 11, was woven in a double-layer structure with a plain weave. As a weft yarn, thermoplastic-structured shrunken 300-denier polyester yarn and Nm 25/2 cotton yarn were used. The fabric was woven in a double-layered structure by choosing the connection points in diagonal form. Thanks to the regions where the connection points are after heat treatment, wavy relief effects have been formed on the fabric.

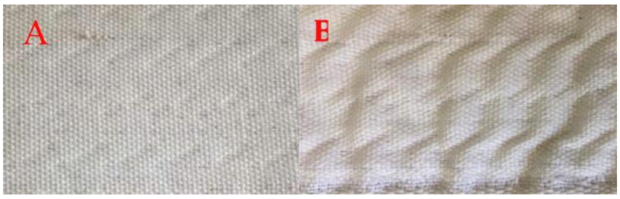

Figure 11. A) Appearance of Sample 7 before heat treatment, B) Appearance of Sample 7 after heat treatment [2].

When the relief effects occurred after heat treatment on all fabrics are compared; it has been observed that higher relief effects formed in fabrics woven in a single-layer structure where thermoplastic yarns and non-thermoplastic yarns are used together. With this result, it has been determined that the ratio of thermoplastic shrink yarn used as weft yarn should be at least 50% to obtain a relief effect on woven fabrics. This result also supports the findings in Ann Richards' book "Woven Textiles Shaping Themselves" [1].

When we evaluated the relief effects in terms of weave factor;

- It was determined that the weave factor is also important in the formation of relief.
- It was understood that the use of 2/2 ribs and 2/2 twill weaves caused a higher relief effect than the tightly connected plain weave.
- It was concluded that the lower bonding rates in the weft and warp yarns were effective in the shrinkage rates of the thermoplastic yarn after heat treatment and increased the degree of relief effect.

It is seen that the use of cotton yarn together with thermoplastic yarn in the weft increases the relief effect in plain weave fabrics where single and double layer structures are used together. The use of polyester yarn as the second weft yarn resulted in a low relief effect. It has been determined that the connection points in double-layer structures are also effective in the degree of relief effect. The effect of the connection points on the relief effect is also valid for the fabrics where double layer and bag structure are used together.

3.2. Design and Production Process of Main Fabrics

The first step in the design and production process of main fabrics is the design process. The main fabrics are designed and produced as upholstery or curtains for the interior. During the design process, first of all, current fabric fashion trends were researched. A 'Timeless' collection was created with the idea of a future-oriented approach. The science of biomimetics, which is the science of imitation of nature by human beings, has been integrated with the idea of timelessness, and four themes have been determined under the title of ‘Timeless’, inspired by the ever-changing but inexhaustible formations of nature. These themes are respectively; it was named Bankiz, Kanyon, Tsunami, and Mistral. Three designs were made for each theme. While determining the inspiration sources of the themes, the relief effects obtained in the preliminary research fabrics were also taken into consideration.

Bankiz-themed designs are based on the view that is formed by the breaking of the 1-2 meter thick ice sheets formed by the freezing of the sea surface in the regions close to the polar points, due to natural or artificial reasons. Kanyon-themed designs are based on the flow of water, which easily passes through layers such as soft soil and limestone, forming a deep, curved valley. In Tsunami-themed designs; Along with the high wave movements on the sea, the environmental changes in the coastal areas as a result of this were also taken into consideration. In Mistral-themed designs; The winds formed by the gradually narrowing movements of the low and high-pressure points have been the source of inspiration.

During the design process, only white and beige colors were used, considering that the color would affect on creating relief. In the designs, relief effects related to light-shadow were aimed to be brought to the fore. Based on the data in the preliminary research fabrics, weave, technique, and material selection were determined with the aim of creating a relief effect depending on light-shadow.

The designs for each theme were produced in four different ways by keeping the density, technique and weave constant, and the yarn factor variable. The yarn properties of the fabrics are given in the method section. The designs were prepared for production in the NedGraphics computer-aided design program. It was sized according to the product type according to material-technical differences.

In the production preparation process; In line with the information obtained from the preliminary research fabrics, the weft and warp densities of the materials to be used were calculated. It was passed through a number 11 comb suitable for a 2400 platinum loom, with 6 warp threads in one heald wire, as 66 threads/cm. Depending on the dimensions of the patterns and the weft insertion order of the yarns used, 2400 platinum numbers were kept constant, but different peak numbers were used. The warp and weft densities, platinum counts, reed numbers, and reed counts of the 12 fabrics produced are given in Table 2. The reed change count is the count of picks required to complete one repeat of the pattern.

As a result of the design and production of the preliminary research fabrics, it has been observed that the double-ply bag structure is the most effective weaving technique in the formation of relief effects in woven fabrics with the use of thermoplastic yarn. For this reason, a double-layered bag structure was preferred in the main designs. In the areas where these structures are used, plain weave is used and the weave is kept constant. The reason why the weave was chosen as plain is that, based on the data of the preliminary research fabrics, it is desired to obtain a low relief effect on the fabrics with this weave, which has the most frequent connection structure. Weaving structures and weaves used in woven fabrics are given in Table 2.

As a result of the data of the preliminary research fabrics, it was seen that the optimum relief effects were obtained by using a thermoplastic yarn in the weft and different yarn. For this reason, polyester yarn, polyester chenille yarn, polyester air-textured yarn were used together with thermoplastic shrink yarn in the production of main fabrics.

The main fabrics were woven on 2400 platinum Somet Staubli Jacquard Loom. All information of production is given in Table 2, under ‘Material and Method’. The heat treatment application was performed on a heat treatment machine named ~~as~~ Monforts Ram Toptex/ Monfortex 8000. A temperature of 155^{0}C at 16m/min was applied to the first and third group fabrics woven with a weft density of 20 threads/cm. The second group of fabrics, woven with a weft density of 21 threads/cm, was heat-treated at 14m/min at 165°C. According to the heat treatment, it was observed that twelve fabrics shrunk by 17,64% and had a permanent shape (Table 4). Since the shrink yarn with thermoplastic structure was used only as weft yarn, shrinkage occurred in the fabrics only in the weft direction. No shrinkage was observed in the warp direction of the fabrics.

Before and after heat treatment appearances of the fabrics produced with three different weft yarn groups are given in Figures 12-23 and relief effects are examined. The first groups of fabrics (Figures 12-15) were woven in double-layer bag fabric structure, 66 threads/cm warp density, 20 threads/cm weft density, 11/6 reed number. As a warp yarn, 150-denier polyester yarn was used. 300 denier polyester shrunken yarn, Nm 4 micro-polyester chenille yarn were used as weft yarns.

After the heat treatment applied to the fabrics in all main fabrics, because of shrinkage of the thermoplastic yarn, the pattern areas in which the double-layered bag structure is used gained volume. In different visuality relief effects have emerged according to their patterns designed depending on the themes of the fabrics. Accordingly, when we examine the visual effects of all fabrics in groups one by one, the results are as described below. Due to the structure of chenille yarn used as weft yarn, the fabrics have a soft handle. These fabrics are suitable for use as upholstery and curtain fabrics.

Fabrics belonging to the first group are Bankiz 1, Kanyon 1, Tsunami 1, and Mistral 1. The views of the fabric named Bankiz 1 before and after heat treatment are given in Figure 12. The relief effect on the fabric has an amorphous structure depending on the origin of the theme. These amorphous relief views increase or decrease depending on the angle of incidence of light.

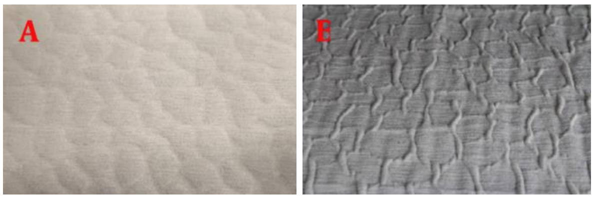

Figure 12. A) Appearance of Group 1-Bankiz fabric before heat treatment, B) Appearance of Group 1-Bankiz fabric after heat treatment [2].

The views of Kanyon 1 fabric before and after heat treatment are given in Figure 13. Depending on the theme of the fabric, a relief effect has been achieved giving the appearance of water waves. The wavy relief effect changes shape according to the position of the light.

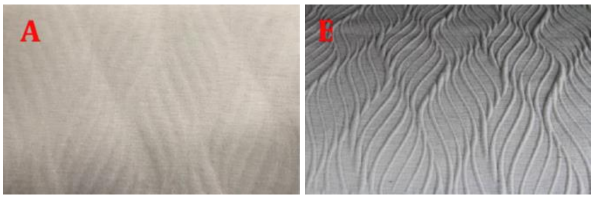

Figure 13. A) Appearance of Group 1-Kanyon fabric before heat treatment, B) Appearance of Group 1-Kanyon fabric after heat treatment [2].

The views of Tsunami 1 fabric before and after heat treatment are given in Figure 14. It consists of amorphous triangular patterns with shapes suitable for the relief effect theme of the fabric.

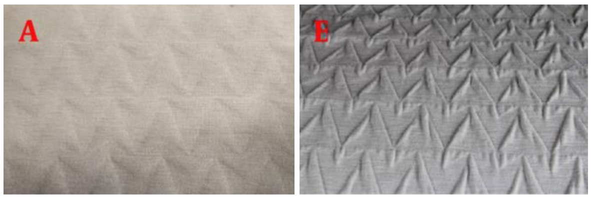

Figure 14. A) Appearance of Group 1-Tsunami fabric before heat treatment, B) Appearance of Group 1-Tsunami fabric after heat treatment [2].

The views of Mistral 1 fabric before and after heat treatment are given in Figure 15. The design of the fabric consists of lozenge-shaped patterns in different sizes depending on the theme. The thermoplastic yarn was shrunk after heat treatment, creating a voluminous semi-amorphous relief effect in double-ply bag-structured areas.

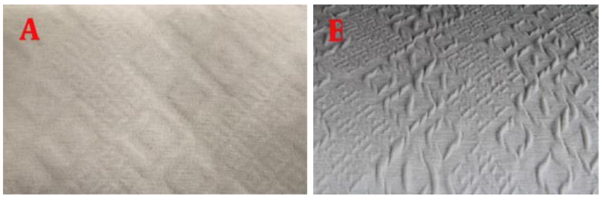

Figure 15. A) Appearance of Group 1-Mistral fabric before heat treatment, B) Appearance of Group 1-Mistral fabric after heat treatment [2].

The second group of fabrics (Figures 16-19), were woven in double-layer bag-structured with 66 threads/cm warp density, 21 threads/cm weft density, 11/6 reed number. As a warp yarn, 150-denier polyester yarn was used. 300-denier polyester shrunken yarn, 300-denier polyester yarn, and Nm 4 micro-polyester chenille yarn were used as weft yarns. These fabrics are softer than the first group fabrics due to the 300 denier polyester yarn added as weft yarn. Fabrics belonging to the second group are Bankiz 2, Kanyon 2, Tsunami 2, and Mistral 2.

Table 4. Dimensional changes of main fabric designs

Main fabric designs		Fabric witdh on the loom	Fabric width before heat treatment	Fabric width after heat treatment*
Group 1	Bankiz 1	170 cm	169 cm	140 cm
	Kanyon 1	170 cm	169 cm	140 cm
	Tsunami 1	170 cm	169 cm	140 cm
	Mistral 1	170 cm	169 cm	140 cm
Group 2	Bankiz 2	170 cm	169 cm	140 cm
	Kanyon 2	170 cm	169 cm	140 cm
	Tsunami 2	170 cm	169 cm	140 cm
	Mistral 2	170 cm	169 cm	140 cm
Group 3	Bankiz 3	170 cm	169 cm	140 cm
	Kanyon 3	170 cm	169 cm	140 cm
	Tsunami 3	170 cm	169 cm	140 cm
	Mistral 3	170 cm	169 cm	140 cm

**155^{0}C, 16m/min for Group 1 and Group 3, 165^{0}C and 14m/min for Group 2.*

The views of the fabric named Bankiz 2 before and after heat treatment are given in Figure 16. In the design made depending on the theme of the fabric, the motifs in amorphous structure have a complex arrangement. The shrinkage of the thermoplastic yarn after the heat treatment applied to the fabric caused relief effects in the amorphous structure in the double-ply bag structured pattern areas.

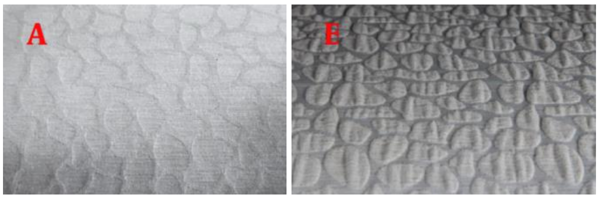

Figure 16. A) Appearance of Group 2-Bankiz fabric before heat treatment, B) Appearance of Group 2-Bankiz fabric after heat treatment [2].

The views of the fabric named Kanyon 2 before and after heat treatment are given in Figure 17. In this fabric that has a wavy pattern reminiscent of water waves depending on its theme, double-layered bag areas have gained volume with the shrinkage of the thermoplastic yarn after heat treatment. The fact that the areas in the double-layer bag structure are very dense in the pattern increased the degree of relief effect.

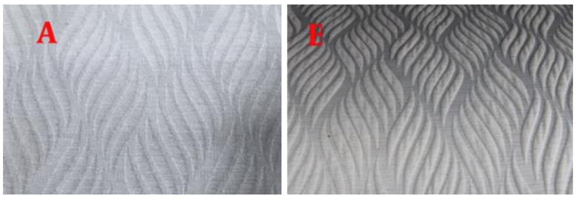

Figure 17. A) Appearance of Group 2-Kanyon fabric before heat treatment, B) Appearance of Group 2-Kanyon fabric after heat treatment [2].

The views of the fabric named Tsunami 2 before and after heat treatment are given in Figure 18. After the heat treatment on the fabric with triangular motifs, high relief effects similar to tidal waves were formed in the direction of the fabric's theme.

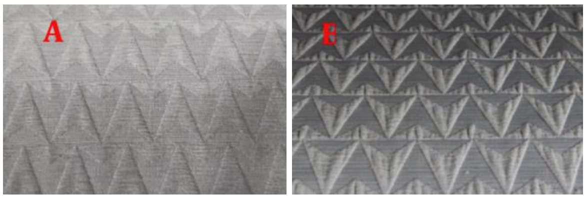

Figure 18. A) Appearance of Group 2-Tsunami fabric before heat treatment, B) Appearance of Group 2-Tsunami fabric after heat treatment [2].

The views of the fabric named Mistral 2 before and after heat treatment are given in Figure 19. The design of the fabric consists of lozenge-shaped patterns in different sizes, depending on the theme. The thermoplastic yarn shrank after heat treatment, creating a voluminous semi-amorphous, regular relief effect in the double-ply bag-structured areas.

The third group of fabrics (Figures 20-23), were woven in double-layer bag fabric structure, 66 threads/cm warp density, 20 threads/cm weft density, 11/6 reed number. As a warp yarn, 150-denier polyester yarn was used. 300-denier polyester shrunken yarn and 1800-denier polyester air-texturized yarn were used as weft yarns.

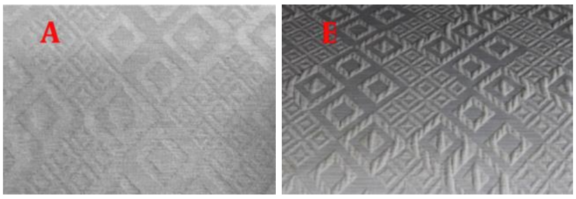

Figure 19. A) Appearance of Group 2-Mistral fabric before heat treatment, B) Appearance of Group 2-Mistral fabric after heat treatment [2].

The views of the fabric named Bankiz 3 before and after heat treatment are given in Figure 20. In the design made depending on the theme of the fabric, the motifs in amorphous structure have a complex arrangement. The shrinkage of the thermoplastic yarn after the heat treatment applied to the fabric caused amorphous embossed effects in the double-ply bag structured pattern areas, as in Bankiz 1 and 2 fabrics. After the heat treatment, a very low embossing effect occurred on the fabric as an expected result of the design. This is because the air-textured polyester yarn is used together with thermoplastic yarn in the weft. Air-textured yarn, which is a hard-touched yarn, reduced the shrinkage rate of thermoplastic yarn after heat treatment. The use of plain weave in the areas where air-textured yarn is used has been effective in the degree of low relief effect.

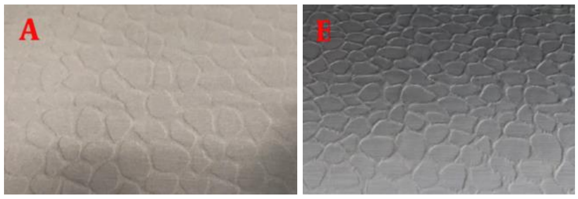

Figure 20. A) Appearance of Group 3-Bankiz fabric before heat treatment, B) Appearance of Group 3-Bankiz fabric after heat treatment [2].

The views of the fabric named Kanyon 3 before and after heat treatment are given in Figure 21. The fabric that has a long wavy appearance depending on the design of the fabric has a low relief effect after heat treatment. The fabric that has a long wavy appearance depending on the design of the fabric has a low relief effect after heat treatment. Due to the structure and flatweave of the air-textured yarn used as weft yarn, the fabric has a hard touch and the shrinkage rate of the thermoplastic yarn has decreased.

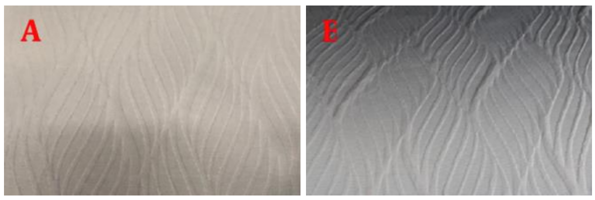

Figure 21. A) Appearance of Group 3-Kanyon fabric before heat treatment, B) Appearance of Group 3-Kanyon fabric after heat treatment [2].

The views of the fabric named Tsunami 3 before and after heat treatment are given in Figure 22. After the heat-treatment was applied to the fabric, the relief effect in the double-layered bag structures was very low. The reason for this is; in addition to the design of the fabric, air textured polyester yarn is used in the weft. Air textured yarn is a tough yarn. Flat weaving is also used in areas where yarn is used. Both factors reduced the shrinkage rate of the thermoplastic yarn and a low relief effect occurred.

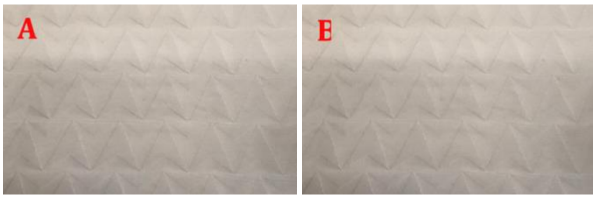

Figure 22. A) Appearance of Group 3-Tsunami fabric before heat treatment, B) Appearance of Group 3-Tsunami fabric after heat treatment [2].

The views of the fabric named Mistral 3 before and after heat treatment are given in Figure 23. As with Bankiz 3, Kanyon 3, Tsunami 3 fabrics, the relief effect of Mistral 3 fabric is low relief. In the lozenge-shaped patterns of the fabric, a voluminous, semi-amorphous, irregular relief effect compared to Mistral 2 and 3 was formed in the double-layered bag-shaped areas after heat treatment. The reason for this desired result due to the design of the fabric is that the second yarn used in the weft is air-textured. Another reason is the use of plain knitting in areas where air-textured yarn is used.

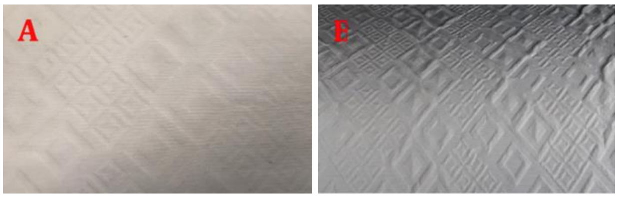

Figure 23. A) Appearance of Group 3-Mistral fabric before heat treatment, B) Appearance of Group 3-Mistral fabric after heat treatment [2].

When we evaluate the transition process of fabrics belonging to three groups from design to production, the main aim was to obtain relief effects suitable for the designs made in line with the themes of the fabrics during the transition to production. For this purpose, the yarn type, weaving structure and weave, yarn density, and the degree of heat treatment to be applied were determined by considering the data in the preliminary research fabrics. Production calculations of the main fabrics were made with the determined data.

When we evaluate the fabrics of the three groups in terms of the formation process of the relief effects, it has been observed that the yarns used and the heat treatment applied is of primary importance. Another important factor is the choice of the weave. The selected plain weave, the determined yarn types belonging to each group, gave the right result in obtaining low and high relief effects suitable for the designs depending on the weaving structure.

As a result of these choices, the first layer of the fabric gained volume after the heat-treatment, and relief effects were formed in the pattern areas of the fabrics where thermoplastic yarn is used. No relief effect was observed at the junction of the 1st and 2nd layers. Bag-structured areas have gained volume thanks to the points where the two layers meet and the shrinking ropes. Depending on the angle of the light, the forms of relief effects are perceived differently. A decrease in the degree of relief effect is observed in the light incident at an angle of 180 degrees.

4. CONCLUSION

With the widespread use of synthetic fibers in the 1940s, heat treatments were applied to create permanent different visual effects on the fabric. Especially Japanese designers played a major role in the 1980s in giving fabrics permanent shapes with different appearances. This movement of Japanese designers has been described as an innovative movement in fabric design. Today, by applying heat treatment to the garment and home textile fabrics in which thermoplastic yarns are used is obtained pleat, relief, volume, etc. texture effects. Designed and produced with the use of thermoplastic yarns with fabrics, especially in fashion; creative solutions are offered to designers in search of innovative materials and forms.

In addition to heat treatment; weaving, fabric structure, raw materials used, density and color are also of great importance in the formation of relief effects in woven fabrics. With the variability of all these factors, an infinite number of fabric types can be provided. In the production of the fabrics designed within the scope of the study, it is aimed that the relief effects created depending on the theme take permanent forms. To achieve this goal, thermoplastic yarns were used in the production of fabrics, and heat treatment was applied after the fabrics were removed from the loom. While creating permanent relief effects, the functionality of the fabrics is also kept in the foreground. In terms of functionality, it is desired that the fabrics can be used for a longer period ~~of time~~ without being deformed during washing and use, depending on the permanent shape they have gained thanks to the use of thermoplastic yarn.

This contributes to the establishment of the concept of slow fashion in home textile fabrics by giving the product a sustainable quality. The aesthetic visual contribution of this function, which enables the use of interior textiles produced with thermoplastic yarns for a longer period; These are the relief effects that change according to the angle of the light, together with the permanent low and high relief effects with an aesthetic texture and voluminous structure. Different appearances due to low and high relief effects together with the angle of the light coming on the surface of the fabric can create more than one aesthetic appearance on the same product. Such appearances will make a difference in terms of visuality in the interior use of fabrics and will be the reason for preference.

In the research phase of the study, first of all, the ability of thermoplastic yarns to take permanent shape with heat treatments in creating relief effects was investigated. Examples from designers working on this subject were examined. The differences in the fabrics of the designers who produce fabric using thermoplastic yarn have been observed in terms of technical and aesthetic visuality. The information obtained was evaluated together with the factors that were effective in the formation of design and production. With the results of the research, the concepts of design and creativity were evaluated in terms of woven fabrics, and an innovative and aesthetic interpretation that would make a difference was desired to be brought to the designed fabrics.

According to this; for thermoplastic yarns to create aesthetically quailfied low and high relief effects on woven fabrics:

- Thermoplastic yarns should be used together with non-thermoplastic yarns,
- The properties of non-thermoplastic yarns such as fineness, thickness, hardness-softness, twist are effective in the permanent shaping of the thermoplastic yarn after heat treatment,
- Fabrics designed with double-layer bag structures have better relief effects than single-layer fabrics,
- It has been concluded that the selected weaves and the determined densities of yarns are the factors that affect the formation of low and high relief effects on the fabric, depending on the fabric structure and yarn type.

In addition to all these results of the study, it is predicted that the effect of colored yarns will create different depth perceptions in these relief-affected weaving fabrics. Thus using the thermoplastic structured-shrunken yarns in woven fabrics and the effect of the color factor in creating these relief effects will carry out the next study.

Acknowledgment

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REFERENCES

1. Richards, A. 2012. *Weaving textiles that shape themselves.* London: Crowood Press.
2. Kurtuldu, E. 2017. Dokuma kumaş tasarımı ve üretiminde termoplastik yapılı ipliklerle rölyef etkilerinin araştırılması (Master's Thesis). Dokuz Eylul University Institute of Fine Arts, İzmir. Available from www.tez.yok.gov.tr (Thesis Number 469772).
3. Brackmann, H. (2008). http://www.hollybrackmann.com/2008/Gallery/Details/Folded-CurrentsDetail.html 19.04.2017
4. Acar, S., Meriç D., Kurtuldu, E. 2019. Pleat effects with alternative material and finishing methods *Journal of Textile and Apparel* 29(1), 41-49.
5. Handley, S. 2000. *Nylon: The story of a fashion revolution.* USA: The Johns Hopkins University Press.
6. Kitamura, M. (ed). 2012. *Pleats Please: Issey Miyake,* Taschen.
7. Yaşar, N. 2008. Kumaş modasında yenilikçi etkiler *Atatürk Üniversitesi Güzel Sanatlar Fakültesi Sanat Dergisi*, 13, 117-127.
8. Özkavruk Adanır, E. 2015. *Tekstil lifleri, özellikleri ve kullanım alanları*. İzmir: Mungan Kavram Press.
9. Huntürk, Ö. 2016. *Heykel ve sanat kuramları.* İstanbul: Hayalperest Press.
10. Sözen, M. Tanyeli, U. 2016. *Sanat kavram ve terimler Sözlüğü*, 16. Press, İstanbul: Remzi Books.
11. Önlü, N., Halaçeli, H. 2005. Dokuma kumaşlarda farklı malzemelerin estetik açıdan oluşturduğu yüzey görünümlerinin araştırılması, Tekstil Maraton 4.
12. Elsasser, V. H. 1997. *Textiles: Concepts and principles.* London: International Thomson Publishing Inc