The Effect of Warp Tension on the Colour of Jacquard Fabric Made with Different Weaves Structures

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Abstract. The aims of this paper is to demonstrate the effect of warp tension on fabric colour for several types of weaves structures, and found a relationship between them. The image analyse technique used to determine the proportion of yarns colour appearance, the advantage of this techniques is the rapidity and reliability. The woven fabric samples are consisting of a polyester warp yarn with continuous filaments and density of 33 end/cm, a polypropylene weft yarn with a density of 24 pick/cm, and the warp tension ranged between 12-22 cN/tex. The experimental results demonstrate the effect of the warp tension on the colour of fabric, and this effect is related to several factors, where the large proportion of warp appearance leads to larger effect on fabric colour. The difference in the value of colour differences $\Delta E_{cmc}$ is larger is in the range 16 to 20 cN/tex of warp tension. Using statistical methods, a mathematical model to calculate the amount of the colour difference $\Delta E_{cmc}$ caused by the change in warp tension had been proposed.

1. Introduction
Designing of fabrics require using a set of coloured yarns, which in combination give a wanted visual appearance. This is done by combining the yarns in the weave, either by showing the colour or hiding a warp above the weft or vice versa \cite{1}\cite{2}.

The use of weft and warp coloured yarns with weave structure allow to development fabric designs, by appear the desired colour in one area of the design, and we can obtain more large of colours effects by changing the fabric constructional parameters \cite{3} \cite{4} \cite{5}, this constructional parameters of fabric can influence even more the fabric reflect \cite{6}.

The relation between colour and weave structures have been analysed in several paper, The effect of small waves repeat in the derivation of colours is analysed by Dawson \cite{7}, where the sizes of the smallest sets of yam colour sequences that cover all possibilities are determined, and all effects with plain weave identified.

Dimitrovski and Gabrijelic\textsuperscript{c} \cite{8} gave a mathematical relationship to determine the proportion of yarn colour appearance in any weave structure.

The warp tension in the weaving loom have been the subject of many investigation \cite{9} \cite{10}\cite{11}\cite{12}\cite{13} to increase loom producing by decrease cutting of warp yarn, by suitable warp tension value, and to improve the fabric quality.
Musa Kılıç and Ayşe Okur [15] were investigate the relationships between yarn diameter measured and yarn strength, and they gave a statistically relationships between yarn diameter variation and strength variation. 

The image analysis techniques used for the identification of textile products [15][16], where the relation between weave diagram and its diffraction pattern established using digital image processing technology.

A different process techniques had used to analyses the pictures or images that have been converted to numerical form. The advantage of image analysis techniques is rapid and reliable instrumental method for measurement, analysis, and real time dynamic controls [17]. This research aims to demonstrate the effect of warp tension on fabric colour for several types of weaves structures, and found a relationship between them. And determine the proportion of yarns colour appearance using the digital image analysis.

2. Materials and methods

2.1. Specimens preparing
The studies woven fabric samples are consisting of a polyester warp yarn with continuous filaments and density of 33 end/cm, a polypropylene weft yarn with a density of 24 pick/cm. The warp tension ranged between 12-22 cN/tex. The specimen fabrication had done on the loom model (Alpha) from the production company (Somet) Italy, Figure 1. The tests of specimen have been done after the production without any finishing process.

![Figure 1. used loom.](image)

2.2. Digital image analysis to determine the proportion of yarns colour appearance
To determine the proportion of yarn appearance from the weft and from warp, we use the image analysis program. Were in the first steps a fabric images taken using optical microscope, this image was first compressed from 256 to 16 and filtering in the pre-processing.

The used yarns diameters are determine by a microscope, Figure 2. These values will be introduced in the program with the weave structure to detect the yarn area; the component analysis determines the proportion of warp yarns colour.
| Weave structure | Yarn colours                                                                 | Structure weave |
|-----------------|-------------------------------------------------------------------------------|-----------------|
| S1/4            | Satin 1/4, Warp colour is black, weft colour is white                        |                 |
| S1/4e1, S1/4e2 | Satin 1/4 1st weft, Satin 1/4 2nd weft, Warp colour is black, 1st weft colour is white, 2nd weft colour is golden |                 |
| S4/1a1, S4/1a2 | Satin 4/1 1st warp, Satin 4/1 2nd warp, 1st warp colour is white, 2nd warp colour is black, weft colour is black |                 |
| S1/9e1, S9/1a2 | Satin 1/9 1st weft, Satin 9/1 2nd warp, Warp colour is black, 1st weft colour is white, 2nd weft colour is black |                 |
| S7/1            | Satin 7/1, Warp colour is black, weft colour is white                        |                 |
| S6/2            | Satin 6/2, Warp colour is black, weft colour is white                        |                 |
| T7/1            | Twill 7/1, Warp colour is black, weft colour is white                        |                 |
Figure 2. Diameters of used yarns.

2.3. Measure the colour of the samples
A spectrophotometer device was used to measure the colour of the samples, by measuring the difference between the previous values of the reference sample and the location of the sample conducted by the measurement process we get the colour differences $\Delta E_{\text{cmc}}$.
When the colour differences $\Delta E_{\text{cmc}}<1$ the difference of colour cannot be detected visually by the eye.

Figure 3. Flowchart of yarns colour proportion determined method.
3. Results and discussion

From Figure 4 it can be observed that there is a relationship between the warp tension and the colour differences $\Delta E_{cmc}$ value for different types of weave structures, the difference in the value of colour differences $\Delta E_{cmc}$ is larger in the range 16 to 20 cN/tex of warp tension.

![Figure 4. Relationship between warp tension and $\Delta E_{cmc}$ value for different structure.](image)

In the zone of 16 to 20 cN/tex of warp tension the relations between warp tension and the colour differences $\Delta E_{cmc}$ are approximately linear, Figure 5.

![Figure 5. Relationship between warp tension and $\Delta E_{cmc}$ value for different structure in the range 16 to 20 cN/tex of warp tension.](image)
The first parameter of fabric structure is the warp appearance, and from the digital image analysis we demonstrated the relationship between warp appearance proportions and different weaves structure, Figure 5.

![Figure 5. Relationship between warp appearance proportion and different weaves structure.](image)

The linear relations between warp tension and the colour differences $\Delta E_{\text{cmc}}$ and the value of represented in the table 2 for each weave structure used in the range 16 to 20 $cN/tex$ of warp tension with value of warp appearance proportion, from this table we observe a relation between the constants in the linear equations and the warp appearance.

**Table 2.** Relationship between warp tension $T_a$ and $\Delta E_{\text{cmc}}$ for a different wave structure in the range 16 to 20 $cN/tex$ of warp tension for different wave structure.

| Weave structure | Warp appearance % | Relationship between warp tension $T_a$ and $\Delta E_{\text{cmc}}$ |
|-----------------|-------------------|----------------------------------------------------------|
| S1/4            | 17.9              | $\Delta E_{\text{cmc}} = 0.0350 T_a + 0.0533$          |
| S1/4e1, S1/4e2  | 20.8              | $\Delta E_{\text{cmc}} = 0.0763 T_a - 0.4658$          |
| S4/1a1, S4/1a2  | 79.8              | $\Delta E_{\text{cmc}} = 0.6225 T_a - 9.1217$         |
| S1/9e1, S9/1a2  | 35.2              | $\Delta E_{\text{cmc}} = 0.0888 T_a - 0.2075$         |
| S7/1            | 87.5              | $\Delta E_{\text{cmc}} = 0.7200 T_a - 10.66$          |
| S6/2            | 75                | $\Delta E_{\text{cmc}} = 0.5325 T_a - 7.6983$       |
| T7/1            | 87.5              | $\Delta E_{\text{cmc}} = 0.7150 T_a - 10.457$        |

From table 2, and using statistical methods, the mathematical model to calculate the amount of the colour difference $\Delta E_{\text{cmc}}$ caused by the change warp tension in the in the range 16 to 20 $cN/tex$, is the following:
\[ \Delta E_{\text{cmc}} = (\beta \cdot W_a - \mu) \cdot T_a - \lambda \cdot W_a + \eta \]

Where:

- \( \Delta E_{\text{cmc}} \): Colour differences,
- \( W_a \): Warp appearance,
- \( T_a \): Warp tension [cN/tex].

**Table 3.** value of mathematical model constants

| \( \beta \) | \( \mu \) | \( \lambda \) | \( \eta \) |
|-------------|-------------|-------------|-------------|
| 0.01        | 0.172       | 0.15        | 3.56        |

### 4. Conclusions

Warp tension has an effect on the colour of fabric, and this effect is related to several factors. The large proportion of warp appearance leads to larger effect on fabric colour.

The difference in the value of the colour differences \( \Delta E_{\text{cmc}} \) is larger in the range 16 to 20 cN/tex of warp tension.

Using the digital image analysis we demonstrated the relationship between warp appearance proportions and different weaves structure.

Using statistical methods, a mathematical model to calculate the amount of the colour difference \( \Delta E_{\text{cmc}} \) caused by the change in warp tension had been proposed.

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