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Development of the Weaving Mechanism for the Pleated Fabrics

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Abstract:

Pleated fabrics represent one of the most important 3D-fabrics. They contain the wrinkles effect in the longitudinal or cross-direction or in the diagonal direction, and are formed as folds. These folds or pleats are laid at 90° up to the ground fabric. This type of woven structures is called also folded fabrics or Plissé. Their production methods are enclosed in three methods till nowadays, which are weaving, synthetic resin equipment and sewing. In the weaving method, only wrinkles effect in the longitudinal direction could be woven. On the other hand, this effect and the others could be achieved by the different production methods which are mentioned before. The main goal of this paper is development of some mechanical devices on the weaving machine. Through which, the performances of the woven pleated fabrics could be enhanced. The development´s procedures have to secure the high quality of the woven pleated fabrics. Dimension stability, balanced structure and manufacturing economics are the desired characteristics of the research. These performances are difficult to be carried out by actual traditional weaving machines. From a practical point of view, it was found that these performances couldn't be achieved by the other production methods in spite of their additional operations after weaving. The development of the weaving machine enclosed in control of the warp tension in the distance between let-off device and the healds and also control of the movement of the take-up device. These developed operations have to be controlled by control-system program which has to be built in according to constants of the weaving machine.

Keywords:

Weaving mech*anism*
Pleated fabrics
Plissés, 3D-fabrics
Synthetic resin equipment
Wrinkles
Control device
Programing system
Servo-motor.

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1. Introduction

Day by day, the progresses in technology are growing to provide the world with innovative products, production methods and also both of them in all fields of technology. In industrial fields, there isn't a completely independent entity. It requires most of all inputs manufactured by other industries. In the textile industry, the most important supporting industries are the production of textile machinery which closely linked with electronics.

The main goal of this research is to develop innovative devices on the modern weaving machine to produce pleated fabrics with good performances. These performances are difficult to be achieved whether by traditional weaving machine or other manufactured methods.

All over the world, there are many common weaving methods for pleated fabrics. Some of them are still using in old and traditional weaving machines and the modern method represents as an improvement for the old method. All of these methods have their advantages and disadvantages. There is no doubt that the utilized techniques of ancient and modern methods have been great effect in the development of the existing method in this paper.

2. Background

The traditional pleated fabric is an ancient art that dates back to the old Egyptians, who used hot stones to make pleats. The plissé formation is predominantly used, as it ensures a much better extensibility of the fabrics, which are currently used in dresses, blouses, skirts, accessories and also leisure clothes. While pleating can be achieved at home with a steam iron and a ruler or pleating board, some fabrics come pre-pleated, or have been pleated post-production by designers /1/.

To pleat a fabric manually by folding and pressing it, the fabric should in that case contain some synthetic for the pleats to be permanent. Wash proof pleated fabrics usually need to have more than 50% synthetic fibers such that the pleats do not fall out during wearing or washing. Pure cotton and wool fabrics also can be made pleated by applying synthetic resin finishes. This paper spots the light on the manufacturing of permanent pleats on the weaving machine without synthetic fibers or finishing processes. The development of the machine is very essential to achieve the objectives of this paper /2, 3/.

2.1 Traditional manufacturing method of pleated fabrics

This method is summarized in two main phases, pressing and fixing plissé. Originally it was made only of wool, which was used for formability. Smooth wool fabrics were wrinkled and set in place by heat-setting. Later, the synthetic resin equipment made it possible to also pleat cotton and viscose fabrics. This method is summarized in impregnating the fabrics in synthetic resin solutions; then drying to a certain percentage of residual moisture. The plissé treatment is done by machine, but also by hand (straight, wavy, smog-like, that is folded by embroidery stitches, creases) /4/.

The fiber-genus and fabric construction play a great importance in the pleated effect, which should be fixed in any case. Cotton fabric is compressed dry (mechanically), and then is impregnated with synthetic resins which are condensed out. Since good pleated effect isn't possible with cotton fabric, therefore, wrinkles are produced in finishing process. This finishing process is carried out in foulard or wet equipment. There aren't special machines; it depends on the know-how and the experience of the technicians to use the existing machinery (yarn dyeing equipment, dyeing machines, etc.).

Cotton fabrics can also be folded in the longitudinal direction, then packed into nets and processed in large slings. This results in an over- pleated effect, which is then fixed with reactant resins. Man-made fibers are pleated onto dyeing machines before heat-setting. Of course, the heat-setting of the pleats must pass through the clamping frame in the weft direction without tension. The regulation of the upper and lower air is very important.

2.2 Weaving methods of pleated fabrics

Woven pleated fabric technique, it can`t be pulled apart like the pressing and fixing method, because the pleats are woven similar to the terry fabrics technique. The weaving machine of pleated fabrics must be equipped with two warp beams, one beam for the ground fabric and the other for the pleats. Pleats can be achieved on one side or both sides of pleated fabrics. A ground warp needs to be much longer than tight warp, which must be more tensioned. The weaving machine must be supplied with a special device /5, 6/.

The fabric formation includes 3 phases:-

- Middle fabric 'inter-fabric' weaving,
- Pleated length weaving,
- Formation of wrinkles (folds).

Fig. 1 illustrates cross-section in weft direction for the formation phases of a pleated fabric as follows:

A. Pleated fabric structure, the warp threads are arranged 1 ground yarn: 1 tight yarn,

B. Before the formation of wrinkles,

C. After the formation of wrinkles.

Points a and b represent the positions of the back rest and breast-beam

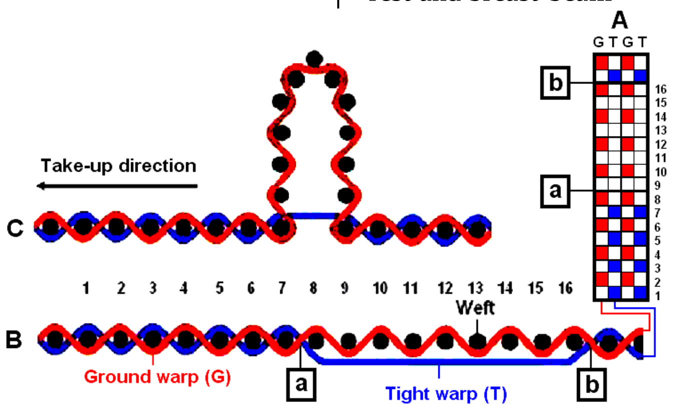


Fig. 1: Cross-section in weft direction for the formation of pleated fabric /5/.

1.2.1 Traditional Weaving Method

At the beginning of the weaving operation, both of elements 'back rest and breast-beam' take the most far on the right lying position as illustrated at point A in Fig. 2; when the intended folds length is reached, they are farther on the left (B). The distance between the two limit points A and B is determined by the fold length.

After the last weft insertion within the fold length and with beginning of the next inter-fabric part, the pleated length is formed by returning back of the back rest and breast-beam into the starting position (A), at that moment the back rest pull the tight warp to the back position (A).

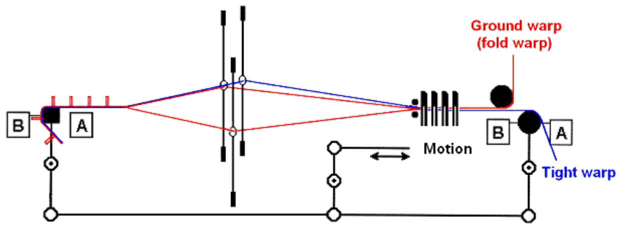


Fig. 2: Device for pleated fabrics weaving /5/

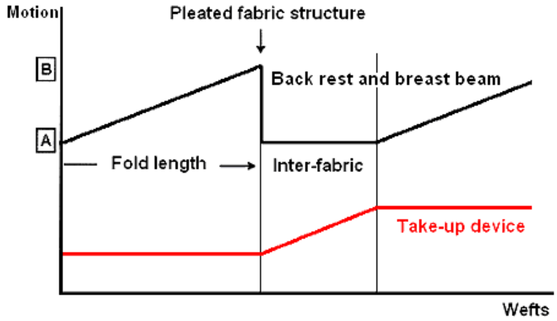


Fig. 3: Movement coordination of pleated fabric and take-up device /5/

The coordination of pleated fabric and take-up mechanism are shown in Fig. 3. The height of the formed fold is equal to about half of the fold length before the backward-movement of the tight warp yarns /5, 6/.

2.2.2 Modern weaving method

To make pleated fabrics by this method, an electronically controlled sley drive is used. In this mechanism, the beating up point is changed by small but precise steps from the normal beating up point. Figure 4 shows the formation of woven pleats. Only some of the warp yarns are used for weaving a pleat, which are stored in a separate warp beam. A greater weft density is used in the pleat area which compensates for the small proportion of warp yarns. The other warp yarns lie underneath the fabric when the pleat is woven as represents in Fig. 4a.

When the pleated area is woven, the fabric is not taken up and the weft density is achieved by shifting the beat-up point of the sley Fig. 4b. For example, with a weft density of 40 wefts/cm, the beat-up position has to be shifted only 0.25 mm filling by weft. Once the pleated portion is woven, which can be up to 20 mm long, the sley is returned to the normal beat up position (full beating) within two milliseconds. All the warp yarns are used again. The warp yarns wound on the separate warp beam are let off and the pleat falls into line Fig. 4c.

Weaving a pleat uses only some of the warp threads which are wound onto a separate warp beam. The small proportion of warp threads in the pleat area is compensated for by a greater weft density. The remaining warp threads are left lying underneath the fabric while the pleat is being woven (a). The fabric is no longer taken off, and the sley stays back a given distance in each weft (b). Once the pleat has reached the desired length, all the warp threads are again used in the weaving of the fabric. The sley executes its complete Movement, known as full beating. The threads wound onto the separate warp beam yield, and the pleat falls into line (c) /7/.

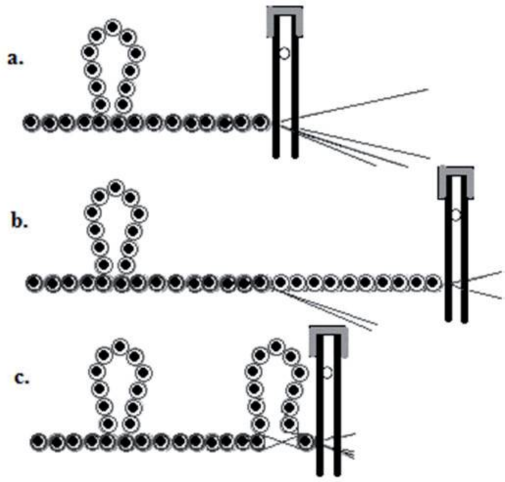


Fig. 4: Beat-up motion during pleat formation /7/

3. Methodology

3.1 Analysis of the Problem

The problem of the research was limited in two main points. These points were determined according to the actual production methods that are mentioned before. The first problem is maintaining the stability of the pleated fabrics which isn't guaranteed by the synthetic resin equipment method, where the pleats effect is formed by additional operations depending on pressing and heat-setting. The variety of production steps are raising the costs and decreasing of quality in according to the efficiency values for separated steps.

The second problem is the limitation of fold-height by using weaving methods of pleated fabrics, whether it is traditional- or modern method. This failure related to mechanical reasons for the traditional method and also to technical reasons for the modern method.

3.2 Theory of technology

The innovative technology used in this research depend on the utilization of the previously used weaving techniques with the development of the mechanical-motion method based on the electronic control engineering of the mechanical elements that have been developed in this paper.

It is very important for the most kinds of fabrics to maintain their dimensions stability. The pleated fabric construction has its characteristic privacy beside the conventional properties. It can be summarized in the connection between the ground- and pleated length. This connection line between the two surfaces can be determined as the most important factor, which greatly effects in the fabric characteristics.

Form this realization, the ground fabric cover factor must equal to its similar of pleated length. Theoretically, the weft-density of the pleated length must be two times as in the ground fabric, as half of the warp-yarns chaired in the pleated length. Practically, it isn´t acceptable to maintain that on the traditional weaving machine, but it will be possible to achieve that by the developed technology which has been applied in this paper. In addition they may change and develop the pleat-length to be suitable for the future demands, if it is required. That means, multi height-lengths of pleats could be achieved in the same specimen.

3.3 Development of the weaving machine

The weaving technique of pleated fabrics must be developed by modifying conventional weaving mechanisms in according to uncomplicated mechanisms as much as possible. The weaving technique of pleated fabrics contains three phases, as indicated before, which are ground fabric weaving, pleated length weaving and formation of wrinkles. During the weaving of pleated length, just half of warp yarns shared in weaving process, the second half have to be tight floated under/upper the beating point as represented in Fig. 5B.

The first and second phases have to be carried out normally, but all the development´s procedures must be done for the third phase (formation of wrinkles). This development has to be achieved in longitudinal movement on the weaving machine. This movement connects between warp let-off and fabric take-up operations. This phase enclosed in the drawing of floated tight warp yarns (backward movement) after a number of wefts of the new middle fabric (the number depends on the elements of fabric structure) as represented in Fig. 5B and C.

The backward drawing of the floated tight warp yarns must be achieved between 315° and 360° rotation degrees of the main shaft (during the beating-up of a new weft). To determine the required force for the backward-movement, the warp yarn tension during weaving have to be tested, hence the force-value would be accurately defined.

In general, the development procedures have to be enclosed in the control of the longitudinal movement on the weaving machine, which divided into two items:

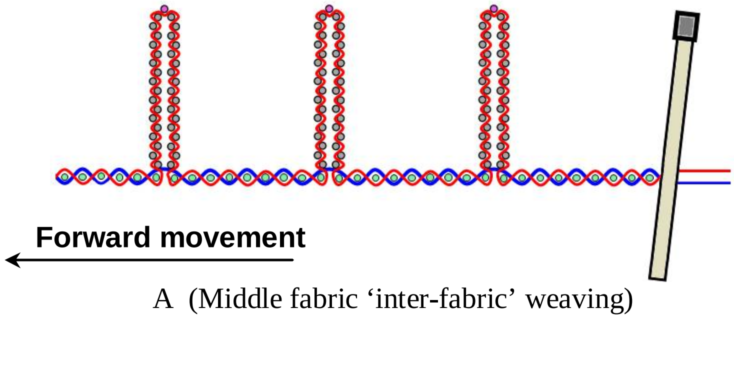
1- Warp yarns let-off mechanism,

2- Fabric take-up mechanism

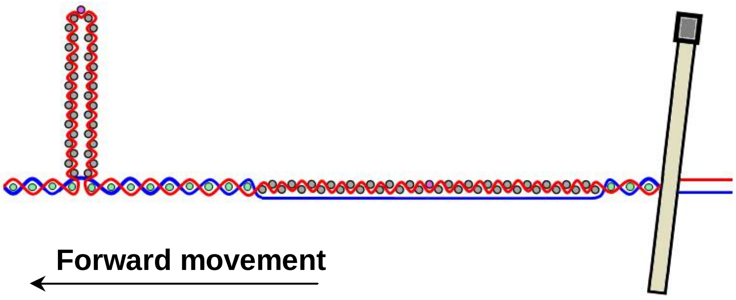
3.4 Woven structures of the pleated fabric

The structure of woven sample was traditional structure, because the main goal of this paper is just development of weaving method. The structure elements of woven sample were restricted in the next points:

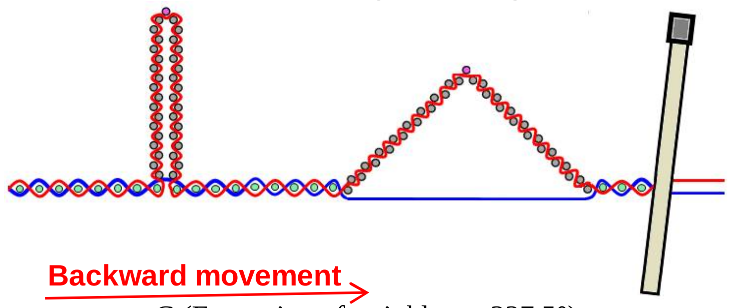
- **Material**: Polyester (textured Den. 600),
- **Construction**: Plain weave 1/1,
- **Fabric set-up**: According to the used construction, the number of warp yarns in ground fabric equal two times as their number in pleated length, so the wefts number of pleated length must be two times like their similar of ground fabric. That maintains the relative cover of the fabric in ground fabric and pleated length also.



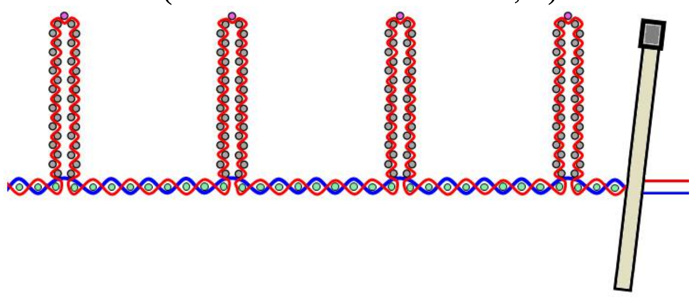
A (Middle fabric ‘inter-fabric’ weaving)



B (Pleated length weaving)



C (Formation of wrinkles at 337,5°)



D (Formation of wrinkles at 360°)

Fig. 5: The weaving technique phases of pleated fabric

4. Experiments

The *experiments* have been *carried out* on narrow-weaving machine (J. Müller Company), which was equipped with two warp beams /8/. On the other side, the machine equipped for inserting up to three wefts in three simultaneously sheds during wefts insertion. The machine has equipped with 20 heald frames.

The experimental works were divided to four phases:

1. Weaving of Indicative sample.
2. Measurement of the mechanical tension during weaving process.
3. Development of additional control devices and programing system.
4. Weaving of the final pleated fabric sample.

4.1 Weaving of indicative sample

The purpose of this procedure is to measure the amount of force affecting the warp yarns during the weaving process. Based on the measurement result, the value of the mechanical force which is required to draw the floated tight warp yarns for forming the wrinkles (as represented in Figs 5B and C) will be determined. The indicative sample had been woven by using PES yarns (Textured Den. 600) for the warp and weft yarns. The main elements of the woven fabric structure variables were:

1- Fabric construction: plain weave 1/1.
2- Warp yarns density: 24 yarns/cm.
3- Wefts density: 10 wefts/cm.
4- Fabric width: 12 cm.

4.2 Measurement of the mechanical tension during weaving process

The warp yarns tension while the weaving machine is running has been measured by using digital yarn tension meter (Hans-Schmidt Model: DTSB-500) /9/. The values of the tension force for a single warp yarns ranged between 30.5 cN and 36.2 cN during one revolution of the machine. Whereas the number of floated warp yarns according to fabric structure variables (as it is mentioned later in 4.4) is determined by 144 yarns. As it is scientifically known, the value of tension force for all tight warp yarns must be less than the component of their individuals. From these results, the value of required mechanical force for drawing all floated tight warp yarns (as represented in Figs 5B and C) to form the wrinkle is 52 N (approx. 5.3 Kg).

4.3 Development of additional control devices and programing system

The weaving machine has to be equipped with two warp beams as shown in Fig. 6, the first for the wrinkles and the second for the floated tight warp yarns. The rotation of the second warp beam has to be developed by using servo-motor. On the other side, the longitudinal-movements of the take-up device have been controlled by using two servo-motors. Fig. 7 represented the control system block-diagram for the movement devices on the weaving machine.

The most advantages of this type of motors are its ability to move the output shaft through an arc of 180 degrees, any position of the weaving machine within this arc is selected, and held, based on input control signals. The control logic generates positive going pulse width control. With power applied and no pulses, the output shaft is free turning /10/.

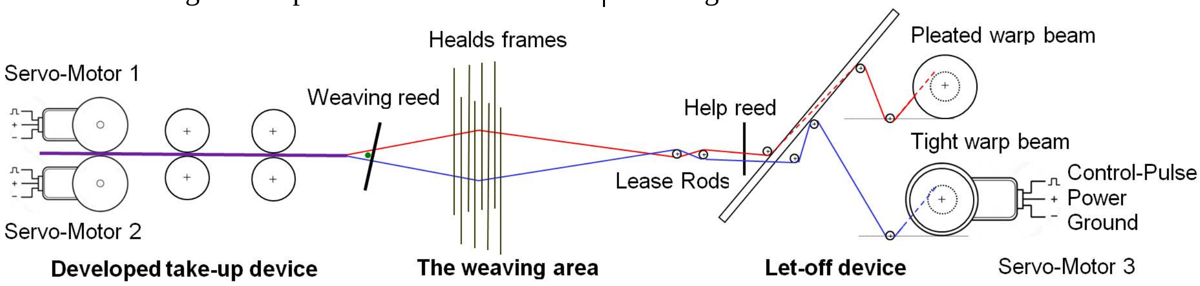


Fig. 6: Running of the wrinkles warp yarns (Red), tight floated (Blue) warp yarns and developed take-up device on the weaving machine

The length of pulse tells the on-board electronics what angular position to move to and then stay at. Pulse widths between 0.5 and 2.5 milliseconds, and 2.5 milliseconds will result in the output shaft moving 0 to 180 degrees /10/. Using this technology-method makes it very easy to change motion-direction quickly without damage to the system. They transmit the power to move the tight warp yarns beam and the take-up device according to the main-shaft rotation degrees. These data reach to the control-system through an electronic sensor which is built in above the main-shaft.

The developed let-off device has controlled the warp yarns of middle fabric (inter-fabric) by servo motor. And also, the take-up device has controlled by two servo motors as represented in Fig.7. The theory of motion for the let-off and take-up devices depends on stability of the speed for the front movement of this device according to the machine speed.

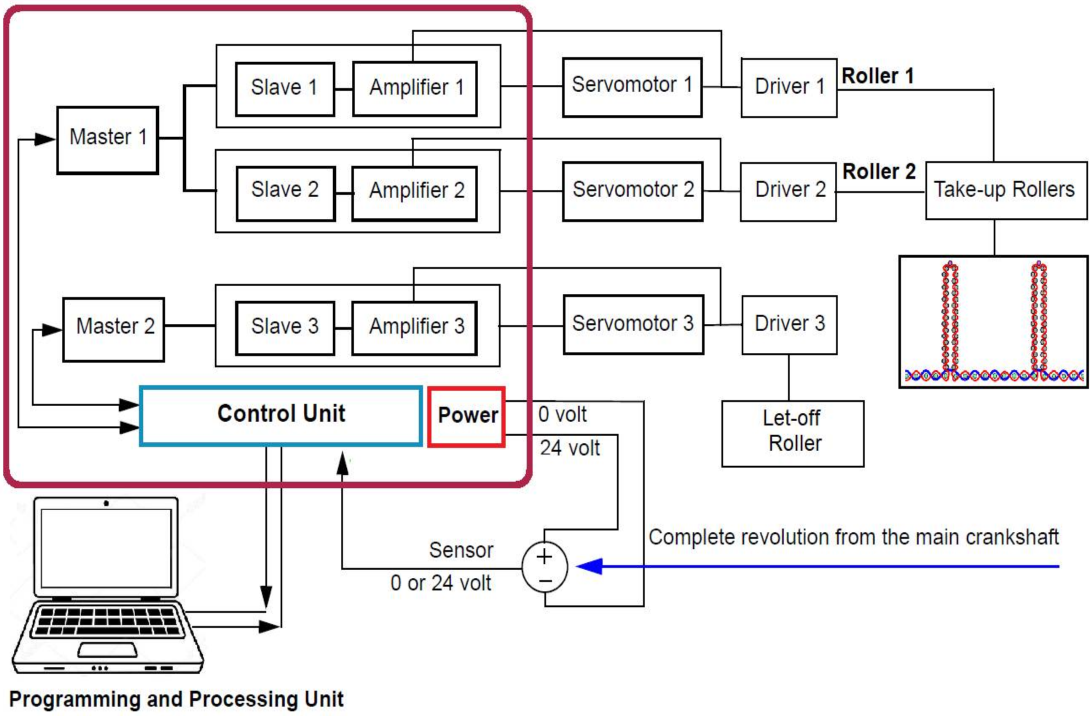


Fig. 7: Control system block-diagram for the movement devices on the weaving machine

The high speed has been demanded for the backward-movement with maintaining the quality of weaving process. The length of middle fabric (inter-fabric) is 20 mm, and the length of the pleated length (Wrinkle) is 20 mm. The woven pleated length was 40 mm; it would be 20 mm after the backward movement of the tight floated warp yarns and wrinkle formation. The forward movement of take-up device was 20 mm for middle fabric (inter-fabric), and 40 mm for the pleated length with half speed (the wefts density of pleated length was two times as its similar of ground fabric). The sudden backward-movement for let-off device of floated warp yarns must be identical with the backward-movement of take-up device. This movement must be begin at 330°degree of the crankshaft-rotation and end at 360°.

4.4 Weaving of final pleated fabric sample

The experimental sample has been woven after the evolution of mechanical tension during the weaving of indicative sample. According to this result the required force of the developed devices has been limited. Development and enhancement of the weaving machine is determined in let-off and take-up devices. Table 1 represented the structure-elements of the pleated fabric sample which its weaving formation includes three phases as shown in Fig. 5:-

- Middle fabric 'inter-fabric' weaving,
- Pleated length weaving,
- Formation of wrinkles.

On the other hand, the structure-geometry of the pleated fabric sample is shown in Fig. 8. The weaving of the experimental sample has been executed after the development of the let-off and take-up devices of the weaving machine. Fig. 9 shows the design, draft system and lifting plan of the pleated fabric construction.

Table 1: Structure-elements of the pleated fabric sample

Material	**PES (HT Texture yarn)**	Count **tex**	$\varepsilon - F_{max}$ **%**	F_{max} **N**	F_{max} **cN/tex**
		66.8	54.1	48.3	72.3

Fabric	**Specification**	**Warp density [yarn/cm]**	**Weft density [yarn/cm]**	**Dimensions**
	Middle fabric (Inter-fabric)	24	10	20 mm (Length)
	Pleated length (Wrinkles)	12	20	20 mm (Height)
	Width [in mm]	120 mm		
	Construction	Plain weave 1/1		

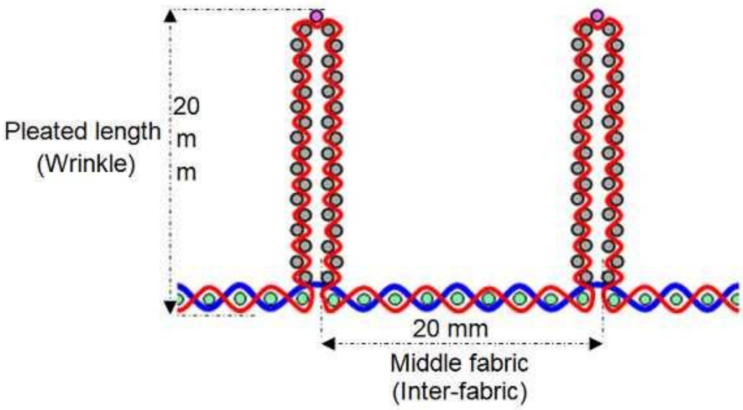


Fig. 8: Structure-geometry of the pleated fabric sample

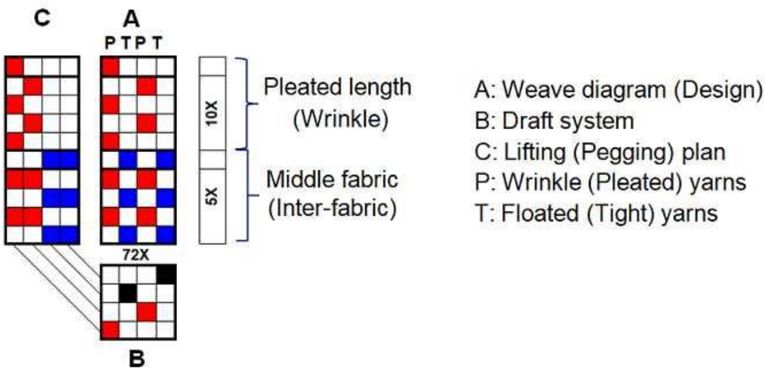


Fig. 9: The weave diagram, draft system and lifting plan of the pleated fabric construction

5. Results and discussions

The importance of this research lies in the development of innovative devices on the weaving machine as well as their control programming. The outcome of these developed processes is the flexibility to weave pleated fabrics with required characteristics and better performance. It is concluded from the pre-mentioned research´s procedures, that this development allows the designers to expose new technical and aesthetic dimensions of the pleated fabrics. These dimensions couldn't be achieved by the traditional weaving methods. The performance evaluations of the developed devices are very important for the quality of weaving process. The evaluation procedures are enclosed in the analysis of mechanical forces and kinematic equations and their feedback of the developed devices as the following:

1. Analysis of the demanded forces for the take-up device (forward motion).
2. Analysis of the demanded forces for the reverse motion of let-off device (backward motion).
3. The kinematic equations of longitudinal backward-movement.

5.1 <u>Analysis of the demanded forces for the take-up device</u>

The take-up motion of the woven fabric is carried out by using a developed device. That device consists of two servo-motors, which are controlled by control system unit as shown in Fig. 7. The take-up device includes also two pairs of guidance and compression cylinders as represented in Fig. 10, which compress the fabric in according to its thickness. The rotation speed of servo-motors has to be changed dependence on the difference of weft-set between the ground fabric and pleated length. The analysis of the take-up tension force can be calculated by the mathematical equations.

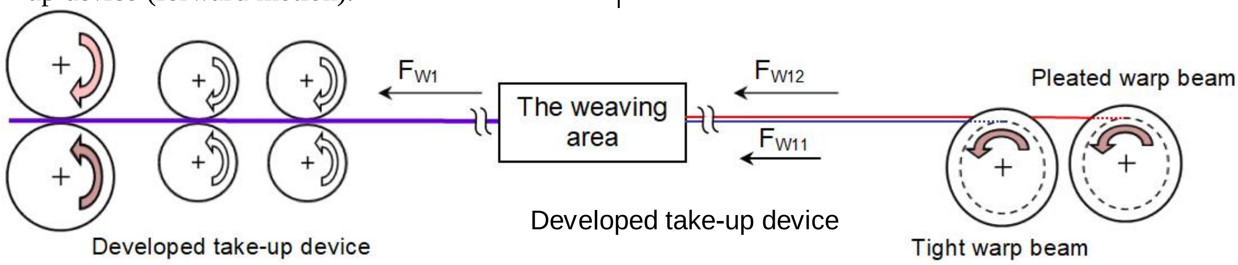


Fig. 10: The developed take-up device (forward motion)

The mechanical force of take-up servo-motors during forward motion is equal:

$$F_{w1} = F_{w11} + F_{w12}$$

where: $F_{W11} = F_{W12}$,

and: $N_{WT} = N_{WP}$,

then: $F_{w1} = 2F_{w11}$,

$$F_{w1} = 2F_{WS} \times N_{WT} = 2 \times 36.1 \times 144 \approx 104 \text{ N.}$$

5.2 <u>Analysis of the demanded forces for the</u>

Simultaneously, the developed take-up device and

: F_{W1}	Tension force of all warp yarns during forward motion
: F_{W11}	Tension force of tight warp yarns during forward motion
: F_{W12}	Tension force of pleated warp yarns during forward motion
: F_{W2}	Tension force of all warp yarns during backward motion
: F_{W21}	Tension force of tight warp yarns during backward motion
: F_{W22}	Tension force of pleated warp yarns during backward motion
: F_{WS}	Tension force of single warp yarn during weaving (max. value)
: N_{WT}	Number of tight warp yarns

5.2 <u>Analysis of the demanded forces for the reverse motion of let-off device</u>

The reverse motion of let-off device for tight warp is carried out by using servo-motor.

guidance cylinders have to be rotated in a reverse direction as represented in Fig. 11. The rotation speed of let-off servo-motor has to be changed dependence on the diameter-difference of tight warp beam. That maintains the stability of the longitudinal speed for backward movement throughout this process. The analysis and calculations of the mechanical forces and inverse kinematics can be limited by the equations presented in the following.

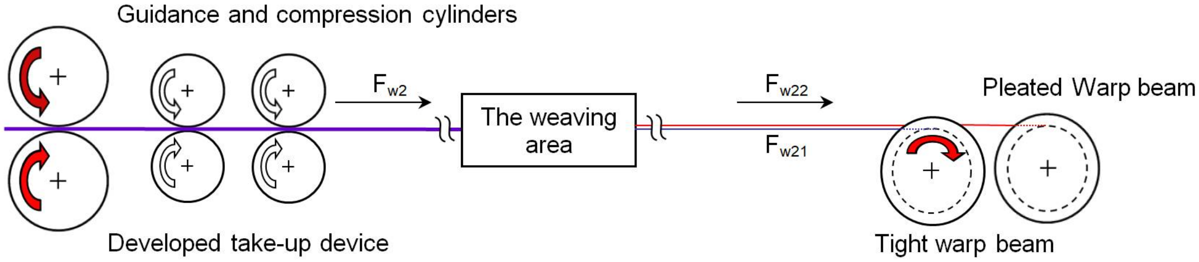


Fig. 11: The developed take-up and let-off devices (backward motion)

The mechanical force of the backward motion is equal:

$$F_{w2} = F_{w21} + F_{w22}$$

where: $F_{W22} = 0$,

then: $F_{w2} = F_{w21}$

and: $F_{w2} = F_{WS} \times N_{WT} = 36.1 \times 144 \approx 52 \text{ N.}$

5.3 <u>Analysis of the kinematic equations of let-off device</u>

The kinematic equations of longitudinal backward-movement are calculated as following: When the time of the longitudinal backward-movement (90°) equals one-quarter of the weaving machine revolution ($270^{\circ} - 360^{\circ}$), the machine speed (v) equals 180 rpm and the backward movement length (ℓ) equals 40 mm. Then:

Time of a revolution in second $= \dfrac{60}{\text{rpm}} = \dfrac{60}{180} = 0.333 \text{ sec.}$

Time of one-quarter revolution in second $(\text{t}) = \dfrac{0.333}{4} = \dfrac{60}{180} = 0.08333 \text{ sec.}$

Speed of the longitudinal backward-movement $(v) = \dfrac{\ell}{\text{t}}$

Speed of the longitudinal backward-movement $(v) = \dfrac{0.40}{0.08333} = 4.8\, ms^{-1}$

6. Conclusions

The product always needs to be developed to improve its functional characteristics, increase production and also reduce production costs, etc. All of these factors increase the added value of the product, as well as the quality of the product and thus the end-user acceptance. Pleated fabric is one of the most important three-dimensional fabrics; it has unique structural properties that enable it to be well used in technical applications in particular. This is directly related to the development of the production methods of these fabrics to meet the requirements of modern uses. The new products replace the other components which are already used, but have some faults in technical side or high production costs or both of them.

This paper aims to establish a technical basis for the weaving method of this type of fabric structures, so as to enable the future development of the product itself in a manner that can be used in technical fields. Therefore, this structure was studied referring to its production methods and usage. From this study, it was found that the pleated fabrics are limited to use in women's clothing, In spite of the richness of this structure, which qualifies it for new unusual uses.

This paper presents a development method for the weaving machine, especially for let-off and take-up devices, through which the folding length can be controlled. The folding length represents the fabric height after taking-down of the fabric, the height´s value is very important for the later using; it indicates the third dimension of pleated fabrics. It is noteworthy that the third dimension of traditional fabrics is defined as thickness.

The innovative technology which was used in this paper depended on the utilization of the previously used weaving techniques with the development of the mechanical-motion method based on the electronic control engineering of the mechanical elements that have been developed. The weaving technique of pleated fabrics was developed by modifying some of conventional weaving mechanisms in according to uncomplicated mechanisms as much as possible.

References

1. Zurcapellen, T. M.: 2001 Lexikon der Gewebe. Frankfurt am Main, Germany: Dt. Fachverl.,. – ISBN 3-87150-725-3
2. **Badawi, S.** : 2008 Development of the Weaving Machine and 3D Woven Spacer Fabric Structures for Lightweight Composites Materials. Germany: Vdm Verlag Dr. Müller,. –ISBN 3-639-04114-3.
3. Kirchenberger, H.: 1984 Florwaren Frottierwaren, Samt und Plüsch, Teppiche und Bodenbeläge. Wien-Perchtoldsdorf: Bondi,. ISBN 3-900008-08-6
4. Down, J.: 1999 Textile Technology. UK: Oxford Uni. Press,. –ISBN 0-19-832813-1
5. Kienbaum, M.: 1996 Bindungstechnik der Gewebe, Bd.3, Drehergewebe, Faltengewebe, Florgewebe und Jacquardgewebe. Berlin: Schiele & Schön,. ISBN 3-794-90607-1
6. Hennig, H.: 1968 Gewebetechnik. Leipzig, Germany: VEB Fachbuchverlag,.
7. Han-Yong Jeon: 2012 Woven Fabrics. UK: IntechOpen Limited,. –ISBN 9-53-510607-4