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Method of Separating Fabric from a Stack – Part 1

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Abstract
A model of the gripper mechanism driven by three electric motors is presented. The model of the gripper developed, characterised by an increased working surface, on 31.01.2008 was granted a patent for an invention entitled "Device for gripping a single layer from the material stack" No. PL 197340. This gripper employs friction drags between fabric layers and between the fabric and base to separate the fabric. On the basis of its model, the operation of fabric separation from the stack was analysed.

Key words: *gripper for textiles, computer control, mathematical model, garment production, robotisation.*

Introduction. Applications of grippers for textiles

For European countries to compete effectively with those of cheap labour in the mass production of clothing, they should strive to achieve maximum productivity while maintaining high output quality and repeatability of products. This could be achieved through the use of automation and robotisation of the textile industry.

The full automation of the production of clothing was the theme of three large research projects: the Japanese program MITTI, American $(TC)^2$, and the European BRITE. This research was abandoned as it was considered impossible for the time being. The main reason for this situation is the lack of object rigidity of manipulation, that is to say of processed fabric leading to easy local folding or stretching.

The manufacture of clothing is characterised by high labor intensity, where preparatory and auxiliary operations cover most of the time needed to fabricate the product. Robots are used therein relatively rarely and for specific purposes. Specially designed manipulators and industrial robots with grippers perform relatively simple but time-consuming operations.

The most common grippers for textiles based on the use of needles as the gripping element are similar to the Littelwood gripper [1]. They can be used for textiles of different thickness by adjusting the degree of the eject needles.

At present technological lines composed of robots and sewing machines are rarely used. The use of grippers in cooperation with a sewing machine is advantageous when used as auxiliary instrumentation such as the administration of small elements (e.g. stripe) to the operator [2] or transporting blanks from one machine to another.

The best tasks for manipulators equipped with grippers for textiles are associated with the transportation or administration of cut parts or semi-finished products from one machine, from the table, out of a container, etc. to another machine, on the stack or to a container.

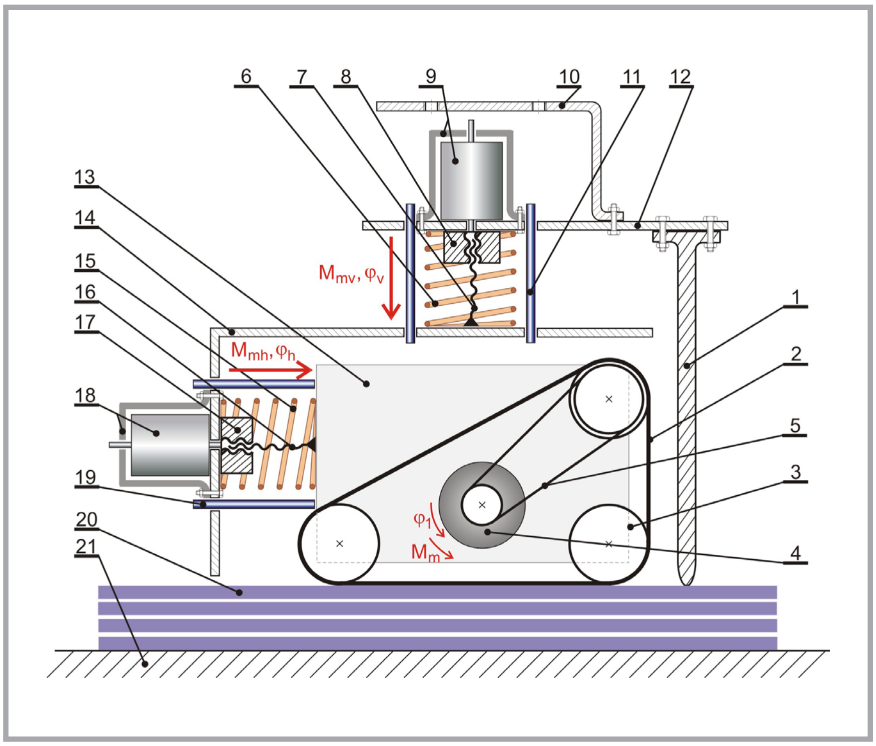


***Figure 1.** Scheme of the gripper for picking up one layer of the material from the stack: 1- foot for maintain the fabric stack, 2 - rubber belt, 3 - guide roller belt, 4 - electric motor for driving the rollers 3 which lead the belt 2 (allowing the movement of the rubber belt in two directions), 5 – transfer of belt drive from the electric motor 4 to the guide roller belt, 6 - spring eliminating clearances in the vertical direction, 7 - screw, which suits the vertical movement of the movable part of the gripper, 8 - nut cooperating with the screw 7, 9 - electric motor, which initiates the vertical movement of the gripper, 10 - device handle, 11 - guide, stabilising the vertical movement, 12 - connecting plate, 13 - plate constituting the mainstay for guide rollers 3, 14 – cover, 15 - spring eliminating clearances in the horizontal direction, 16 - screw, which suits the horizontal movement of the movable part of the gripper, 17 - nut cooperating with the screw 16, 18 - electric motor, which initiates the horizontal movement of the gripper, 19 - guide, stabilising the horizontal movement, 20 - fabric layers in a stack, 21 – table.*

From the point of view of safety and ergonomics, we need to establish tasks for manipulators and grippers that would eliminate human presence with simple actions, and therefore avoided would be also tedious and tiring tasks causing mental workload or those that cause a nuisance to the human body because of the unfavorable microclimate, such as increased temperature or harmful vapours near the presses.

The subject of considerations in this study was to develop a method of the separation of fabric from a multi-layered stack as well as a tool of analysis to enable simulation of the device separating fabric from a stack, and investigate accompanying phenomena during the actions of separation.

The tool developed would help the process of designing new devices for manipulating a package of materials, along with the ability to study the behaviour of the fabric during the action of its characteristic forces in these type of tasks, which in the future could help automate the clothing industry because they are still interesting issues and research is being carried out in this direction, especially in Japan [3].

Phenomenon of friction in gripper for separating fabric

Figure 1 shows a diagram of the gripper enabling the download of a single layer of material from the stack using existing differences in friction resistance values between the belt and fabric, layers of the fabric, and between the fabric and substrate [4, 5].

The separation is based on the fact that after pressing to the stack of the material *20* of the gripper, consisting of a movable gripping part made of a rubber belt *2*, stretched on three guide rollers *3* that are mounted on plate *13* and driven by an electric motor *4*, and a stationary element called a foot *1*, fixed to a connecting plate *12*, follows the first phase of separation. Pressing the gripper against the material stack *20* is initiated by means of a screw mechanism consisting of a screw *7* and nut *8* permanently attached to the shaft of the second electric motor *9*. In the arrangement of the screw-nut-engine, there follows a change in the rotation motion of the engine to a rectilinear vertical motion required for the proper working of the device. The rollers *3* guiding the rubber belt *2* rotate, which makes a fold on the material edge (***Figure 2.B***). The belt rotates until the folded material becomes straight. The screw *16*, nut *17* and third electric motor *18* transform the rotary motion from the motor to a rectilinear horizontal motion and initiates the pressing of the belt *2* of the movable element against the stationary foot *1*. The straightened end of the material is clamped between elements *1* and *2*, which makes its raising possible (***Figure 2.C*** and ***2.D***). An additional advantage of this solution consists in the fact that when two pieces of the material are folded simultaneously, there is a possibility of pushing the undesired fold off by means of a repeated reciprocating motion of the belt *2*.

In order to provide a steady and smooth motion of the device, both along the ver-

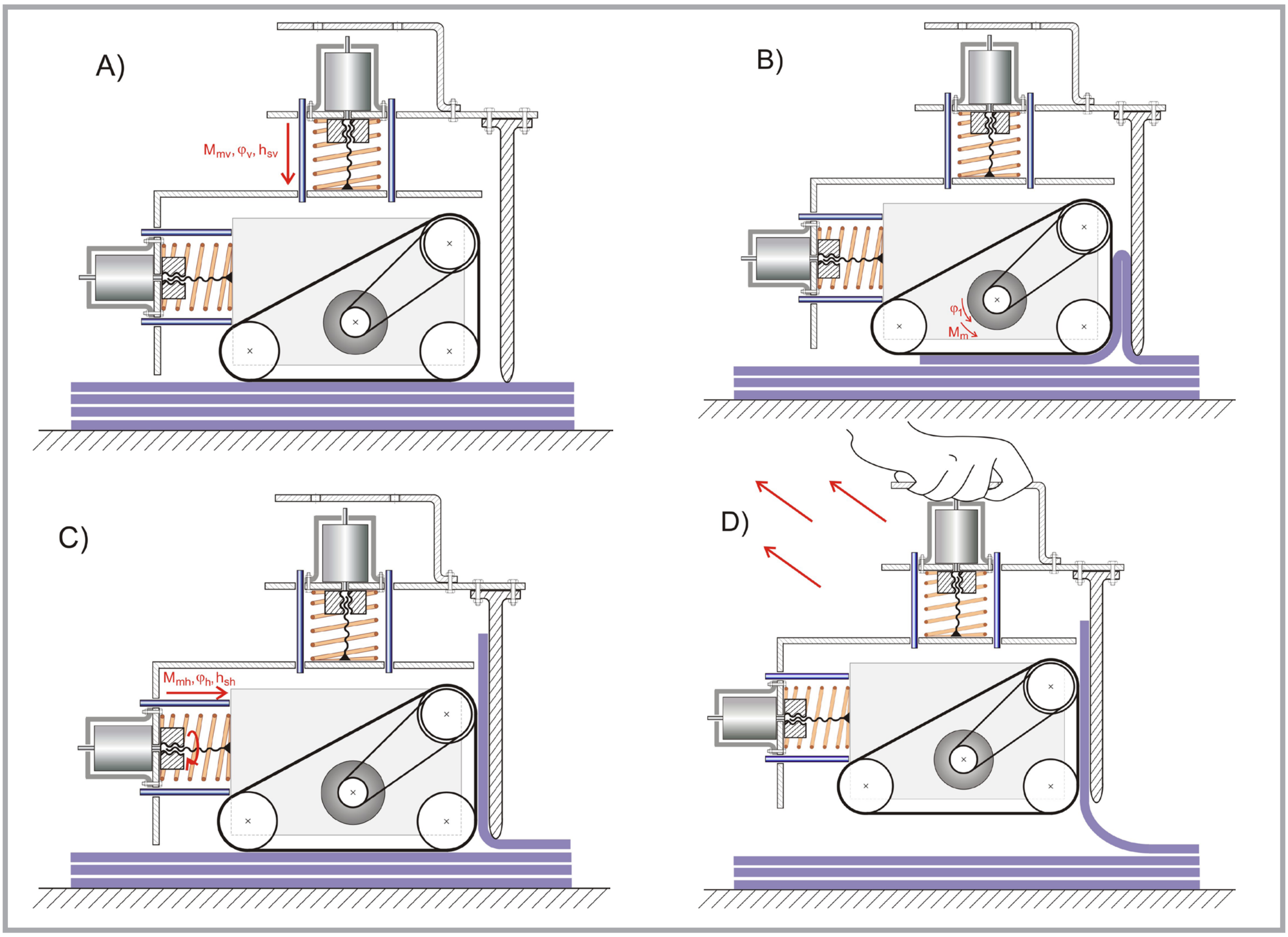


Figure 2. *Principle of operation of the device for separating a single layer of textile from the stack.*

tical and horizontal directions, springs *6* and *16* and pairs of guides *11* and *19* were mounted. Electric motors *9* and *18* were screwed to the connecting plate *12* and casing *14*, respectively.

During the separation of fabric from a stack of material, the following phases can be distinguish (***Figure 2.A - 2.D***):

A) lowering the gripper and tightening it via the arrangement screw *7* – nut *8* – motor *9* to the stack of material and the table. The force in the screw eliminates clearances and moves the force of gravity to the upper part of the mechanism, mediating in the transfer of the force of gravity to the fabric,
B) the stage of tightening the packet of textiles to the table and grip of the partly separated layer between the foot and movable part the gripper,
C) straightening the end of the separated layer and movable pressing of the movable element with tape 2 by means of the arrangement: screw 16 – nut 17 – motor 18. Motor 18 rotates until the separation of the layer of the fabric does not straighten between belt 2 and foot 1,
D) lifting a single layer of fabric, which is a jammed between elements *1* and *2*.

Distribution of friction forces

In order to maintain the correct operation of the system shown in ***Figure 1*** and ***3***, a slide should take place between the first and second layer of the fabric, but it should not occur between the belt and fabric or between the fabric and table.

To prevent the belt from sliding along the fabric, the boundary value between the belt and fabric friction force $T_{p\ gr}$ has to be higher than that of the friction force between the first and second layer of the fabric $T_{1\ gr}$. This condition can be written as follows and ***Figure 4***:

$$T_{p\ gr} > T_{1\ gr}$$
$$\mu_p N_v > \mu_t (N_v + m_{1tk} g) \qquad (1)$$
$$\mu_p > \mu_t \left(1 + \frac{m_{1tk} g}{N_v}\right)$$

The slide should take place between the first and second layer of the fabric. The boundary value of the friction force between the first and second layer $T_{1\ gr}$ should be lower than that of the friction force between the second and third layer $T_{2\ gr}$, which should be satisfactory.

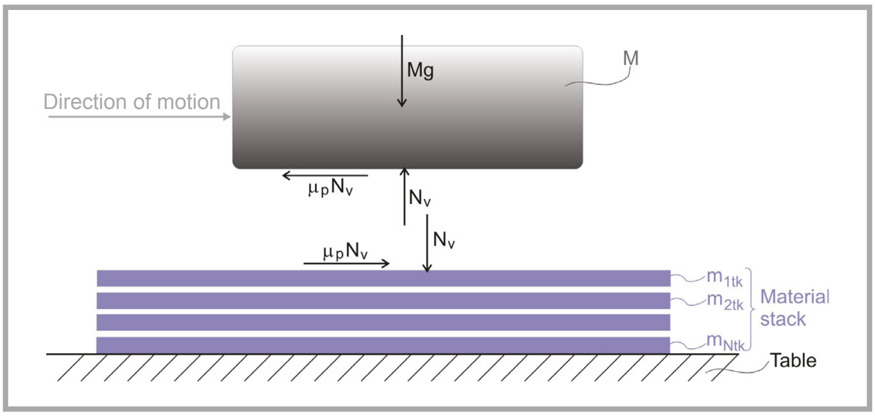


Figure 3*. Distribution of forces between the device of mass M and first layer of the fabric.*

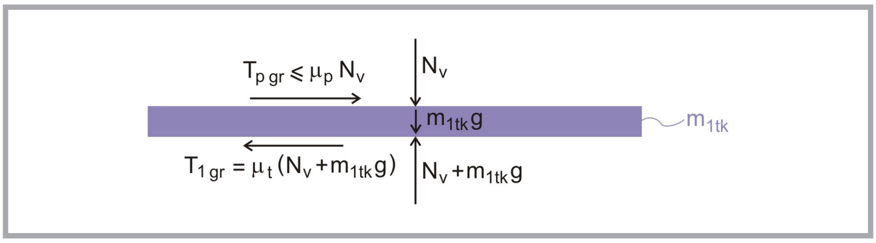


Figure 4. *Distribution of the forces in the first layer of fabric in the stack.*

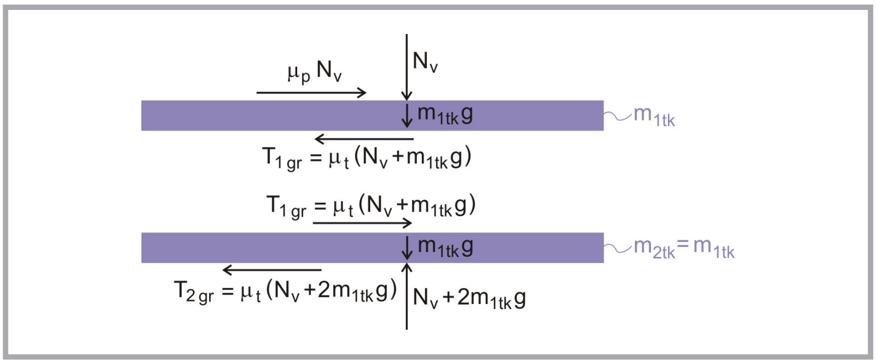


Figure 5. *Distribution of forces in the second layer of fabric in the stack.*

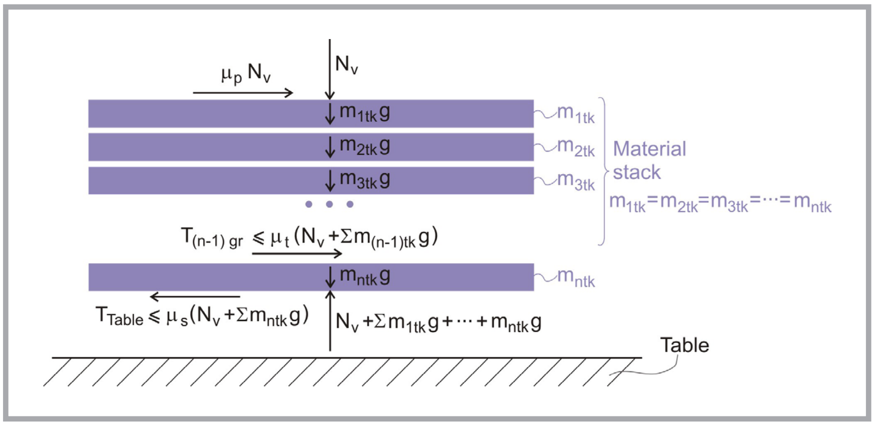


Figure 6. *Distribution of forces in the last layer of fabric in the stack.*

It was obtained from here and ***Figure 5***:

$$T_{1\ gr} < T_{2\ gr}$$
$$\mu_t (N_v + m_{1tk} g) < \mu_t (N_v + 2m_{1tk} g) \qquad (2)$$

The fabric package should not slide along the table. Therefore the value of the friction force between the last layer of the fabric and table T_{Table} has to be higher than that of the friction force between the

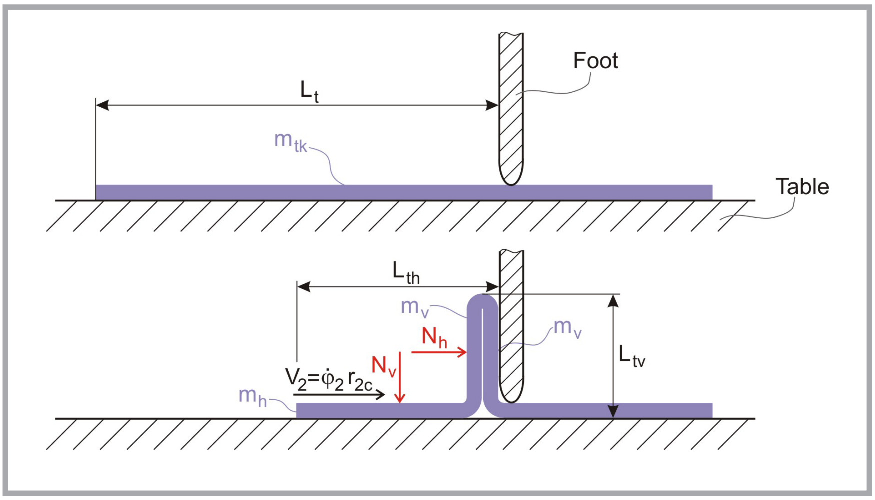
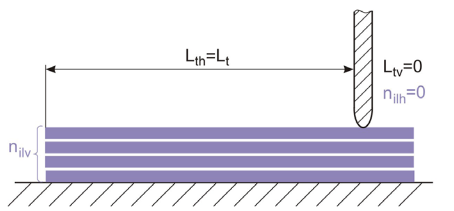
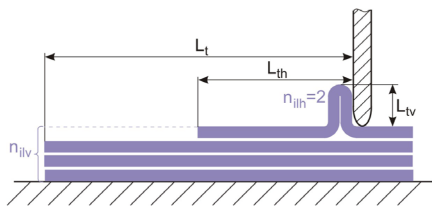
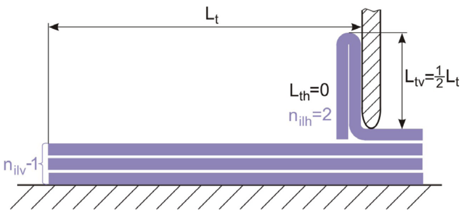
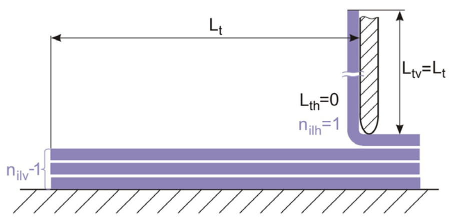


***Figure 7.** Scheme of the distribution of fabric mass m_{tk} during its picking up. Notations in the figures: m_{tk} – mass of fabric of length L_t, m_h – mass of fabric lying on the table (not picked up yet), m_v – mass of fabric between the foot and belt, N_h - Compressive force of fabric between the foot and moving part of the gripper, N_v - pressure force on the stack of textile lying on the table, L_{th} – length of fabric lying on the table, L_{tv} – length of fabric located between the foot and belt, V_2 – speed at which the fabric moves along the table.*

***Table 1.** Statement of specific phases of length distribution of the fabric layer, with the number of layers in a stack, and that between the gripper and foot:*

<table>
<tr><th>No.</th><th>Graphical interpretation</th><th>Length of fabric L_t, L_{th}, L_{tv}, m</th><th>number of layers in the stack n_{ilh} [-] between belt - foot n_{ilv} [-]</th></tr>
<tr><td>1</td><td>
</td><td>$L_{tv}= 0$
$L_{th}=L_t$</td><td>$n_{ilh}=0$
$n_{ilv}=n_{ilv}$</td></tr>
<tr><td>2</td><td>
</td><td>$L_{tv}= (L_t-L_{th})/2$
$L_{th}=L_t- 2L_{tv}$</td><td>$n_{ilh}=2$
$n_{ilv}=n_{ilv}$</td></tr>
<tr><td>3</td><td>
</td><td>$L_{tv}= L_t/2$
$L_{th}=0$</td><td>$n_{ilh}=2$
$n_{ilv}:=n_{ilv}-1$</td></tr>
<tr><td>4</td><td>
</td><td>$L_{tv}= L_t$
$L_{th}=0$</td><td>$n_{ilh}=1$
$n_{ilv}:=n_{ilv}-1$</td></tr>
</table>

penultimate and last layer of the fabric in the stack (***Figure 6***).

$$T_{table}>T_{1\,gr}$$
$$\mu_s(N_v+\Sigma m_{ntk}g)>\mu_t(N_v+n_{ilv}\cdot m_{1tk}g) \quad (3)$$

It is possible to calculate the friction coefficient of the table μ_s from:

$$\mu_s > \mu_t \frac{N_v + m_{1tk}g}{N_v + 2m_{1tk}g} \quad (3a)$$

An analogy can be drawn from the relation of μ_s for the second and each subsequent layer:

$$\mu_s > \mu_t \frac{N_v + m_{1tk}g}{N_v + \Sigma m_{ntk}g} \quad (3b)$$

The conditions described above show that slippage will take place between the first and second fabric layer. This phenomenon occurs due to the fact that the pressing force between the first and second layer is increased by the additional weight of the first layer.

Although we operate on a stack of the same normal force N_v, in the subsequent layers the normal force is increased by the weight of overlying layers.

Accordingly the boundary value of the friction force between the belt and fabric is greater than that of the friction force between the first and second fabric plies, and slippage occurs between the layers of the fabric, and not between the belt and first layer in the stack.

Distribution of fabric mass

During the separation of a layer from the fabric stack, the distribution of the woven fabric mass changes in time (***Figure 7***).

As shown in ***Figure** 7*, the weight of fabric m_{tk} and its length L_t is:

$$m_{tk} = m_h + 2m_v \quad (4)$$
$$L_t = L_{th} + 2L_{tv} \quad (5)$$

During the operation of layer separation from the stack by the gripper, the fabric moves at speed V_2, which is:

$$V_2 = \frac{d\varphi_2}{td} r_{2c} \quad (6)$$

where φ_2 - angle of rotation of the guide roller belt (all rolls are the same), and r_{2c}, - radius of the roll.

With the assumption that the gripper will move at a uniform speed, the weight of the fabric m_h and m_v will amount to:

$$m_h = m_{tk} - V_2 t \frac{m_{tk}}{L_t} = m_{tk} - \frac{d\varphi_2}{td} r_{2c} t \frac{m_{tk}}{L_t} \quad (7a)$$

$$m_v = \frac{m_{tk} - m_h}{2} = \frac{m_{tk}}{2} - \frac{1}{2}\left(m_{tk} - V_2 t \frac{m_{tk}}{L_t}\right) = \\ = \frac{1}{2} V_2 t \frac{m_{tk}}{L_t} = \frac{1}{2} \frac{d\varphi_2}{td} r_{2c} t \frac{m_{tk}}{L_t} \quad (7b)$$

and the length of fabric L_{th} and L_{tv}:

$$L_{th} = L_t - V_2 t = L_t - \frac{d\varphi_2}{td} r_{2c} t \quad (8a)$$

$$L_{tv} = \frac{L_t - L_{th}}{2} = \frac{1}{2} L_t - \frac{1}{2}\left(L_t - \frac{d\varphi_2}{td} r_{2c} t\right) = \frac{d\varphi_2}{td} r_{2c} t \quad (8b)$$

During the separation of one layer of fabric from the stack, there are four characteristic phases of the distribution of the fabric length (***Table 1***):

1. The length of the separate layer of the fabric lying in the stack L_{th} is equal to the total length of fabric therein L_t,
2. The length L_{th} after the start of separation decreases in relation to the total length of the fabric L_t , and the number of fabric layers between the foot and moving part of the gripper is 2,
3. All the actual length of fabric is between the foot and moving part of the gripper, and the number of layers in the stack n_{ilv} is less by about one piece,
4. Fabrics located between the foot and belt are straightened, and the number of layers is $n_{ilh} = 1$.

Experimental verification of the effectiveness of separation of the material layer from the stack by the gripper in terms of an increased work surface for selected materials, with the use of three belts of different coefficients of friction, is limited in so far as it is indeed possible to separate fabric by the principle presented. For all the samples of fabrics suitable belt was elected.

Conclusions

Taking into consideration the research and analysis, a mathematical model of the gripper separating single layers from the stack was developed and phenomena of the operation of separating the fabric layer studied.

The following assumptions are made:

- The force exerted by the gripper on the separated fabric should reach a value to prevent slipping out of the grip between the belt and foot. The pressure exerted on the fabric at this time should not cause its damage. The size of the resultant pressures should not exceed the pressure taken as acceptable for the fabric.
- To control the size of the pressure on the fabric and not exceed the limit of its value, and to realise the pressure of the belt of the leading fabric (***Figure 1*** - part 1) on the foot (***Figure 1*** - part 2) instead of the spring, an engine was used, whose moment of the force is controlled as a function of the size of the pressures (***Figure 1*** - part 18).
- To reduce the pressures necessary to maintain the fabric, the surface pressure on the fabric must be increased, i.e the surface of the belt and foot (elements of the gripper that are involved in separating fabric).

Effective separation of the fabric is not possible when done by grasping it by an area of the surface similar in size to the point [6]. This requires the use of a different method of introducing the fabric between the gripper fingers.

- Entering the edge of the fabric between the respective elements of the griper can be realised by using the endless belt, pulling the fabric by friction force in the direction of the blockage place where the fold entering between the belt and foot is formed. Further movement of the belt will unfold the fabric between the elements involved in separating the fabric layer. In order to avoid selecting two layers simultaneously, adhesiveness between belt and fabric should be higher than between layers of fabric.

References

1. Needle Grippers: Techno-Sommer Automatic: http://www.techno-sommer.com/GrDesign12.htm
2. Reeves A, Harbor MO, Reina PV, Sandgren RT. All of Nashville, Tenn: Fabric Pickup Device; Patent Number: 5,018,715; Date of Patent: May 28, 1991.
3. Tsourveloudis NC, Kolluru R., Valavanis K.P., Gracanin D.: Suction Control of a Robotic Gripper: A Neuro-Fuzzy Approach. *Journal of Intelligent and Robotic Systems* 2000; 27, 3: 215-235.
4. Stasik K. A Gripper Separating Fabric with Friction Forces. In: *IX Conference, Faculty of Engineering and Marketing of Textile*. Technical University of Lodz. March, 2006.
5. Zajączkowski J, Stasik K. Urządzenie do pobierania pojedynczej warstwy z nakładu materiału. Patent nr PL 197340 z dnia 31.01.2008 r.
6. Stasik K. Mathematical Model of a Mechatronic Pinch-Type Gripper for Textiles. *Fibres & Textiles in Eastern Europe* 2005; 13, 1, 49: 67-70.

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