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Analysis of the pressure roll system on a warp knitting machine with multiaxial weft insertion

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Analysis of the pressure roll system on a warp knitting machine with multiaxial weft insertion

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Aachen, August 2015

Abstract

Aim of the work:

Nowadays, pressure roll systems are installed on warp knitting machines, but it is unknown how the pressure level affects the quality of the fabrics.

The main target of the project is to verify what is the suitable pressure to be applied to the pressure roll system of a LIBA Copcentra MAX 3 CNC to get no gaps on the fabric and the best final quality.

Approach:

Several experiments are designed to determine the right pressure value for each possible configuration of the machine. There are a lot of possible configurations, changing parameters like the bond type, the stitch length or the number of layers of the fabric.

Results:

The right pressure value for each configuration is determined by checking if the result is at best quality. It means that there are no gaps on the final fabric.

Keywords:

Pressure roll system, multiaxial non-crimp fabrics, warp knitting machine and quality control.

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Acronyms and symbols

Fig.	Figure
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NCF	Non-crimp fabrics
DoE	Design of Experiments

1 Introduction

In recent years multiaxial fabrics have begun to find favor in the construction of composite components. These fabrics consist of one or more layers of long fibres held in place by a secondary non-structural stitching thread. The main fibres can be any of the structural fibres available in any combination. The stitching process enables the multilayer approach as they are "connected". The number of layers allows a variety of fibre orientations, beyond the simple 0/90° of woven fabrics, to be combined into one fabric.

The two key improvements with stitched multiaxial fabrics are:

- Good mechanical properties, primarily from the fact that the fibres are always straight and non-crimped, and that more orientations of fibre are available from the increased number of layers of fabric and
- Improved component build speed based on the fact that fabrics can be made thicker and with multiple fibre orientations so that fewer layers need to be included in the laminate sequence [net15].

The fabric production process can be slow and the cost of the machinery high. Furthermore the more expensive fibres are required to get good surface coverage for the low weight fabrics. It means the cost of good quality, stitched fabrics can be relatively high compared to wovens. Extremely heavy weight fabrics, while enabling large quantities of fibre to be incorporated rapidly into the component, can also be difficult to impregnate with resin without some automated process [net15].

The most common forms of this type of fabric are shown in the following picture:

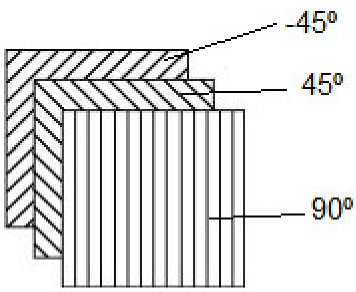


Fig. 1.1: Fabric forms

Some of the applications are: rotor blades for wind turbines, the ski industry or the car industry (fig 1.2).

Fig 1.2: Applications [wik15, BMW15, cur15]

In this bachelor thesis, one part of the fabrication process of multiaxial fabrics is studied. The machine used is the “LIBA Copcentra MAX 3 CNC”, from the Karl Mayer Liba GmbH, Naila, Germany. The thesis focuses on the pressure roll of the machine (fig.1.3).

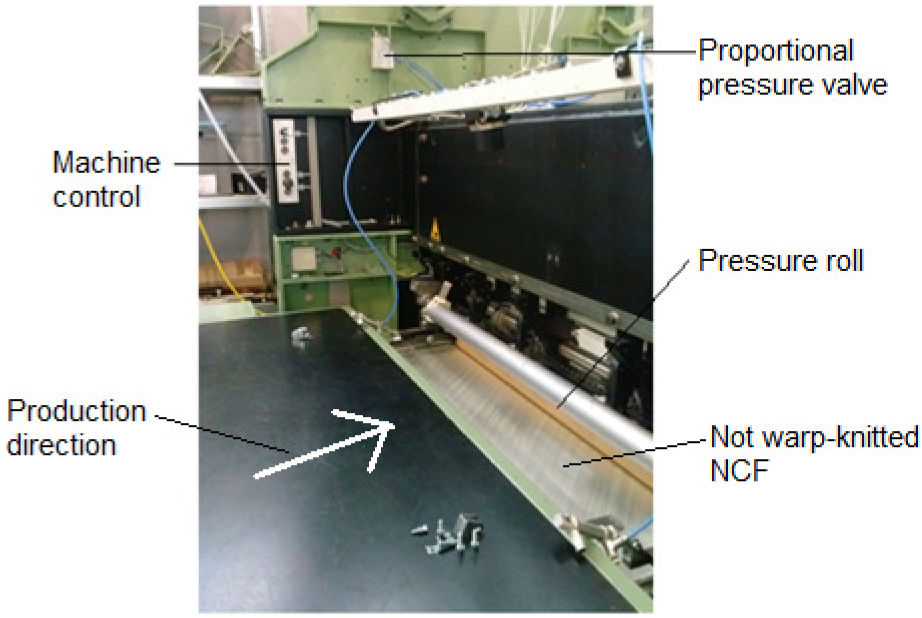


Fig. 1.3: Pressure roll

This pressure roll is special because a new system to control the pressure is installed on it. It is used to homogenize the rovings of the fabric.

The second chapter is the “State of the Art”. In this chapter an overview of the technological progress of the topic accomplished on the last years is given. In the third chapter, all the performed modifications in the machine are explained. The main reason of these modifications is that the system to control the pressure of the pressure roll has to be installed. In the fourth chapter the software of the system that controls the pressure of the machine as well as the design of the experiments are explained. In the fifth chapter the results of the project are given. In the last chapter, the conclusions derived from the experiments are explained.

2 State of the art

In this chapter an overview about the State of the Art is given. There is information about the main textiles in technical applications, like woven and nonwoven fabrics, and the multiaxial non-crimp fabrics (NCF). Following this, the production of multiaxial NCF and its different characteristics are explained. Finally, several examples and applications of this technology are given.

2.1 Textiles in technical applications

Woven fabrics (fig. 2.1) are produced by the interlacing of warp (0°) fibres and weft (90°) fibres in a regular pattern or weave style. The fabric's integrity is maintained by the mechanical interlocking of the fibres. Drapeability (the ability of a fabric to conform to a complex surface), surface smoothness and stability of a fabric are controlled primarily by the weave style. The following is a list of some of the more commonly found weave styles: plain, twill, satin, basket, leno and mock leno [net15].

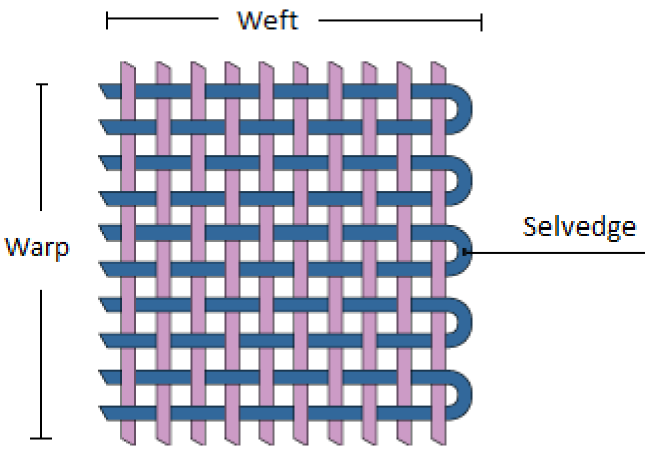


Fig. 2.1: Woven fabric [BBC15]

Nonwoven fabrics (fig. 2.2) are broadly defined as sheet or web structures bonded together by entangling fiber or filaments (and by perforating films) mechanically, thermally, or chemically. They are flat, porous sheets that are made directly from separate fibers or from molten plastic or plastic film. They are not made by weaving or knitting and do not require converting the fibers to yarn. Nonwovens may be a limited-life, single-use fabric or a very durable fabric. Nonwoven fabrics provide specific functions such as absorbency, liquid repellency, resilience, stretch, softness, strength, flame retardancy, washability, cushioning, filtering, bacterial barriers and sterility. These properties are often combined to create fabrics suited for specific jobs while achieving a good balance between product use-life and cost. They can mimic the appearance, texture and strength of a woven fabric, and can be as bulky as the thickest paddings [ind15].

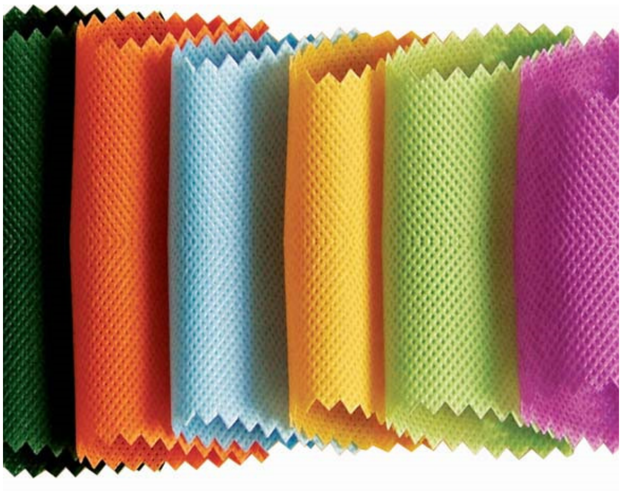


Fig. 2.2: Non-woven fabric [fan15]

Knitting is done by set of connected loops from a series of yarn in warp of weft direction. Knitted fabrics are divided into two main types, which they are shown in Fig. 2.3: warp knitting and weft knitting. In a warp knitted structure each loop in the horizontal direction is made from different thread. Sweater is made by this warp knitting techniques. In a weft knitted structure a horizontal row of loops can be made using one thread and the thread runs in the horizontal direction. Most of the knitted fabrics are produced by weft knitting [tex15].

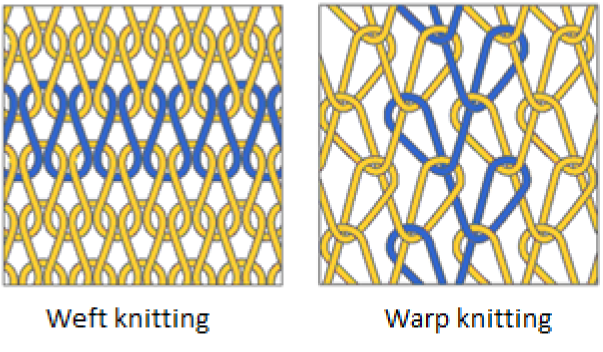


Fig. 2.3: Weft/warp knitting [tri15]

Multiaxial reinforcements are fabrics made up of multiple plies of parallel fibres, each laying in a different orientation or axis - hence the term 'multi-axial'. These layers are typically stitchbonded (usually with a polyester thread) to form a fabric. Commonly used as a reinforcement within composite structures, "multiaxials" or "non-crimp fabrics", effectively allow the composite manufacturer to process multiple layers of unidirectional fibres (the optimum fibre form) in a single ric [for15].

2.2 Multiaxial non-crimp fabrics (NCF)

Multiaxial warp-knitted NCF with coursewise weft insertion has not yet become generally accepted in practice. The productivity of the machine depends mainly on the number of stitches per minute and on the stitch length of the warp-knitting module as well as the frecuency and the width of the weft insertion. Warp-knitting with multiaxial weft insertion is one of the most commonly used production technologies for the manufacturing of multiaxial NCF. Multiaxial warp-knitted NCF with coursewise weft insertion is generally made of up to four reinforcing fibre layers consisting of diagonal weft threads (e.g. ±45°), weft threads (90°) and warp threads (0°), as it is shown in fig 2.4, although it can be made of more layers [Ano15].

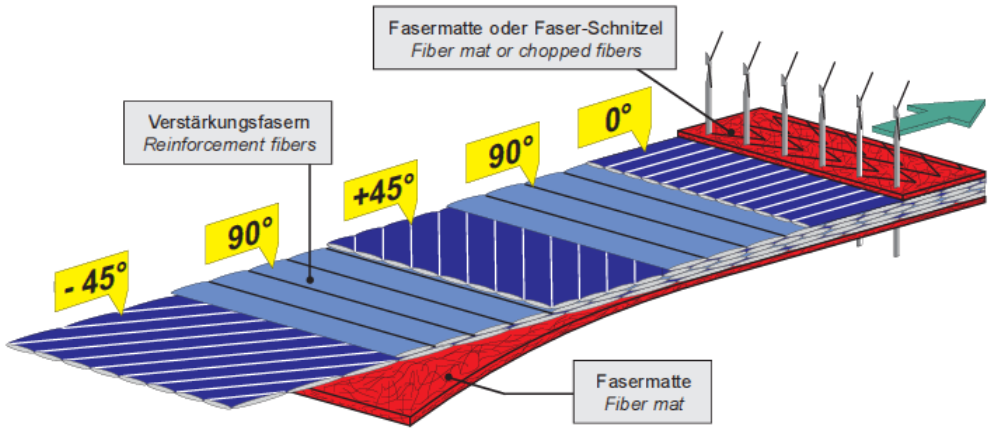


Fig 2.4: Schematic set-up of a multiaxial warp-knitted non-crimp fabric [LIB03]

Standards are very helpful in terms of allowing for successful communication between customers and textile producers. Terms and units must be defined, as well as a unified designation system for textile construction. Furthermore, important process parameters such as the layer orientation or testing procedures for the areal weight, fabric thickness, moisture, length and width should also be standardised. A very comprehensive standard in respect to the aspects quoted above is the European standard EN 13473, Parts 1, 2 and 3.

Non-crimp fabrics (NCF) are officially defined and standardised as multiaxial multi-ply fabrics. Contrary to other production technologies for textile fabrics, the fibres of each layer are orientated straight, and are only laid upon each other during the production process. Finally, the fixation of the single layers to a useable fabric is done by warp-knitting or by binder application. The fibre materials and the orientation, as well as the areal weight of each layer can be chosen in a very flexible manner. Furthermore, fibre mats or nonwoven fabrics can be inserted between each layer.

A standard for the designation of a multiaxial NCF is given in EN 13473, Part 1. It consists of three data blocks. The three data blocks provide the following information:

- Data block 1: identification of the layer stacking sequence and textile construction,
- Data block 2: identification of the binding system and
- Data block 3: identification of the fabric manufacturer.

In general, the individual item block shall be separated from the identity block by a comma (,). The three data blocks of the individual item block are framed by rectangular brackets ([…]). If a data block is not used, this shall be indicated by empty rectangular brackets ([]).

The descriptions of the single layers in data block 1 are separated by a double slash (//), starting with the first layer due to the production succession. In position 1 of each layer description, the material types and grades used in the layer are identified by code letters. In position 2 of the layer description, the areal weight is identified in the unit grams per square metre. Position 3 indicates the orientation of the layers.

In data block 2, the binding system is defined and described by three values, which are separated from each other by a comma (,). In position 1 of the binding description, the used materials are identified by abbreviations. In position 2, the areal weight or the mass per unit area is identified [g/m^2]. In position 3, the binding type is identified. Data block 3 can be used as a code for the NCF's producer.

For example, the correct designation for a NCF is:

EN 13473,[G,235,-45º//G,235,+45º//G,425,0º][PES,12,L]

One very important standard used to define the layer orientation is the reference coordinate system. According to the ISO/DIS 1268-1 the 0º direction is parallel to the direction of production, e.g. the movement of the transport chains. This is shown in fig. 2.5 [KG11].

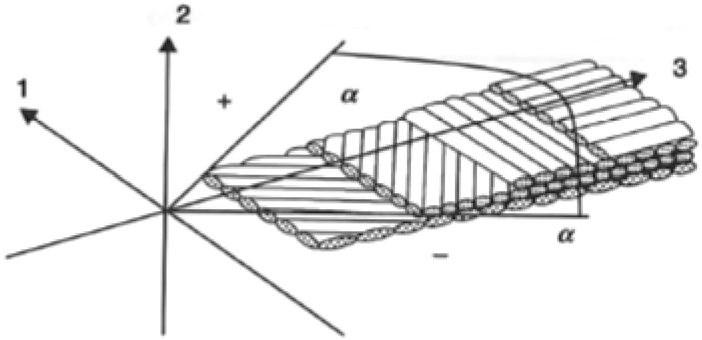


Fig. 2.5: Definition of the layer orientations [ISO/DIS 1268-1/EN]

2.3 Production of multiaxial NCF

In non-coursewise weft insertion machines, the knitting unit, a beam with multiple pillar threads (0°), a transport system for weft insertion (90°) and a take-up unit are mounted on a large turntable, which rotates around its own vertical axis. Stationary beams or creels supply reinforcing threads for the diagonal weft insertion to the rotating knitting machine. Up to two diagonal thread systems can be fed. Because of the superposition of the stationary and the rotating systems, the threads are laid diagonally across the width of the fabric [AHS+00].

2.3.1 Copcentra MAX 3 CNC

Two substantial weft insertion technologies in non-coursewise multiaxial warp-knitting machines exist:

- Insertion of endless weft threads and
- Insertion of finite weft threads.

Weft carriage systems for the insertion of endless weft threads manipulate roving and small spread fibre tows (<12k) from bobbins. A fibre tow with 12k consists of 12000 single filaments. The insertion of finite weft threads was developed for the precise and distortion-free placing of discontinuously and continuously spread fibre tows (>12k) made of carbon. These tows are less expensive than conventional carbon fibre rovings. A weft carriage system with a clamping and cutting device is used for the placement of the fibre tows.

Transport chains with needle, pin-hook and pin-pin systems are used for the production of multiaxial warp-knitted NCF, which are made out of endless weft threads. Finite weft threads are fixed and transported with needle fields or clamping systems in warp-knitting machines with multiaxial weft insertion.

The pin-pin system was developed for the processing of small fibre tows (<12k). Small mass per unit areas of the fabric can be produced (150 g/m^2). The pins are arranged in two separate rows. The upright pin row fixes the position of the weft layers, whereas the horizontal pins take up the tensile force of the weft threads. The weft threads are filled directly into the weft lay-in units with the corresponding weft carriage system [Ano02].

Needle-field systems consist of upright needles, which are arranged in several shifted rows. In these systems, the fibre tows are fed above the needles from a weft carriage system. Afterwards the fibre tows are kneeled down to the transport chain, by means of insertion profiles. Due to the needle field, the fibre tows are divided into strand-shaped sections and clamped between the needles. An additional magnetic tape can clamp the weft threads [EEP+05].

The machine used is the Copcentra MAX 3 CNC:

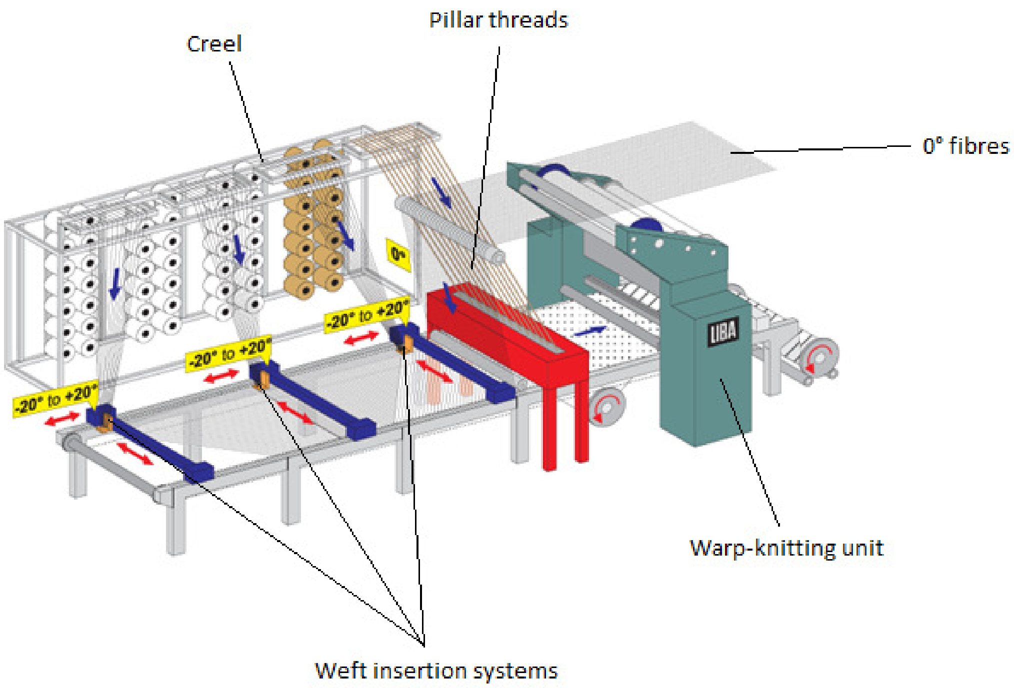


Fig. 2.6: Copcentra MAX 3 CNC [LIB03]

2.3.2 Copcentra MAX 5 CNC

The new Copcentra MAX 5 CNC machine (Fig. 2.7) provides efficient production of multi-axial carbon fiber fabric.

The fact that the Copcentra MAX 5 CNC works with strips of tape cut precisely to length plays an important role in its unparalleled efficiency. Other machines typically run a single continuous tape, which invariably leads to excess waste around the clamps that needs to be trimmed off later. LIBA's solution handles the carbon fiber like the valuable raw material it is, and consequently utilizes it much more economically than conventional systems [bra15].

Fig. 2.7: Copcentra MAX 5 CNC [LIB11]

In clamping systems, spring devices bear a versatile weft clamp against a steady clamping plate. The weft carriage system conveys spread fibre tows to the insertion position. The current as well as the previously inserted fibre tows are fixed with a supporting clamping unit. Afterwards, the self-locking clamping system on the transport chain is opened with a rocker. The new fibre tows are pressed into the open clamping unit on the transport chain. After closing the clamping system, the support clamping unit releases the fibre tows [Ano05].

Carbon fibres are often provided in form of carbon fibre with high fibre content (heavy tows) by the manufacturer, which can consist of over 46k filaments. The fibre tows are wound on bobbins or placed in containers. They are too thick as textile reinforcement materials, where small mass per unit areas are desired. For the subsequent treatment, the filament bundles have to be spread to achieve a constant areal weight. The spreading of the filament bundles can be increased if the filaments are heated during the process. The filament bundles can be heated with hot air, heated rollers, heat radiators and electrodes. A spreading device consists, for example, of three staggered electrodes so that the filaments rest on the electrodes. The heated filament tows runs through a spreading device [Ano05].

Other spreading methods exist, but will not be taken into consideration here since it would go beyond the scope of this work.

2.3.3 Stitching (warp knitting)

Stitch-Bonding is a special form of warp knitting and is commonly used for the production of composite materials and technical textiles. As a method of production, stitch-bonding is efficient, and is one of the most modern ways to create reinforced textiles and composite materials for industrial use. The advantages of the stitch-bonding process include its high productivity rate and the scope it offers for functional design of textiles, such as fiber-reinforced plastics. Stitch-bonding involves layers of threads and fabric being joined together with a knitting thread, which creates a layered structure called a multi-ply. This is created through a warp-knitting thread system, which is fixed on the reverse side of the fabric with a sinker loop, and a weft thread layer. A needle with the warp thread passes through the material, which requires the warp and knitting threads to be moving both parallel and perpendicular to the vertical/warp direction of the stitch-bonding machine. Stitch-bonded fabrics are currently being used in such fields as wind energy generation and aviation. Research is currently being conducted into the usage and benefits of stitch-bonded fabrics as a way to reinforce concrete. Fabrics produced with this process offer the potential of using "sensitive fiber materials such as glass and carbon with only little damage, non-crimp fiber orientation and variable distance between threads". An example is shown in Fig. 2.8 [war15].

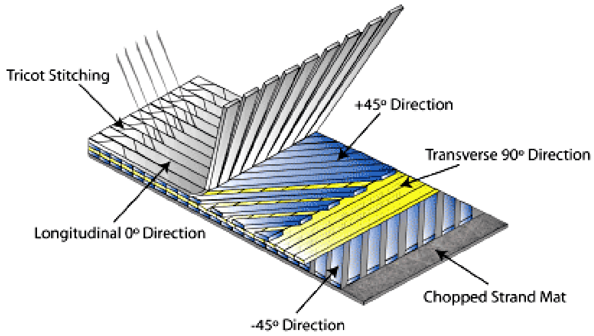


Fig. 2.8: Stitch bonded example [vec15]

2.4 Applications of non-crimp fabrics (NCF) in the automotive industry

The first application of NCF in batch production of automobiles can be found at BMW AG, Munich, Germany. They employed NCF with 150 g/m^2 and 300 g/m^2 mass per unit area and fibre orientations of 0º, +45º and -45º. BMW AG, Munich, Germany, incorporates the process of preforming for the manufacture of components. For the production of the preforms, the required layers are made from the above-mentioned NCF. Between two layers, a binding agent is applied to keep the fibres in place. Before the stack of layers is shaped in the preforming tool, the semi-finished textile products are heated with an infrared spotlight. After the shaping, the semi-finished product is called a preform. One example of an NCF component produced by BMW AG, Munich, Germany, is the BMW i8 (fig. 2.9) [Der07].

Fig. 2.9: BMW i8 (left) [BMW15] and Lamborghini Gallardo (right) [LAM15]

NCF are also used for hybrid methods of construction at BMW Group, Munich, Germany. Within these, preforms consisting of NCF are glued to conventional body-part materials. Glue is spread across the complete surface of the preforms. Incorporating these hybrid constructions helps to improve the properties of the body and to meet crash regulations and stiffness requirements. A typical example is the side frame of BMW Hydrogen 7. Due to the very small quantity of required parts, at present, they are still laminated manually.

Another example for the use of NCF-based components in the automotive industry is the boot lid of Lamborghini's Gallardo Spyder (Fig. 2.9). The required properties of this component have been derived from a comparable part with an aluminum shell structure.

The painting of the boot lid is realised offline, in order to spare the component from the high temperatures of online painting. With this component a weight reduction of 5 kg, as compared with the aluminum part, could be achieved. At the same time a class-A surface is realised [Dei07].

In addition to the automotive industry, NCF have more applications, for example, in aviation industry. The NCF provide the strength and stiffness in multiple directions. The content of composite materials is 52 % in the *Airbus A350XWB* [dry15]. Another application is the rotor blades for windmills. The effect on laminate tensile stiffness made out of NCF is an increase from approximately 25-30 GPa to over 37 GPa, which means an increase of around 25% [Lom11].

2.5 NCF quality control systems

In order to judge the textile quality of Non Crimp Fabrics (NCF) (e.g. homogeneity and orientation of the reinforcement fibers, gaps between the fibers, etc.) a discontinuous laboratory testing method is developed which is based on a digital image processing system. A flat bed PC scanner with an additional transmitted light device is used for the digital image acquisition of flat fabric reinforcement. In principle, the pixels of a digital image are similar to a map of numbers, which in this case range from 0 (i.e. black pixel) to 255 (i.e. white pixel). In this map all pixels within user-defined ranges can be detected by the software. Finally, the user selects geometrical dimensions (e.g. distance, size of an area) to be measured and the software analyses all pixels according to the selection. All data is automatically displayed in tabular form and can be immediately converted into diagrams or histograms [toh15].

3 Machine modifications

In this chapter the main target of the project is explained. The most important part of the machine in this project is the pressure roll. In the following picture (fig 3.1) the location of this pressure roll is shown.

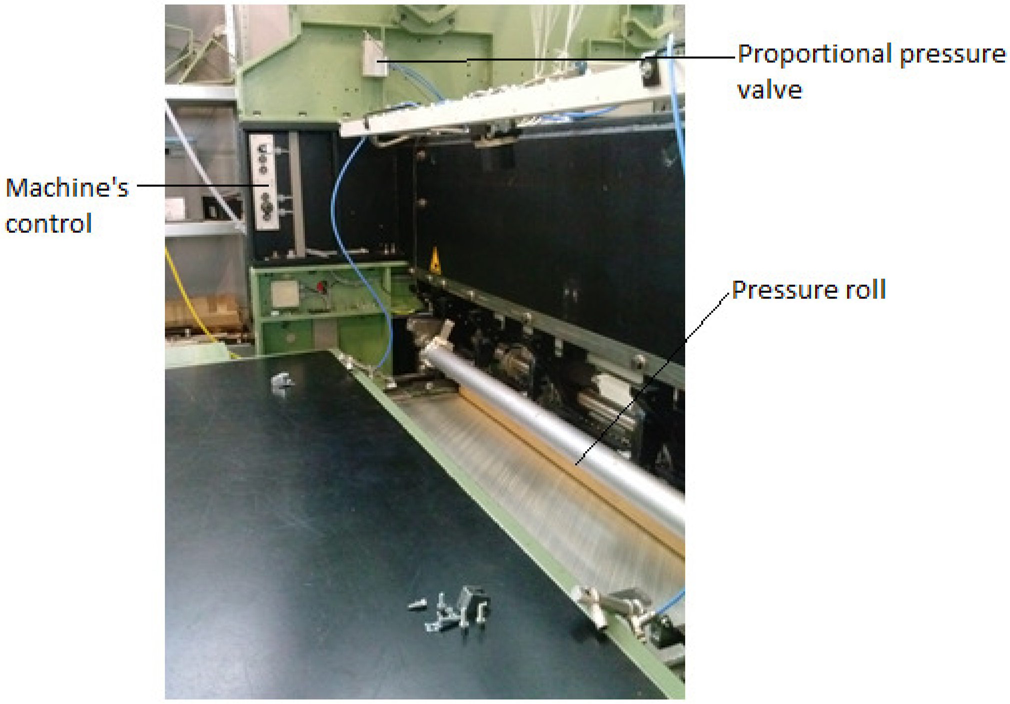


Fig. 3.1: Pressure roll's location

The principal function of this pressure roll is to homogenize the rovings of the fabric. This homogenization is due to the pressure that is performed by the pressure roll. It has a convex shape. For the optimization of the process the required pressure is different for each fabric type in order to reach a good result and the target of this project is to investigate the optimal value of this pressure. Modifications on the machine are necessary, to be able to control the pressure at all time. Before the new pressure system is installed two springs were used, which means that the pressure of the roll was not adjusted, but constant at all time. The following picture (fig. 3.2) is a scheme about this homogenization process.

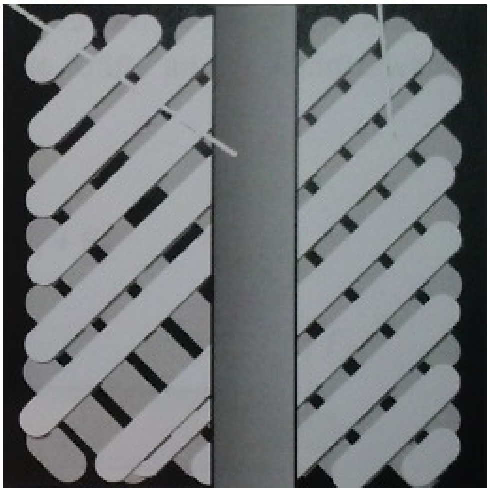


Fig. 3.2: Homogenization process

The homogenization is taking place because of the pressure that is performed by the pressure roll. If the pressure value is right, all the gaps will disappear. But if it is too high or too low, some of the gaps will remain on the fabric.

3.1 Overall system

In the following figure a system's overview is shown:

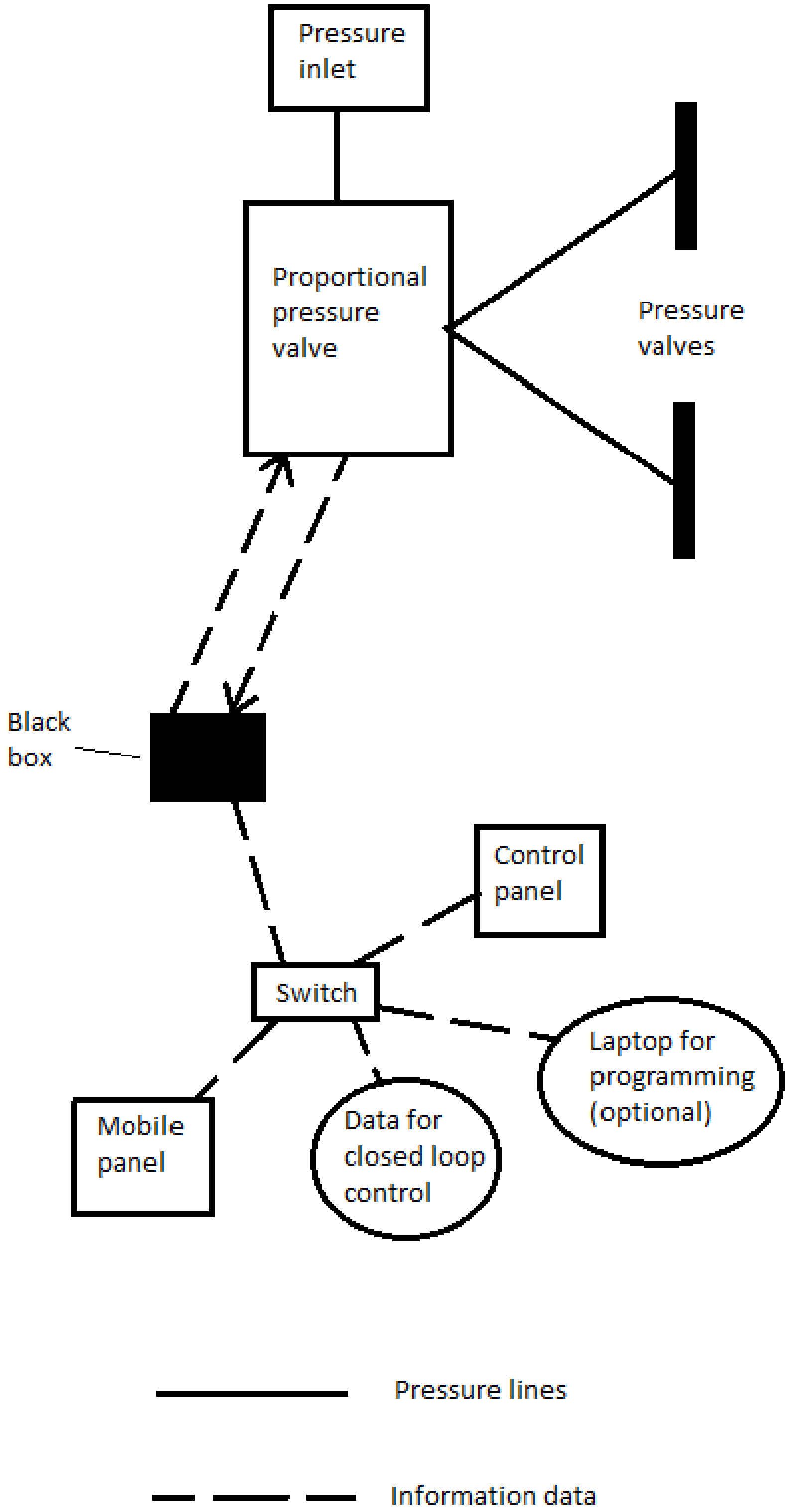


Fig. 3.3: System's overview

All the parameters introduced by the user are sent to the switch, and from there to the “black box”. This box is the information center of the system. There is an exchange of information between the box and the proportional pressure valve. The proportional pressure valve transmits the actual real pressure to the system. The box sends the correction value in case the real one is not the pressure the user wants. The pressure inlet is six bars.

3.2 Installation of proportional pressure valves

In the first step, a CAD model of the warp knitting unit is developed (fig. 3.4).

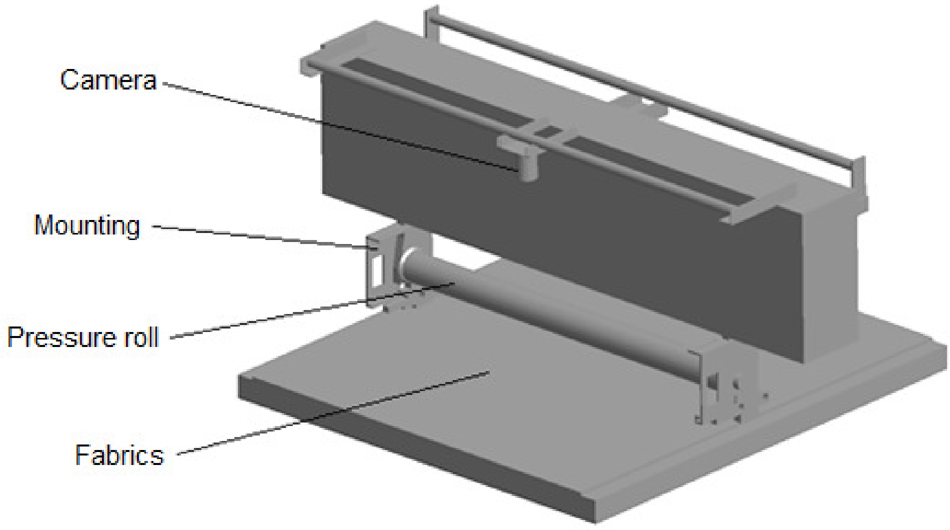


Fig. 3.4: Machine’s scheme

To be able to install the pressure valves on the machine two pieces of the pressure roll are built. For that, drawings are realised with the CAD program “Autodesk Inventor Professional 2013 - Deutsch” (see fig. 3.5 and appendix) and they are sent to the workshop, where the two pieces are constructed and assembled. The drawings are made according to official standards with the objective of not to have any trouble with the machines in the workshop.

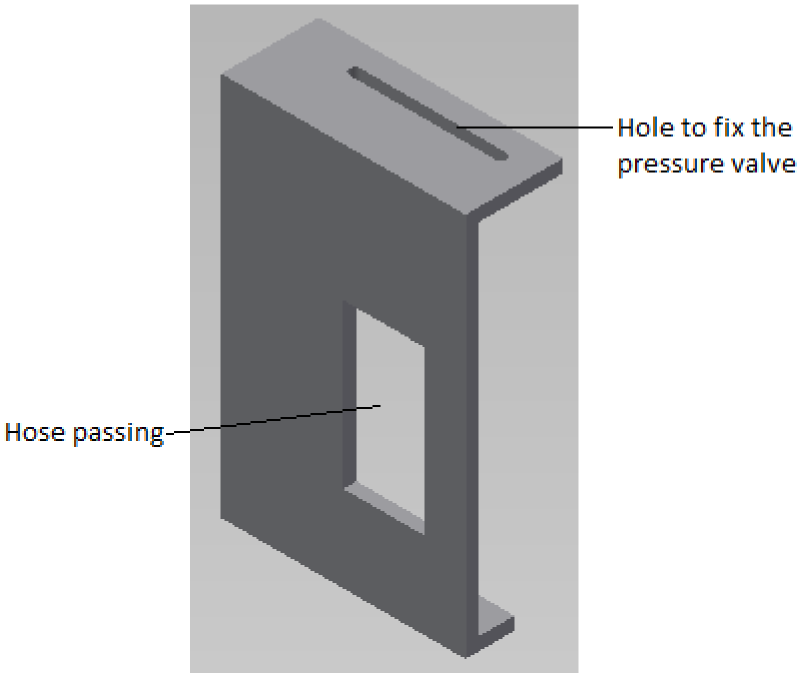


Fig. 3.5: Piece's 3D scheme

The pieces assembled on the machine are illustrated in figure 3.6.

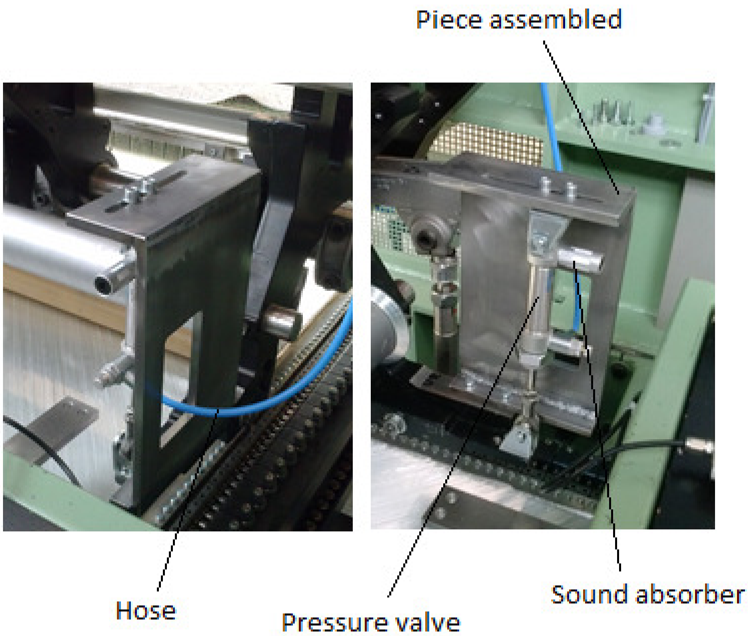


Fig. 3.6: Pieces assembled on the machine

In the next step the proportional pressure valve is installed on the machine. The function of this element is to regulate the pressure performed by the pressure roll. It receives compressed air up to six bars and it is connected with each one of the two pressure cylinders.

Fig. 3.7: Proportional pressure valve

The display can show the input and the output pressure, as well as the current configuration of the device. With the buttons the user can select what he wants to see and change some settings also. In the right picture an empty hole can be seen. This is an outlet pressure hole and it is used to regulate the pressure. It releases pressure if the selected value and the value on the pressure roll is not equal.

To be able to control the proportional pressure valve, a new panel had to be installed into the control cabinet of the machine. First, a hole with the size of the panel is made on the cupboard's door. Then the panel is installed with four screws (Fig. 3.8).

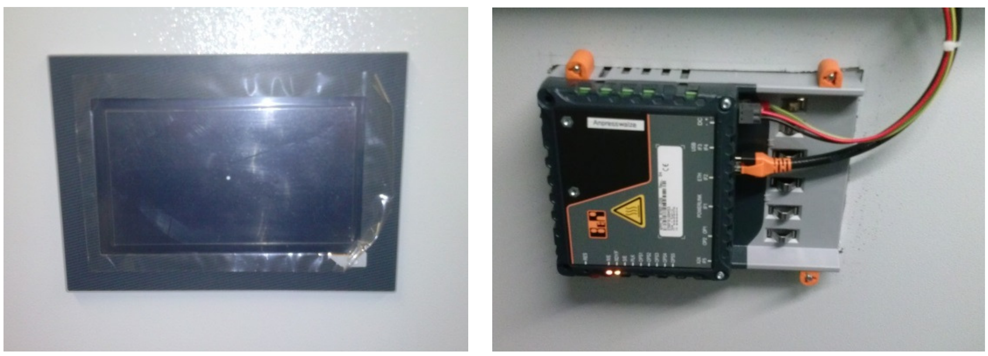


Fig. 3.8: Control panel from the front (left) and form the back (right)

The following picture illustrates the connection of the control panel on the “black box”:

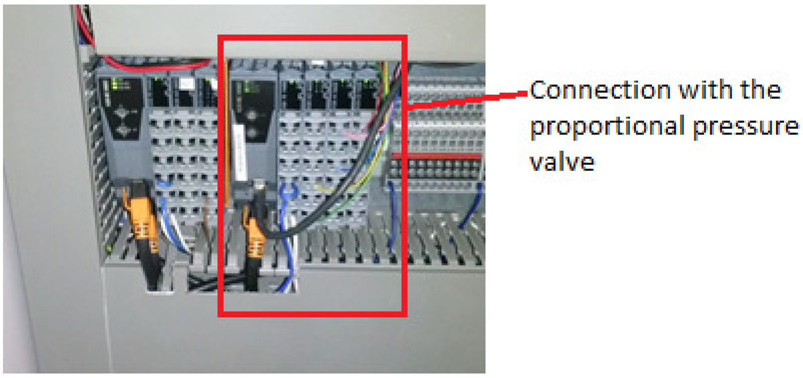


Fig. 3.9: Connection of the control panel on the “black box”

Since the electrical connections are performed by a third company, a detailed description is not done in this thesis.

4 Methods

In this chapter the principal methods used in this project are explained. First of all, the software of the pressure system is explained. Then, the cameras' system used is shown and explained. At last the table with the "Design of Experiments" is given.

4.1 Software explanation

In this chapter, the usage of the software that controls the pressure system of the machine is explained.

The software has three principal modes of working: "Manual", "Auto" and "Auto II". The "Manual" mode is used to change the pressure manually with the proportional pressure valve installed on the machine. The "Auto" mode is used to have a "recipe", so a fixed configuration with lots of data (compared to the "Manual" mode where only the pressure can be adjusted). The "Auto II" mode is the closed loop control. The camera sends a signal via Ethernet and if there is a gap, the pressure is adjusted (by certain value, for example 0.1 bar) until the camera sends the signal "no gap".

4.1.1 Making a new "recipe"

To make a new "recipe" the following steps have to be taken:

First of all the principal mode has to be selected. Most of the time the choice will be the "Auto" mode, because it can configure much more data compared with the "manual" mode:

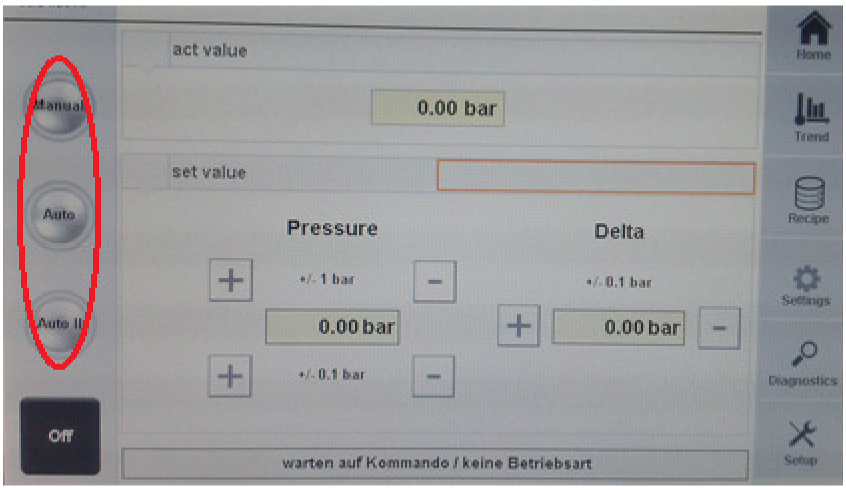


Fig. 4.1: Step 1

The next step is to press on “Recipe”, located on the right side of the screen:

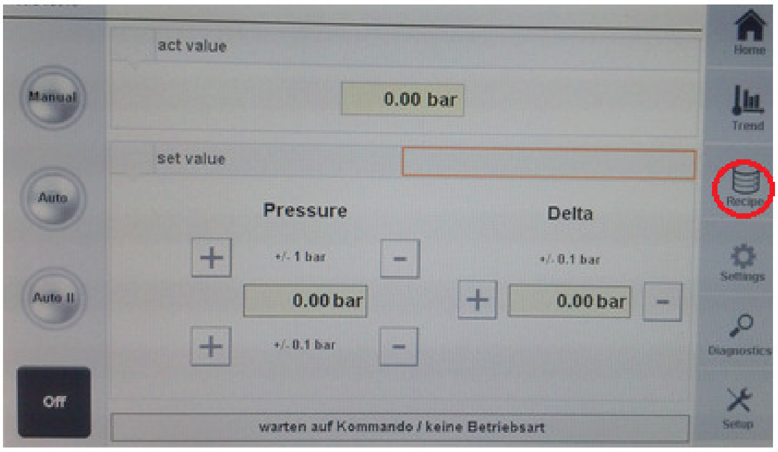


Fig. 4.2: Step 2

After this, a new menu appears:

Fig. 4.3: “Recipe“ menu

Focusing on the top side of the screen:

Fig 4.4: Top side of “Recipe” mode

- Refresh: It is used to check if new recipes have been created.
- Save: It is used to save the current recipe.
- Delete: It is used to remove a recipe.
- Load: It is used to load a recipe from the list.
- Create: It is used to create a new recipe.
- Apply: It is used to load on the system the selected recipe.
- The buttons on the left side are used to classify in different ways the recipes of the list.

If a new recipe wants to be created, all the parameters have to be selected. The parameters are on the bottom side of the screen, but they are not all the parameters that can be configured. Pressing on the button shown on fig. 4.5, a new menu appears (fig 4.6):

Fig. 4.5: Configuration button

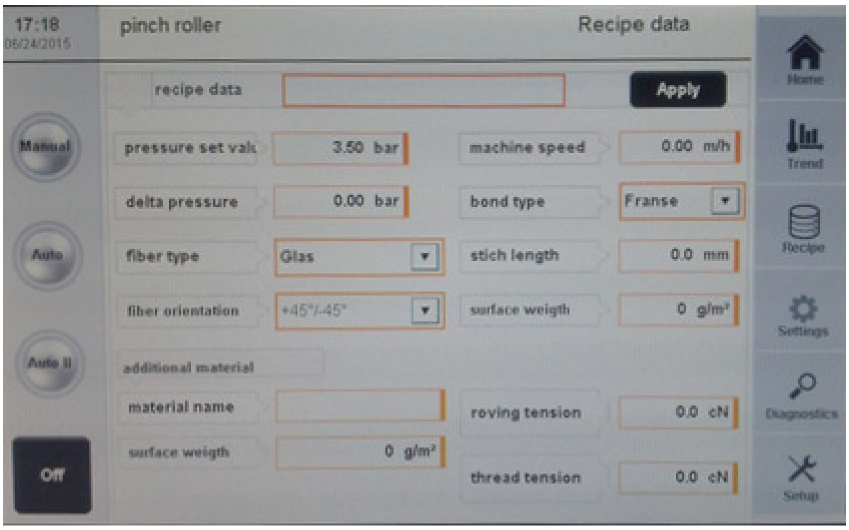


Fig. 4.6: Configuration menu

- Pressure set value: It is the output pressure of the system.
- Delta pressure: It is the variation of pressure between the wanted value and the real value.
- Machine speed: It is the speed the machine runs the fabric.
- Bond type: There are five options; “Trikot”, “Tuch”, “Franse”, “Satin” and “Samt”.
- Fiber type: It can be glass or carbon.
- Fiber orientation: There are three options; +45°/-45°, +45°/-45°/+90° and +45°/+90°/-45°.
- Stitch length: It is the length of the stitch on the fabric.
- Surface weight: It depends on the fiber type and the number of layers.

Additional material:

- Material name: It is the name of the additional material.
- Surface weight: It depends on what additional material is used.
- Roving and thread tension: They are defined by the properties of the additional material.

The final step is to press the “Home” button:

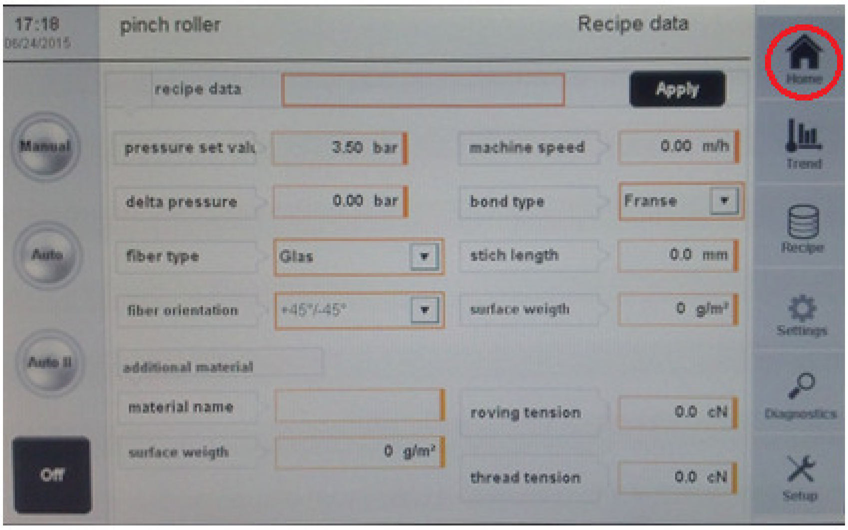


Fig. 4.7: Final step

Then the initial menu appears:

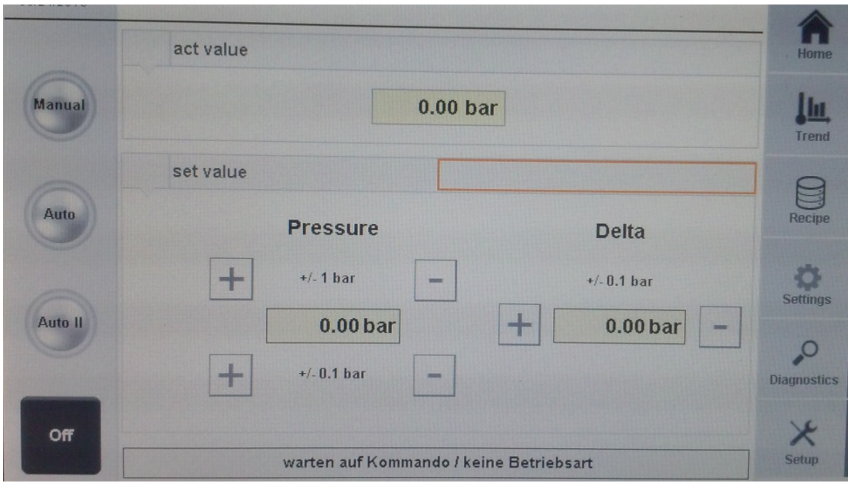


Fig. 4.8: Initial menu

In this menu, the actual real value and the set value can be seen. Also the output pressure value and its variation can be selected.

4.2 Camera system set-up

To be able to take the images, an "Aramis" image system with two cameras is installed on the machine. Both cameras are connected with a computer, which it is used to take the pictures that are necessary to find the gaps on the fabric. The first camera takes pictures before the fabrics pass through the pressure roll and also before the warp knitting process. The second camera takes pictures after these processes. This way it can be proved if there are gaps or not. In the following pictures (fig. 4.9) the camera system installed on the machine is shown.

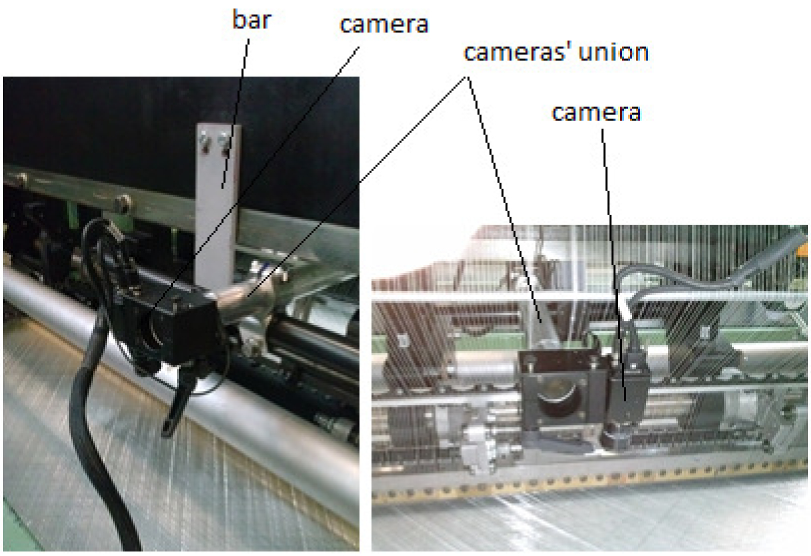


Fig. 4.9: Pre-camera (left) and post-camera (right)

4.3 Design of Experiments

To achieve a good database a Design of Experiments (DoE) is set up. In Table 4.1 the different experiments are shown. To achieve that, the values and parameters that can be changed must be known. Once they are known different possible combinations are combined.

				WEIGHT		EBC value
Bond type	**Stitch length**	**Fiber orientation**	**Pressure set value (bar)**	**Per location**	**Overall**	**normal**
Franse	2 mm	45º/-45º	5.5	300 g/m2 + 300 g/m2	600 g/m2	3500
Franse	2 mm	45º/-45º	5.5	600 g/m2 + 600 g/m2	1200 g/m2	3850
Franse	2 mm	45º/-45º/90º	5.5	300 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	3700
Franse	2 mm	45º/90º/-45º	5.5	600 g/m2 + 600 g/m2 + 300 g/m2	1500g/m2	4000
Franse	4 mm	45º/-45º	5.5	301 g/m2 + 300 g/m2	600 g/m2	6250
Franse	4 mm	45º/-45º	5.5	601 g/m2 + 600 g/m2	1200 g/m2	6500
Franse	4 mm	45º/-45º/90º	5	301 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	6320
Franse	4 mm	45º/90º/-45º	4.5	601 g/m2 + 600 g/m2 + 300 g/m2	1500g/m3	6600
Franse	6 mm	45º/-45º	4.5	302 g/m2 + 300 g/m2	600 g/m2	9200
Franse	6 mm	45º/-45º	5.5	602 g/m2 + 600 g/m2	1200 g/m2	9500
Franse	6 mm	45º/-45º/90º	5.5	302 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	9350
Franse	6 mm	45º/90º/-45º	5.5	602 g/m2 + 600 g/m2 + 300 g/m2	1500g/m4	9650
Trikot	2 mm	45º/-45º	5	303 g/m2 + 300 g/m2	600 g/m2	5600
Trikot	2 mm	45º/-45º	6	603 g/m2 + 600 g/m2	1200 g/m2	5800
Trikot	2 mm	45º/-45º/90º	6	303 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	5750
Trikot	2 mm	45º/90º/-45º	4.5	603 g/m2 + 600 g/m2 + 300 g/m2	1500g/m5	5900
Trikot	4 mm	45º/-45º	5	304 g/m2 + 300 g/m2	600 g/m2	7200
Trikot	4 mm	45º/-45º	5	604 g/m2 + 600 g/m2	1200 g/m2	7500
Trikot	4 mm	45º/-45º/90º	5.5	304 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	7400
Trikot	4 mm	45º/90º/-45º	5.5	604 g/m2 + 600 g/m2 + 300 g/m2	1500g/m6	7650
Trikot	6 mm	45º/-45º	5	305 g/m2 + 300 g/m2	600 g/m2	9800
Trikot	6 mm	45º/-45º	5	605 g/m2 + 600 g/m2	1200 g/m2	10100
Trikot	6 mm	45º/-45º/90º	5	305 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	9900
Trikot	6 mm	45º/90º/-45º	5	605 g/m2 + 600 g/m2 + 300 g/m2	1500g/m7	10250
Tuch	2 mm	45º/-45º	5	306 g/m2 + 300 g/m2	600 g/m2	7400
Tuch	2 mm	45º/-45º	5	606 g/m2 + 600 g/m2	1200 g/m2	7800
Tuch	2 mm	45º/-45º/90º	5.5	306 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	7600
Tuch	2 mm	45º/90º/-45º	4	606 g/m2 + 600 g/m2 + 300 g/m2	1500g/m8	8000
Tuch	4 mm	45º/-45º	4	307 g/m2 + 300 g/m2	600 g/m2	8800
Tuch	4 mm	45º/-45º	4	607 g/m2 + 600 g/m2	1200 g/m2	9100
Tuch	4 mm	45º/-45º/90º	4.5	307 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	9050
Tuch	4 mm	45º/90º/-45º	4.5	607 g/m2 + 600 g/m2 + 300 g/m2	1500g/m9	9250
Tuch	6 mm	45º/-45º	4.5	308 g/m2 + 300 g/m2	600 g/m2	11300
Tuch	6 mm	45º/-45º	4.5	608 g/m2 + 600 g/m2	1200 g/m2	11500
Tuch	6 mm	45º/-45º/90º	4.5	308 g/m2 + 300 g/m2 +150 g/m2	750 g/m2	11250
Tuch	6 mm	45º/90º/-45º	4.5	608 g/m2 + 600 g/m2 + 300 g/m2	1500g/m10	11550

Tab. 4.1: Design of Experiments (DoE)

- Bond type: The machine can produce three different shapes of fabric depending on the bond type: Franse, Trikot and Tuch (fig 4.10). In the experiments, twelve different configurations were used with each bond type.

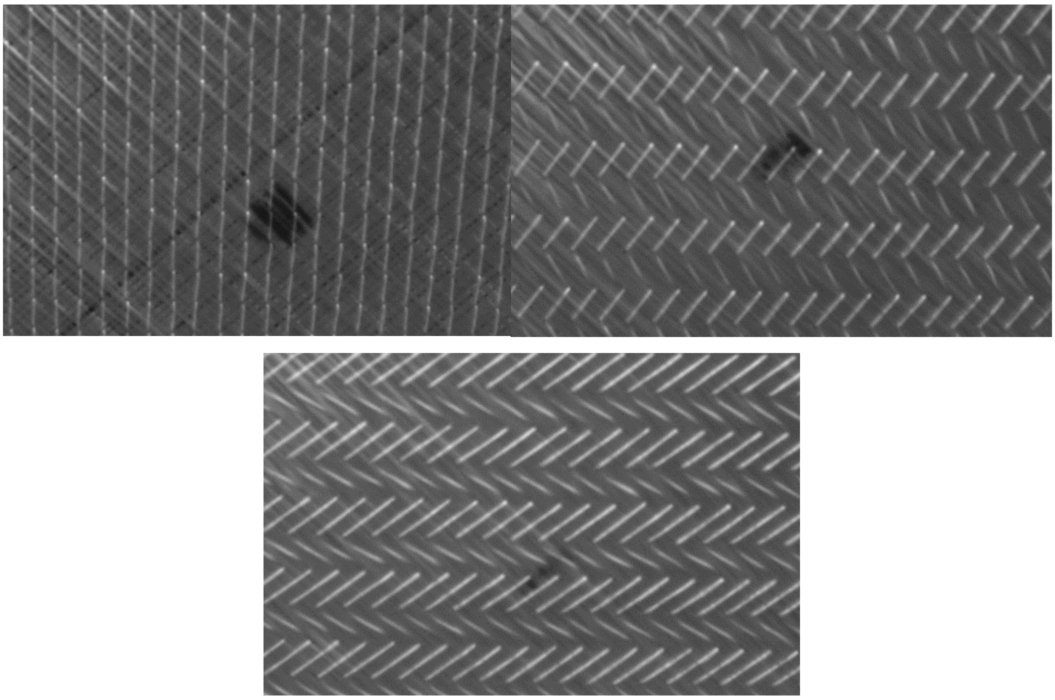


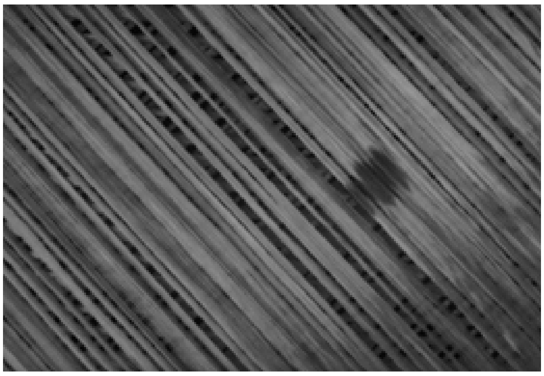
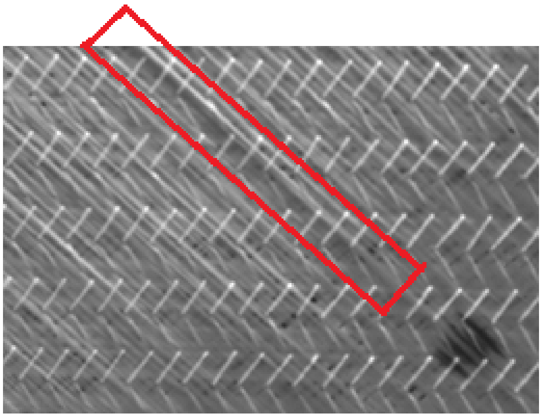
Fig. 4.10: Franse (top left), Trikot (top right) and Tuch (bottom)

- Stitch length: Three different length values were used for the experiments, the minimum and the maximum possible length, and a middle value.
- Fiber orientation and weight: The fiber orientation has four different combinations, depending on the weight and the fiber orientation. The surface weight can be 300 g/m^2 or 600 g/m^2. And the machine can produce 2-layers or 3-layers fabric with an orientation of 45°, -45° or 90°. The four configurations were used on the experiments.
- EBC value: It is the tension value the machine works. It is on mm per rack, and the rack is a constant value that equals 480 revolutions per minute [min^{-1}].
- The speed of the machine is set up to 30 m/h and the material used is glass fibers.
- Pressure set value: The maximum pressure available is six bars. Furthermore, it was checked on previous experiments that with the rank of pressures from zero to three bars the results are not good. That is why the rank of pressures chosen for these experiments is from four to six bars. It is also checked that if the variation of pressure is 0.1 or 0.2 bars, it does not affect the final result. So the variation chosen for these experiments is 0.5 bars. This way, the pressure values for each configuration are: 4, 4.5, 5, 5.5 and 6 bars.

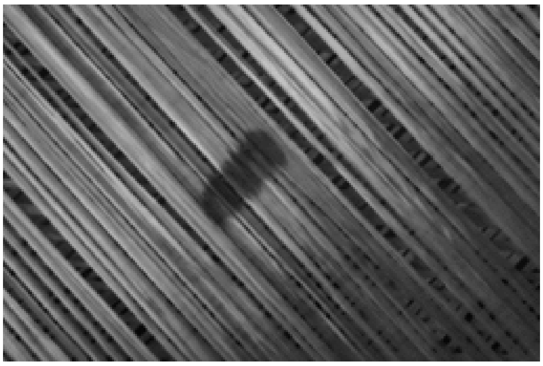
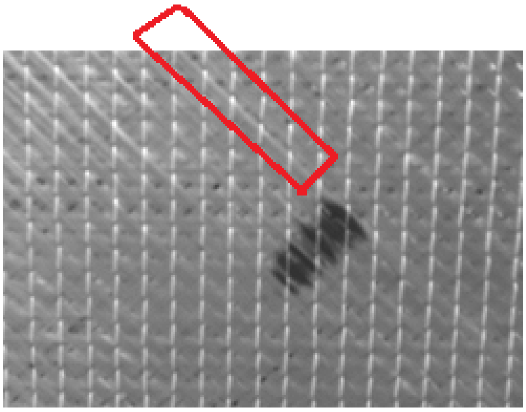
5 Results

In this chapter, the pictures taken with the experiments of all the configurations are shown. If the pressure value selected is not the right one some gaps will remain on the fabric after passing through the pressure roll. The following pictures are some examples of bad quality experiments. The dot seen on the pictures was made to take pictures of the same section of the fabric:

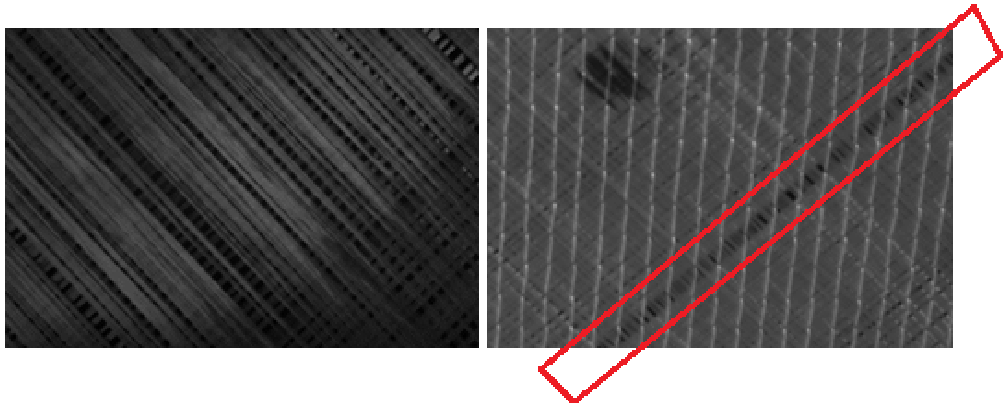
Three layers – 750g – Trikot – 6 mm – 4 bars:

Three layers – 750g – Franse – 4 mm – 4 bars:

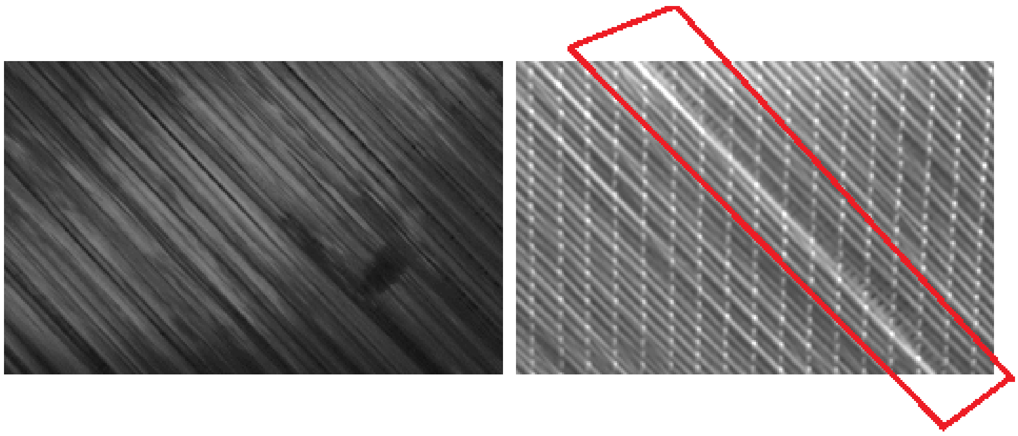



Two layers – 600 g – Franse – 6 mm – 4 bars:

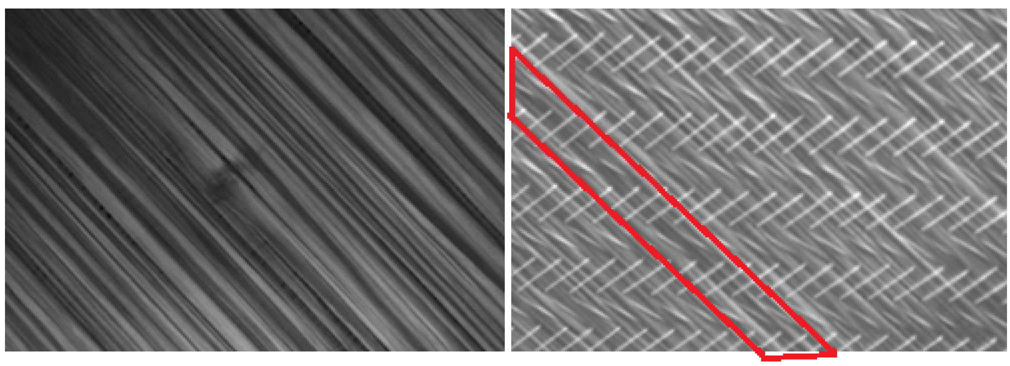


In this case there is a big gap on the second layer of the fabric. That is why it can be seen through the top layer.

Two layers – 1200 g – Franse – 2 mm



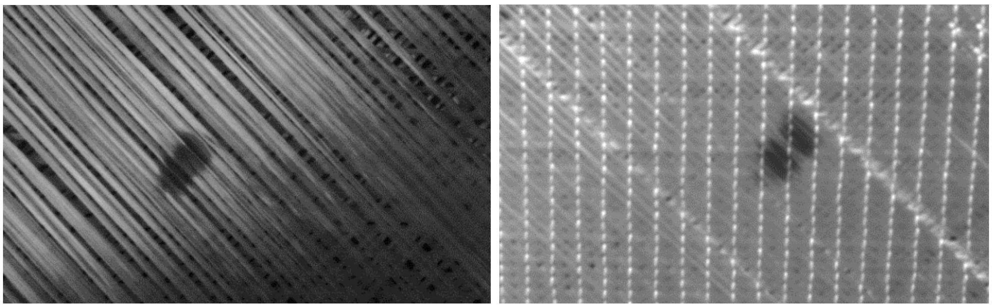
Two layers – 1200 g – Tuch – 6 mm – 4 bars:



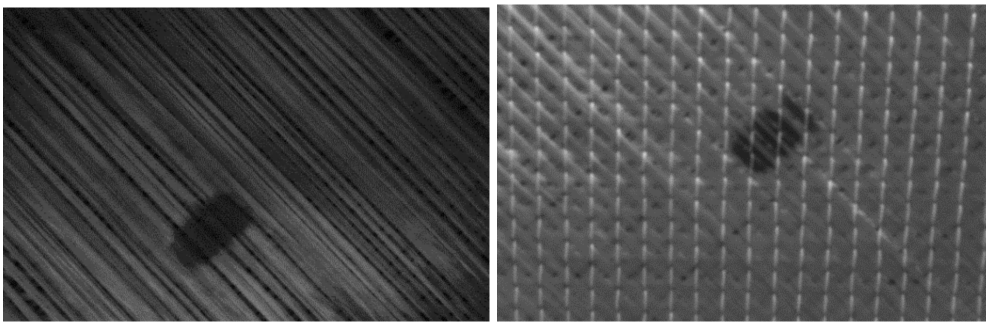
5.1 Three layers – 750 g

In the following pictures most of the gaps have disappeared. This is because the right pressure value has been selected.

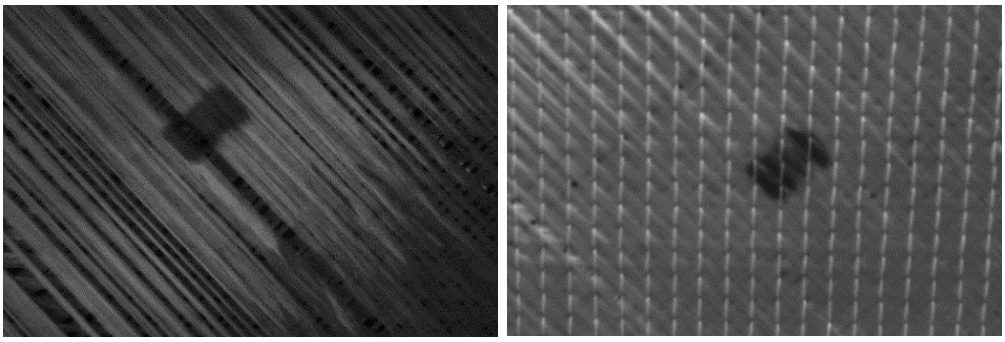
Three layers – 750 g – Franse – 2 mm – 5.5 bars:



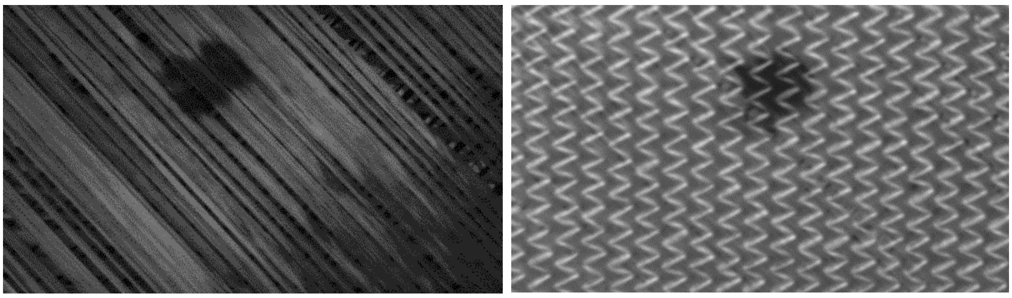
Three layers – 750 g – Franse – 4 mm – 5.5 bars:



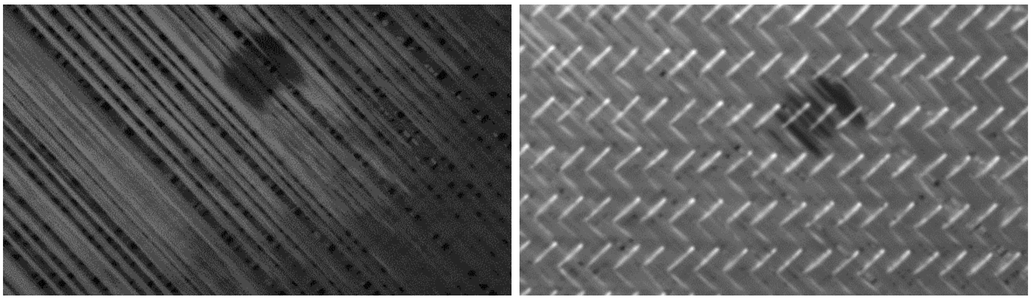
Three layers – 750 g – Franse – 6 mm – 5.5 bars:



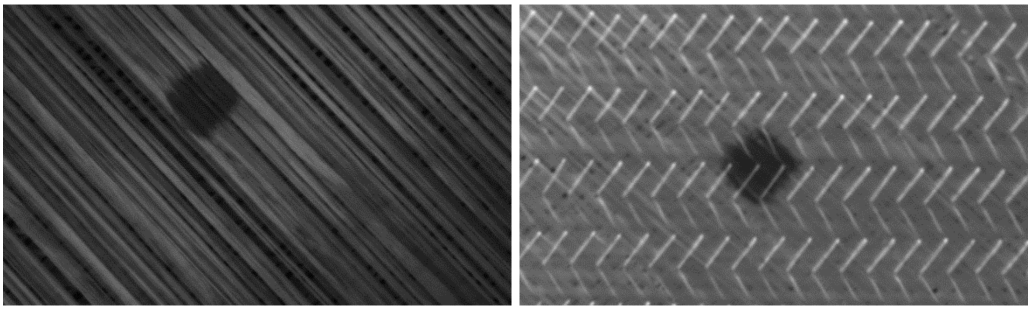
Three layers – 750 g – Trikot – 2 mm – 5.5 bars:



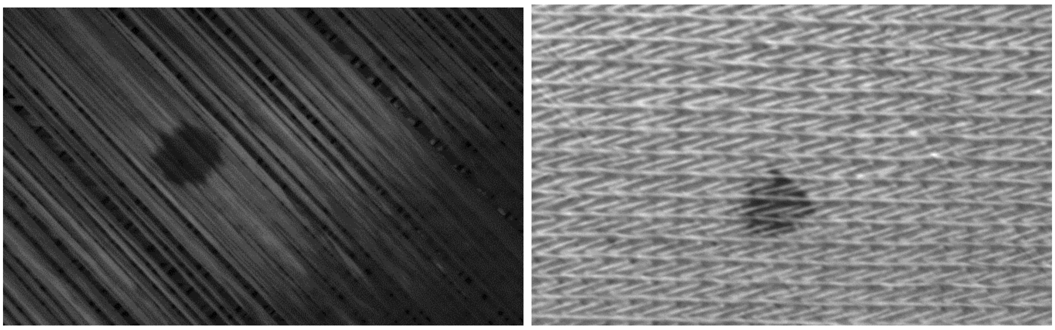
Three layers – 750 g – Trikot – 4 mm – 5.5 bars:



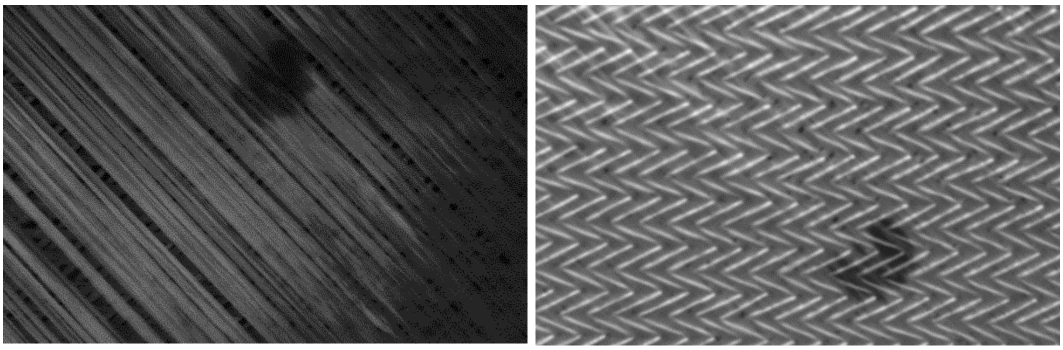
Three layers – 750 g – Trikot – 6 mm – 5.5 bars:



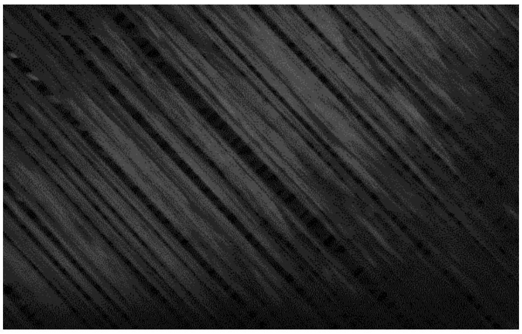
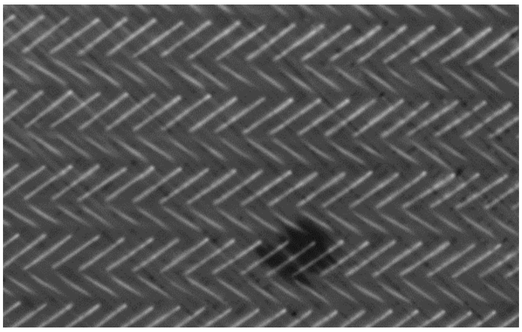
Three layers – 750 g – Tuch – 2 mm – 5 bars:



Three layers – 750 g – Tuch – 4 mm – 4.5 bars:

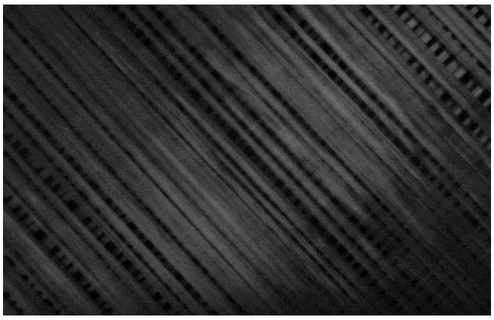
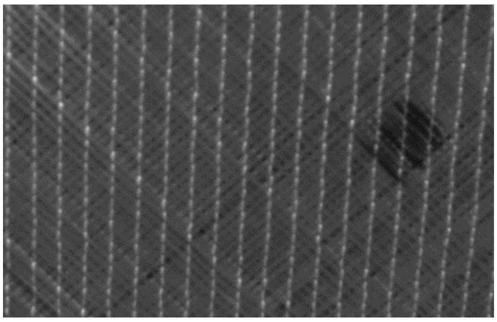


Three layers – 750 g – Tuch – 6 mm – 4.5 bars:

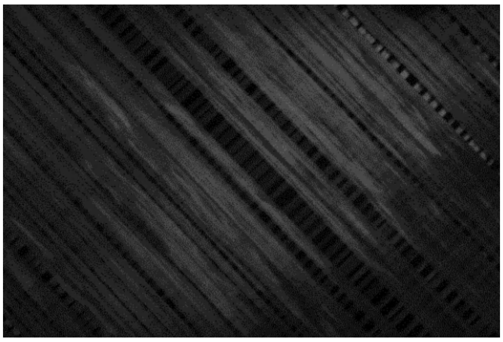
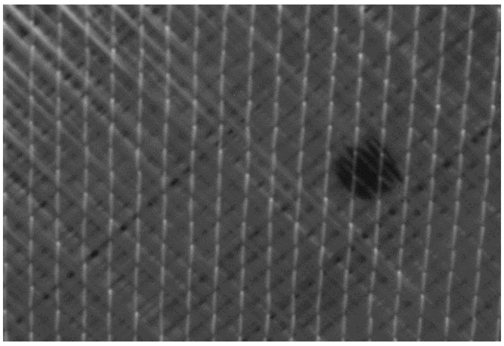
 

5.2 Two layers – 600 g

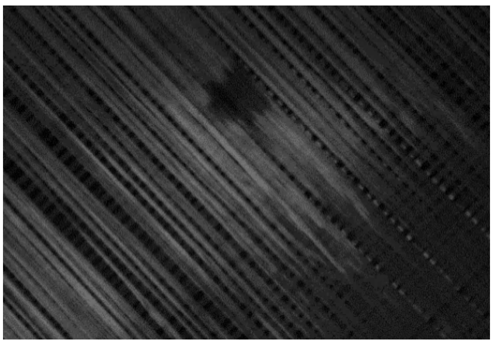
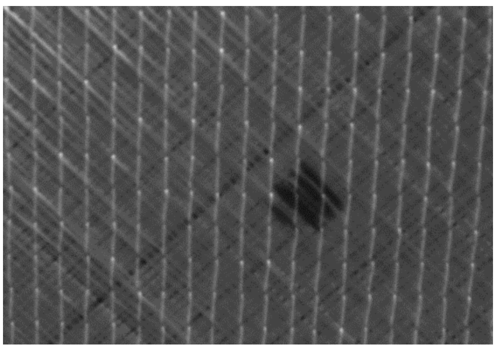
Two layers – 600 g – Franse – 2 mm – 5.5 bars:

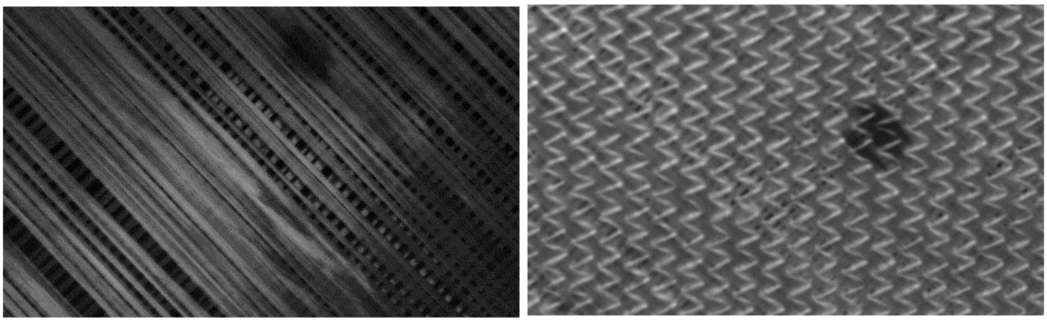
Two layers – 600 g – Franse – 4 mm – 5.5 bars:

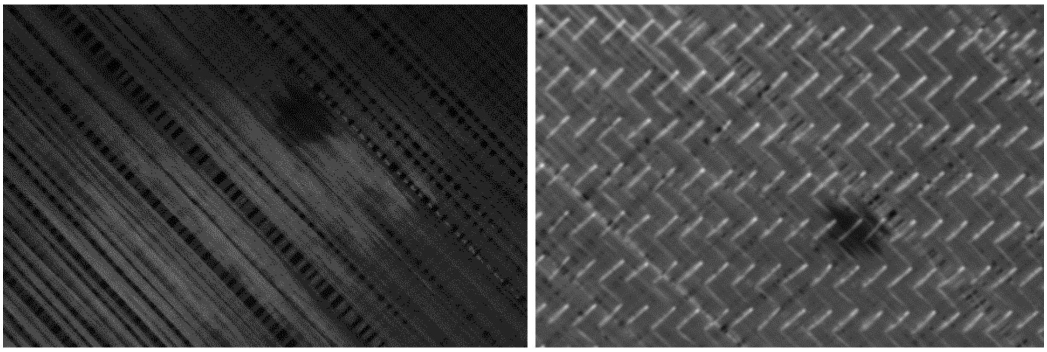
Two layers – 600 g – Franse – 6 mm – 5.5 bars:

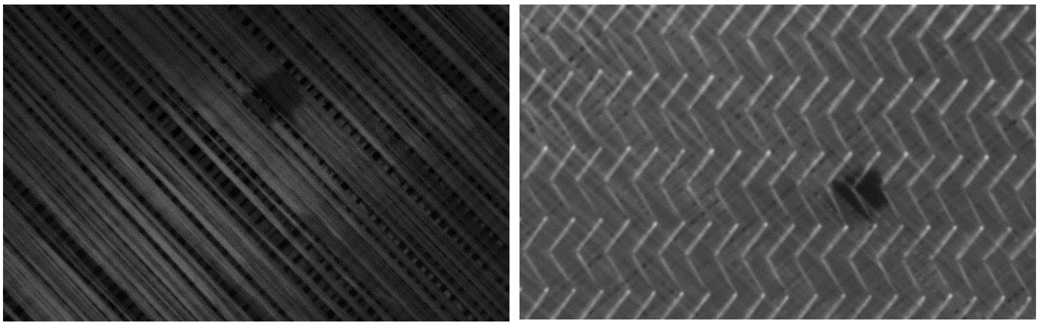
Two layers – 600 g – Trikot – 2 mm – 5 bars:



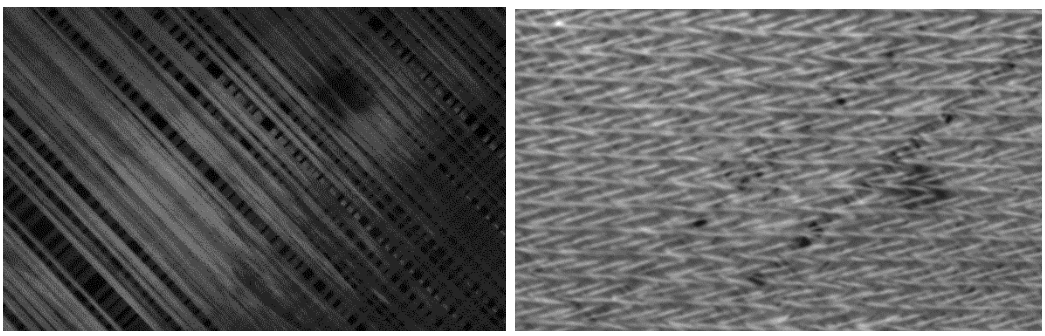
Two layers – 600 g – Trikot – 4 mm – 6 bars:



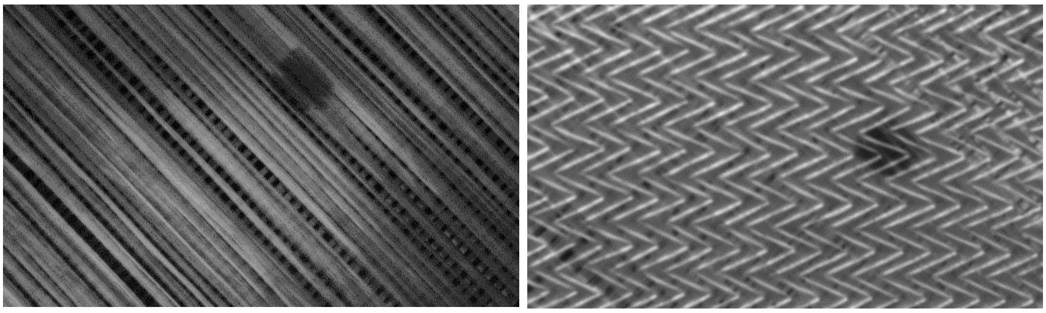
Two layers – 600 g – Trikot – 6 mm – 6 bars:



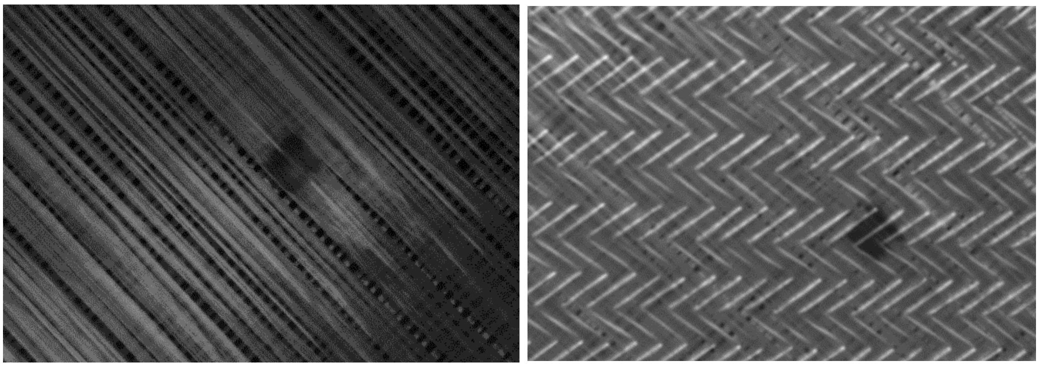
Two layers – 600 g – Tuch – 2 mm – 4.5 bars:



Two layers – 600 g – Tuch – 4 mm – 5 bars:

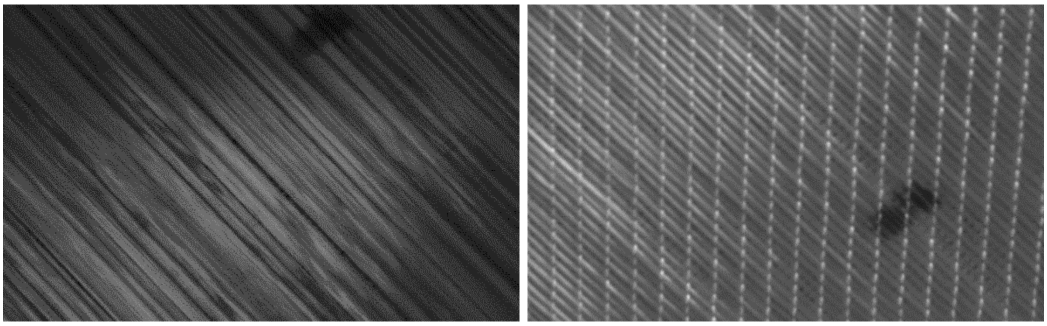


Two layers – 600 g – Tuch – 6 mm – 5 bars:

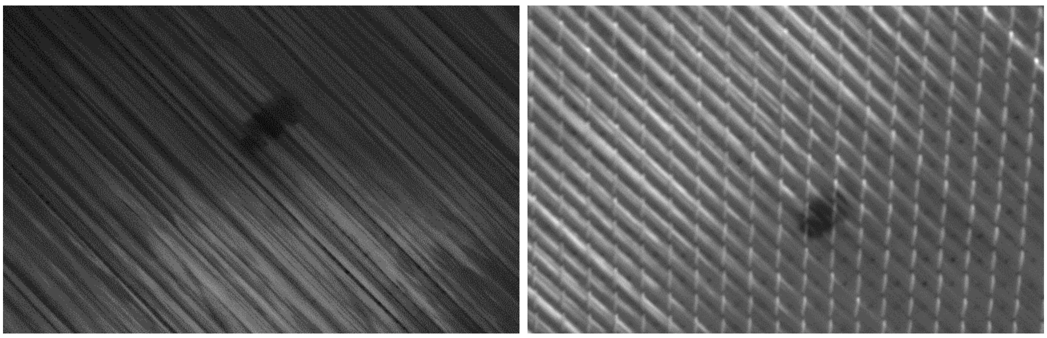


5.3 Two layers – 1200 g

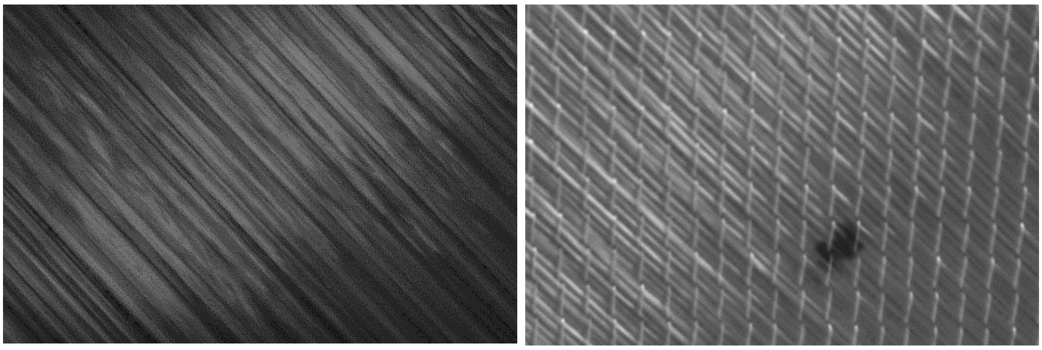
Two layers – 1200 g – Franse – 2 mm – 5.5 bars:



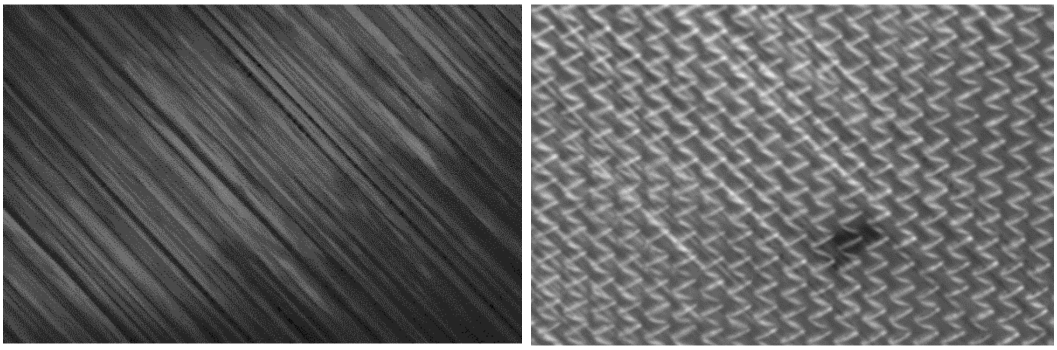
Two layers – 1200 g – Franse – 4 mm – 5.5 bars:



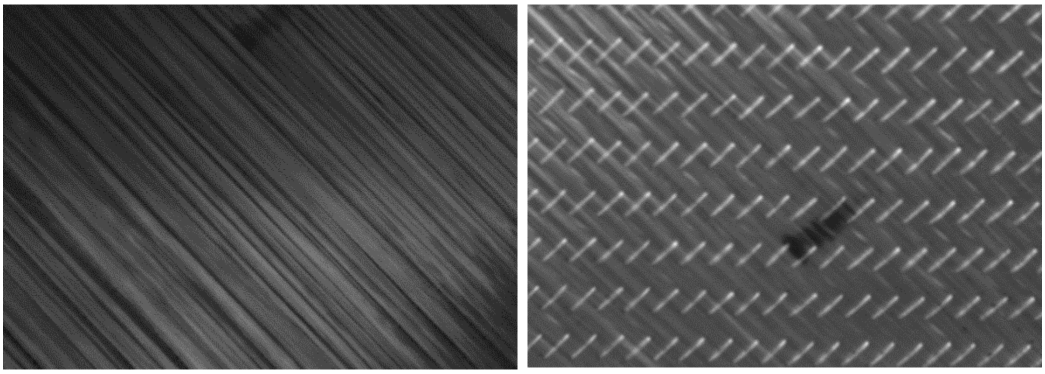
Two layers – 1200 g – Franse – 6 mm – 5 bars:



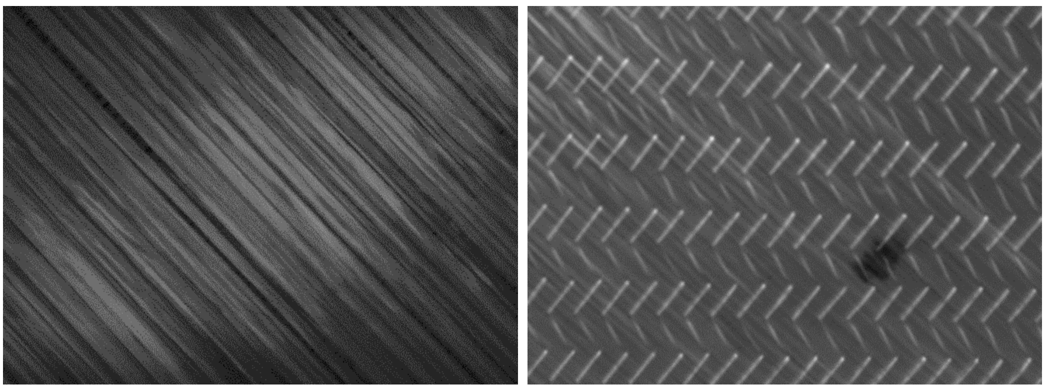
Two layers – 1200 g – Trikot – 2 mm – 5 bars:



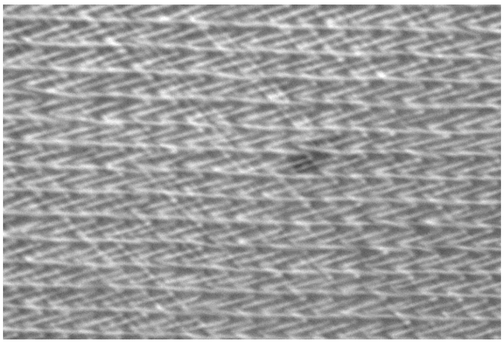
Two layers – 1200 g – Trikot – 4 mm – 5 bars:



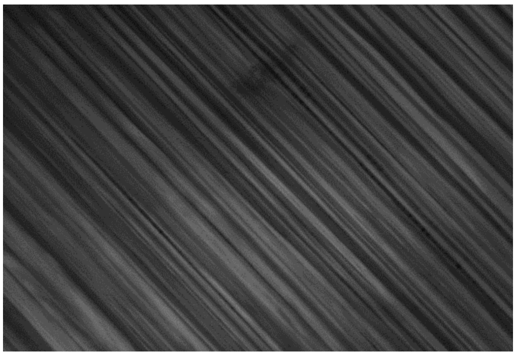
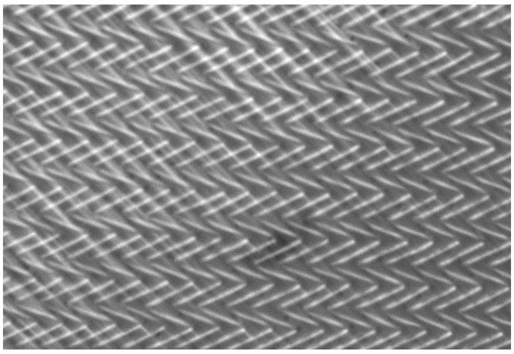
Two layers – 1200 g – Trokot – 6 mm – 5 bars:



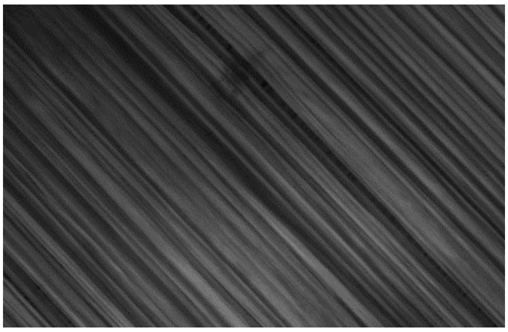
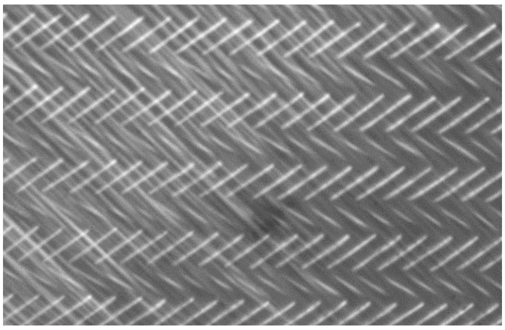
Two layers – 1200 g – Tuch – 2 mm – 5 bars:

Two layers – 1200 g – Tuch – 4 mm – 5 bars:

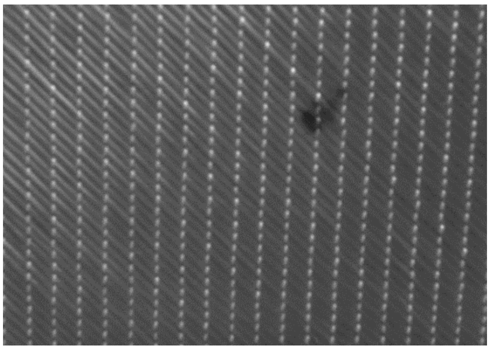



Two layers – 1200 g – Tuch – 6 mm – 5.5 bars:

5.4 Three layers – 1500 g

Three layers – 1500 g – Franse – 2 mm – 4 bars:

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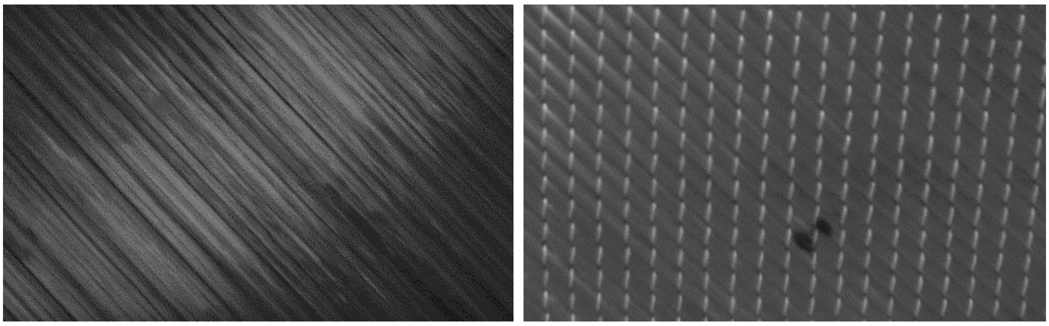

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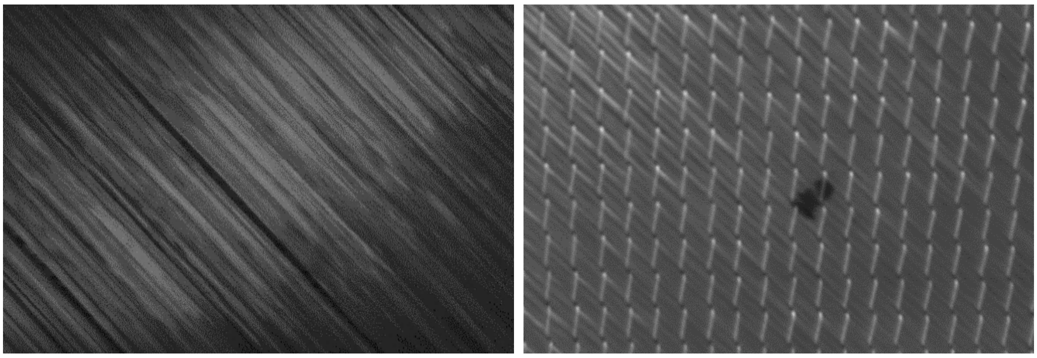
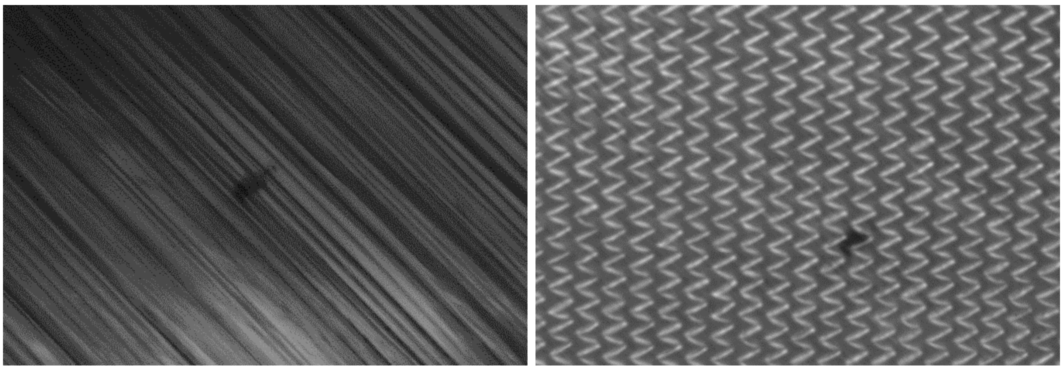


Three layers – 1500 g – Trikot – 2 mm – 4.5 bars:



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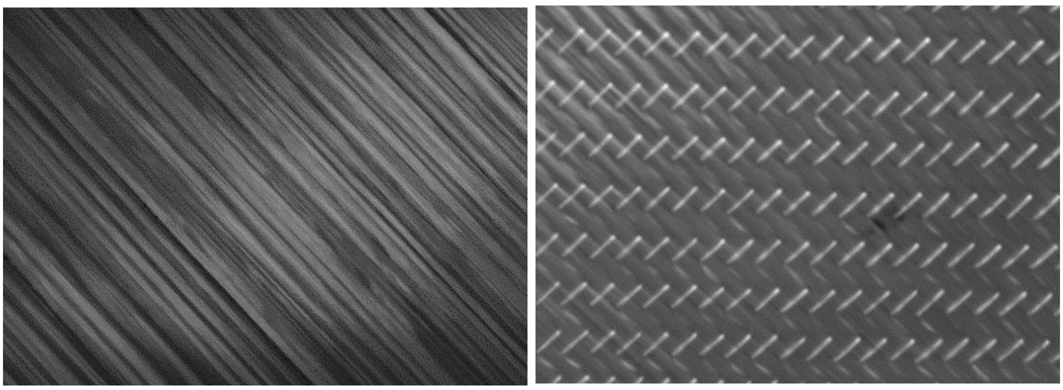

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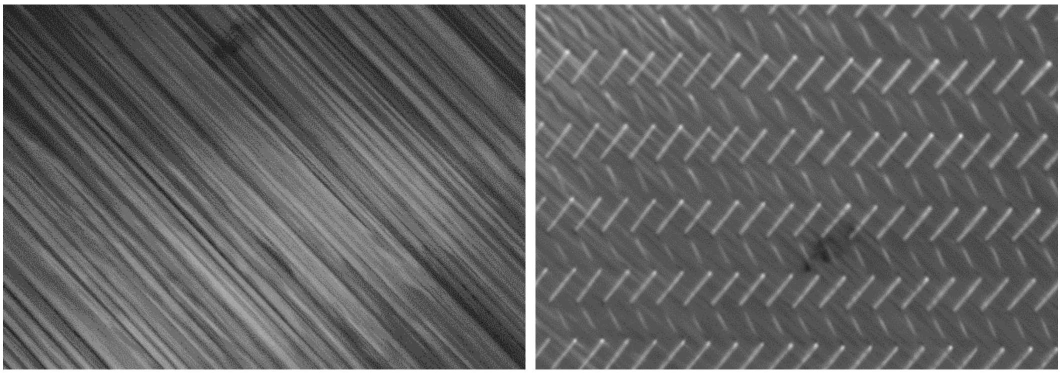

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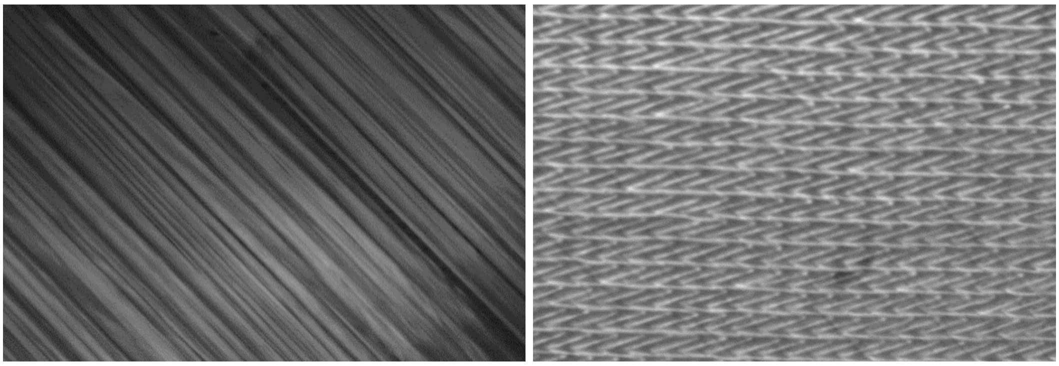
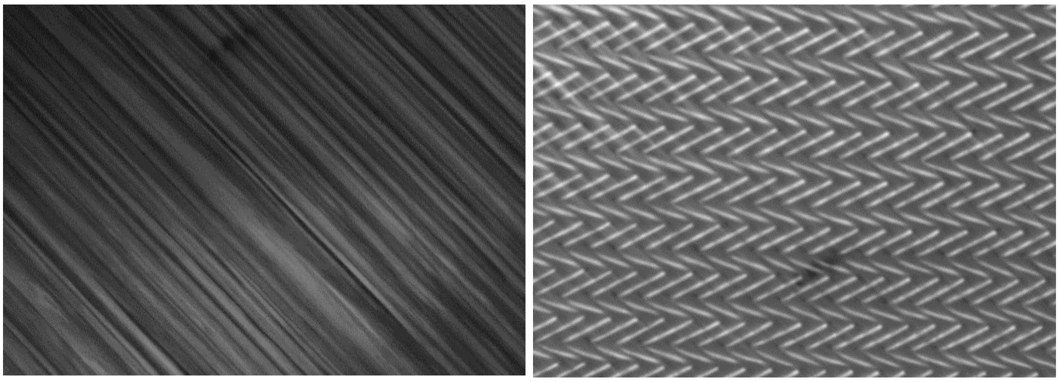


Three layers – 1500 g – Tuch – 4 mm – 4.5 bars:



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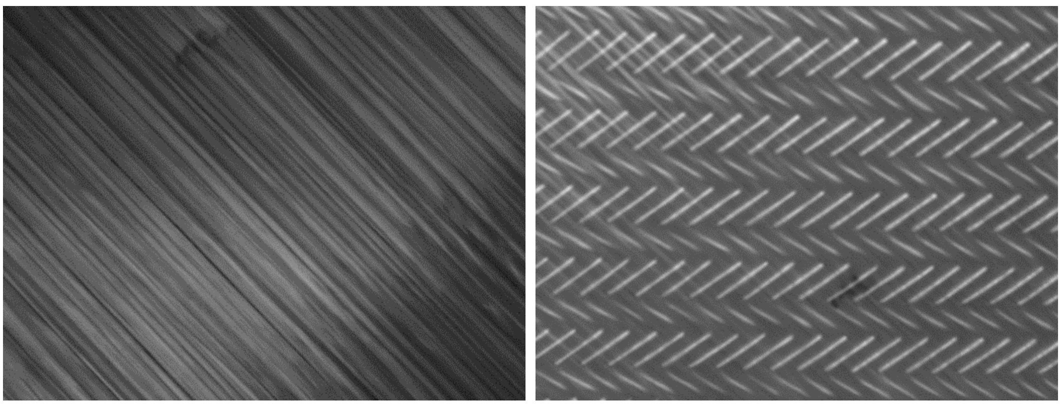

6 Conclusion and summary

In this research project, one part of the fabrication process of multiaxial fabrics is studied. The machine used is the “LIBA Copcentra MAX 3 CNC”. The thesis focuses on the pressure roll of the machine.

An overview of the technological progress of the topic accomplished on the last years is given. All the performed modifications in the machine are explained. The main reason of these modifications is that the system to control the pressure of the pressure roll has to be installed. Also the software of the system that controls the pressure of the machine as well as the design of the experiments are explained. Finally the results of the project are given.

The following conclusions are derived from the experiments:

Focusing on the bond type of the fabric, the highest pressure value is needed for the “Franse” type, around 6 bars, and the lowest pressure value is needed for the “Tuch” type, around 4 bars. The “Trikot” type needs a medium pressure value of 5 bars approximately.

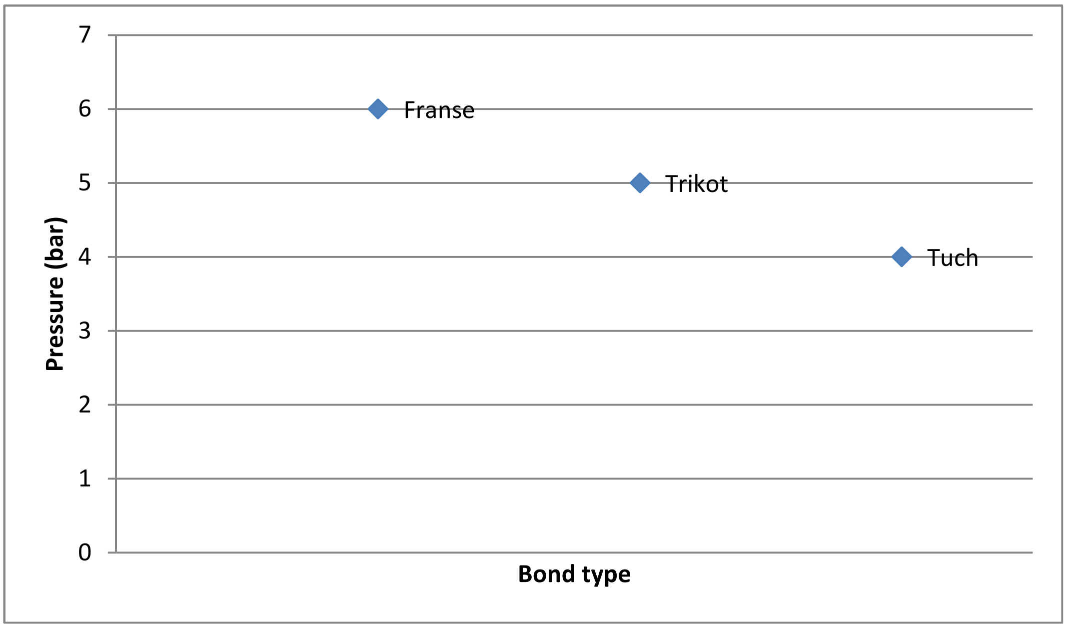

Fig. 6.1: Pressure values related to the bond type of the fabric

The “Franse” type is the most simple bond type. That is a possible reason why the pressure required for a good final quality is higher than the other two types.

About the stitch length, there is not much variation between one and another. The best option is setting a medium pressure value of 5 bars and then, depending on the bond type, change up or down 0.5 bars.

Regarding the number of layers, a higher pressure of about 5.2 or 5.3 bars is required for two layers. With three layers, the optimum pressure is about 4.7 or 4.8 bars.

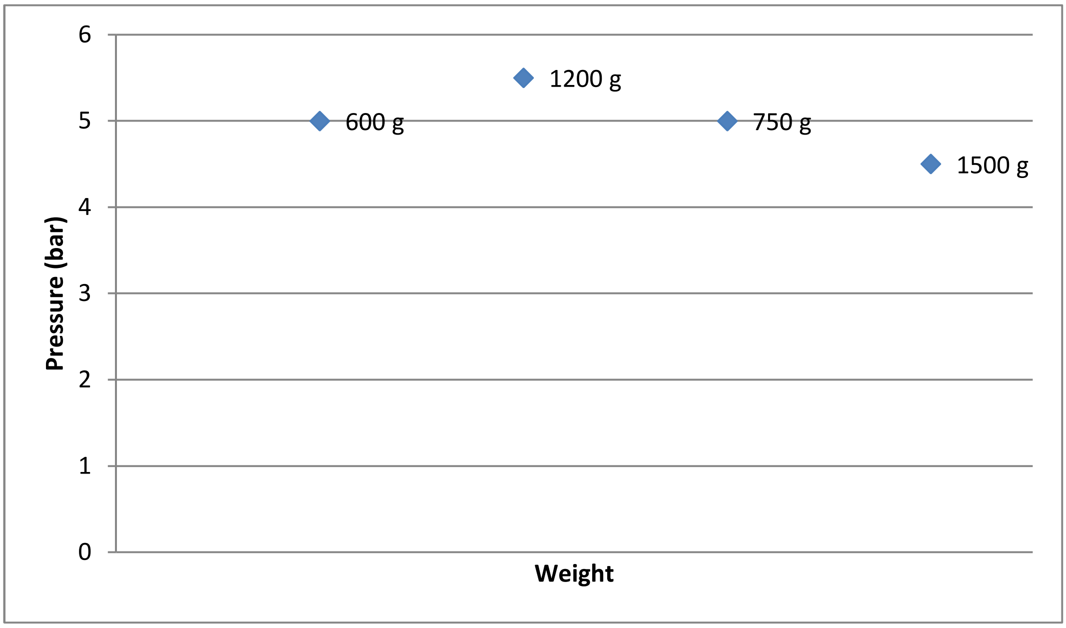

Fig. 6.2: Pressure values related to the fabric weight

A possible reason why the higher pressure is required with two layers is because there is less material, so more pressure is needed to get a fabric without gaps. The convex shape of the pressure roll may have an influence also.

For the future research projects there are further questions to solve. For example, what happens if the fabric has four layers. And a very interesting thing to do is getting an automation of the machine to control the pressure all the time. This way the pressure roll would be always applying the right pressure and the final quality would be optimal.

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Appendix

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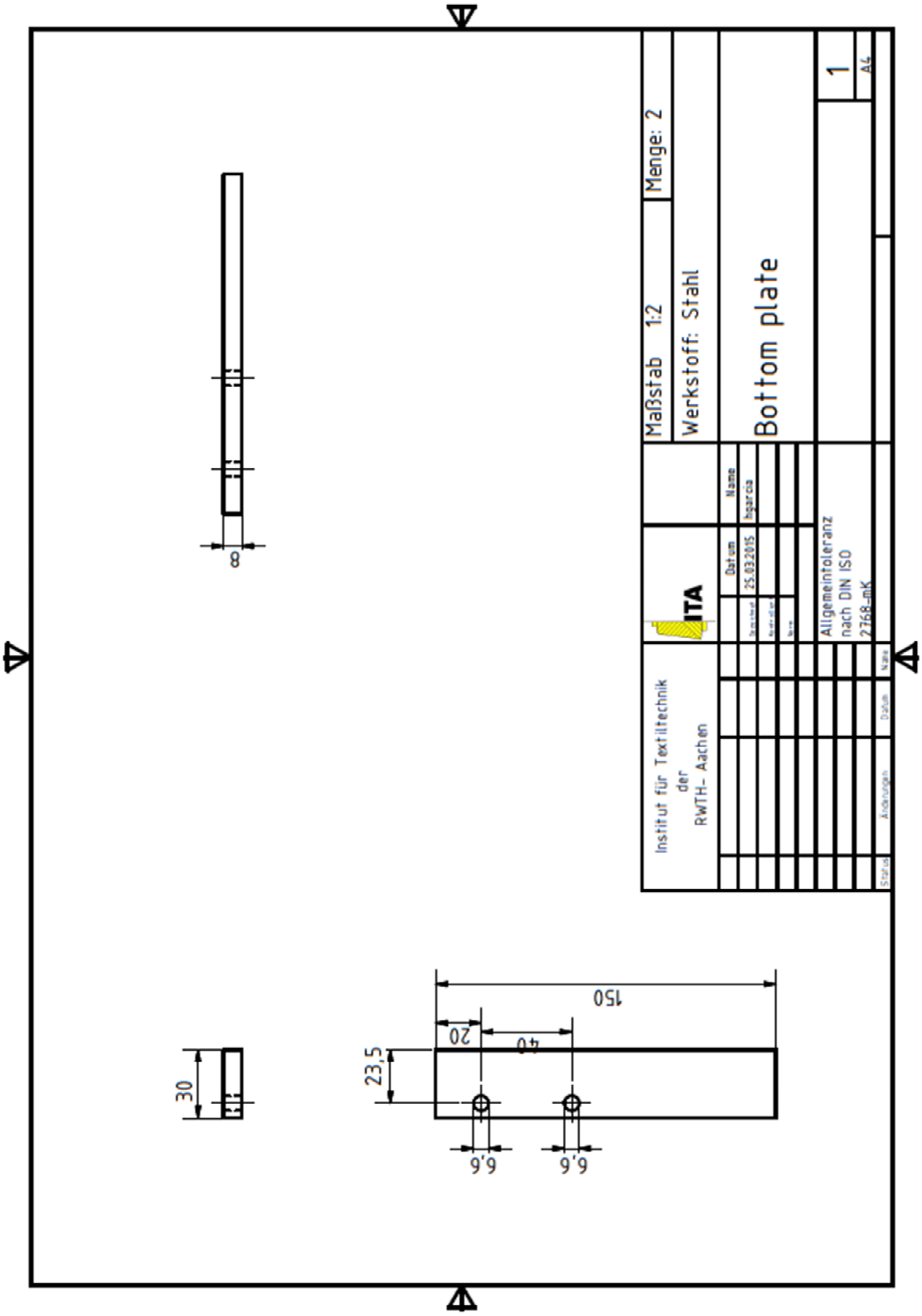

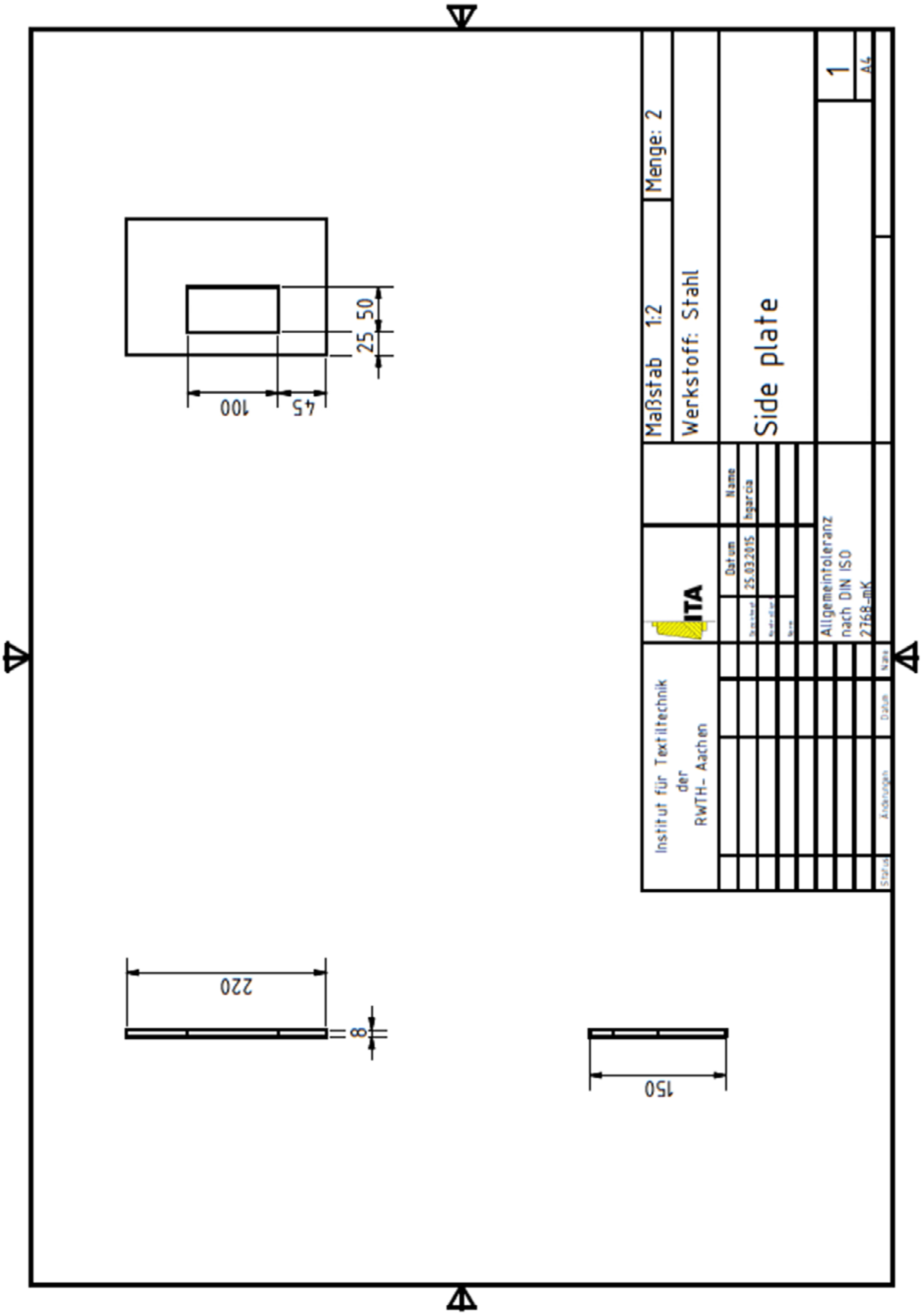
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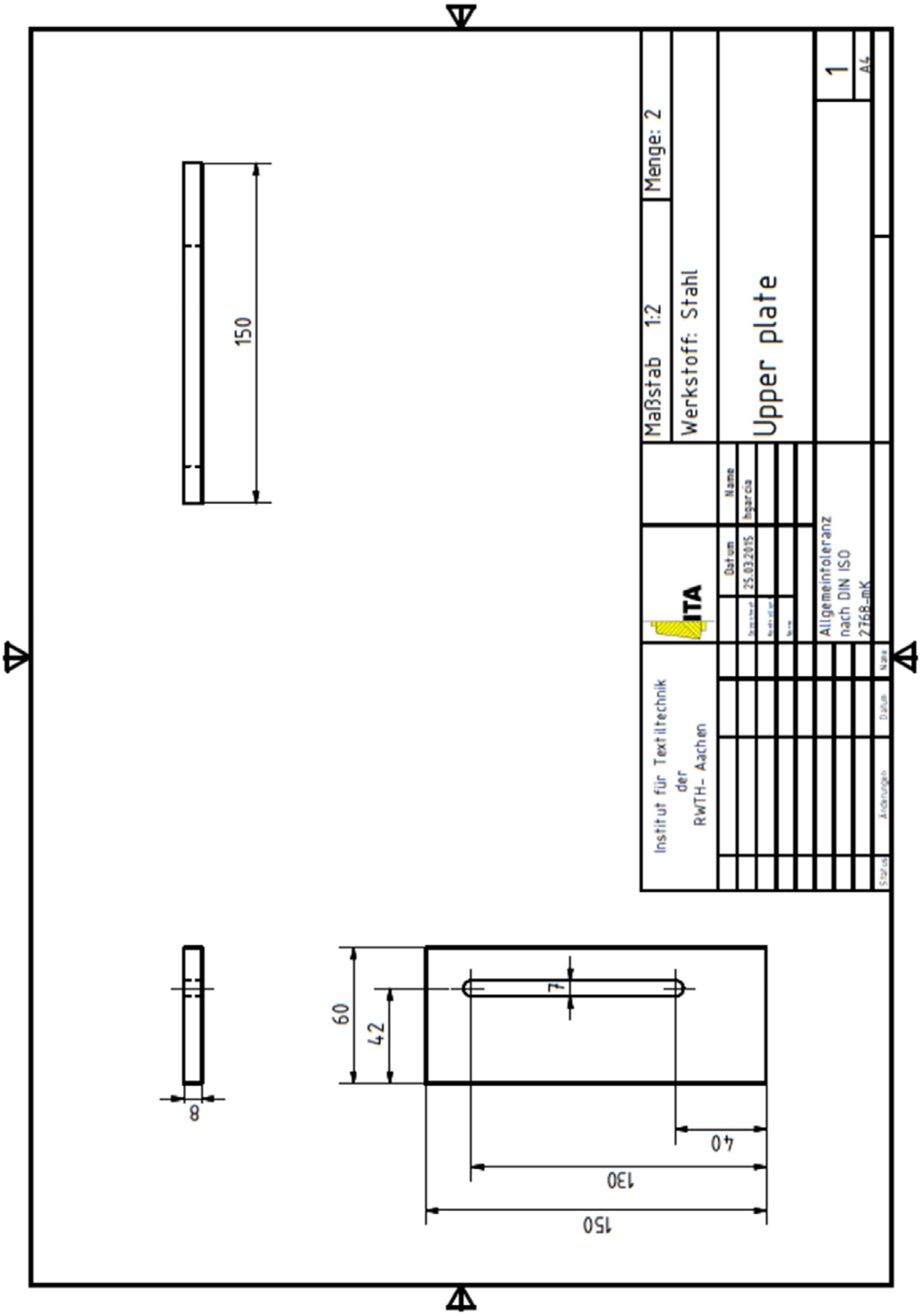
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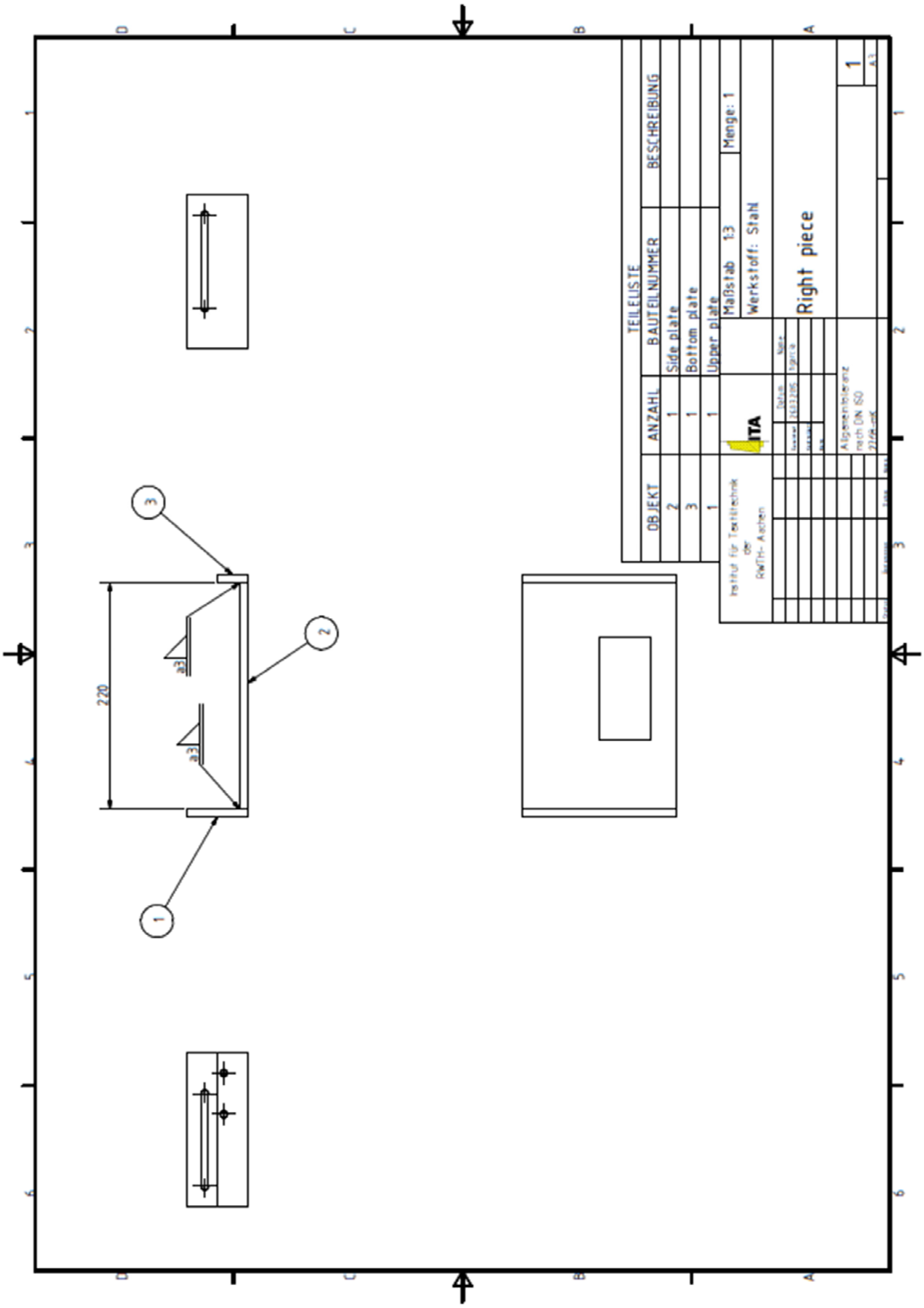
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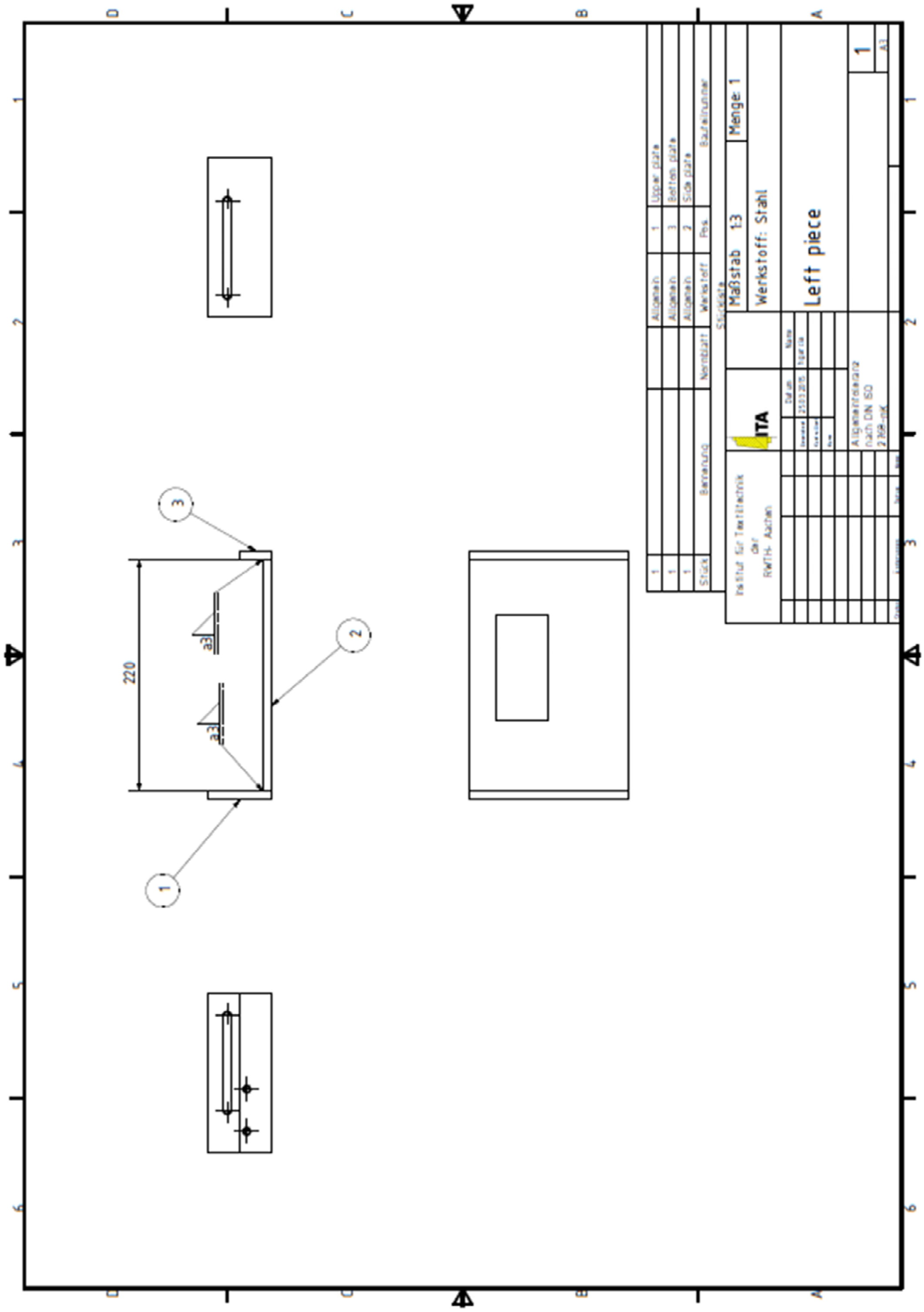
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Institut für Textiltechnik der RWTH- Aachen

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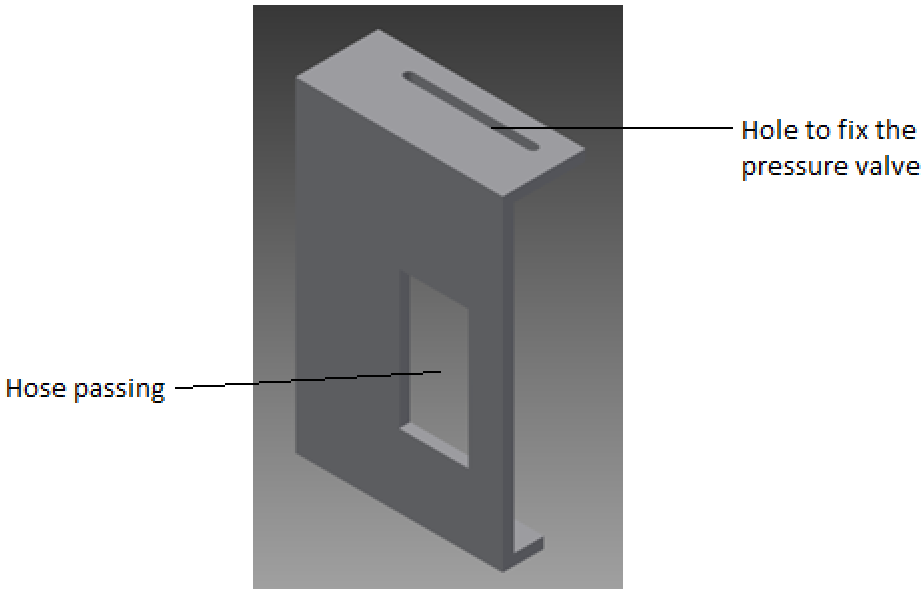

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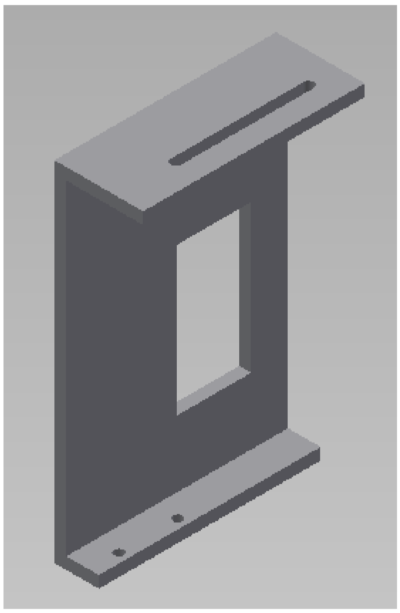

7 Statement

I hereby declare to the best of my knowledge that this thesis contains no material previously published or written by any other person. The work submitted in this thesis is the product of my own original research, except where I have duly acknowledged the work of others.

City, Date

Signature