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Kristofer Ott Sutt

Maculature feeder for the printing line

Makulatuuri etteandeseade trükiliinile

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Author's declaration

I declare that I have written this graduation thesis independently.

These materials have not been submitted for any academic degree.

All the works of other authors used in this thesis have been referenced.

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Student	Kristofer Ott Sutt 132407
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THESIS TOPIC:

(in Estonian) Makulatuuri etteandeseade trükiliinile
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Assignments to be completed and schedule for their completion:

No.	Task description	Deadline
1.	Determine the requirements and functions for the maculature feeder by understanding the process of changeover. Model the surrounding environment, where the maculature feeder will be located.	12.02.2016
2.	Fix the general concept for each function.	February 2016
3.	Fix the detailed design for each function.	March 2016
4.	Conduct an economic analyses, based on the fixed design.	April 2016
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Student Kristofer Ott Sutt, kristofer.o.sutt@gmail.com /signature/ date 08.02.2016

Supervisor Priit Põdra /signature/ date 08.02.2016

Confidentiality requirements and other corporate terms and conditions shall be set out on the reverse side

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FOREWORD

The motivation for the given master thesis came from the company Metaprint AS. There was a need to work out a preliminary design for the maculature feeding process in order to understand what would be the possibilities. The thesis was done in the printing department in Tallinn, all of the data was collected from there. In the collection of data, the technical personnel of the printing factory where of great help.

EESSÕNA

Käesoleva magistritöö motivatsioon tuli firmalt Metaprint AS, kus oli vaja välja töötada makulatuuri etteandmisprotsessi esialgne tehniline lahendus, aru saamaks, millised on selle automatiseerimise võimalused ja eeldatav hind. Töö viidi läbi Metaprint AS'i trükikojas Tallinnas, kust koguti ka kõik andmed. Andmete kogumisel oli suureks abiks trükikoja tehniline personal.

1 INTRODUCTION

This master thesis is done in collaboration with Metaprint AS's printing factory. The task is to create a preliminary design for an automatic maculature feeder that would be able to reduce the manual labor required for the changeover of the printing line, to increase the safety of the maculature transportation process and to enhance the productivity of the ultraviolet (UV) printing line by speeding up the changeover process.

Metaprint AS is an Estonian capital based metal packaging producer. Its headquarters as well as its component and aerosol can making and printing facilities are located in Tallinn. One aerosol can manufacturing facility is located in Pärnu. Metaprint AS employs nearly 300 people in Estonia. The company has three manufacturing profiles: printing and coating of metal sheets, producing tops and bottoms for aerosol cans and producing aerosol cans themselves. Most of the products are exported to other European states.

As Metaprint AS is constantly growing, the need for using the existing production capability is becoming more important. At the moment, the productivity on the main printing line, the UV printing line is not as high as it could be and one factor for this is that small batches are being produced. This means, that there are many changeovers on the line. A part of the changeover process is the maculature transportation process, which at the moment is done manually. It was decided to study, if this process could be automated and what would the technical complexity and the price of this solution be. The preliminary design created in this thesis will be used as an input in the decision making process to assess, if it is profitable to automate this process and to see how big does the investment need to be.

In the first chapter of this thesis the UV printing line will be described and its most important parameters given. Furthermore, the printing and the changeover processes will be analyzed in order to understand what is the as-is situation on the printing line and why is there a need for the maculature feeder. The first chapter will define the borders of the preliminary design and the level of detail.

The second chapter will talk about the market analysis made and give the requirements for the maculature feeder and explain them.

In the third chapter the process of maculature feeding will be specified on the basis of existing processes, when the process functions are defined, then the location for the maculature feeder will be determined. After that, the conceptual solutions for the process functions will be provided and a final conceptual solution for the entire machine done. The third chapter will end with the checking of whether the requirements are met or not.

In the fourth chapter the working principles of the most important systems of the maculature feeder are described and based on these principals the technical solutions worked out and the main components for each described system chosen. Based on the design done, the concept of the control algorithm for the machine is provided.

In the fifth chapter, the economic chapter, the cost of the main catalogue parts of the maculature feeder will be given.

The thesis will be completed by a summary and a conclusion.

2 BACKGROUND

In the following chapter firstly the printing line, where the work will be done, will be defined and its parameters given. When the printing line is defined, then the printing and the changeover processes will be described in order to understand if there is a need for the maculature feeder. The chapter will end with the description of the need for the maculature feeder.

2.1 Printing line description

Metaprint AS has two metal sheet printing lines, one conventional printing line and one ultraviolet (UV) printing line. The names originate from the technology of how the paint is cured. On the conventional line the freshly printed sheets are conveyed through a gas oven, which raises the temperature of the sheets and cures the paint in a conventional way with heat, thus the name conventional. On the UV printing line, the freshly printed sheets are conveyed through an UV drier, which cures the paint instantly. As the UV printing line is the main printing line for Metaprint AS, because it is faster, it is more desirable to improve operations of this line, not the conventional printing line. This is why the thesis is done on the UV printing line. Figure 2.1. shows the UV printing machine from the direction of material motion.

Figure 2.1 UV Printing line Sprint 950

In the following Table 2.1 the most important parameters of the UV printing line are brought out.

Table 2.1. UV printing line parameters

Parameter of the line	**Value**
Maximum sheet format	1000*1220 mm
Minimum sheet format	510*710 mm
Sheet thickness	0,12…0,4 mm
Nominal speed	8000 sheets/h
Actual line speed	5800…6000 sheets/h

As the task of this master thesis covers only the maculature feeding process of the UV printing line, the conventional printing line will not be part of further explanations and discussions.

2.2 Overview of the printing process

Printing on the UV printing line is described as follows. Figure 2.2 shows the layout of the printing machine and the main parts of it are described.

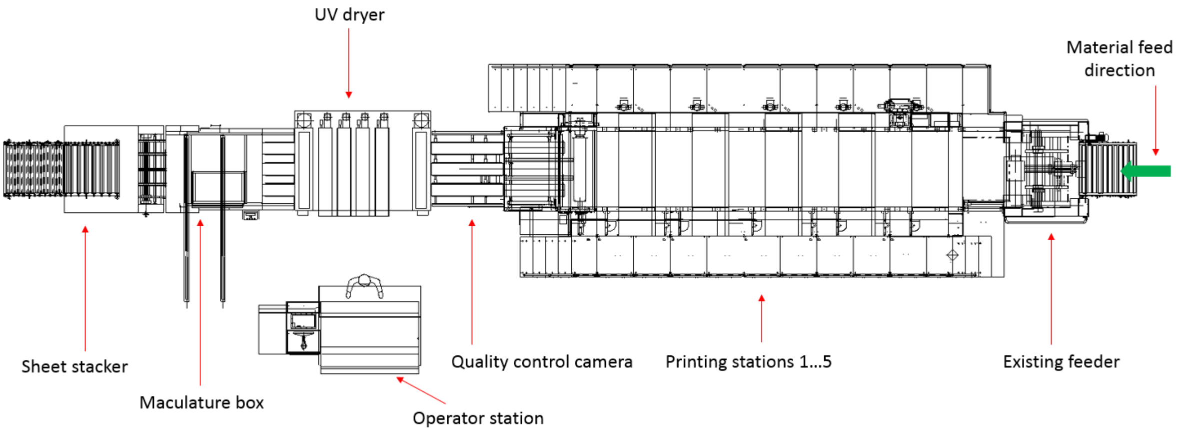

Figure 2.2 UV printing line layout

The printing process starts from the feeder, which can be seen in the right side of the figure above. It feeds blank material sheets to the printing machine. The material sheets are loaded into the feeder by the operator with the forklift. The sheets are transported through the printing stations, shown on the middle part of the figure, and the image is pressed onto the sheet by a rubber cylinder carrying paint. The UV line is a five-color printing line, which means, that five different colors are printed successively onto the sheet. After all of the colors have been printed onto the sheet, it exits from the printing machine and is conveyed under a machine vision quality control system. After the quality control the freshly printed sheets go through the previously mentioned UV drier. Finally, the dried sheets are stacked by the stacker and the printing process is finished [1]

2.3 Overview of the changeover process

The changeover on the printing line means, that either the sheet size, thickness, printed design, colors or all of the above mentioned need to be changed. All of the changeovers are design changeovers, sometimes sheet size is also changed. These changeover processes will be described below.

The design changeover comprises the replacement of the five printing plates in the five printing stations of the machine [2]. The old printing plates are detached from the plate cylinders and the new ones are placed in the machine and automatically rolled around the cylinder. The printing plates are aluminum sheets with a thickness of 0,4 mm, they have a digitally engraved design on them. Inside the printing machine the plate cylinder rotates, transferring the design onto a rubber cylinder, which is called the impression cylinder. This cylinder also rotates and in turn presses the design onto the blank sheet.

During the design changeover with sheet format change the material sheets with previous format have to be removed from the feeder. Also the used maculature sheets have to be removed from the maculature box and the ready printed sheets from the stacker. After all these old format sheets removed, the feeder and stacker need to be reset to the new sheet format. This means that the guides that touch the sheet need to be positioned according to the new sheet size.

After the design or sheet format changeover ended, the printing process needs to be started again. In order to ensure a good printing quality, there are so called maculature sheets sent through the printing stations first. They are sent through the printing machine as long as the aforementioned cylinders inside the printing machine are covered with paint. In best case it needs around 80 sheets of maculature to get the colors correct. The stack of 80 maculature sheets is loaded on top of a stack of around 2000 blank material sheets with the new format. By using a forklift, they are loaded into the feeder. The stack is centered to the printing line by the feeder. The 80 maculature sheets are then fed through the printing machine followed by one blank material sheet from the stack. The operator checks the color parameters on the printed sheet and if necessary repeats the previously described cycle until the correct print parameters are reached. The result is satisfactory after an average of three repetitions. At present the loading of the maculature sheets is done manually by the operator. For the first feeding run the operator only needs to load the maculature sheets onto the material stack before it is loaded to the printing machine feeder. For the second cycle however, the operator needs to load the maculature sheets on top of the material sheet stack, that is already inside the feeder. This loading process is more laborious, because the operator has to carry the maculature sheets from a stack about 5 m away, as can be seen in Figure 2.3, and to load them onto the material sheet stack. The printing result is satisfactory after an average of three repetitions. This cycle repetition means, that the operator has to manually transport around 240 metal sheets for every changeover, the mass depends on the sheet format, but it is on an average of 300 kg. He can carry about 20-30 sheets at a time, so he is walking the 5 m distance between the maculature stack and the feeder in worst case 8 times.

The following figure shows the as-is maculature transportation journey and the existing feeder in a top view.

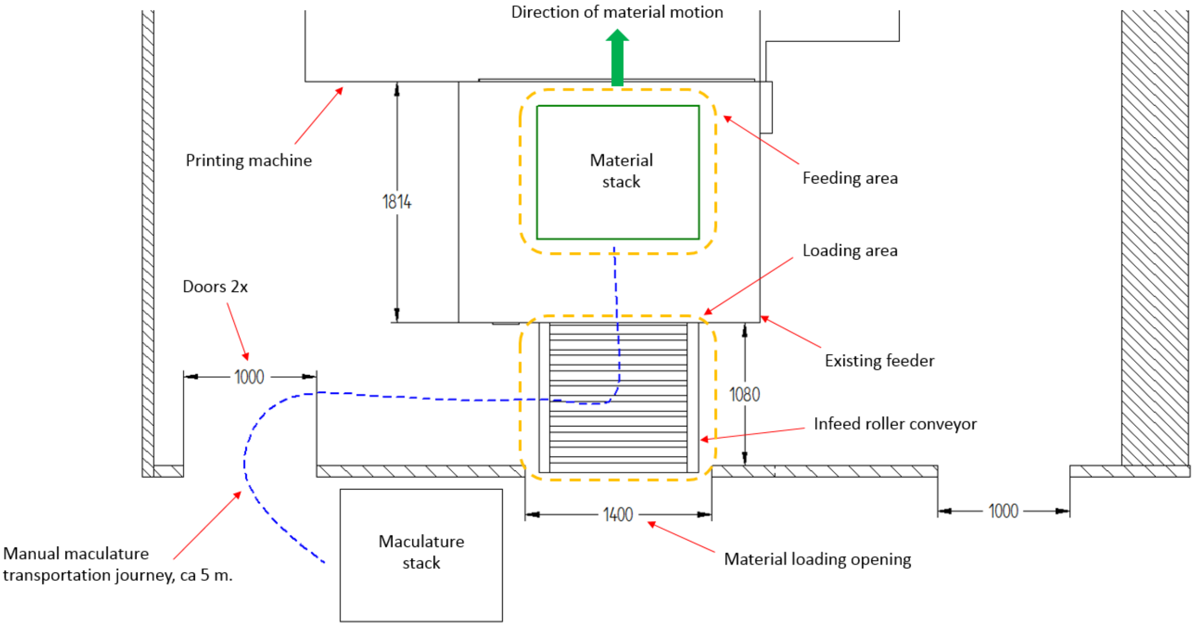

Figure 2.3 The as-is situation of transporting the maculature manually

In the Figure 2.3 the maculature stack is shown. The printing line’s separating wall with its doors lies between the stack and the printing machine. The material loading opening can be seen right hand side of the maculature stack. In the middle of the figure the infeed roller conveyor is shown. The material stack is loaded onto this conveyor with the forklift through the material loading opening and following transported to the feeder. Over the infeed conveyor the existing feeder and the printing machine are shown. The blue dashed line shows the maculature transportation journey made in the second and following maculature repetitions. In green color is shown the material stack positioned inside the feeder and the thick blue arrow represents the material motion through the printing machine. The two dashed orange boxes represent the loading area and the feeding area. The bottom one represents the loading area, where the loading of the material stack takes place and the top one represents the feeding area, where the feeding takes place.

2.4 Need for the maculature feeder

As described above starting the printing process including every changeover is very labor intensive. The changeover process however is done eleven times within a twelve-hour shift in average. The flexibility in usage of the printing machine is one of the companies' most important competitive edges.

The problem to be solved in this thesis is to find an automated solution for the maculature feeding process, which eliminates the need for the operator to transport the metal sheets from the maculature stack to the feeder manually. This maculate feeder should shorten the time of the changeover process as well as save manual labor.

The motivation for this automated solution is consequently both economics and working environment safety related. Economics related in the sense, that the faster the maculature transportation is done, the more time the operator could spend on other changeover related tasks and hence, the less time the changeover would take in total. An automated solution is also working environment safety related in the sense, that the mass of the sheets lifted manually is on an average of 300 kg, and as the sheets are (0,17…0,25) mm thick the threat of a cutting or heavy weight lifting injury is very high. By automating this process, it is possible to solve both of these problems.

2.5 Level of detail of the design

A general engineering design process follows the steps; first a problem is defined and the requirements for the solution are given [3]. Then research is done in order to collect information about this problem, measurements are taken, layouts created. After there is enough information, conceptual solutions for the problems are created. Then comes the first decision phase, the conceptual solutions are compared and the most suitable one chosen. During the whole process new information about the problem is collected. Based on the conceptual solution, a preliminary design is created, the level of detail of which is greater than in the conceptual phase. In the preliminary design phase, technical solutions are provided for the conceptual design, possible parts are chosen from catalogues, conceptual control algorithms are created. The preliminary design phase ends with a detailed understanding of how to solve the problem and an estimate of how much would it cost. After the preliminary design phase comes the second and final decision. The decision about will this problem be solved and to which extent, how much money will be spent. After the final decision is taken, the detailed design phase begins where the solution is worked out in full detail and manufactured [4].

In this thesis, the engineering design process is completed until the preliminary design. This work aims to be a helping material in the decision making process by providing information about the technical solution which are required to solve the task of maculature feeding and how much would the task of automating this process cost. Since this is the preliminary design for the maculature feeder, all of the detailed drawings and schematics will be done in the next step of design, in the detailed design process. Accompanied by a risk analyses based on the European machinery directive [5] and the Low voltage directive [6].

3 REQUIREMENTS FOR THE FEEDER

A conducted market analysis didn't give any satisfactory results for a suitable technical solution from either the printing machine manufacturer or any third party. The reason could be, that as this model of printing line is a high speed printing line and it is meant for long time production runs, the task of transporting the maculature is not done so often and the problem is not so relevant, because in long runs are usually few changeovers done. Because of this, the need on the market is low and manufactures don't produce automated maculature feeding systems. As nothing was found on the market, the decision to create a new system for Metaprint AS needs was taken.

Following the requirements for the machine are defined and analyzed.

3.1 Requirements

These requirements listed here are defined by Metaprint AS and are taken as a basis to create conceptual solutions.

1. Inputs for the feeder have to be the existing maculature stacks with formats from (510x710…1000x1220) mm, thickness of (0,12…0,4) mm and height of (10…160) mm;
2. Maculature stack weighing up to 1600 kg;
3. The maculature feeder has to be a removable part of the existing feeder;
4. Option to choose the maculature amount with an accuracy of ± 5 sheets;
5. Sheet separation before feeding;
6. Automatic fed stack positioning;
7. Cycle time under 1 min 30 seconds;
8. Has to be as compact as possible;
9. Use of as many standard parts as possible.

The requirements listed above are analyzed and divided into two groups: fixed ("must-have") and not fixed ("nice-to-have"). Following, each of the above listed requirement will be described and explained.

There are six fixed requirements that have to be met in the automatic solution for a maculature feeder.

The first requirement about the format of the maculature sheets is important, because the formats of maculature are existing and known and they fall into this range. It is important to note, that the minimum and maximum of this range are the theoretical smallest and largest formats. They are the formats that the printing machine is capable of using, so it is preferred, that the maculature feeder would be able to work with the same formats. This is a fixed requirement.

The idea of the third requirement is, that the maculature feeder has to be a standalone machine or a collection of standalone subsystems. This is required, because it is not favorable to rebuild or redesign any parts of the existing feeder. This is a fixed requirement.

The fifth requirement about the sheet separation is a fixed requirement, because the maculature sheets sometimes stick to each other. It is not allowed to feed double sheets (two sheets stuck to each other) to the printing machine, because this can damage the printing machine. The stickiness of the sheets depends on how many times they are run through the printing machine, what is the temperature they are stored in and how long are they stored. The maculature sheets are in fact scrap sheets. They are run through the printing machine many times, this means that there are many layers of paint printed on each other that will never completely dry hard, so all the above mentioned factors contribute to the sheets sticking.

Also the seventh requirement of having the cycle time under 1 minute 30 seconds is a fixed requirement, because the new machine being built can't be slower than the existing work cycle, because at present there is already problems with the efficiency of the line.

Finally, also the eighth and ninth requirement are both fixed in order to use the space rationally and to simplify the design.

The following requirements are considered as nice-to-have features.

The second requirement comes from the height of the maculature stacks. This is not a fixed requirement, as the height of the maculature stack can be modified by the operator.

The fourth requirement of choosing the amount of maculature in a range of ±5 sheets is a nice-to-have feature, it is not fixed.

The sixth requirement of automatically positioning the fed stack means that when the maculature stack is fed to the material stack, it needs to be checked, if it is in the correct position relative to the material stack and if not, then positioned correctly so that the edges of the combined stack are straight. To do it automatically is a nice-to-have feature.

4 GENERATING THE CONCEPT

In the following chapter, the maculature feeding process and the functions inside of it will be defined, taking as a base process the material feeding process. The differences in the two processes will be described and the functions explained. When the process and the functions are determined, then the location of the feeder will be decided. When the location for the feeder is known, then different solutions for every function will be proposed and finally decisions taken, how to solve each function.

4.1 Determining the process for maculature feeding

In order to work out the concept for the maculature feeding machine, the process of feeding the maculature sheets to the printing machine feeder has to be determined and analyzed and the single tasks respectively have to be defined. In order to determine the process for maculature feeding, the existing process of material sheet feeding is taken as a base to which the requirements for maculature feeding and the resulting characteristics are added in order to create a new process of maculature feeding. Following the steps in the material feeding process done by the printing machine feeder are described.

Step 1 - positioning of the material stack

As described on Figure 2.3, the material stack is loaded with the forklift onto the loading roller conveyor and transported to the feeder. Inside the feeder the front edge of the stack (in the direction of moving shown on Figure 2.3), the height and the sides of the stack are determined by the feeder in order to position the material stack by its center to the printing machine. The front edge of the stack is determined by pushing the front edge against a fixed stack stop. The height is determined by lifting the stack's top edge to the feeding level, which is about 1 m off the ground. The stack's top edge is kept constantly on this level, when sheets are fed to the printing machine, then the stack is lifted by this amount, as described below. The sides of the stack are determined by automatically moving side magnet assemblies. These moving assemblies have ferrite magnets inside of them for separation purposes and end switches to stop them from moving, when they have reached the stack's side. Positioning the material stack is the first step in the process of material feeding.

Step 2, separating an individual sheet

The second step in the process of material feeding is to separate the top sheet of the stack from the rest. This is done in combination with side magnets, that lift the sides of the stack, with air nozzles, that blow air under the sheets and with suction cups that grab the top sheet and lift it up, separating it from the remaining stack.

Step 3, feeding the sheet

The third and final step in the process of material feeding is to feed the separated sheet to the printing machine. This is done by the aforementioned suction cups, which move in a straight line and carry the sheet onto a centering table, which pushes it into the printing machine. Now the whole stack is lifted by a small amount to ensure that the top sheet is on the feeding level. This was the last step in the process, now the cycle will start all over from the second step and run as long as the stack of sheets is empty.

As described in the beginning of this chapter, the material feeding process will be taken as a base and the requirements for maculature feeding as well as the resulting characteristics will be added to this process to create a new process. Following the requirements for maculature feeding and the characteristics resulting from these requirements are described.

As mentioned above in the process of material feeding one sheet is separated from the main stack and then fed to the printing machine. Different from that the requirement for the maculature feeding process is not to separate and feed a single sheet, but rather a stack of maximum 20 mm is separated and fed from the maculature stack to the top of the material stack. 20 mm, because this is the amount of maculature sheets required to run through the printing machine in order to get a single test sheet as described in the changeover process. Since there is a requirement of 1 minute and 30 seconds for the cycle time, then to feed a stack of sheets is more reasonable. From this requirement two characteristics for the maculature feeding process become clear.

Characteristic 1, pushing the separated stack

As the requirement is to separate a stack of sheets and not a single one, lifting the stack as was done in the feeding process is not reasonable, because the separated stack of sheets can weigh up to 190 kg. It is more reasonable to push it from the maculature stack to the material stack. Pulling the stack is not desirable, as this requires gripping the stack in order to pull, which can scrape or damage the stack.

Characteristic 2, separating individual sheets in the separated stack

As described in the requirements chapter for the maculature feeder, the maculature sheets can stick to one another. As it is a requirement for the maculature feeding process to feed a stack of sheets, the individual sheets need to be separated from each other so they could be fed to the printing machine.

Following the differences of the material feeding process and the maculature feeding process are brought out in Table 4.1.

Table 4.1 Differences between the material and the maculature feeding processes

Material feeding process	**Maculature feeding process**
One sheet is separated and fed	A stack of sheets is separated and fed
The sheet is lifted in order to be fed	The stack is pushed from the maculature stack to the material stack
Sheets don't stick to each other and are separate in the stack	Separation of individual sheets in the stack to be fed

Based on the analysis described above the maculature feeding process and its individual functions are brought in the Figure 4.1. The process functions follow the journey of the feed stack from the maculature stack to the feeder of the printing machine.

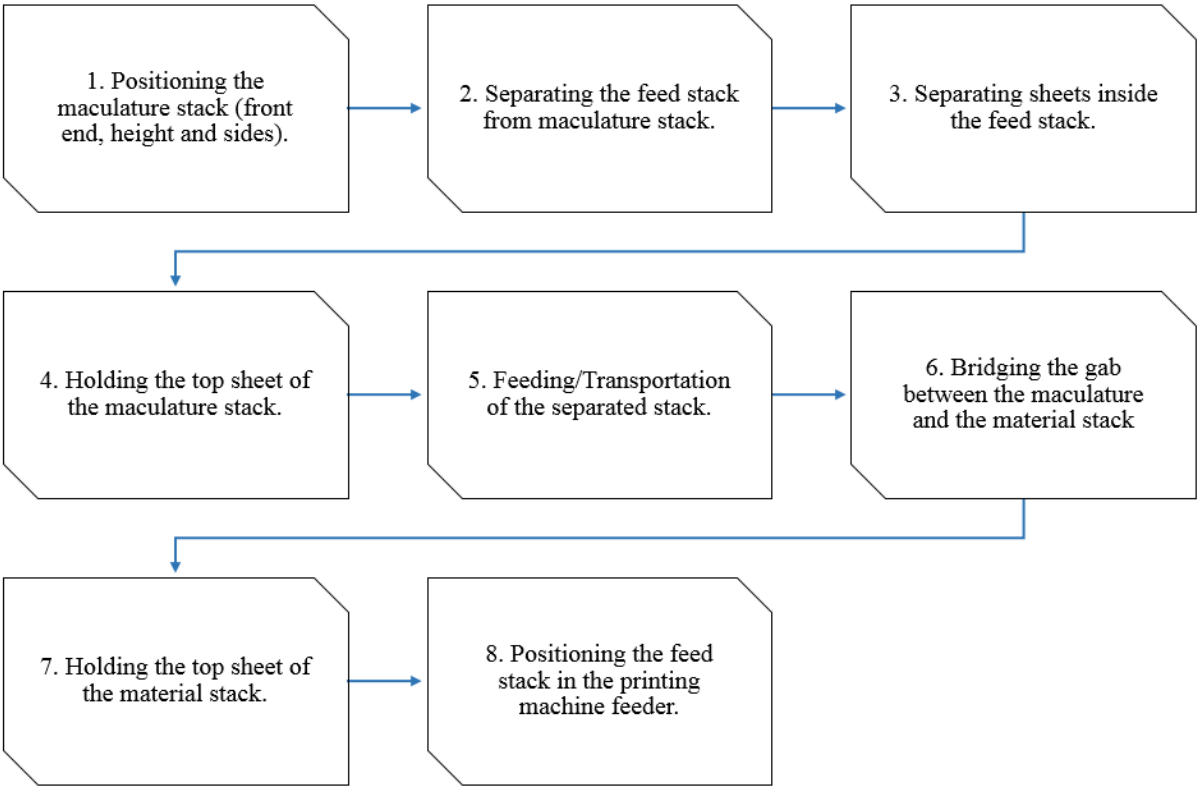

Figure 4.1 Maculature feeding process functions

Function 1, Positioning the maculature stack

As described in the process of material feeding, the external borders of the material stack need to be defined by the printing machine's feeder. The same applies for the maculature feeding, in order to work automatically with any given stack format, external borders of it need to be defined.

Function 2, Separating the feed stack from the storage stack

This is the requirement for the maculature feeding process, that a stack of maculature sheets is to be separated and fed, feeding a stack speeds up the process considerably. The feed stack needs to be separated from the storage stack, because the sheets can stick to each other due to the many layers of paint on them.

Function 3, Separating sheets in the feed stack

This function was already described in the characteristics section for the maculature feeding process. As described, the purpose is to separate individual sheets in the stack being fed, because maculature sheets can stick to each other.

Function 4, Holding the top sheet of the maculature stack

As described in the first characteristic for the maculature feeding process, the maculature feeder separates a stack of sheets, that can weigh up to 190 kg, and the method of feeding it is to push it off the maculature stack. The top sheet of the remaining maculature stack needs therefore to be held stationary, so it would not move with the stack being fed.

Function 5, Feeding the separated stack

The main function in the process of maculature feeding is the transport/moving of the maculature sheets to be fed from the maculature stack onto the material stack inside the printing machines feeder.

Function 6, Bridging the gap between the maculature stack and the material stack

This function refers to the fact that there are two stacks: the maculature stack and the material stack. The maculature feeder should move the separated stack from the maculature stack onto the material stack. There has to be a bridge between the stack to overcome the gap.

Function 7, Holding the top sheet of the material stack

As the separated stack is pushed from the maculature stack onto the material stack, the top sheet of the material stack needs to be fixed to stop it from moving.

Function 8, Positioning the fed stack

This function refers to the act of ensuring that the edges of the stack, that was fed, and the existing material stack are aligned. This is important for the printing machine feeder to be able to work properly.

4.2 Location of the maculature feeder

Before possible engineering solutions, a high level decision has to be taken about the location of the maculature feeder in relation to the existing feeder. The following figure shows the position of the existing feeder, the possible locations 1 and 2 of the maculature feeder and their surrounding in top view.

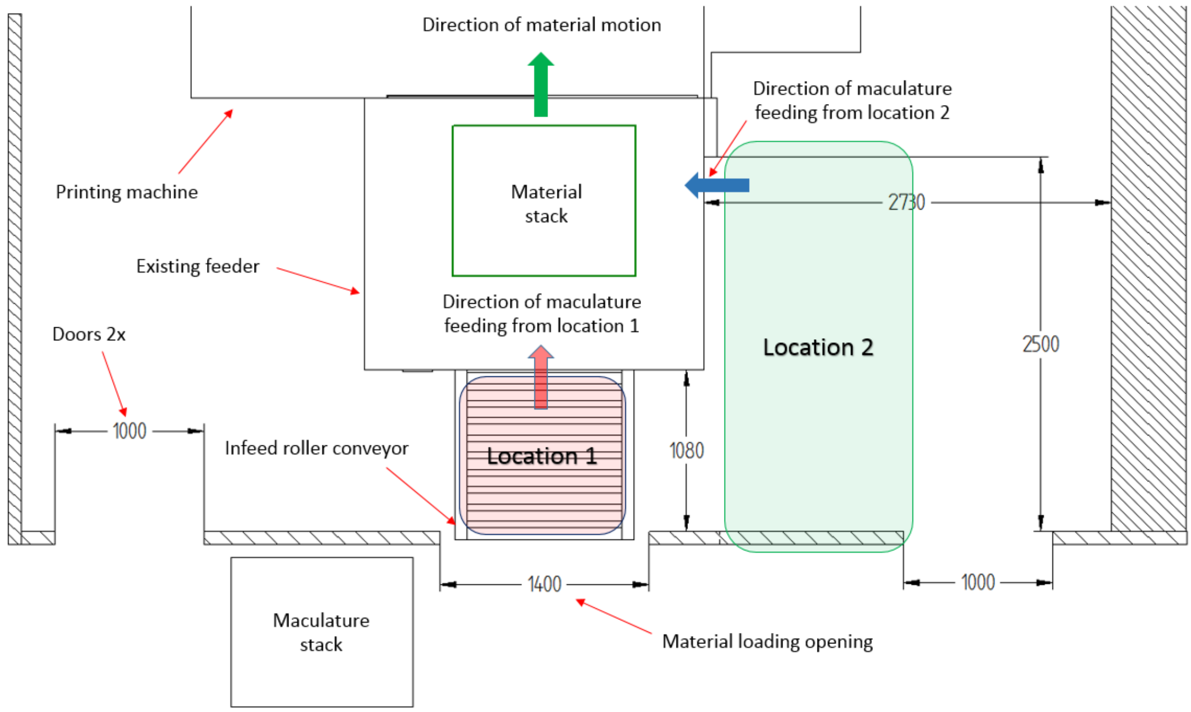

Figure 4.2 Possible location for the maculature feeder

On the above figure the two realistic locations for the maculature feeder are shown in red, location 1, and in green, location 2. The first location is in front of the existing feeder on top of the infeed conveyor. The thick red arrow shows the possible maculature feeding direction from this position. The second possible location is on the right side of the printing machine feeder. The thick blue arrow is showing the maculature feeding direction. The thick green arrow shows the direction of how the material is printed and moved through the machine. Following the two possible locations are analyzed and their advantages and disadvantages brought out.

Location 1, in front of the printing machine

The location in front of the existing printing machine feeder could be advantageous, because then the maculature feeder would follow the material feed direction. The material is also loaded onto the printing machine feeder in this direction. Furthermore, the material and maculature stacks could be loaded onto the machine from the same location. The disadvantage of this position is, that the front side of the existing printing machine feeder needs to be accessible by the operator for adjustments. So, the future maculature feeder located on top of the infeed conveyor would need to be removable on request. This removing feature of the feeder certainly adds to the technical complexity of the design.

Location 2, next to the printing machine

As can be seen on Figure 4.2, the space on the right side next to the printing machine feeder is free. A system placed or installed there wouldn't need to be removable from its place in order to adjust the existing feeder or the printing machine. This is an advantage over the first location. The disadvantage of this position is that the action of maculature feeding, shown with the thick blue arrow, will not follow the normal material feed direction, shown with the thick green arrow. This means, that from that location the material stack inside the existing feeder is not naturally accessible, as it would be from the back of the feeder. The existing feeder has a functional part (the side magnet assembly mentioned above) on its right side and that side is covered by a steel cover as well.

Final location

Comparing the two locations and their advantages and disadvantages, the decision was taken to position the maculature feeder on location 2, on the right side of the feeder. The reason being, that the space there is free and the systems there would not have to be removed, also the covers from that side of the existing feeder can be removed and the material stack can be lowered in order to bypass the side magnet assembly, which is located on that side in the feeder. From now on, all the solutions discussed will apply to the maculature feeder located in location 2. The Figure 4.3. shows the final location.

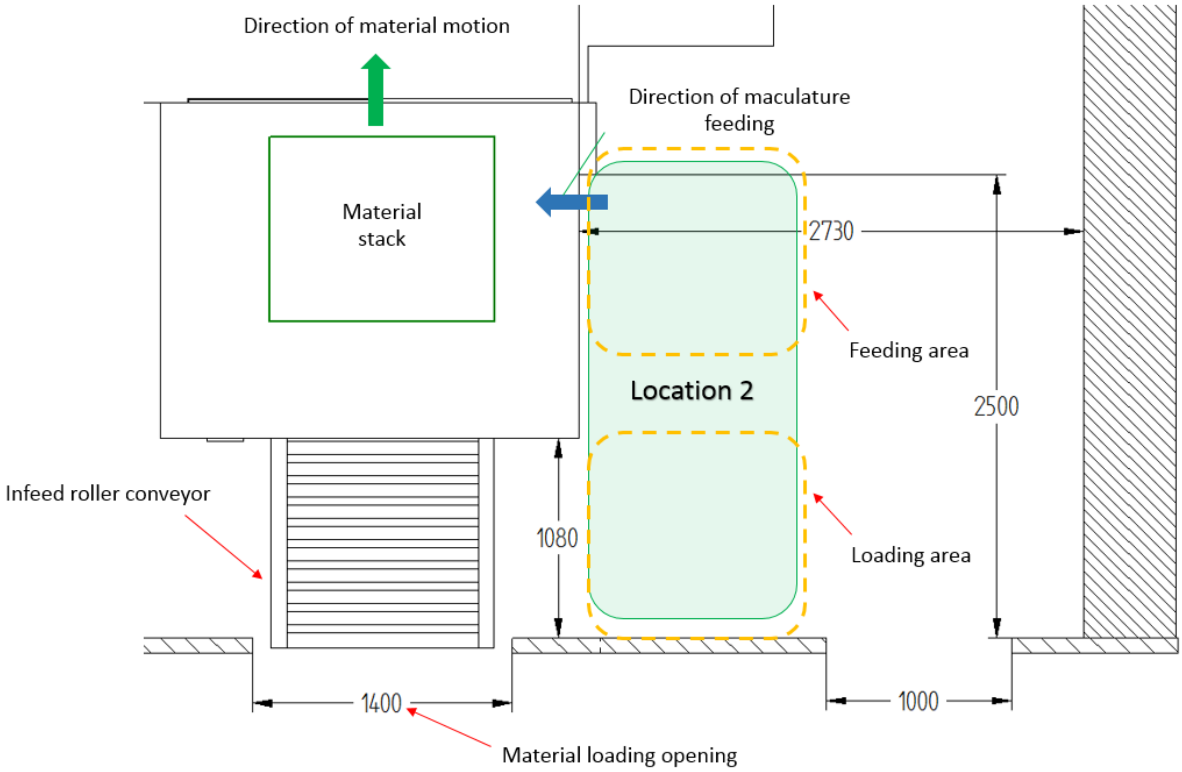

Figure 4.3.Final location of the maculature feeder

The above figure shows the location, where the maculature feeder will be placed and the feeding direction, the blue thick arrow. The area of location 2 is divided into two sections like was done in Figure 2.3: the loading area, the bottom orange box and the feeding area, the top orange box. As with the existing feeder, the area where the stack is loaded with the forklift, on the bottom side of the figure is the loading area and where the feeding actions take place, this is the feeding area, this distinction is necessary for the following chapters.

4.3 Conceptual solutions for process functions

In the Table 4.2 below the main functions for the maculature feeding process are brought out, accompanied by possible solutions for each function. The solutions given are a result of a brainstorming session, they are not based on each other consecutively [3]. The given morphological matrix [7] in Table 4.2, helps the designer to think of different solution for the same task. In this chapter the presented solutions are firstly described and finally compared to find the best solution for every function.

Table 4.2 Different solutions for realization of the process functions

No	**Function**	**Solution 1**	**Solution 2**	**Solution 3**
1	Positioning of the maculature stack (front end, height and sides)	Stack is moved in one axis, surrounding systems move	Stack is moved in 3 axes, surrounding systems are stationary	Stack is moved in 2 axis, surrounding systems is stationary
2	Separating the feed stack from the maculature stack	Separator moving through the stack	Pressurized air and separating knives	Manually
3	Separating sheets in the feed stack	Bending the stack with a tilted transfer table	Manually	-
4	Holding the top sheet of the remaining maculature stack	Side support for the maculature stack	Pneumatic cylinder clamping the stack	-
5	Feeding the separated stack	Linear axis fixed from one point	Cable pulley	Horizontal linear axis
6	Bridging the gap between the maculature stack and the material stack	Movable, angled transfer table	Telescopic, horizontal transfer table	-
7	Holding the top sheet of the material stack	Edge stop in the feeder	Transfer table holds the sheet	-
8	Positioning the fed stack	Rear edge pushers	Manually	-

4.3.1 Positioning of the maculature stack

As described above, positioning the maculature stack means defining the front edge, the height and the side positions of the stack. All of the solutions below describe the actions taken in the feeding area, as shown in Figure 4.3. It is taken as a base reference, that a roller conveyor moves the maculature stack from the loading area to the feeding area. Following three possible solutions are described, that aim to solve the tasks set forth.

Solution 1, Stack is moved in one axis, surrounding systems move

This solution describes a system where the maculature stack is moving only forward and backward on a fixed height roller conveyor and the systems around it would define the positions of the top of the stack and the sides of the stack. The Figure 4.4. shows the existing feeder on the left side and the described system on the right side from a back view. The direction of the material motion is forward and the maculature feeding direction is to the left like shown in Figure 4.3.

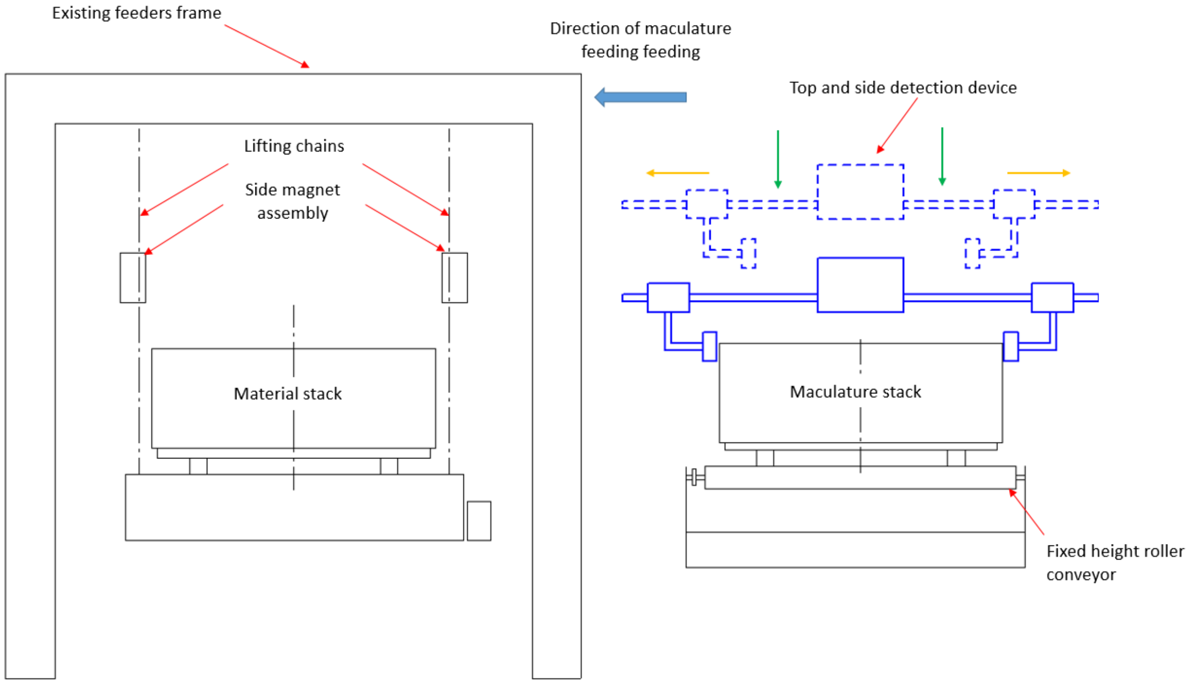

Figure 4.4 Function 1, solution 1, maculature stack height and side detection device

On Figure 4.4 a concept of the above described system is shown. On the left side of the figure the maculature stack is shown hanging inside the printing machine feeder from the lifting chains. On both sides of the stack the side magnet assemblies can be seen. A sketch of the printing machine feeder’s frame is shown, surrounding the material stack. On the right side of the figure the maculature stack is shown laying on the fixed height roller conveyor that is responsible for transporting the stack from the loading area to the feeding area. The same roller conveyor is used to define the stack’s front edge by moving it against a fixed stack stop plate. Above the maculature stack the main part of the given solution, the height and side detection device, is shown in a blue full line and a blue dashed line. The full line shows the end position of it when it has already recognized the sides and the height of the stack. The dashed line shows the start position of it. The small green and orange arrows show the movements of the device. The green lines show the vertical motion of the device to recognize the height of the stack and the orange arrows show the horizontal movement to recognize the sides of the stack. In the top, middle of the figure, the maculature feeding direction is shown in a blue thick line.

The advantages of the described solution are, that the maculature stack itself is not lifted and all the edge positions of the stack are precisely known. Not lifting the stack is advantageous, because the entire storage stack could weigh up to 1600 kg and lifting the stack would require heavy weight lifting equipment. The disadvantage of this solution is, that by having vertically and horizontally moving height and edge detection device, the design of this assembly would be complicated.

Solution 2, Stack is moved in 3 axes

The following solution describes another way of how the three edge position could be defined. The idea of this solution is, that instead of a fix height roller conveyor in the feeding area, there is a scissor lift table that can change its height. The side positions of the stack could be defined by moving the scissor lift table with the stack on top of it horizontally. The following sketch illustrates the concept. The view is from the back as with the previous sketch.

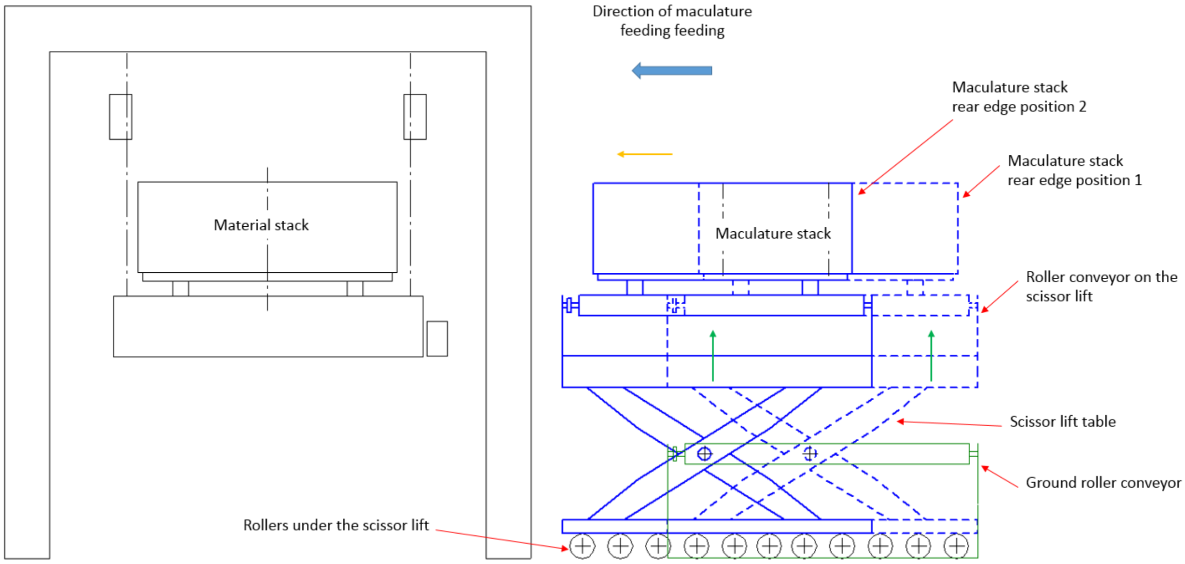

Figure 4.5 Function 1, solution 2, scissor lift table on rollers

As can be seen on Figure 4.5, the left side of the sketch is the same as on Figure 4.4, the right side however is completely different. On the right side on the bottom can be seen the roller conveyor, in thin green lines, that moves the maculature stack from the loading area to the feeding area. This conveyor is located near the ground level. Behind it in thick blue lines, the scissor lift table on rollers with another roller conveyor and the maculature stack on top of it can be seen. The roller conveyor on the scissor lift is responsible for taking the maculature stack over from the ground roller conveyor, moving its front edge against the stack stop to position it and lifting its top edge to the feeding level to determine it (on the figure marked as position 1). The small green lines illustrate the lifting action. With the dashed blue lines, the second position of the scissor lift is shown. With this leftwards motion the left side edge of the stack is determined. The small orange line illustrates the leftwards motion.

The advantage of this design, that the complicated height and side position recognition device is gone. The lifting of the stack could be solved with a standard catalogue solution, a scissor lift table. The disadvantage is, that the stack has to be moved in three axes, it would be complicated to move the scissor lift and the stack on top of it horizontally.

Solution 3, Stack is moved in 2 axes, periphery is stationary

The third solution is similar to the second, but simpler. The general components are the same, a roller conveyor near the surface level, a scissor lift with its own roller conveyor on top of it, but there are no rollers under the scissor lift. The left side positioning is done by the forklift operator during the stack loading. The following sketch illustrates this concept.

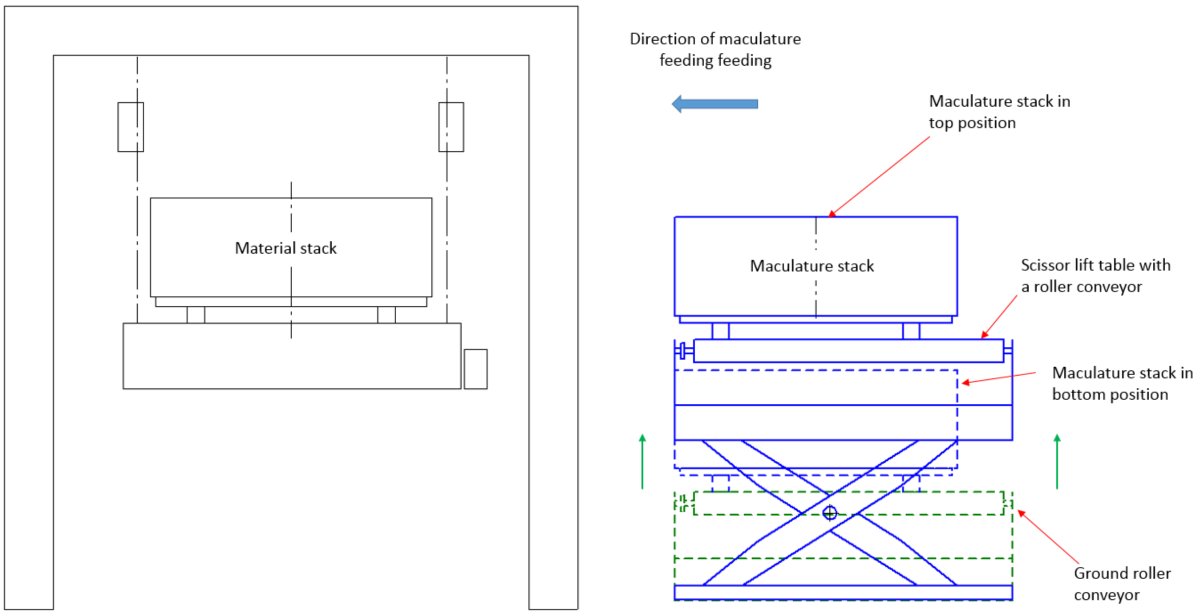

Figure 4.6 Function 1, solution 3, scissor lift table, manual positioning

The left side of the sketch is unchanged compared to the two previous ones. On the right side on the bottom with dashed green lines the ground roller conveyor can be seen, which transports the stack from the loading area to the feeding area. As can be seen, the left side of the maculature stack on the table is already parallel to the left side of the conveyor, this would be done during the manual loading action with the forklift and ensures, that the side position of the stack is known. When the maculature stack reaches on top of the scissor lift table roller conveyor, its front edge is pushed against the stack stop to determine its position. After this the stack is lifted to the feeding level to recognize the final edge of the stack, the top side.

The advantage of this solution is, that the maculature stack is only moved in two axes: forwards, backwards and up, down. Also the fact that the surrounding systems do not have to change their positions, makes their constructions much simpler. The disadvantage of this system is, that the left side positioning of the stack is done with the forklift by the operator. The positioning accuracy can vary.

4.3.2 Separating the feed stack from the maculature stack

This function refers to the action of determining how many maculature sheets need to be fed and then separating them from the maculature stack. The action of physically separating the feed stack from the storage stack is necessary, because the maculature sheets have a tendency to stick to one another. Following three possible solutions are provided to solve this task.

Solution 1, Separator moving through the stack

One way of separating the amount of sheets that need to be fed is to use a triangular shaped separating tool that is placed under the feed stack and pushed through the entire length of the maculature stack, separating the bottom sheet of the feed stack and the top sheet of the remaining maculature stack. The following sketch illustrates this concept.

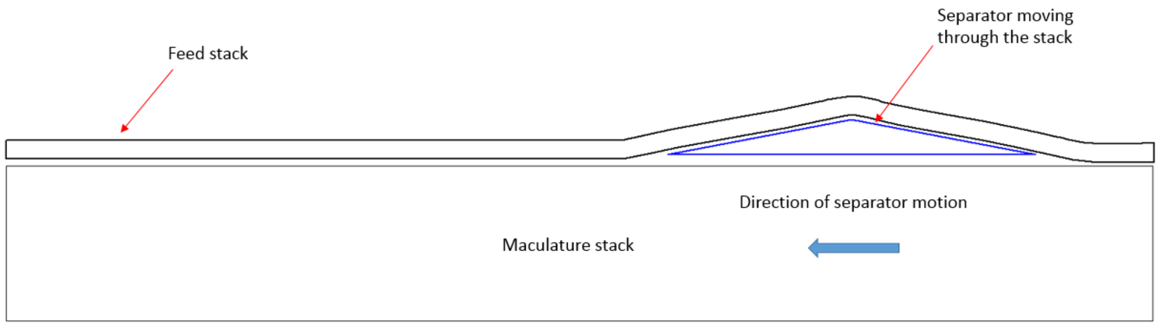

Figure 4.7 Function 2, solution 1, moving a separator through the stack

As can be seen on Figure 4.7 with the blue color, the separator is shown moving to the left, through the maculature stack. The advantage of this system is, that since there is a physical separation between the stacks, they would be definitely separated. The disadvantage is, that the system, that inserts the separator into the stack and the system that moves the separator inside the stack would be complex, because the sheets are (0,15…0,18) mm thick, so the insertion process needs to insure that none of the sheets are damaged. The motion system needs to pull the separator through the stack, so it should surround the stack from both sides.

Solution 2, Pressurized air and separating knives

Another way of separating the feed stack from the main maculature stack would be to use a combination of pressurized air and separating knives. The cycle would consist of the following steps. First, pressurized air is used to blow on the corner of the stack to separate the metal sheets from one another. Then a separating knife will be inserted between the sheets and it will move along the side of the stack, separating the stacks, by blowing pressurized air between the stacks from a nozzle inside the knife itself. This action will be repeated on every side of the stack. On the following sketch, an illustration of this concept is shown.

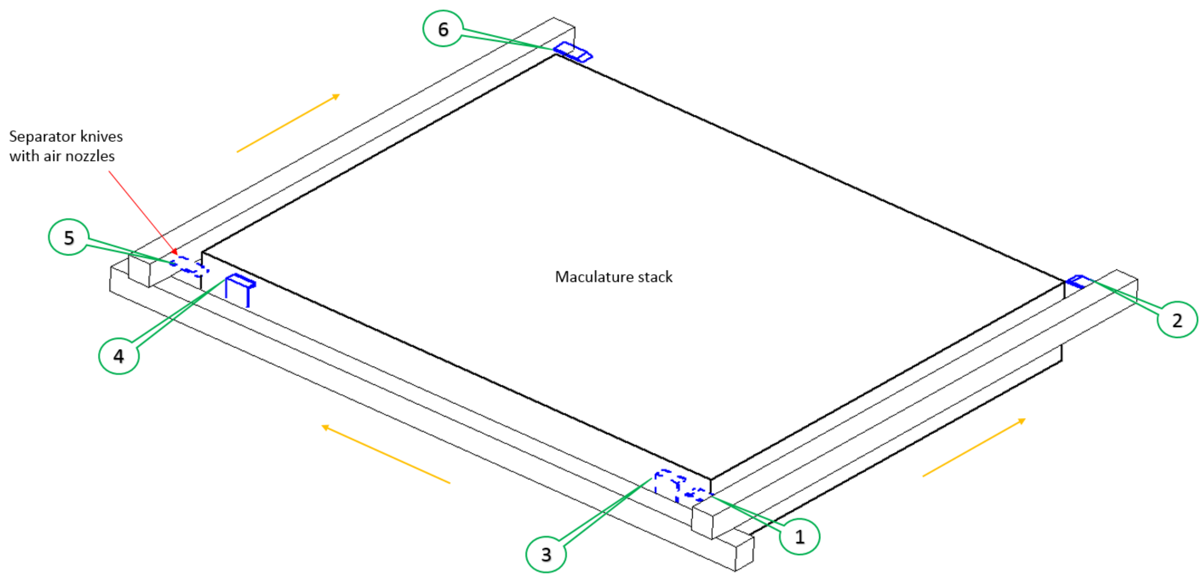

Figure 4.8 Function 2, solution 2, pressurized air and separating knives

On the above Figure 4.8 the concept is shown. In the middle of the figure the maculature stack can be seen in thick black lines. On three sides of it the separation knife construction is shown with the thin black lines. The separation knives are shown with blue lines, the full blue lines symbolizing the first position and the dashed lines symbolizing the second position. The green numbers symbolizing the sequence of the working cycle. The orange arrows are symbolizing the direction of motion of each knife.

The advantage of this solution is that this cycle would be fully automatic. The disadvantage is, that since the maculature stack formats differ considerably and the stack heights vary a lot, the system needs to be complex to cope with these changes.

Solution 3, Manually

The third option how to separate the two stack would be to do it manually. At the moment the maculature sheet transport is done by hand, including the stack separation. This is done by creating a wave that travels through the sheets by rapidly lifting the stack from the corner.

The advantage of doing it manually is, that, none of the above mentioned complicated designs would have to be created so the maculature feeder would have a simpler design. The disadvantage of doing it manually, is that the machine would become semiautomatic.

4.3.3 Separating sheets in the feed stack

As described by the characteristics of the maculature process, the individual sheets in the separated stack need to be separated from each other before they can be fed to the printing machine.. Sheets that are stuck to one another cannot be processed by the feeder. Following, two possible solutions are described.

Solution 1, Bending the stack with a tilted transfer table

The first option for separating the individual sheets in the stack would be to transport them over a tilted surface which would bend the stack as it moves over it. The bending would result in the separation of single sheets. The illustration of this concept is shown on the Figure 4.9.

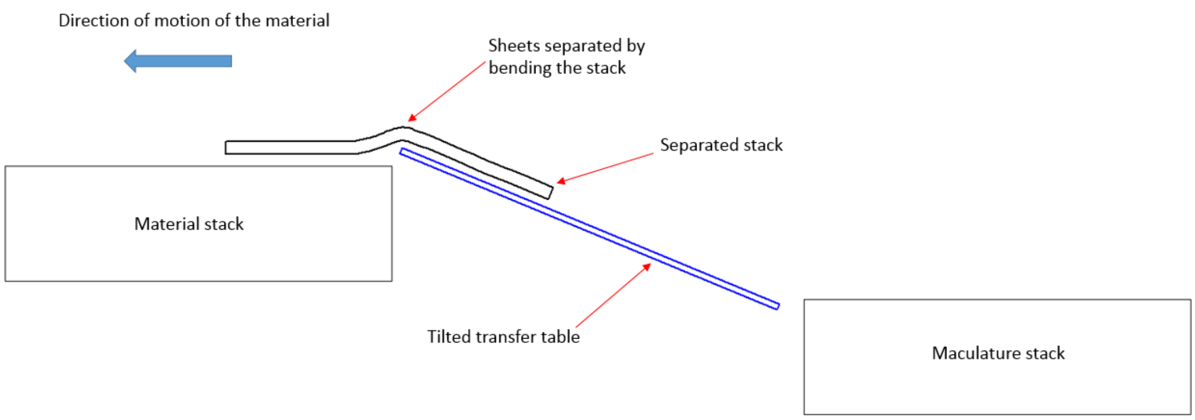

Figure 4.9 Function 3, solution 1, moving the stack over a tilted transfer table

As can be seen on Figure 4.9 the blue colors symbolize the tilted transfer table, which is used as a base by the separated stack (in thick black lines) to move over it. The tip of the transfer table would bend the stack and separate the sheets inside it.

The advantage of this design is, that the bending motion would separate the sheets in the stack. The disadvantage is, that since the stack is heavy, the bottom sheet can be scraped by the edge of the transfer table.

Solution 2, Manually

The second option would be to perform the separation manually. This would be done by holding the stack from the corner and moving it rapidly up and down. This creates a wave that travels through the stack and separates the sticky sheets.

The advantage of doing it manually is, that the sheets would not be damaged. The disadvantage is, that the machine would become semiautomatic.

4.3.4 Holding the top sheet of the maculature stack

When the stack that need to be fed is separated from the main stack and has to be moved to the printing machine feeder, it is important to hold down the top sheet of the remaining stack to prevent extra sheets from moving. Since the maximum separated stack can weigh up to 190 kg, it can drag the sheet directly under it with it due to friction between the two surfaces. Two potential solutions for this function are described below.

Solution 1, Side support for the maculature stack

The first solution for preventing the top sheet of the maculature stack from moving would be to design a side support on the front edge (in direction of feeding motion) of the stack. In order to determine the amount of sheets to be fed, the stack would be lifted by a certain amount. The clearance between the stack's top and the side support's top edge would be the feed stack. The sketch below illustrates the just described concept.

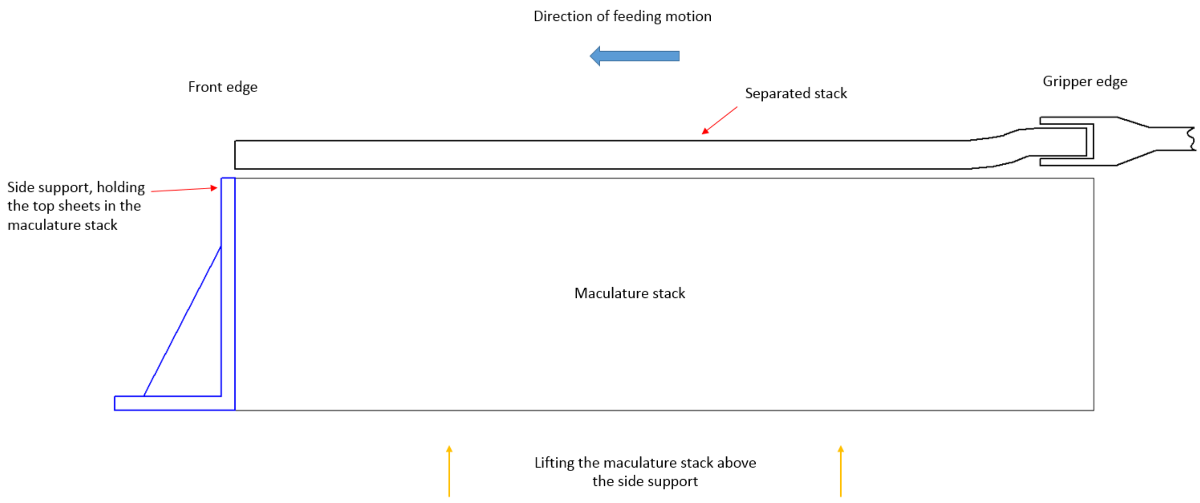

Figure 4.10. Function 4, solution 1, side support

As can be seen on Figure 4.10, with blue is shown the side support that keeps the remaining sheets from moving, while the separated stack is moved in the direction of feeding, shown with a thick blue arrow. The orange arrows show the lifting action that determines the amount to be fed.

The advantage of this system is, that the stop construction would be simple and easily built. The disadvantage with this solution is, that since the sheets are minimum 0,15 mm thick, it is very difficult to ensure, by only lifting the stack, that the amount of sheets that is being pushed by the gripper and the amount of sheets that above the side support are the same. If they are not, some of the pushed sheets that are held by the side support, can be crushed against it.

Solution 2, Pneumatic cylinder clamping the stack

The second solution would be to hold down the top sheets of the maculature stack from the gripper edge, under the gripper itself. This would ensure, that exactly the amount of sheets that are inside the grippers jaws are to be fed, and there can be no threat of crushing sheets on some side support. The concept is illustrated below.

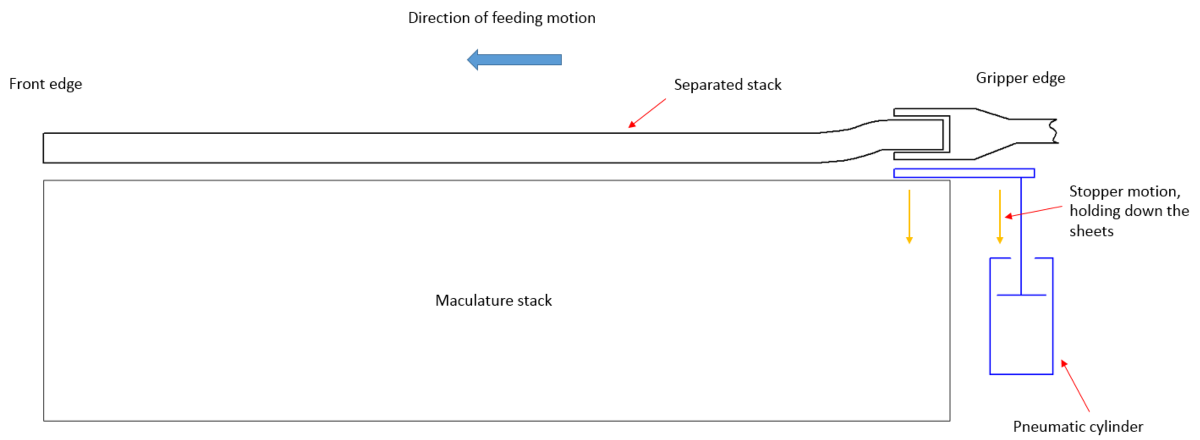

Figure 4.11. Function 4, solution 2, pneumatic cylinder clamping the stack

As can be seen on Figure 4.11 in blue color the pneumatic clamp is located on the gripper side of the stack, ensuring, that when the separated stack is moved in the direction of feeding, shown with a thick blue arrow, there is no threat of crushing some sheets.

The advantage of this system is, that the sheets that are inside the gripper would not be held by anything so no crushing can occur. The disadvantage of this system is, that since the stopper is between the stacks, a complicated inserting device has to be designed or this has to be done manually.

4.3.5 Feeding the separated stack

This is the main function of the given machine, because its task is to get the separated stack of freed maculature sheets from the maculature stack onto the material stack inside the printing machine feeder. As a base assumption to possible solutions for this task, it was decided that there has to be a gripper attached to the feeding system that grips the sheets and is pushed. After the stack has been gripped, it has to be transported onto the material stack. Following three potential solutions are described.

Solution 1, linear axis fixed from one point

The first option would be to use a linear axis, fixed at one end, which can move around this connection point. The rotation around this point would change the height of the free moving end. The gripper would move along this axis and transport the maculature sheets. In the free end of the axis is the gripper's home position. The vertical motion of the linear axis would allow to choose the amount of sheets for feeding. The lower the axis, the more sheets will be grabbed by the gripper. This solution allows to keep the material stack on the same level. The figure below illustrates the concept.

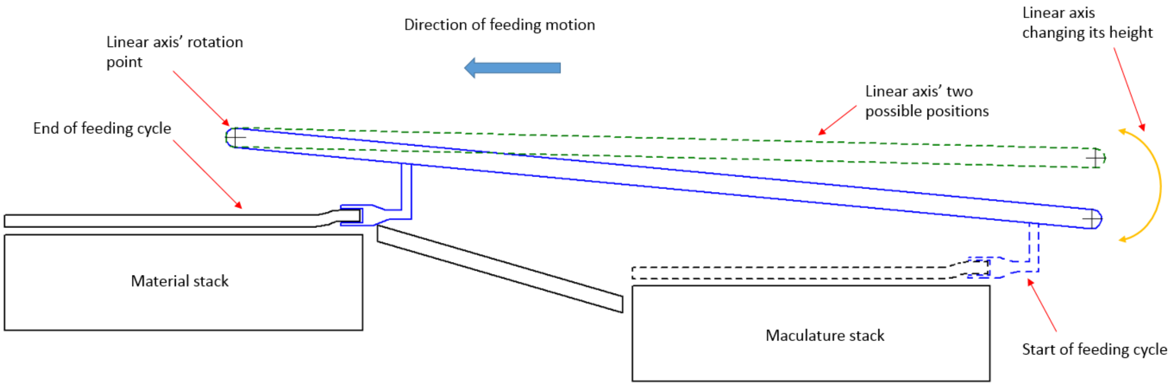

Figure 4.12. Function 5, solution 1, linear axis fixed at one end

Figure 4.12 shows the linear axis in blue, the dashed line directly under it represent the initial position of the gripper. The final position of the gripper after the feeding motion ended is shown on the left side of the figure with full lines. The green dashed lines in the upper part of the figure show the potential position of the linear axis, when rotating it around its connection point.

The advantage of this system is, that the material stack can be stationery and the feeding system would move around it. The disadvantage is, that since the linear axis is changing its angle, the gripper has to change its length vertically and the design for this would be complex. Also, there is not so much space on top of the material stack and with this solution, the linear axis has to be above the material stack.

Solution 2, cable pulley

Another approach to transport the stack would be to use a cable pulley system instead of the linear axis. With this solution the whole maculature stack has to be lifted to ensure a correct feeding height. The following sketch illustrates the concept.

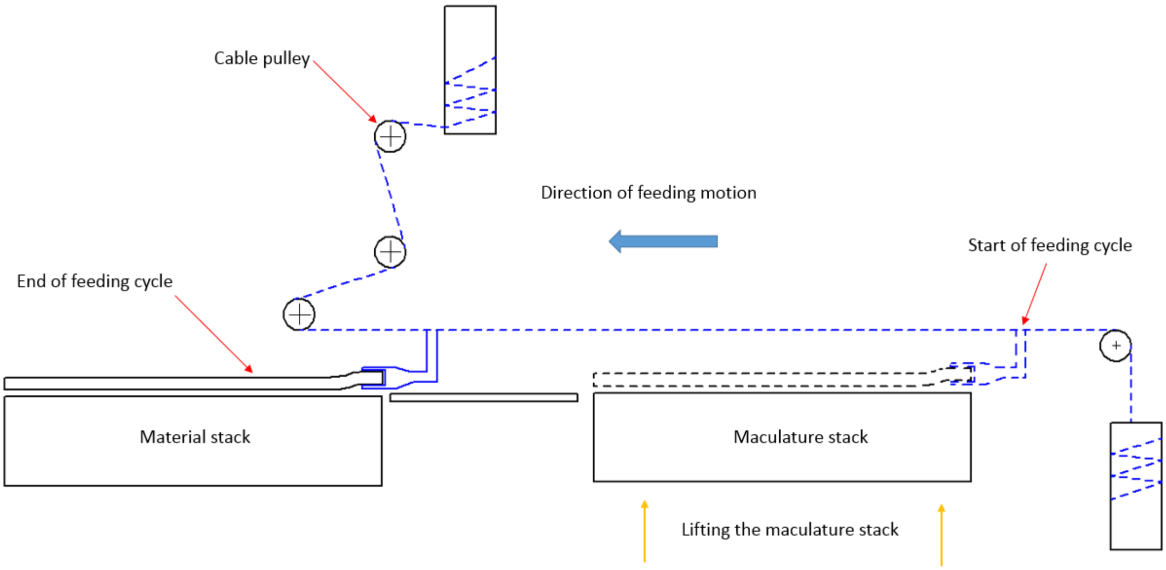

Figure 4.13. Function 5, solution 2, cable pulley

On Figure 4.13 the cable pulley as well as the start and end of the feeding cycle is shown. The orange arrows show the lifting direction of the stack.

The advantage of this design is, that the cable pulley system is slimmer and lighter than the linear axis, so it doesn’t take so much space on the material stack. The disadvantage of this solution is to ensure that the gripper on the cable wouldn’t bend through while pushing the stack, also that the maculature stack needs to be lifted.

Solution 3, horizontal linear axis

A third solution would be to use a horizontal linear axis with a telescopic gripper. The gripper would grip the stack, extend and then be moved by the linear axis. The maculature stack would be lifted and the correct feeding height ensured. The following sketch illustrates the concept.

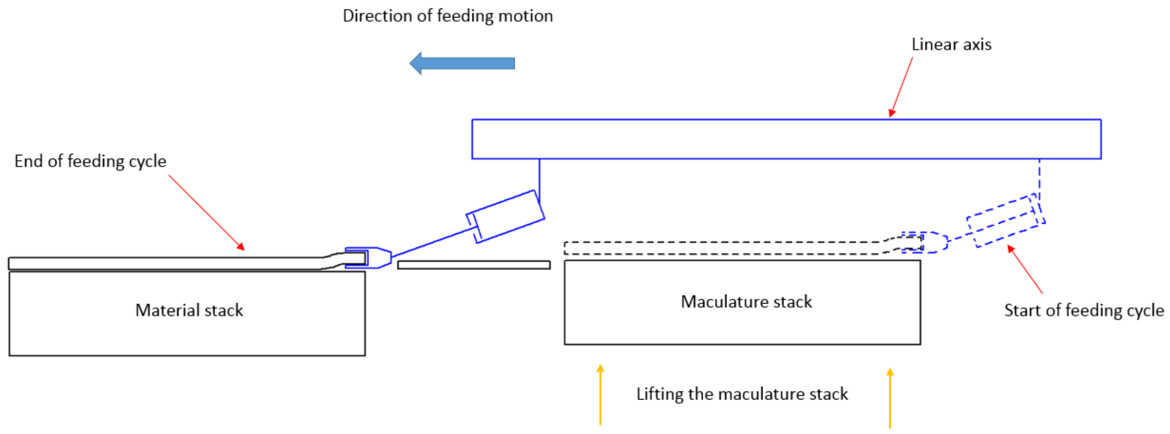

Figure 4.14. Function 5, solution 3, horizontal linear axis

As can be seen in Figure 4.14, the horizontal linear axis is shown with blue and the start position of the feeding cycle and the end position shown respectively with dashed and solid lines.

The advantage of this design is, the linear axis can be short and be positioned not above the material stack where there is not so much space. The disadvantage is, that the maculature stack needs to be lifted.

4.3.6 Bridging the gap between the maculature stack and the material stack

After the stack of maculature sheets is separated, it needs to be transported to the existing printing machine feeder on top of the material stack. Depending on the sheet format, there can be a distance of about (0,5 to 1) m between the two stacks that has to be overcome. The given chapter presents two solutions for how to bridge the gap.

Solution 1, movable, angled transfer table

The first solution would be to use an angled transfer table design. Angled, because by feeding the stack over the table, the sheets inside could be separated in the same step. The different sheet formats will be accommodated by the rotation of the transfer table. Both of the stacks would be positioned by their centers lines. By lifting the maculature stack, the correct feeding level will be ensured.

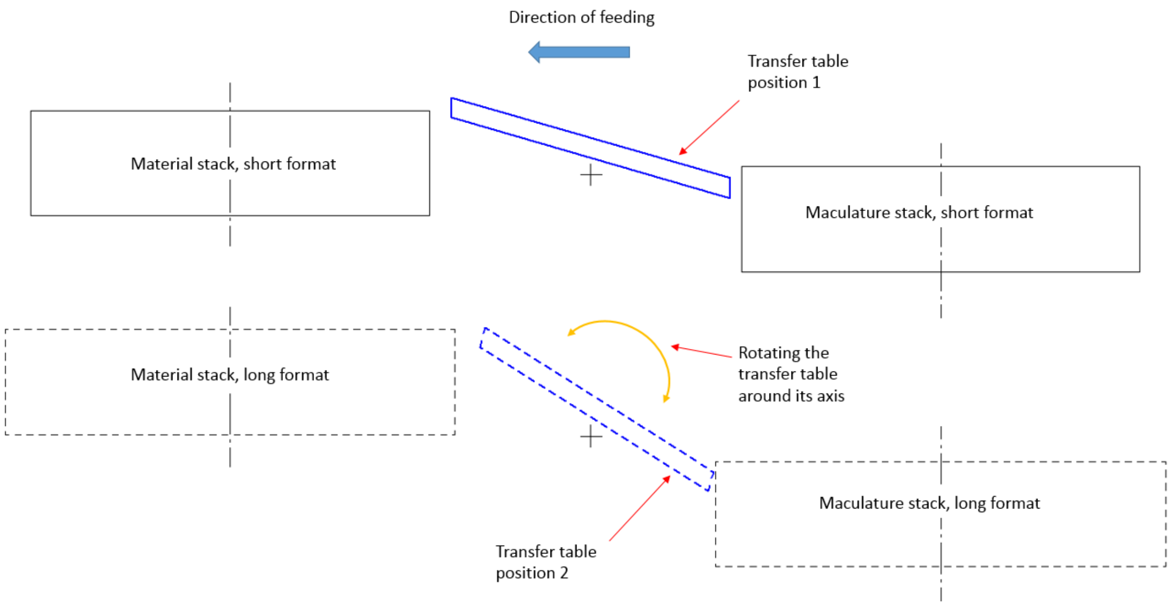

Figure 4.15. Function 6, solution 1, movable angled transfer table

Figure 4.15 shows the two positions of the proposed transfer table design: In the top part of the figure the position with short formats is shown in solid lines and in the bottom part the position with large formats in dashed lines.

The advantage of this design is, that the transfer table design could be relatively simple, the table has to only turn on its axis. The disadvantage of this design is, that by rotating the transfer table, the angle of it can be too steep to feed over it or the edge of the table can scrape the sheets.

Solution 2, telescopic, horizontal transfer table

The second solution proposed is to design the transfer table in a way, that it can change its length in response to the format change of the stacks. The idea would be to position the maculature stack with the forklift always by its left edge. By doing so, the transfer table has to change its length only from the material stacks side. The maculature stack would be lifted to keep the feeding level. The following sketch illustrates the concept.

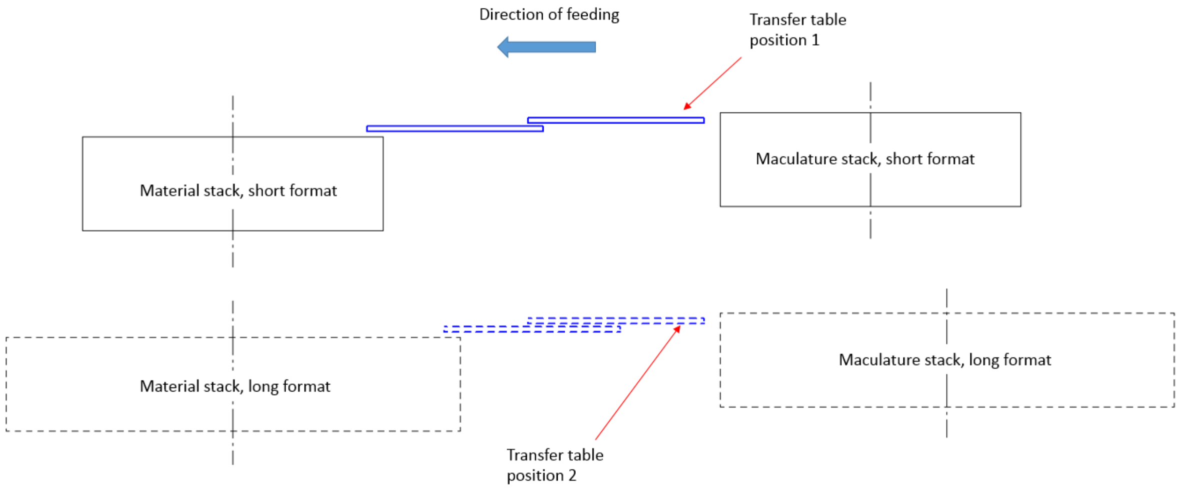

Figure 4.16. Function 6, solution 2, horizontal, telescopic transfer table

Figure 4.16 shows the two work positions of the telescopic transfer table. The idle position where the table if fully retracted and not touching the material stack is not shown. In the upper part of the figure the extension of the transfer table is shown when short formats are used. The bottom part shows the retraction of the transfer table when long format is used. As can be seen, the maculature stack's left side is positioned on the same line in both positions.

The advantage of this design is, that the transfer table's construction would not scratch the sheets. Also standard parts can be used in the construction of the table. The disadvantage is, that the maculature stack has to be positioned by the operator.

4.3.7 Holding the top sheet of the material stack

As mentioned before, the feeding method for the separated maculature stack is pushing. This means, that the top sheet on the material stack needs to be fixed to stop it from moving. Following two solutions are describing that could solve this task.

Solution 1, edge stopper in the feeder

The first solution would be to design an edge stopper for the material stack to keep it from moving. It could be fixed to one of the side magnets in the feeder. The side magnets are controlled by the feeder and they follow the material stack's edges precisely. The edge stop would have two positions. An idle position where it is hidden and a work position where it is next to the edge of the stack, stopping the top sheet from moving when the maculature stack is fed onto it.

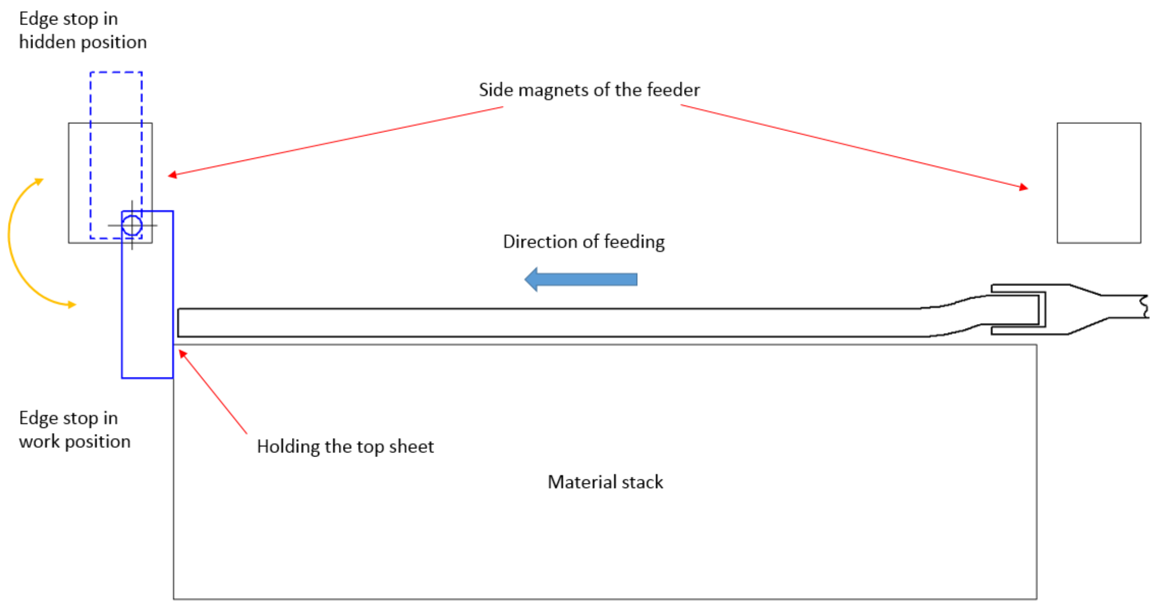

Figure 4.17. Function 7, solution 1, edge stop in the feeder

Figure 4.17 above shows the hidden and the work position of the described edge stop. The advantage of this system is that the edge stopper could be used as an end stop switch for the feeding motion, when the stack touches the edge stopper, then the feeding motion is stopped. The disadvantage of this design is, that the side magnets, where the edge stop is fixed to would need to be strengthened or redesigned.

Solution 2, transfer table holds the sheet

The second solution for the same task would be to use the telescopic transfer table's front edge to clamp the top sheet of the material stack. This solution requires a horizontal transfer table. The transfer tables front edge would be positioned above the material stack's edge and then clamped down to stop the top sheet from moving. The concept is shown on Figure 4.18.

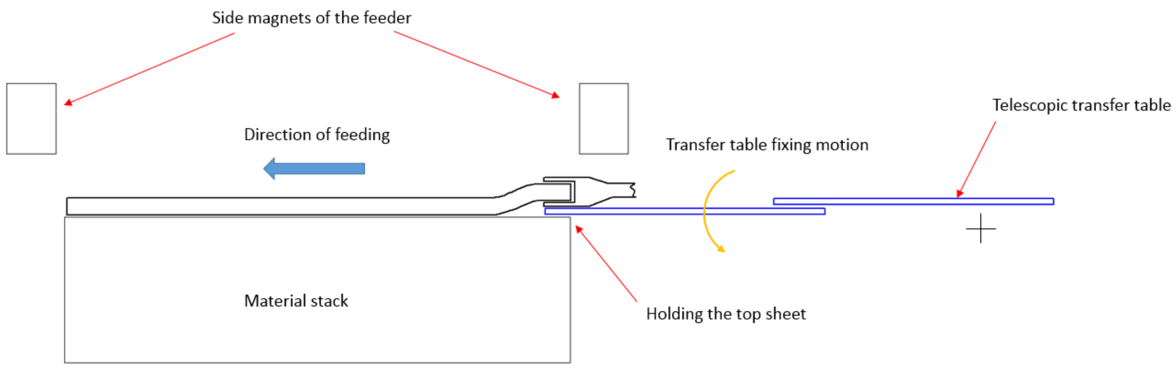

Figure 4.18. Function 7, solution 2, transfer table clamping the top sheet

The Figure 4.18 shows the transfer table being used to clamp the top sheet of the material stack.

The advantage of this design is, that there is no need to redesign any feeder's components. The disadvantage of this system is the positioning complexity of the tables front edge.

4.3.8 Positioning the fed stack

After the stack of maculature sheets has been transported onto the material stack, it needs to be positioned correctly, taking care that the edges of the transported stack are aligned with the materials stack's edges. This extra positioning action is required, because the maculature stack's front edge is 100 mm misaligned from the edge of the material stack. This is due to the lifting chains on the sides of the material stack. As can be seen in Figure 4.19, on the right side, the maculature stack is shown. On the left of the figure the fed maculature stack is shown with thick black lines, positioned on top of the material stack. As can be seen, the material stack's top edge is 100 mm more in the front than the fed maculature stack. To position the fed maculature stack correctly with the material stack, a positioning motion of 100 mm is required. In the following chapter two possible solutions are described.

Solution 1, rear edge pushers

The first way to accomplish the required action would be to design pushers for the rear edge of the stack and to fix them to the rear edge magnets, which are already existing in the feeder. Like the side magnets, that were discussed previously, the rear edge magnets are responsible for separating the top layer of the sheets and they also move according to the sheet format. The idea is, to use this existing movement to push the fed stack against the stack stop.

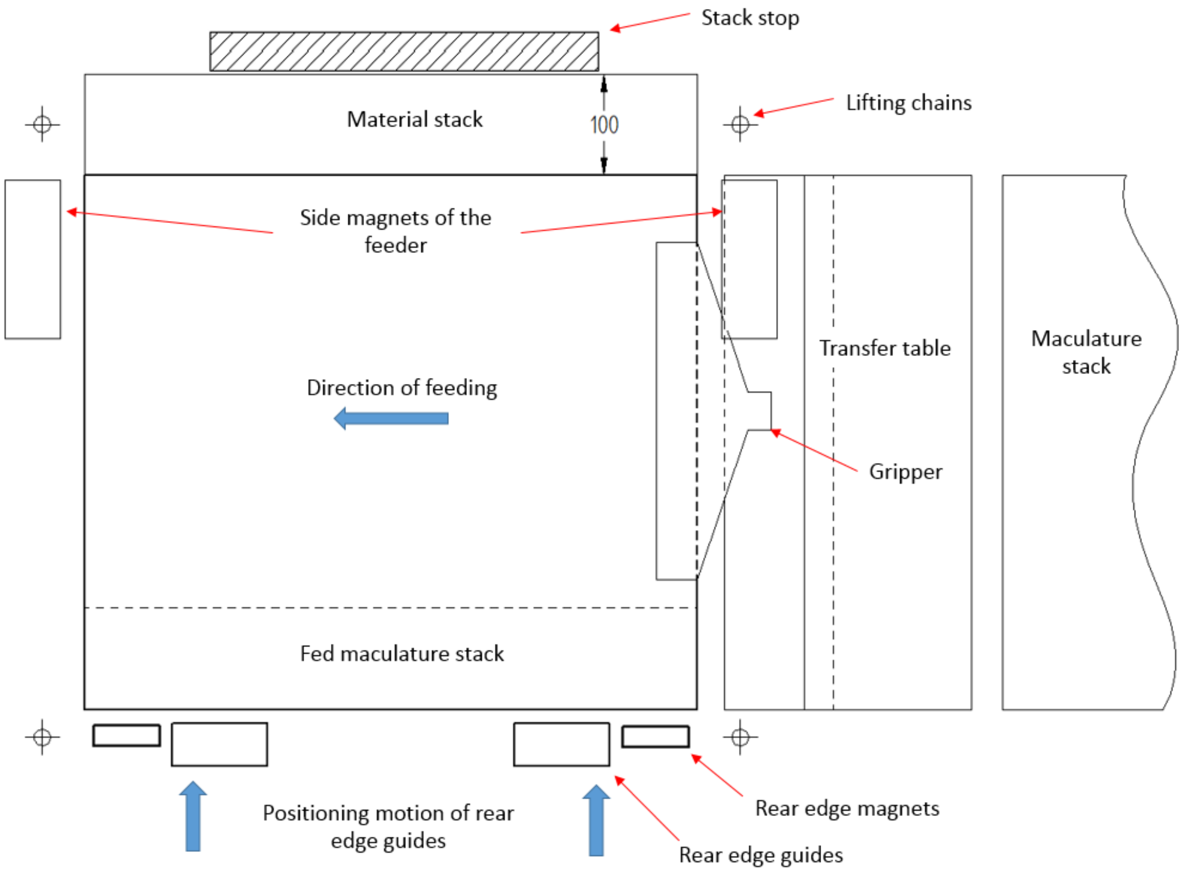

Figure 4.19. Function 8, solution 1, rear edge pushers

As can be seen on Figure 4.19 in the bottom part, the proposed rear edge pushers are shown. Their motion is shown with the vertical thick blue arrows.

The advantage of this solution is, that the existing movement would be used to push the sheets in position. The disadvantage is, that the rear edge magnet system is not designed to withstand the loads that result from the pushing action. This system has to be strengthened or redesigned

Solution 2, push the fed stack to the stack stop manually

The second option would be to do the positioning of the maculature sheets manually. At the moment, the operator transports the maculature sheets to the material stack and pushes it forward against the stack stop. The same action could be continued, it is illustrated in Figure 4.20.

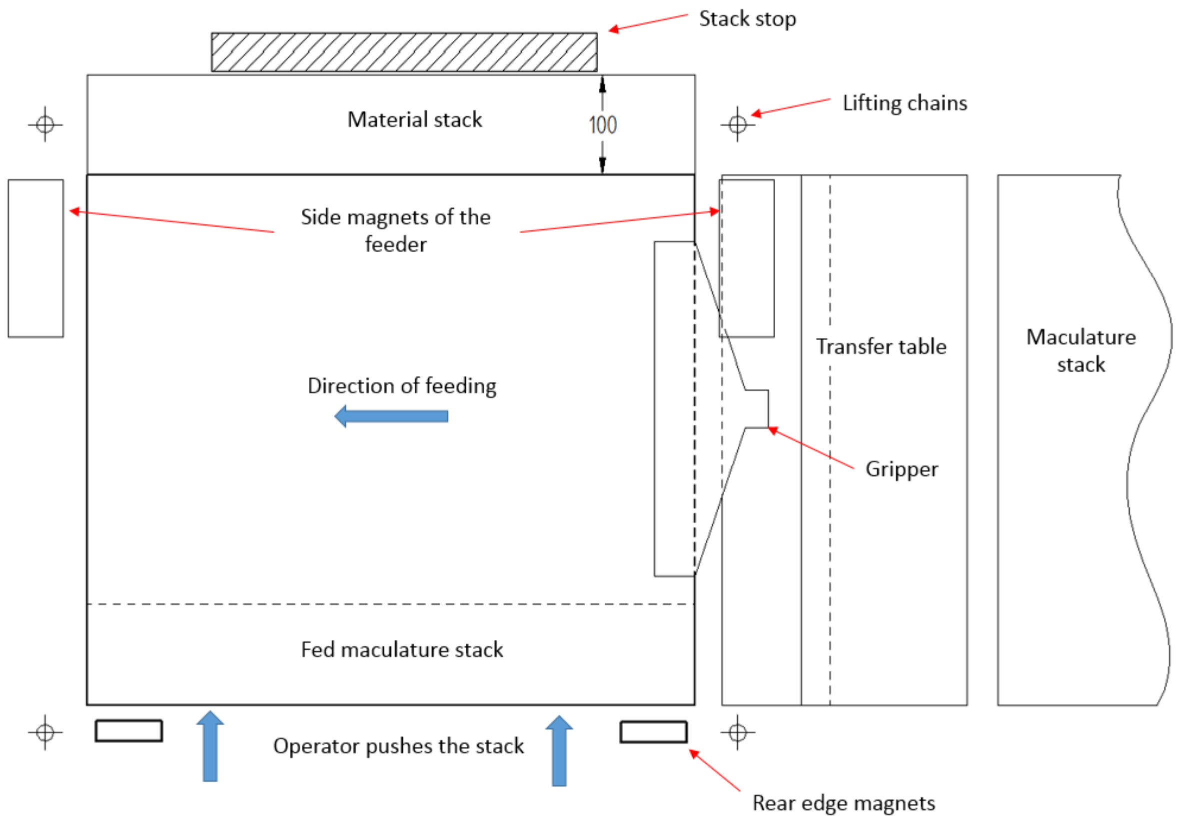

Figure 4.20. Function 8, solution 2, pushing the stack manually

The advantage of this solution is, that no parts of the existing feeder have to be redesigned which makes the whole project simpler. The disadvantage is to use the operator, which makes the maculature feeder semiautomatic.

4.4 Final solution for each function

The aforementioned sequence of the functions follows the process logic. The solution selection process on the other hand follows the order of importance of the functions to the entire process. As described in the previous chapter, the main function for the maculature feeding process is the feeding function. The solution for this will be selected first and following decisions for other solutions will be based on this.

Feeding the separated stack

This is the main function for the feeding process. The chosen solution will be the third proposed solution, using the horizontal linear axis, (Figure 4.14). This decision was made, because the linear axis solution is a standard solution for linear motion. Almost half of the process, the part, that is responsible for majority of the journey, the linear axis, can be chosen from a catalogue and bought. As for example the second solution of using cables would have to be designed and built entirely. The other half of the process, the telescopic gripper can be constructed using telescopic slides and a telescopic cylinder, that are also catalogue parts. The third solution of using the horizontal linear axis, as opposed to the angled linear axis was chosen, because as mentioned above, the gripper construction can be made simple and standard parts can be used. Taking into account also, that there is not so much space on top of the material stack, the third solution is preferable, because with that, the space above the material stack does not need to be used.

Positioning of the maculature stack

The solution for this function is related to the selection of the previous function. As the horizontal linear axis was chosen as a means of transport for the maculature sheets, the maculature stack has to be lifted to ensure the correct feeding height. The best way to do that would be to use a scissor lift as described in the third solution, (Figure 4.6). The maculature stack would be positioned by its left side in the loading area by the operator. It would then be transported by the roller conveyor to the top of the scissor lift and then lifted up to the feeding height. The third solution was chosen over the second, because it is the simplest way of positioning the stack, no left-right motion is required as with the second solution. By observing the operators loading the material stack with the forklift, it was decided, that the positioning accuracy that can be achieved by the operator is enough to position the maculature stack by its left side in the loading area onto the rolling conveyor. Now that the feeding system is a horizontal linear axis and the maculature stack will be positioned by its left side and then lifted, the next step is to bridge the gap between the maculature stack and the material stack.

Bridging the gap between the maculature stack and the material stack, holding the top sheet of the material stack

For the transfer table design the telescopic solution is chosen, (Figure 4.16), because by using the horizontal linear axis for feeding and a scissor lift for stack positioning, a transfer table design is required also to be horizontal and would allow the stack to be positioned always by its left side. It is also considered, that by using the telescopic transfer table, the function of holding the top sheet of the material stack can be accomplished with the same system. By making this decision, the design of the whole machine becomes simpler, because there is no need of having two separate systems, one system can do both tasks. It is also positive not to redesign any parts of the existing feeder as proposed by the first solution. Next the fixing solution for the maculature sheets will be given.

Separating the feed stack from the maculature stack, separating sheets in the feed stack, positioning the fed stack

All of the mentioned functions and their possible solutions were analyzed and a decision was reached to do all of these manually. This is a major decision, that changes the concept of the maculature feeder from an automatic to a semiautomatic machine. The decision was made by first comparing the different solutions within a function and seeing if the advantages of automating this function outweigh the disadvantages of doing it manually. In comparing the solutions, it was looked at whether the cycle time increases when doing it manually and does the operator have to lift heavy weights.

In function two, both of the automatic solutions for separating the feed stack from the maculature stack require complicated systems that have to insert themselves between the thin metal sheets and that have to move through and around the stack. The solutions would automate the function, but since there are many variables, such as random stack heights, different formats, thin sheets, then the reliability of this automatic system would not be very high. Having these different variables, the speed of the system can’t be very high as well, because there is a threat of damaging the sheets. This means, that by automating the function, it is not guaranteed, that the function will be done faster than manually. When doing it manually, the operator doesn’t have to lift anything, the operator would continue doing the wave motion that was described above to separate the stack.

In function three, the automatic solution doesn't fit the selected solutions for feeding and positioning, which were described above. If these would be changed, then there would still be the threat of scraping the sheets. When doing it manually, there would be no threat of scraping the sheets, and it would be done with the same speed as with the automatic solution or faster, depending on the feeding speed, because it would require only a single motion from the operator.

In function eight, the automatic solution provided would accomplish the tasks, but it would require the redesign of parts of the existing feeder. By doing it manually, the operator does not lift anything, but he has the opportunity of checking the fed stack and making sure, that the fed stack is not damaged, also the potential increase in cycle time would not be great, as the operator simply pushes the stack.

After comparing the solutions within the functions with each other, the functions were analyzed to see if any of these can be combined with each other and what would the consequences to the cycle time of the entire maculature feeding process be.

The function of separating the feed stack from the maculature stack and the function of separating the sheets in the feed stack, when done automatically, would be two separate functions, but when done manually, they can be accomplished by a single motion from the operator. When combining these functions by doing them manually, a great advantage in reduced cycle time can be seen over doing both of them individually and automating them. Function eight cannot be combined with anything, but as it is undesirable to redesign the existing feeder's parts and now the operator is involved in the process, then in order to simplify the design of the maculature feeder, the eight function will be done manually as well. The operator can move from where the separating takes place to where the positioning motion takes place quickly, as the distance is two to three meters.

Holding the top sheet of the maculature stack

Comparing the two solutions described for this function, the pneumatic cylinder option, the solution two, is chosen, (Figure 4.11). Although the scissor lift is used for maculature stack lifting, it is assumed, that the lifting motion from the scissor lift is not precise enough to be used to choose the amount of sheets for feeding, as was required by the first solution. Choosing the second solution of the pneumatic cylinder clamping the top sheet of the maculature stack under the gripper, guarantees, that the gripper does not push any fixed sheets and there can be no crushing of sheets. The pneumatic sheet holding device will be placed between the sheets by the operator. This will be done directly after the stack and sheet separation is done.

4.5 Compliance to the requirements

After choosing the solutions for different functions, the concept of the maculature feeder has changed from an automatic machine to a semiautomatic one. It is relevant to go over the requirements again that were set out in chapter 3, to bring out which requirements are met and which are not. There were six fixed requirements and three not fixed requirements. Following the requirements are brought accompanied by the explanation how they will be met.

1. Inputs for the feeder have to be the existing maculature stacks with formats from (510x710…1000x1220) mm, thickness of (0,12…0,4) mm and height of (10…160) mm;
2. Maculature stack weighing up to 1600 kg;

The first requirement is fixed, the second is not, they are both met by choosing the feeding and the positioning systems like described above. With the horizontal linear axis, the existing formats can be fed and by choosing the correct scissor lift, the stack of 1600 kg can be lifted.

3. The maculature feeder has to be a removable part of the existing feeder;

This is a fixed requirement and it is met because the solutions chosen don’t require the redesign of the existing feeder’s parts and they are standalone subsystems.

4. Option to choose the maculature amount with an accuracy of ± 5 sheets;
5. Sheet separation before feeding;

The fourth requirement is a not fixed requirement, the fifth is. Both of them are met, because the operator chooses the amount of sheets manually so he can choose the amount necessary and then he separates the stack from the main stack.

6. Automatic fed stack positioning;

As this is not a fixed requirement, the solution was chosen to do it manually.

7. Cycle time under 1 min 30;

This is a fixed and an important requirement, because the new solution can’t be slower than the existing one. This is met by the overall concept that was chosen, regardless that the stack separation, the sheet separation inside the stack, the placement of the maculature sheet holding device between the sheets and the fed stack positioning is done manually. During the consideration process of doing these functions manually, observations were conducted and the time to accomplish these functions manually was estimated to be around 20 seconds. These functions make up a majority of the maculature feeding process. The main part that is left is the linear feeding action, since this is a simple motion, this can be accomplished in under 10 seconds. In total the maculature feeding process with the chosen concept is estimated to take around (30 to 40) seconds, which will meet the set requirement.

8. Has to be as compact as possible;
9. Use of as many standard parts as possible;

These are both fixed requirements and they are met by every solution that was chosen. In all of the solutions chosen it was considered, that the solutions would be as compact as possible and they would comprise of as many standard parts as possible.

5 DESIGN

5.1 Lifting system

In the following chapter, the lifting system and its working principal is described. From the working principal, the requirements for the scissor lift table are determined. Based on the requirements, the selection of the scissor lift table is explained. The lifting system is a part of the positioning system for the maculature stack, the part which is responsible for lifting the stack and holding the correct feeding level.

5.1.1 Working principal of the lifting system

The solution chosen for the first function of the maculature feeding process was to position the maculature stack on the roller conveyor with the forklift, then the stack is conveyed to the lifting position and then lifted up by a scissor lift table by the operator. A full working cycle of the lifting system is described here below. The cycle starts, when the maculature stack has arrived onto the lifting table and it ends, when the lifting table is lowered. The below figure shows the beginning of the cycle.

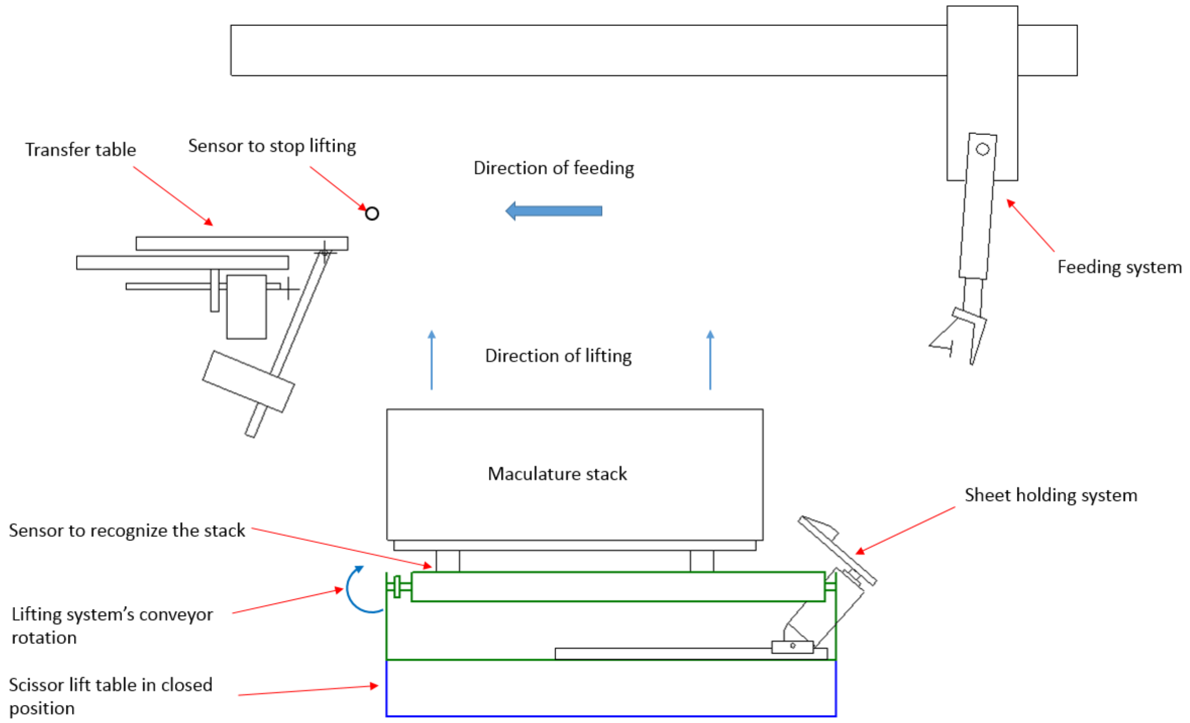

Figure 5.1 Start of the lifting cycle, the arrival of the maculature stack

As can be seen on the above figure on the bottom, the scissor lift table is shown (blue) and on top of it, the conveyor belonging to the lifting system (green). On top of the conveyor is the maculature stack, on the right side of the maculature stack is the sheet holding system in its closed, home position, being out of the way of the moving maculature stack. On the top of the figure, the sheet feeding system in its home, idle position is shown. On the left side of the figure, the transfer table in its retracted, home position is shown. Near the transfer table the sensor position, that stops the maculature stack lifting and determines the feeding level is shown. The start for the lifting cycle is the arrival of the maculature stack on the lifting table. This is recognized by sensor, that is located between the conveyor rollers.

After the stack has arrived, the stack needs to be lifted to the feeding height. This is shown on the following sketch, that describes the next step in the lifting cycle.

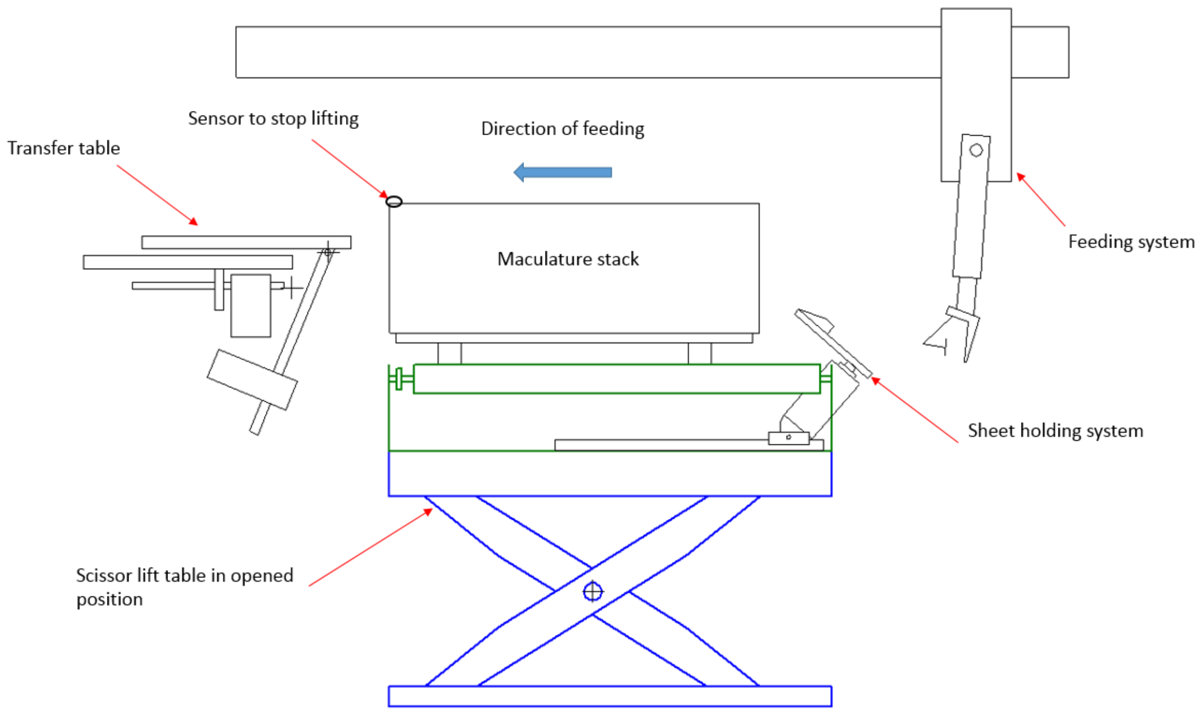

Figure 5.2 The second step of the lifting cycle, lifting the stack

The scissor lift table is extended and the maculature stack together with the conveyor is lifted. The inductive sensor that is located on the corner of the maculature stack stops the lifting motion at the feeding level. From here on, the sheet holding system, the transfer table and the feeding system can start their cycles. When the feed stack of maculature is separated and fed away, the scissor lift is started by the sensor on top of the maculature stack, to keep the feeding level. The cycle for the lifting system ends, when the maculature stack is empty or when there is no need for it anymore and the scissor lift is lowered by the operator.

5.1.2 Requirements for the scissor lift table

In the following chapter, the requirements for the scissor lift table are given in order to choose the suitable one. There are requirements for the lifting capacity of the table, the lifting range of the table and the measurements for the table.

The mass, that the scissor lift table has to be able to lift comes from the different maculature formats and the stack heights that are used currently on the UV printing line. These are brought in the following Table 5.1.

Table 5.1. Different maculature formats

Length (mm)	Width (mm)	Height (mm)	Mass (kg)
510	710	165	466
735	1040	165	984
736	1040	165	985
799	1000	165	1028
807	1040	165	1080
827	1000	165	1064
830	1000	165	1068
847	1092	165	1190
915	1040	165	1225
952	1000	165	1225
954	1008	165	1238
980	1000	165	1261
1000	1220	165	1570

The maximum mass, that the scissor lift is supposed to handle is 1570 kg.

The lifting range comes from the fact, that the maculature stack heights can be in the range of (10…165) mm and the wooden pallets under them can be from (70…100) mm. The lifting range of the scissor lifting table has to be 730 mm. This is shown on the following figure.

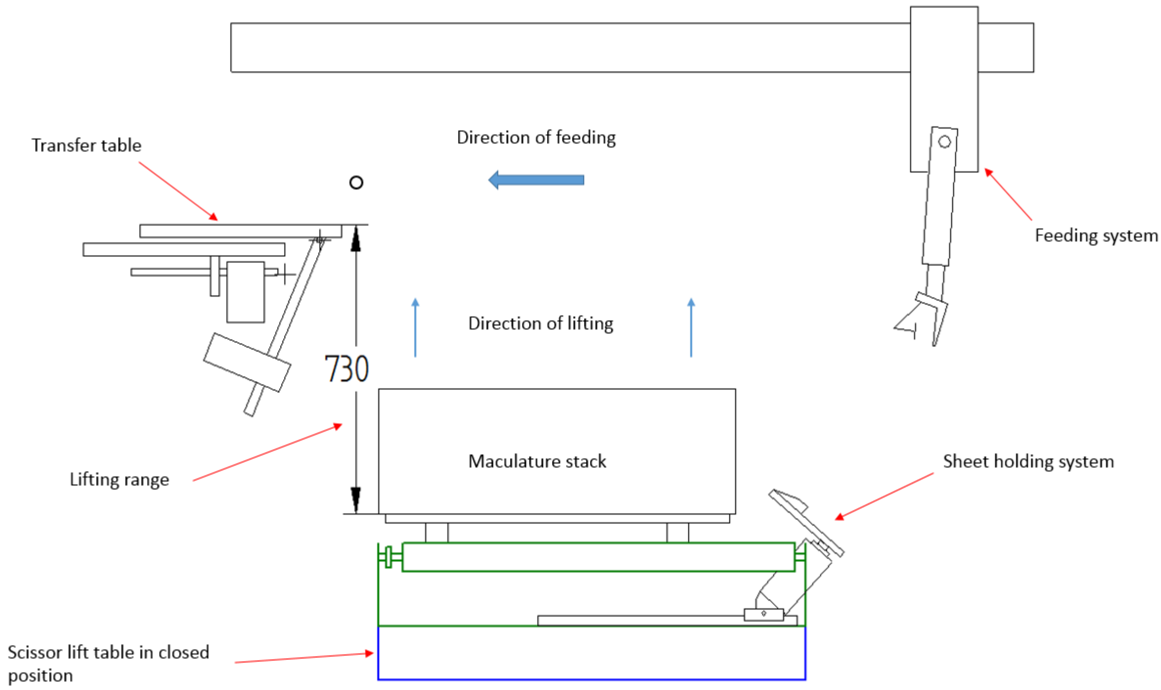

Figure 5.3 Lifting range of the scissor lift table

The external measurements of the scissor lift are important, because it is not desirable that the lifting table is bigger than the conveyor on top of it.

5.1.3 Choosing the scissor lift table

In this chapter, the scissor lift table is chosen, taking into account the requirements set forth in the previous chapter, the lifting capacity of 1570 kg, the lifting range of 730 mm and the external horizontal measurements of the table smaller than (1300x1000) mm.

A scissor lift is a standard product, that is readily available at the market. After comparing different products, it was decided to choose the scissor lifting table from the catalogue of AJTooted [8]. The parameters of the chosen lifting table are brought in the following Table 5.2.

Table 5.2. Parameters of the chosen scissor lift table

Lifting capability	2000 kg
Lifting range	850 mm
External measurements	1300*800 mm

Figure 5.4 Chosen scissor lift table

Figure 5.4. shows the chosen scissor lift table.

5.2 Sheet holding system

In this chapter, the sheet holding system and its working principle is described and from the working principle the requirements are deducted. Based on this, the technical solution is worked out and the different parts for the system chosen.

5.2.1 Working principle of the sheet holding system

As described in the conceptual solution paragraph, the purpose of the sheet holding system is to hold down the maculature sheets under the separated maculature stack, because the separated maculature stack will be pushed (fed) away from the remaining maculature stack by the gripper and the feeding system. There is friction between the bottom of the separated stack and the top of the remaining maculature stack so there is a threat, that the top sheet of the remaining maculature stack will follow the separated stack as it moves when it is not fixed.

On the following sketches the sheet holding system and its full working cycle is described, starting, when the maculature stack has arrived to its position on the lifting table and ending, when the separated stack of maculature sheets has been fed off from the maculature stack.

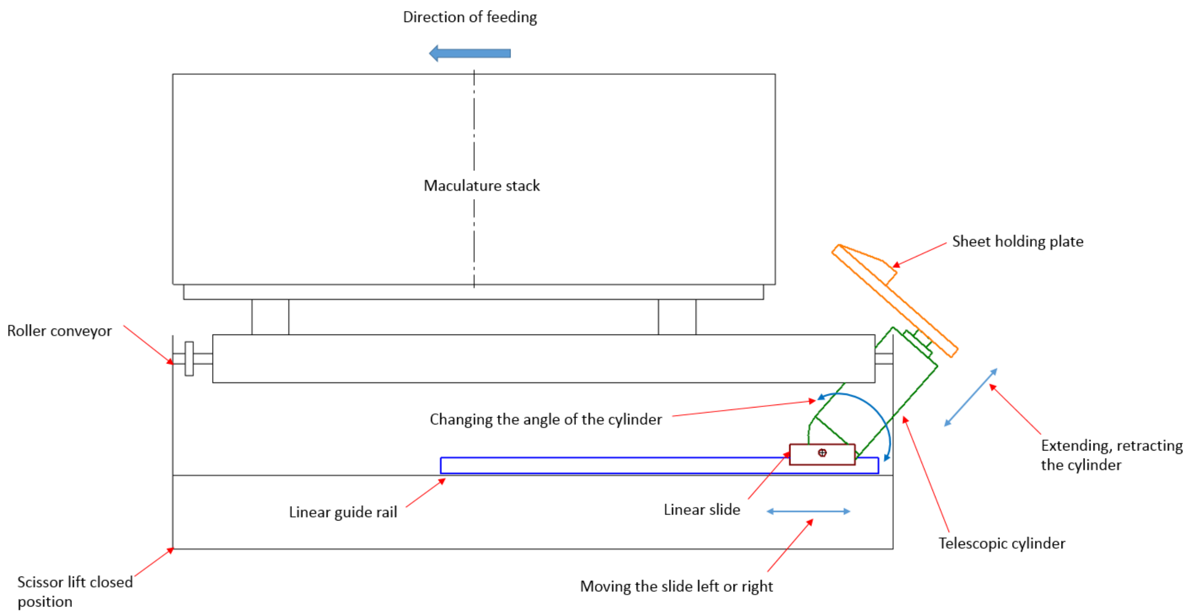

Figure 5.5. The initial position of the sheet holding system

As can be seen on Figure 5.5, the maculature stack is in its ready position. On the right side of the figure, the telescopic cylinder in its retracted position can be seen illustrated by green thick lines. The sheet holding plate, in orange, is connected to the cylinder rod. Connected to the other side of the cylinder is the linear slide, in brown and the linear rail, blue. There are two slide-cylinder assemblies used in the sheet holding system, on the above figure, they are behind each other. The cylinders are attached to the slides, so that the angle of the cylinders can be changed. The slides can be moved on the guide rails to the left and right to accommodate smaller maculature stacks. The cylinders are located between the conveyor rollers. This position shown on the figure above is the start of the sheet holding cycle. Now what is needed is to separate a stack of maculature from the top of the maculature stack and to insert the sheet holding plate between the separated and the remaining stack. The operator separates the stack needed and inserts the sheet holding plate between the two stacks, the next figure illustrates the result.

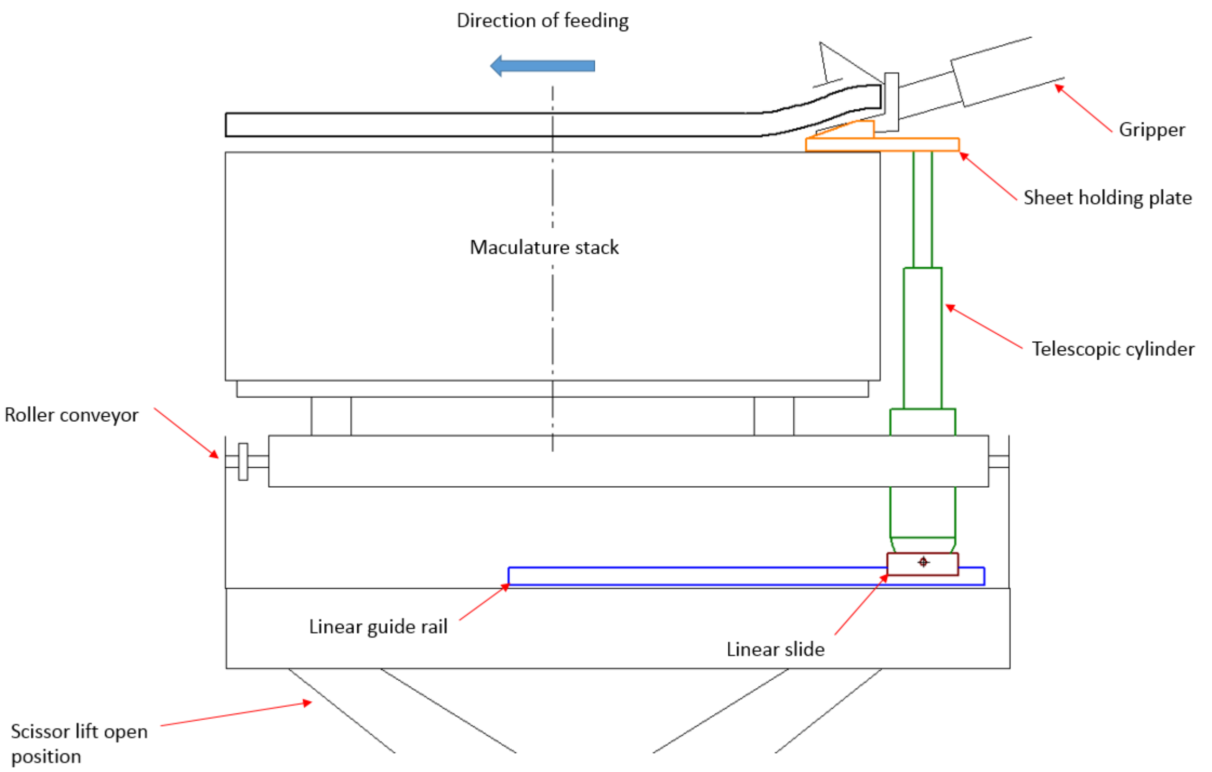

Figure 5.6. The sheet holding system in work position

As can be seen on the upper part of Figure 5.6, the stack of maculature sheets, that needs to be fed is separated from the main stack and it is gripped by the gripper, the stack is shown with thick black lines. On the right side of the figure, the extended telescopic cylinder is shown. The sheet holding plate is inserted between the two stacks and clamped down. Now what will follow, is that the gripper will clamp the separated stack and push it to the left, like shown on the figure by the direction of feeding, the thick blue arrow. This position of the sheet holding system shown on the above figure, is the working position of the system. After the separated maculature stack has been fed, there can be a new stack separated if needed and the sheet holding plate inserted between the two stacks again. If there is no need to separate a new stack, then the sheet holding system is put to its initial position as shown on Figure 5.5.

This concludes the description of the working cycle and the working principal of the sheet holding system. In the following chapter, the requirements for the sheet holding system are described.

5.2.2 Requirements for the sheet holding system

The sheet holding system has to be capable of handling the different maculature formats, from (710…1220) mm of width. It also has to handle the different stack heights, that can be of random height between (10…165) mm and that can be on different height wooden pallets that range from (70…100) mm. The sideways moving range resulting from the format change has to be 710 mm to accommodate the 510 mm of range and the cylinder width. The stroke of the cylinder has to be 200 mm. The different ranges are shown on the below Figure 5.7.

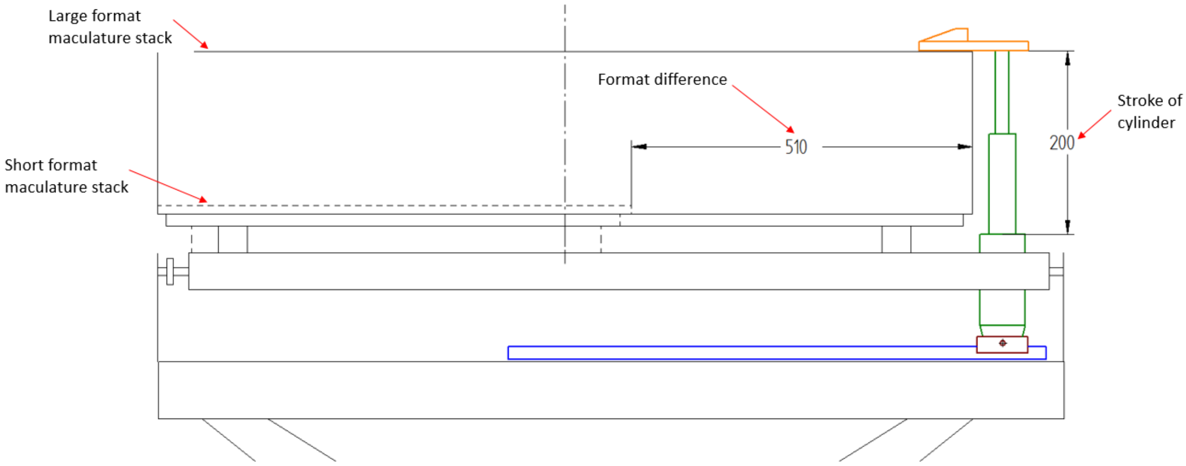

Figure 5.7. Requirements for the sheet holding system

Resulting from the ranges given on the above figure, the following parts are chosen: the telescopic cylinder and the linear rails and slides. The next chapter describes the chosen parts.

5.2.3 Choosing the telescopic cylinder

In the sheet holding system two of the two stage telescopic cylinders are used. Telescopic, because the normal cylinders in their retracted position would be too long, the telescopic cylinder guarantees a short retracted length and a required stroke. The telescopic cylinders have to have a stroke long enough, that they can handle the different sizes of stacks and wooden pallets under them. The stroke length has to be minimum of 200 mm.

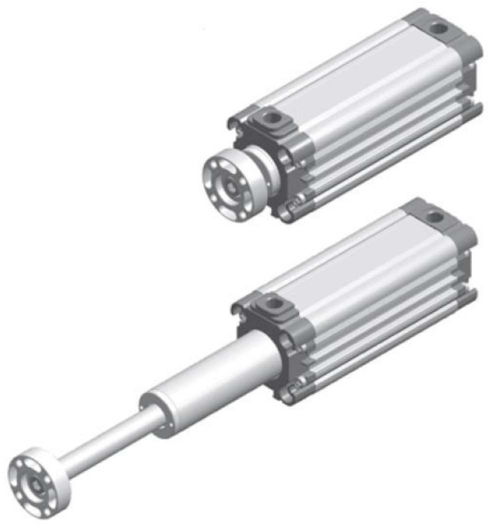

Figure 5.8 Univer two stage telescopic cylinders

The cylinders chosen are Univer two stage telescopic cylinders with a piston diameters of 32 mm and a stroke of 200 mm [9]. The Figure 5.8 illustrates the selected two stage telescopic cylinders. They are chosen, because the retracted length and the stroke length are sufficient. The theoretical force generated by one of the cylinders is 123 N at 6 bar. The total force of 246 N is sufficient enough to hold down the top sheet of the remaining maculature stack, as was noted by the pulling force experiment conducted. The experiment will be explained in chapter 5.3.

5.2.4 Choosing the linear rails and slides

The linear rails and the matching slides are chosen taking into account the requirements put forth in the previous chapter. The rail is chosen 710 mm long and the slide's size is chosen so that the connecting elements to it can be made simple and that it can withstand the resulting loads.

For the sheet holding system, the only loads known, are the working condition loads. They result from the cylinders clamping the stack. There are loads acting on the slide, that are not known, these result from the operator manipulating the cylinders and the sheet holding plate.

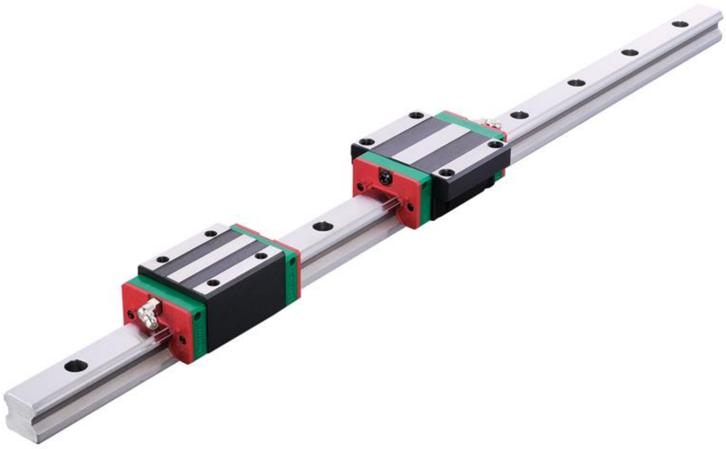

Figure 5.9. HIWIN linear rail and slides

The linear rail and slide chosen are from the company HIWIN, the rail model is HGR20R710C, the slide model is HGW20CAZ0C [10]. Figure 5.9 shows the rail and slides from HIWIN.

5.3 Feeding system

In the following chapter the main system of the maculature feeder, the feeding system, will be described. The working principal will be explained with the help of sketches. From the working principal, the requirements become clear and the technical solution is worked out.

5.3.1 Working principle of the feeding system

As described in the conceptual solution paragraph, the solution that was chosen for the feeding system was to use a linear axis with a telescopic gripper design. The working principle of the sheet feeding system is to fix the separated maculature stack with the gripper, create an air gap under the separated stack with the gripper's pressurized air nozzles and feed the stack over the transfer table to the top of the material stack, release the stack and then move back to its home position.

On the following sketches, the working principle of the sheet feeding system is described, by explaining all of the steps in its working cycle. The cycle is divided into five main steps:

- home position- this is the beginning of the feeding cycle, where the components are at their idle positions;

- fixing the stack – this is the step where the gripper's pneumatic clamps fix the separated stack and the air nozzles create the air gap under the separated stack, in order to reduce friction between the surfaces;
- extending the telescopic gripper arm- during the feeding motion, the telescopic cylinders and the telescopic slides are extended;
- positioning the feed stack- the feed stack's left-right sides are positioned on the materials stack by the linear axis movement, that is controlled by inductive sensors. The stack is released;
- moving back to home position- after the feed stack has been positioned, the telescopic gripper is retracted and moved back to its home position.

The cycle starts, when the gripper is in its home position on the linear axis, when the feed stack has been separated on top of the maculature stack, the sheet holding plate is inserted between the separated maculature stack and the remaining stack and when the transfer table is extended and is clamping the top sheet of the material stack. The below Figure 5.10 illustrates the beginning of the sheet feeding cycle.

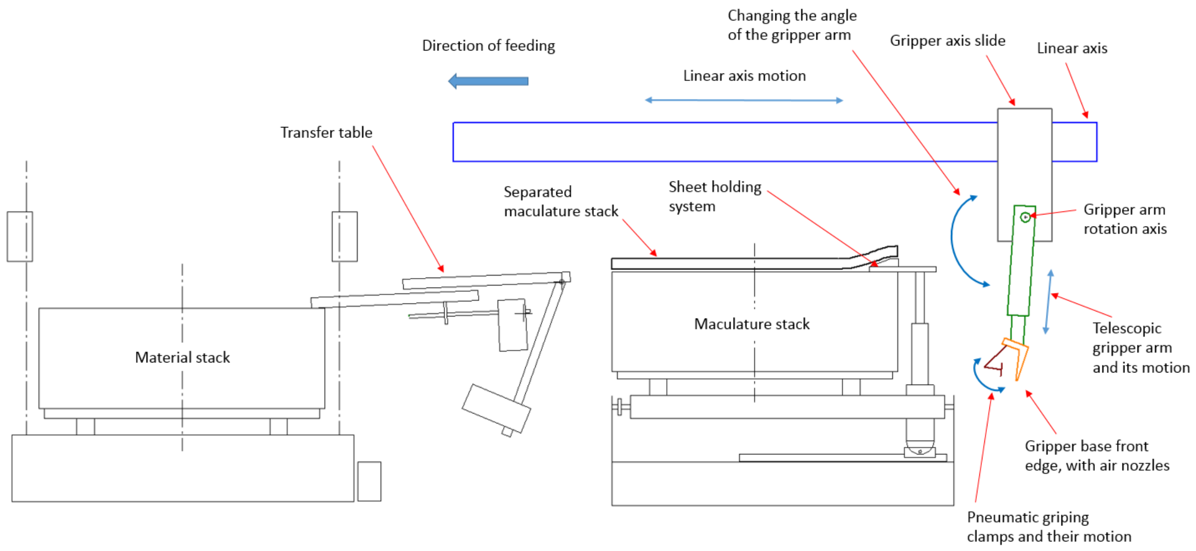

Figure 5.10 The start of the feeding systems' cycle, home position

On the above figure, on the right side, the gripper assembly is shown (gray, green, orange and brown) in its far right, home position. On the top of the figure, the linear axis can be seen (blue). Below the linear axis, the separated maculature stack laying on top of the remaining maculature stack can be seen (black). In the middle of the figure, the transfer table in its working (extended) position is shown and on the left side of the figure, the maculature stack can be seen. This is the beginning of the sheet feeding cycle, following, the feeding system and its components will be described.

The gripper assembly consists of: the gripper axis slide (gray), the telescopic gripper arm (green), the gripper base (orange) and the pneumatic griping clamps (brown). The gripper axis slide is connected to the linear axis' slide and it is responsible for moving the gripper along the length of the linear axis. The telescopic gripper arm is connected to the gripper axis slide via a shaft-bearing assembly and it can rotate around the gripper arm rotation axis. The telescopic gripper arm is responsible for holding the gripper base, the pneumatic griping clamps and subsequently the separated stack and for moving the aforementioned components by extending. The gripper base and the pneumatic griping clamps are connected to the telescopic gripper arm by a rigid connection and they are responsible for holding the separated stack and for creating the air gap between the separated stack and the remaining maculature stack. The gripper base has pressurized air nozzles blowing at its front edge. Following, the next step in the sheet feeding cycle will be described, fixing the stack. Here the gripper is moved under the stack, the pneumatic clamps fix the stack and the nozzles create an air gap under the separated stack.

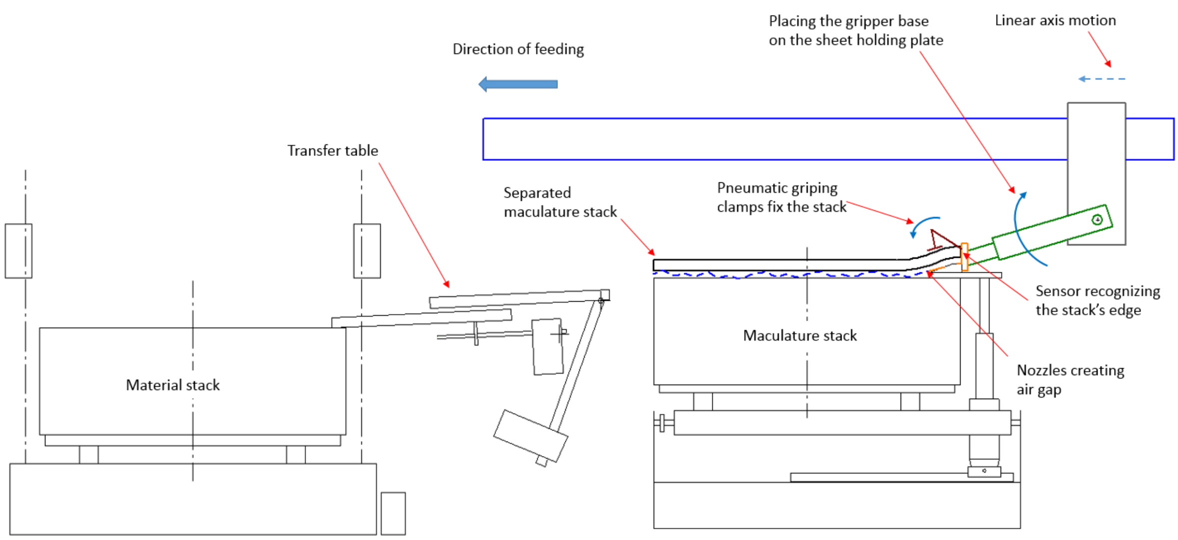

Figure 5.11 Second step in the feeding cycle- fixing the stack

On the above figure, the next step of the feeding cycle is shown. On the right side of the figure, the gripper base, located under the separated maculature stack can be seen. In order to get to this position, the following steps have to be taken. First step, the vertically hanging telescopic gripper arm, (vertical hanging shown on Figure 5.10), has to be lifted by the operator so, that the gripper base would be on the same level with the sheet holding plate. Then the operator drives the linear axis forward by manual control, (dashed blue arrow on the upper right side corner of the figure), as long as the gripper base is sitting on top of the sheet holding plate. Now the operator switches the machine to automatic mode and the entire gripper assembly is moved forward by the linear axis as long as the inductive sensor located in the gripper base recognizes the stack's edge, (the location of the inductive sensor is shown on the above figure). After the inductive sensor in the gripper base has recognized the separated stack, the pneumatic griping clamps are closed. Now the final action is taken, the air nozzle that are located at the front edge of the gripper base are opened and an air gap is created under the separated maculature stack (blue wavy line). Now the system is ready for the next step of the cycle, this is- extending the telescopic gripper arm, this will be described on the following figure.

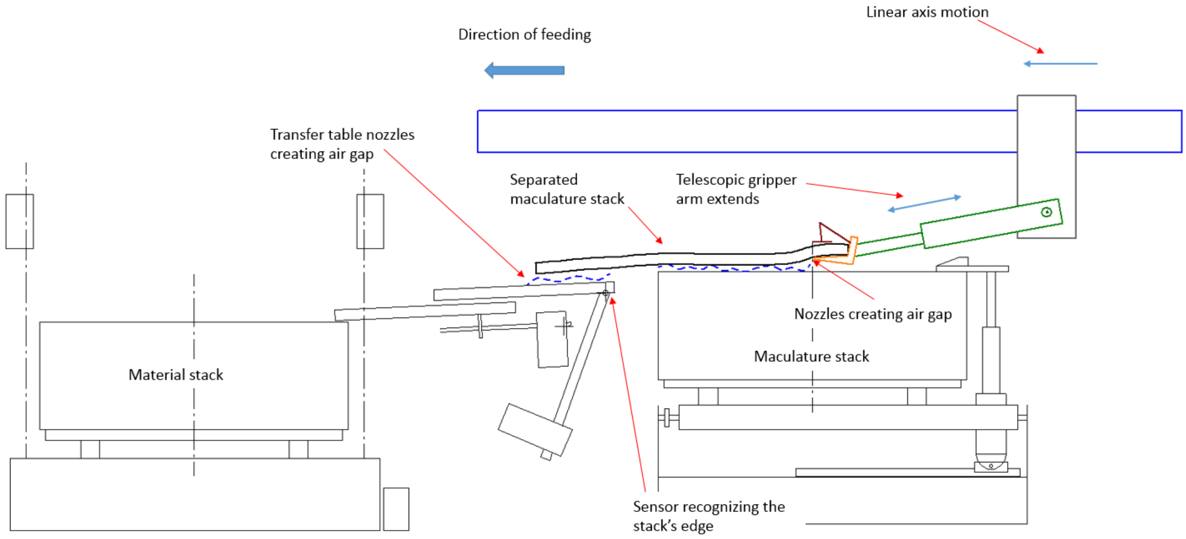

Figure 5.12 The third step in the feeding cycle, extending the telescopic gripper arm

The figure above shows when and how is the telescopic gripper arm extended, following, this will be described. All of the below described actions take place while the gripper assembly is moving. After the stack has been gripped by the pneumatic clamps and the air gap has been created under the stack, the linear axis' slide with the gripper assembly starts to move. While moving, the telescopic cylinder in the gripper arm extends pushing the stack to the left, on top of the transfer table. The inductive sensor located at the edge of the transfer table recognizes the presence of the stack's edge and the air nozzles of the transfer table are opened. Following, the next step in the feeding cycle takes place, the – positioning of the feed stack. The next figure describes the actions preformed performed in this step.

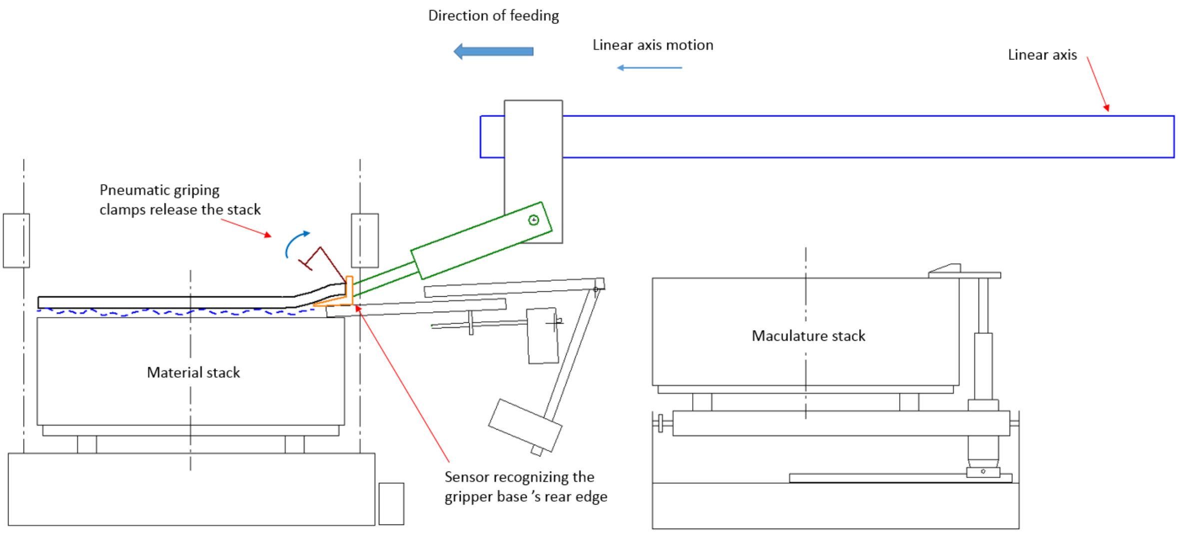

Figure 5.13 Fourth step in the feeding cycle- positioning of the feed stack

On the above figure can be seen, that the gripper assembly has been moved to the left of the figure and the griping clamps released. In order to reach this position, the separated and gripped maculature stack is moved by the linear axis to the top of the material stack. The left-right position of the stack is determined by an inductive sensor located at the transfer table's front edge (shown in Figure 5.13.). The sensor detects the front edge of the feed stack and rear edge of the gripper base. After the inductive sensor has detected the gripper base's rear edge, a counter is started. When the counter is finished, feeding motion is stopped. By the values of this counter and the positioning of the given inductive sensor, the left-right position can be changed. When the stack has been positioned, the pneumatic clamps open, releasing the stack. Now the transfer table and the gripper assembly move simultaneously to the right removing themselves from the material stack's side. The feeding cycle does its last step- moving to home position. The gripper assembly is moved to its home position, shown on Figure 5.10, by the linear axis in order to start a new feeding cycle.

5.3.2 Requirements for the feeding system

From the described working principal, the requirements for the feeding system can be determined in order to work out the technical design. The requirements for the pneumatic clamps are given and a test is described, that was used to determine the requirements for the linear axis.

For the pneumatic clamps, the main requirement is, that is can fit at least 20 mm of sheets in its closed position and its jaws must open up at least 50 mm, also it is preferred, that it is as small as possible. Following, the linear pulling force test is described, the linear axis chosen and in the end of the chapter, the pneumatic clamps chosen.

Linear pulling force test

In order to determine the pulling force in the process of moving the maculature sheets on each other, a test was conducted. One of the largest format of maculature sheets was chosen for the test, the format (915x1040) mm. A stack of 20 mm was separated by hand, the edge of the stack fixed to a scale and then pulled. The force required to move the stack was acquired using the scale and the value in kilograms was multiplied by the gravitational acceleration. Two different conditions were tested and the force on each measured. First condition was pulling the stack with no air blown under the separated stack, and the second with pressurized air blown under the stack with an air nozzle. Following the test setup is shown on the sketch.

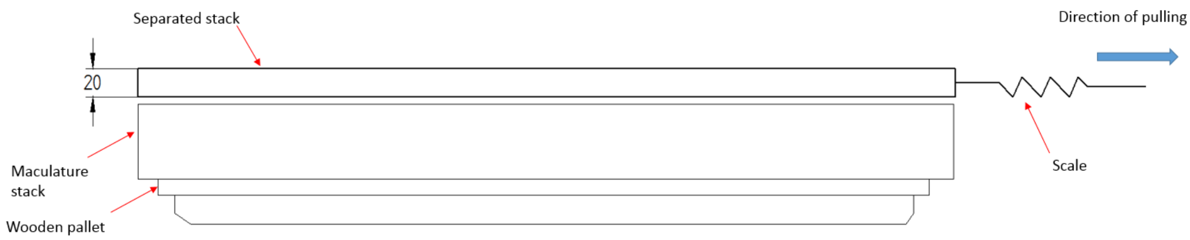

Figure 5.14 First test setup, no air blown under the separated stack

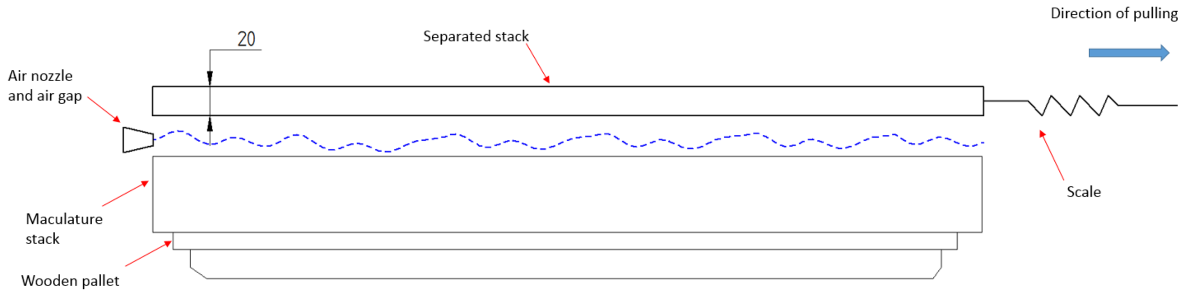

Figure 5.15 Second test setup, air blown under the separated stack

On the two figures above, the test two test setups are shown, the first figure describes the test without any air blown under the separated stack and the second with air blown between the two stacks. On the figures can be seen the stack laying on a wooden pallet and on the right side the scale and the pulling direction is shown. On the second figure, on the left side, the air nozzle is shown and between the stacks, the air stream with blue dashed line shown. The results of the tests are described. When no air was used, the force required to move the stack was 533 N and when air was blown between the two stacks, 66 N of force was needed to move the stack. The force value measured when air was blown between the stacks is used in the selection process of the slide, because the maculature feeder is designed to blow air under the separated stack.

5.3.3 Selecting the linear axis

The linear axis is the main part for the maculature feeder, as it is responsible for feeding the stack of maculature sheets. This chapter describes the selection steps for the linear axis. An appropriate linear axis is found from the company Hepco, because of its good selection of products and technical support. The selection process follows the steps set forth in the catalogue [11]. The first step in the selection process is to determine the required pulling force of the axis and the moments on the slide and to choose the size of the axis profile, the second step is to determine the beam deflection and the third step is to choose the motor for the linear axis based on the required speed.

Determining the required pulling force and loads

The required pulling force is the force that the linear axis has to be able to pull, in the given system this is the sum of the forces and loads acting on the linear axis. The forces and loads acting on the linear axis are: the load resulting from the mass of the gripper assembly, the load resulting from the mass of the linear axis slide and the force required to push the stack, as determined by the pulling force experiment. The following sketch shows the forces and loads acting on the slide.

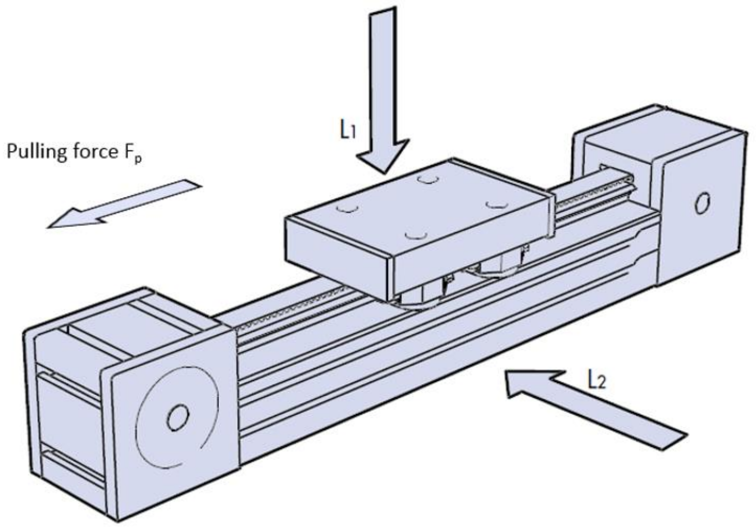

Figure 5.16 The forces and loads acting on the slide

The load L_1 is the sum of the loads resulting from the mass of the gripper assembly of 17,3 kg and the load resulting from the mass of 1,65 kg of the slide itself. This is one part of the required pulling force; the other part is the force required to pull the stack. The load L_2 is considered zero in the given design. Following, the loads and forces are determined and given in a table and the required pulling force found. The pulling force is multiplied with a safety factor of 1,5 to account for unknown factors [12].

The loads are determined by the following equation (5.1):

$$F = m \cdot g, \tag{5.1}$$

where F – the load or force being found (N),

m – mass (kg),

g – gravitational acceleration (m/s^2).

Table 5.3. The pulling force for the linear slide

Name of the force/load	**Value (N)**
Load L_1	185,9
Load L_2	0
Force required to pulling the stack	66*
Pulling force F_p of the linear axis	251,9
F_p with safety factor	**377,9**

*Determined by testing.

Determining the moments on the slide

Following the moments on the axis slide resulting from the given loads are determined. The following figure shows the moments being found and the lever arm of the gripper assembly.

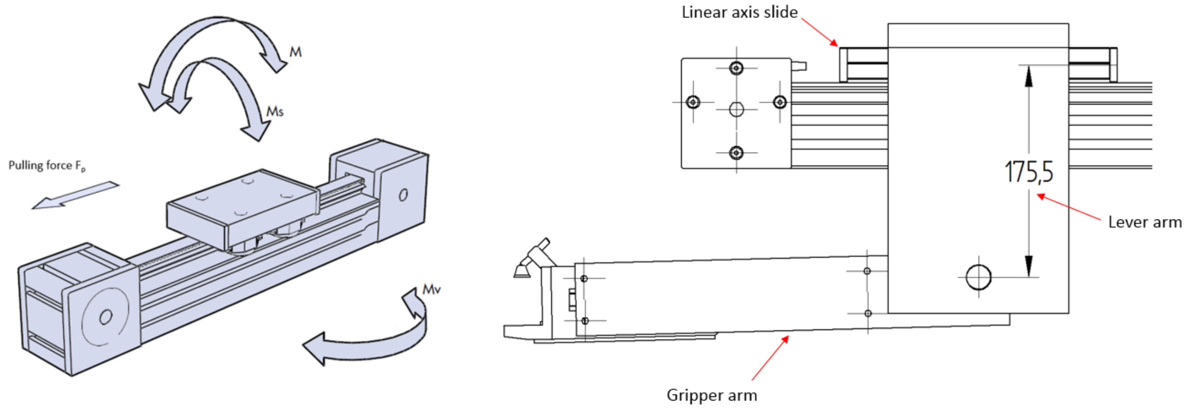

Figure 5.17 The moments being found and the lever arm of the gripper assembly

Following the moments M, M_s and M_v are determined. The moments will be determined using the following equation:

$$M = F \cdot l, \qquad (5.2)$$

where M – the moment being found (Nm),

F – force acting (N),

l – lever arm (m).

The moment M will be calculated:

$$M = 178{,}8 \cdot 0{,}1755 = 31{,}4$$

The moment M_s will be considered zero, because the gripper assembly is designed symmetrically to the linear axis, so both moments being created on each side of it will cancel each other out.

The moment M_v will be considered negligible, because the differences in the center axes of the linear slide and the sheet, that would be responsible for the creation of the given moment are extremely small. The calculated moments are given in the Table 5.4.

Table 5.4. Moments acting on the slide

Moment	**Value (Nm)**
M	31,4
M_s	0
M_v	0
Total	31,4

Choosing the size of the axis profile

Taking into account the forces that the linear axis is required to pull, the loads and moments acting on it, a linear axis model DLS size 3 is chosen. The following Table 5.5. shows the maximum force, load and moment parameters of the chosen linear axis.

Table 5.5. Parameters of the chose DLS 3 linear slide

	Max moments (Nm)			Max loads (N)		Max pulling force (N)
	M	M_s	M_v	L_1	L_2	F_p
DLS 3	120	24	225	1600	3000	560

Determining the beam deflection

It is intended, that the linear axis will be supported from both ends, this means, that the worst case for deflection will occur in the middle of the beam. The beam deflection is found, in order to figure out, if the deflection of the beam has any significant effect on the working behavior of the feeder. After the deflection value is found, a decision is made, if the chosen beam is good enough.

In order to find the total deflection of the beam, three deflection scenarios are looked at and for each a deflection value calculated, then all of them added to find the total deflection. First the beam deflection taking into account only the weight of the beam itself, second, deflection of the beam with the load, and finally the deflection of the slide. The deflection of the beam under its own weight is calculated using the equation (5.3) [11]:

$$d_1 = \frac{5 \cdot L^3}{384 \cdot E \cdot I} \cdot \frac{L \cdot Q \cdot g}{1000}, \tag{5.3}$$

where d_1 – deflection of the beam under its own weight (mm),

L – distance between the supports (mm),

E – Young's modulus of aluminium, 68000 N/mm^2,

I – moment of inertia of the DLS 3 section, 750000 mm^4,

Q – mass of the beam and slide, 7 kg/m,

g – gravitational acceleration, 9,81 m/s^2.

$$d_1 = \frac{5 \cdot 2247^3}{384 \cdot 68000 \cdot 750000} \cdot \frac{2247 \cdot 7 \cdot 9{,}81}{1000} = 0{,}4,$$

The deflection of the beam under the load is calculated using the following equation (5.4):

$$d_2 = \frac{W \cdot L^3}{48 \cdot E \cdot I}, \tag{5.4}$$

where d_2 – deflection of the beam under load (mm),

W – load acting on the beam L_1 = 185,9 N.

$$d_2 = \frac{185{,}9 \cdot 2247^3}{48 \cdot 68000 \cdot 750000} = 0{,}9,$$

The deflection of the carriage is calculated by dividing the load acting on the carriage L_1 with the beam stiffness value for the given load acquired from the catalogue. The equation (5.5) is shown below:

$$d_3 = \frac{W}{s}, \tag{5.5}$$

where d_3 – deflection of the carriage under load (mm), *s* – carriage stiffness for the given load, 10000 N/mm.

$$d_3 = \frac{185{,}9}{10000} = 0{,}02,$$

The total deflection is the sum of the deflection values calculated above, this is given in the following Table 5.6. In Figure 5.18, the deflection directions are shown.

Table 5.6. Deflection values of the DLS 3 beam

Deflection	**Value (mm)**
Under own weight, d_1	0,4
Under load, d_2	0,9
Carriage deflection, d_3	0,02
Total deflection	**1,3**

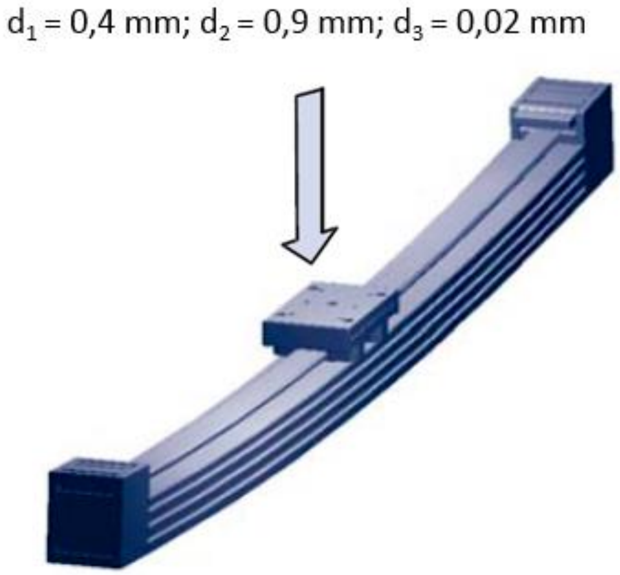

Figure 5.18. Deflections of the beam

The total deflection of 1,3 mm found, is considered to be acceptable, as this has no significant effect on the working behavior of the feeder.

Determining the motor for the linear axis

The last step in the selection process of the linear axis is to choose the driving motor for the axis. The motor is chosen based on the required pulling force and the required speed of the axis.

The required pulling force for the given system can be seen in Table 5.7. and it is 377,9 N. The required speed for the system is 0,5 m/s. The motor is chosen from the following Table 5.7, where different motor sizes are shown, that correspond to the speed of 0,52 m/s.

Table 5.7. Motor selection for the given speed, [11]

Nominal speed m/s at 50 Hz/	Motor poles	Gearbox ratio	Nominal linear force N for axis with motor size						Gearbox rated linear force N
			56 S	56 L	63 S	63 L	71 S	71 L	
0,52	2	12	109	155	239	348	561	-	528

The motor size chosen is the 71 S, with a nominal linear force of 561 N.

In summary, the linear axis chosen is model DLS, size 3, with speed of 0,52 m/s and a total linear pulling force of 561 N.

5.3.4 Selecting the pneumatic clamps

The following chapter describes the selection of the pneumatic clamps that hold the separated maculature stack on the gripper. As mentioned in the requirements chapter, the main requirement for this part are the open and closed positions ranges. The clamping force is not the most important characteristic, because of the shape of the gripper base. The gripper base holds the stack and stops it from moving. The task of the clamp is to support the stack from the top, during the feeding motion, to insure, that the sheets in the stack don’t move relative to each other and that the edge of the stack remains straight.

Figure 5.19. The chosen pneumatic clamp

The chosen pneumatic clamp is from the company Speedyblock [13]. This fits the set requirements, as its clamping jaws open up enough and the closed length can be adjusted, also, it is small enough. The Figure 5.19 shows the chosen pneumatic clamp.

5.4 Transfer table

In chapter 4, the conceptual solutions for different functions, for maculature feeding process were described and final solutions chosen. The conceptual solution for the transfer table was chosen to be a telescopic design, which can change its length from the material stack's side according to the format change of the material. The transfer table has another task as well, it is used to clamp and hold the top sheet on the material stack to prevent it from moving when the maculature stack is fed on top of it.

In this chapter, the working principal of the transfer table is described, from the working principal the requirements are deducted and the locational restrictions found. After the requirements are set, the two main functions of the transfer table: the extension (changing the length to according to the material format) and the clamping of the top sheet are analyzed and the technical solutions for them provided.

5.4.1 Working principal of the transfer table

As described in the conceptual solution paragraph, the transfer table is a bridge between the maculature stack and the material stack. Its main purpose is to extend and to bridge the gap between the maculature stack and the material stack. Its second purpose is to clamp the top sheet of the material stack in order to fix it when the maculature stack is pushed on top of it. In this chapter, the working principal of the transfer table is shown with consecutive sketches and explanations. When the working principal is explained, the requirements and restrictions can be defined and based on them, the technical solution is worked out.

To illustrate the working principal clearly, a full working cycle of the transfer table is shown, starting when the transfer table is in its home position and ending when it has reached there again. Figure 5.20, shows the beginning of the transfer table cycle.

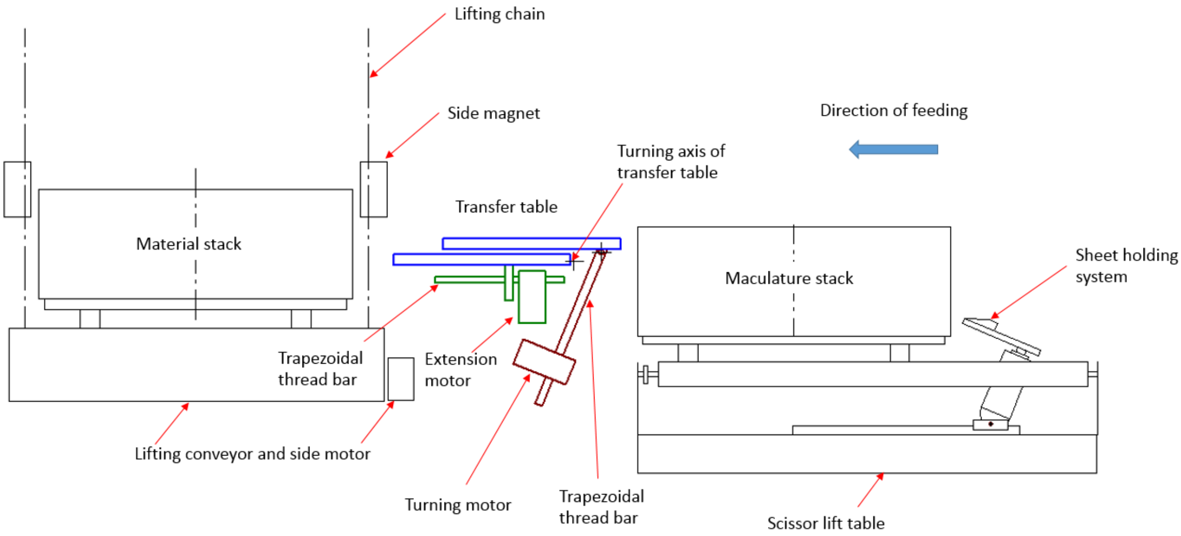

Figure 5.20. Transfer table home position

As can be seen on Figure 5.20, on the left side, the material stack is in its top position, this is the position from where sheets are fed to the printing machine. The side magnets are on the side of the stack, separating the sheets so the suction cups (not shown on the figure) can lift them. On the right side of the figure, the maculature stack is shown in its ready position, this is the feeding position for maculature. In the middle of the figure, the transfer table (with blue) can be seen in its home position, this is the position, where the transfer table will stay, when it is not used and where its cycles will start. Directly below the transfer table (with green) are shown the trapezoidal thread bar and the extension motor. These two components are responsible for extending and retracting the transfer table. Below the extension motor, is the turning motor and the trapezoidal thread bar, they are shown in brown. They are responsible for turning the transfer table around its axis and clamping the top sheet of the maculature stack.

In Figure 5.21, the next step of the transfer tables' cycle is shown, when the transfer table is extended, and the maculature is being fed.

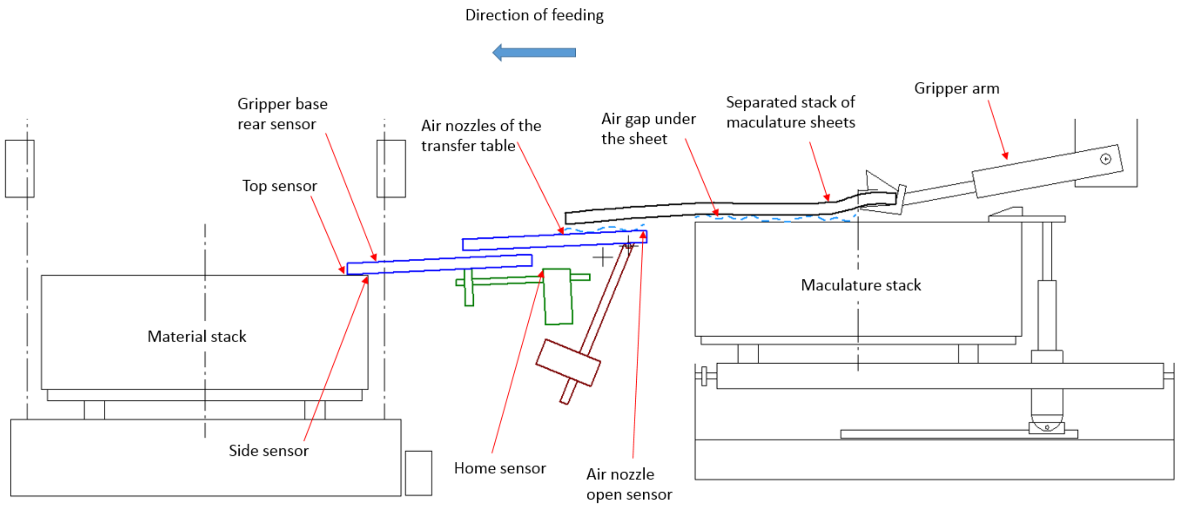

Figure 5.21. Transfer table in its work position

Figure 5.21. shows the transfer table in its extended working position. The first action taken in order to reach this position is to lower the material stack below the side magnets, as can be seen on the left side of the figure. Then two actions have to be performed by the transfer table in order for it to reach the shown position. The first action is to find the side of the of the material stack. This is done by starting the extension motor and turning the trapezoidal threaded bar, extending the transfer table, until the side sensor determines the presence of the stack's side. The second action performed is to clamp the top sheet of the material stack. This is done by starting the turning motor and turning the trapezoidal threaded bar, as a result of this, the transfer table turns on its axis until the top sensor determines the presence of the top side of the material stack. The next step in the cycle is to separate a stack of maculature from the maculature stack by the operator. After the separation, the gripper grips it and starts to move it towards the material stack, as shown on the upper right part in the figure. When the front edge of the feed stack reaches the sensor, which controls the air nozzles in the table, the air nozzles in the transfer table are opened and the stack transferred on an air cushion to the top of the material stack. Figure 5.22 illustrates the final part of the cycle.

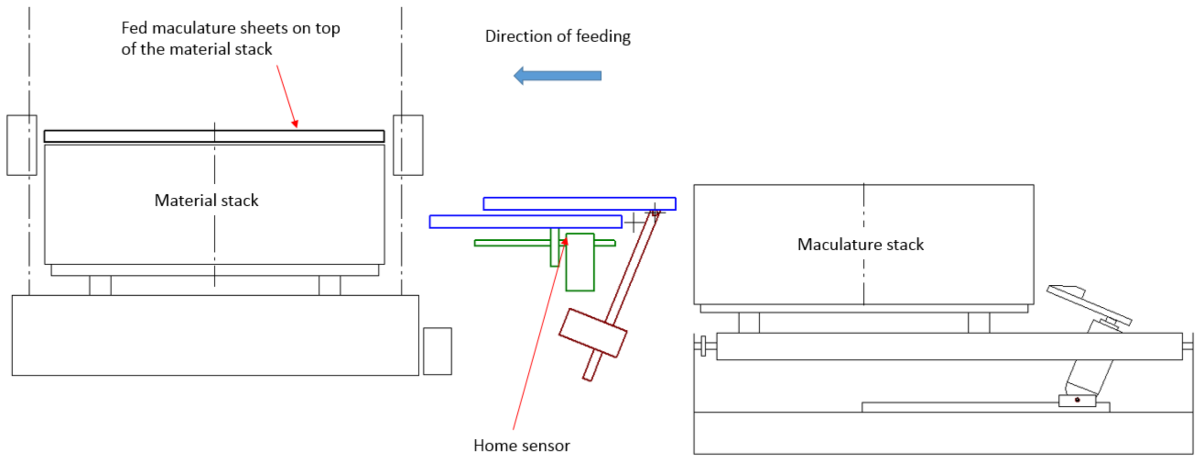

Figure 5.22. The end of the transfer table cycle

Figure 5.22 shows the end state of the transfer table's working cycle. As can be seen in the middle of the figure, the transfer table is retracted. On the left side the material stack with the fed maculature stack on it can be seen. It has been lifted to its feeding position for the printing machine. In the right of the figure, the maculature stack has been lifted by the amount that was fed off the stack. The steps that have to be taken by the transfer table in order to reach this state are: first to unclamp itself from the top edge of the material stack and then to retract itself. The unclamping is done opposite to the clamping action, by rotating the turning motor in the opposite direction, this rotates the transfer table on its axis until the inductive sensor loses its signal from the top side of the stack. The retracting is done opposite to the extending, by starting and rotation the extension motor in the opposite direction until the home position is recognized by the home sensor next to the motor. This concludes the transfer table's full working cycle.

5.4.2 Requirements for the transfer table

From the described working principal, the requirements and restrictions can be deduced, in order to work out the technical solution for the transfer table. Following, the requirements for the transfer table are described.

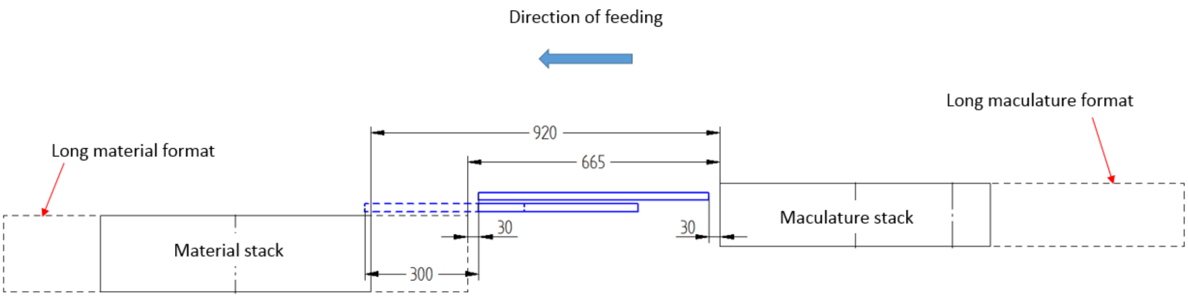

Figure 5.23. Dimensional requirements back view

It is important, that the transfer table can deal with all of the different formats of maculature and material. Figure 5.23 shows the maximum positions that the table has to be able to reach. The gap between the maculature stacks left side and the short material format right side is 920 mm, with the long material format, the distance is 665 mm. In the retracted position, the transfer table can’t touch the material stack, there is a 30 mm distance between the stack side and the transfer table. The stroke of the transfer table has to be 300 mm.

The locational restriction for the transfer table come from the feeder’s lifting chains. The chains that are responsible for lifting the material stack and the roller conveyor under it. The following Figure 5.24 shows the restriction in a top view.

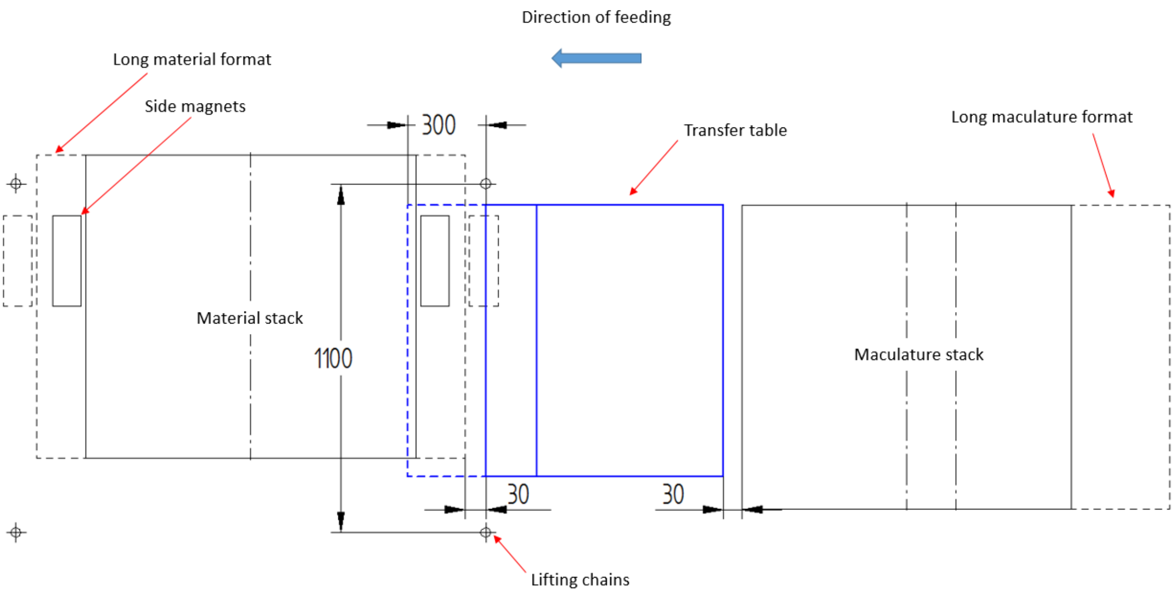

Figure 5.24. Transfer table locational restriction

As can be seen, the lifting chains are 1100 mm apart. The transfer table has to be between the chains.

In order to fulfill the described requirements, appropriate telescopic guides have to be chosen, the next chapter deals with the telescopic guide selection.

5.4.3 Selecting the telescopic guides

The telescopic guide has to allow the transfer table to move 255 mm to accommodate the differences in format plus an extra 30 mm not to be in the way of the material stack. The guide selected is from Chambrelan, the model RA7R, with the retracted length of 300 mm [14]. The extended length is 315 mm and a pair of guides is capable of bearing a mass of up to 180 kg, since the transfer table is never loaded with maculature when it is not resting on the edge of the material stack, then this is load capability is sufficient for the current application.

Figure 5.25. Chambrelan telescopic slide

Figure 5.25 shows the type of the selected guide.

5.5 The concept of the control algorithm

In the previous chapters, the working principals and the technical solutions for the most important subsystems of the maculature feeder were described. In the following chapter, the concept of the control algorithm is given by explaining one full working cycle of the maculature feeder, assuming, that the maculature feeder is empty and there is a material stack in the existing feeder in the feeding position. All the steps required to get the maculature from the loading area conveyor to the top of the material stack will be given accompanied by the conditions that have to be met to accomplish a given step. The following Figure 5.26. shows the control algorithm graphically.

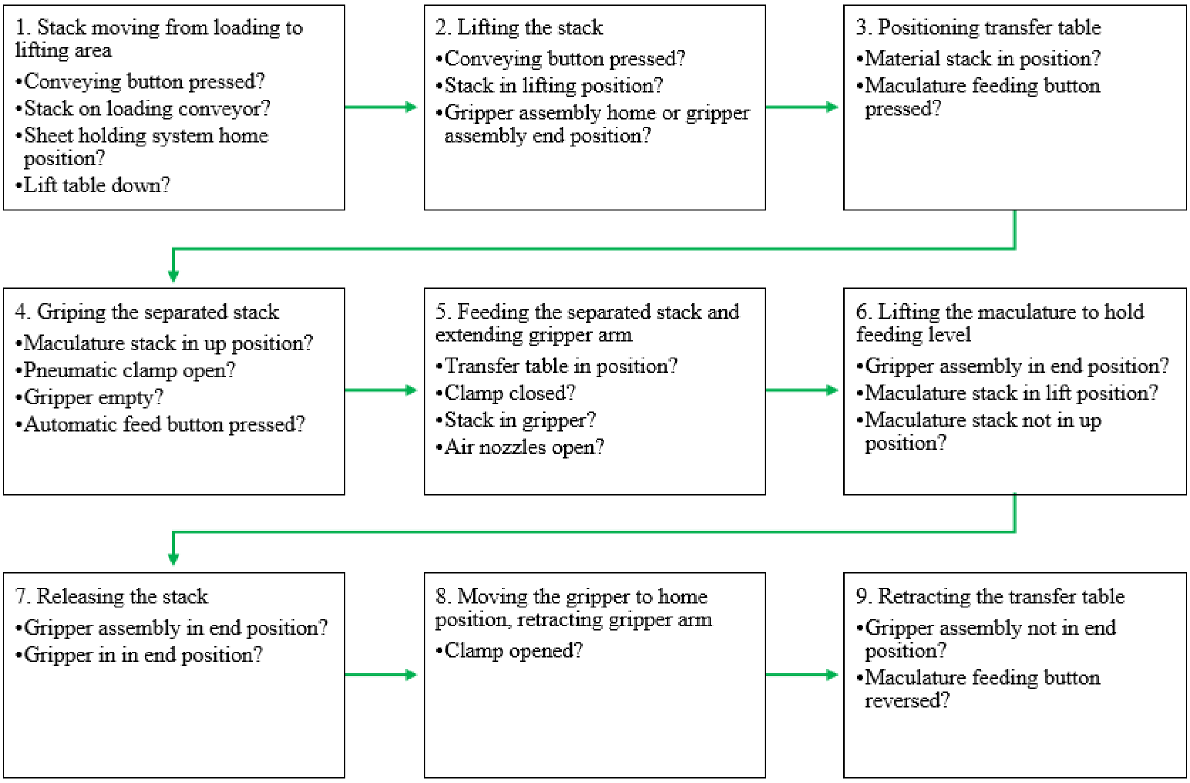

Figure 5.26. Concept of the control algorithm

The figure above shows the steps necessary to get the maculature sheets from the storage stack on the loading conveyor to the top of the material stack in the existing feeder. There are ten steps in the working cycle, following, all of the actions that will be done in these steps will be described, the conditions that need to exist for the action to take place is shown on the above figure.

1. **Stack moving from the loading to the lifting area**

The loading conveyor motor started, it runs until the stack reaches the end of the loading conveyor, loading conveyor end sensor recognizes the arrival and starts the lifting conveyor motor. The lifting conveyor motor is stopped when the stack reaches the end of the lifting conveyor and is recognized by the sensor: lifting position.

2. **Lifting the stack**

The scissor lift table motor is started; the table is lifted as long as the lifting stop sensor is reached.

3. **Positioning the transfer table**

The extending motor of the transfer table is started; it runs as long as the stack side sensor recognizes the material stack's side. Now the rotation motor is started and run as long as the top sensor recognizes the top side of the material stack.

4. **Griping the separated stack**

The linear axis motor is started and run as long as the gripper base sensor recognizes the stacks edge. When this happens, the pneumatic clamps are closed and the air nozzles opened.

5. **Feeding the separated stack and extending gripper arm**

The linear axis is started, whilst moving, the telescopic cylinder in gripper arm is extended. When the front edge of the stack reaches the transfer table's front edge sensor, the air nozzles in the transfer table are opened. The linear axis motor is run as long as the transfer table's rear edge sensor recognizes the rear edge of the gripper base, this is the grippers end position.

6. **Lifting the maculature to hold feeding level**

The scissor lift table motor is started and run as long as the maculature stack edge reaches the lifting stop sensor.

7. **Releasing the stack**

When the given conditions are met, the pneumatic clamps are released.

8. **Moving the gripper to home position, and retracting the gripper arm**

The linear axis is started and run as long as the gripper assembly is in home position, during the motion, the telescopic cylinder is retracted.

9. Retracting the transfer table

The rotation motor is started in reverse direction and run as long as the material stack top side sensor loses contact with the top side of the stack. Then the extension motor is started in reverse direction and run as long as the home position sensor recognizes the bottom table of the transfer table.

6 ECONOMIC PART

6.1 Cost of the feeder to the company

Metaprint AS is a company specialized on producing aerosol cans, although it has its own technical department and workshop, their main task is to maintain and repair the production machinery. Taking this fact into account, all of the parts required to build the maculature feeder can't be manufactured in-house, for example the electrical design and programming, larger welded and bent parts need to be outsourced.

Since at the time of writing the thesis, the final decision about the maculature feeder has not yet been taken and the outsourcing amount and companies have not yet been chosen. The price calculation gives the price of the main catalogue parts for the feeder. Some of the prices are quoted prices from dealers, (see appendices 1 to 3), some of the prices are estimated based on previous purchases made by Metaprint AS. The following Table 6.1. presents the main expense articles

Table 6.1. Cost of main articles

Part	**Quantity**	**Price/pc**	**Total price, €**	**Manuf.**	**Dealer**	**Year**
Conveying system						
Conveyor rollers	14	94,6	1324,4	Rollven	Alas-Kuul AS	2013
Motor	1	275	275	SEW Eurodrive	Alas-Kuul AS	2015
Sensors	2	27	54	-	Viru elektrikaubandus	2016
Lifting system						
Scissor lift table	1	1845	1845	-	AJTooted	2016
Pneumatic valve	1	80	80	Festo	Festo	2015
Telescopic cylinders	2	408,58	817,16	Univer	Lektar	2016
Linear guides	2	80	160	HIWIN	Alas-Kuul AS	2015
Linear slides	2	26	52	HIWIN	Alas-Kuul AS	2015
Conveyor rollers	10	94,6	946	Rollven	Alas-Kuul AS	2013
Motor	1	275	275	SEW Eurodrive	Alas-Kuul AS	2015

Sensors	4	27	108	-	Viru elektrikaubandus	2016
Feeding system						
DLS3	1	2798	2798	Hepco Motion	Mekanex	2016
Telescopic guides	2	144	288	Chambrelan	Mekanex	2016
Telescopic cylinders	1	557,54	557,54	Univer	Lektar	2016
Pneumatic valve	2	80	160	Festo	Festo	2015
Sensors	1	27	27	-	Viru elektrikaubandus	2016
Transfer table						
Telescopic guides	2	118	236	Chambrelan	Mekanex	2016
Bearings	2	16	32	SKF	Alas-Kuul AS	2015
Motors	2	150	300	SEW Eurodrive	Alas-Kuul AS	2015
Trapezoidal bar	2	23	46	Mädler	Alas-Kuul AS	2016
Trapezoidal nut	2	25	50	Mädler	Alas-Kuul AS	2016
Sensors	5	27	135	-	Viru elektrikaubandus	2016
Total			10566,1			

SUMMARY

The aim of the given thesis was to create a preliminary design for an automatic maculature feeder that would reduce the manual labor required for the changeover process, increase the safety of the maculature transportation process and enhance the productivity of the UV printing line by speeding up the changeover process. The preliminary design was needed to understand what are the technical possibilities, what is the complexity and what is the price of automating the maculature feeding process. This information will be used in order to make a decision about whether to automate the process or not.

As a result of the given thesis, a preliminary design for a semiautomatic maculature feeder was completed, that meets all of the requirements set out except being fully automatic, the price for the main catalogue components is around 11000 euros. The maculature feeding process and the possible fully automatic technical solutions were analyzed and a realization was made that in order to meet the process related requirements set out, the maculature feeder needs to be semiautomatic.

The requirements set by Metaprint AS for the maculature feeder were that it needed to be able to work with the existing maculature stacks and the formats being used at present. The maculature feeder had to be a standalone solution or a combination of standalone solutions, it was not preferred to redesign any existing parts of the printing machine's feeder. The maculature feeder had to be faster than the existing manual process of 1 minute 30 seconds.

First a market analysis was conducted to find existing solutions for maculature feeding. This didn't give any satisfactory results as there were no solutions available. The reason was thought to be that Metaprint AS's usage of the printing line is unique and this brings out the problem of maculature feeding. Metaprint AS is using the printing machine for short runs and the machine is subject to many changeovers, which mean many maculature feeding cycles. It was decided to work out a solution for maculature feeding.

In order to come up with a solution for the maculature feeder, first the maculature feeding process and its functions needed to be defined. This was done by analyzing the material feeding process and taking this as a base to build the maculature feeding process on. The maculature feeding process uses the logic of the material feeding process but requirements for maculature feeding are added to it. The main difference between the two processes is, that when in the material feeding process one sheet is taken and fed, then in the maculature feeding process a

stack of maximum 20 mm is separated from the main stack and fed, this is a requirement for the maculature feeding process in order to have the cycle time under 1 minute 30 seconds.

When the maculature feeding process and its function steps were defined, different conceptual solutions for process functions were provided. In analyzing different solutions for process functions, a realization was made, that in order to fulfill the most important process related requirements set out for the maculature feeder, it needs to be semiautomatic, meaning, that some of the process functions will be done by the operator. The decision was made, because the solutions provided could not guarantee the reliability and an error free operation of the system.

Regardless that some of the functions are done by the operator, the maculature feeder will still reduce the amount of manual labor in the changeover process, it will increase the safety of the maculature transport, because the operator will not be lifting anything and the cycle time will be more than twice as short as with the manual situation, estimated to be about 40 seconds.

With the final conceptual solution, the maculature stack is loaded onto the roller conveyor using the forklift and always positioned by its left side. It is then conveyed onto the scissor lift table by the loading area roller conveyor. The front side of the maculature stack is moved against the stack stop that is fixed to the scissor lift table by the roller conveyor positioned on the scissor lift table. The stack is then lifted to the feeding height by the scissor lift table and an appropriate stack of maculature sheets is separated from the main stack by the operator. The sheet holding plate is positioned under the separated stack by the operator and the gripper positioned onto the sheet holding plate. From there the gripper will grip the stack, create an air gap under the stack and feed it over the telescopic transfer table onto the material stack inside the feeder. The gripper and the transfer table will then move away from the vicinity of the material stack. The operator then comes and pushes the fed maculature stack against the stack stop in front of the material stack inside the feeder and check if the sides of the fed stack are aligned correctly with the material stack. The material stack is then lifted and the maculature sheets on the material stack fed to the printing machine.

After the conceptual solution for the maculature feeder was fixed, the preliminary design for the feeder was done. In the preliminary technical design done, the working principle of the main systems of the feeder were described and the main catalogue parts chosen. The concept of the control algorithm was created. For the lifting system a scissor lift table from the catalogue of AJTooted with a lifting capacity of 2000 kg will be used. For the sheet holding system two Univer telescopic cylinders will be used. For the feeding system a 2200 mm stroke DLS 3

Hepco linear axis with the speed of 0,52 m/s and with a linear pulling force of 561 N will be used. For the transfer table, Chambrelan RA7R telescopic slides will be used.

When the preliminary technical design was finished, the price of the chosen parts was calculated and the price of parts that were not chosen was calculated based on the previous purchase of similar products made by Metaprint AS. The total cost of the parts was found to be around 11000 euros. The price of the control system and the production of parts is not given.

The next step for the maculature feeder project is to use the information provided by this thesis to make a decision whether or not to automate the maculature feeding process. When the decision is taken to automate it, then the detailed design phase will start and the provided preliminary design will be designed further and in full detail in order to produce detailed drawings for the production of individual parts.

The set goals for the thesis are regarded as fulfilled as a working design for the maculature feeder has been created and the main cost of it found. The thesis writing process has been interesting and challenging to the author because during the writing process design compromises had to be made and the initial requirements for the machine had to be reassessed.

LAIENDATUD KOKKUVÕTE

Käesolev lõputöö teostati Metaprint AS'i Tallinna tehase UV trükiliinil, selle töö eesmärk oli välja töötada makulatuuri automaatse etteandeseadme esialgne tehniline lahendus ning hinnata selle eeldatavat maksumust. Välja töötatav seade pidi olema võimeline vähendama operaatori töökoormust trükidisaini vahetuse protsessi ajal, suurendama makulatuuri transportimise töö ohutust ning võimaldama trükiliini tootlikkust tõsta kiirendades disainivahetuse protsessi. Antud töö lõpptulemust kasutatakse otsuse tegemiseks, kas makulatuuri etteandmise protsessi automatiseeritakse või mitte.

Nõuded etteandmeseadmele seati Metaprint AS'i poolt. Seade pidi olema võimeline töötama kasutusel olevate makulatuuri formaatidega ning paki kõrgustega, mis võivad varieeruda piirides 10 mm kuni 165 mm. Makulatuuri etteandeseade pidi olema iseseisev seade või kombinatsioon iseseisvatest seadmetest, olemasolevate seadmete ümberehitamine polnud eelistatud. Etteandeseade pidi olema kiirem olemasolevast käsitsi makulatuuri transportimise protsessist, milleks oli 1 minut 30 sekundit.

Lahenduse leidmiseks esmalt uuriti olemasolevaid seadmeid ning võimalusi. Selleks teostati turuanalüüs, mis ei andnud oodatud tulemusi, kuna turul puudusid valmis lahendused. Põhjus lahenduste puudumiseks arvati olevat Metaprint AS'i iseäralikus trükiliini koormamises, nimelt trükiliiniga toodetakse väikseid partiisid, mis tähendab, et seadet seadistatakse tihti ühelt disainilt teisele. Tihedate disainivahetuste teostamisega kerkib esile makulatuuri transportimise probleem, mida hetkel tehakse käsitsi. Kuna turult eil leitud sobivat lahendust otsustati luua makulatuuri etteandmisseadme esialgne lahend.

Makulatuuri etteandeseadme tööprintsiibi aluseks on makulatuuri etteandmise protsess ja selle erinevad funktsioonid. Makulatuuri etteandmise protsessi defineerimiseks analüüsiti olemasolevat materjali etteandmise protsessi. Eelnimetatud protsess võeti aluseks ja sellele lisati makulatuuri etteandmise iseäralikud sammud. Põhiline erinevus nimetatud kahe protsessi vahel on, et kui materjali etteandmine toimub ühe lehe kaupa, siis makulatuuri antakse ette maksimaalselt 20 mm paksuse paki kaupa. See on vajalik, et täita tsükliaja nõuet; saavutada makulatuuri etteandmine kiiremini, kui 1 minut 30 sekundit.

Pärast makulatuuri etteandmise protsessi ja selle funktsioonide defineerimist, pakuti iga funktsiooni tegemiseks erinevaid kontseptsionaalseid lahendeid. Erinevate lahendusvariantide analüüsimise käigus jõuti järelduseni, et etteandeseade peab olema poolautomaatne. See tähendab, et mõned makulatuuri etteandmise protsessi etapid tehakse operaatori poolt, kuna töökindlaid ja automatiseerimist võimaldavaid tehnilisi lahendusi ei õnnestunud leida.

Olenemata sellest, et operaator on makulatuuri etteandmisprotsessis siiski osaline, väheneb operaatori füüsiline koormus disainivahetuse tsükli ajal ning suureneb makulatuuri etteandmisprotsessi ohutus kuna operaator ei pea tõstma makulatuuri lehti. Tsükliaeg lüheneb hinnanguliselt rohkem kui kaks korda, 40 sekundini.

Makulatuuri etteandeseadme välja töötatud kontseptsioon näeb ette makulatuuri paki asetamist tõstukiga laadimisala rullkonveierile paki vasaku külje järgi. Seejärel pakk liigutatakse laadimisala rullkonveieri poolt käärtõstukil olevale rullkonveierile. Käärtõstuki rullkonveier liigutab paki esimese külje vastu liikumatut pakitõket. Makulatuuri pakk tõstetakse käärtõstuki poolt ülesse etteandmistasemele, mille järel operaator eraldab vajaliku paki makulatuuri lehti ülejäänud pakist ning asetab eraldatud makulatuurilehtede paki alla lehe-tõkestusplaadi. Seejärel paigutab paki-haaraja lehe-tõkestusplaadi peale, mis haarab eraldatud makulatuurilehtede paki, tekitab paki alla õhupadja ja liigutab makulatuurilehtede paki üle teleskoopilise vahelaua materjali paki peale, mis asub olemasoleva etteandja sees. Paki-haaraja ja vahelaud liiguvad seejärel materjali pakist eemale, misjärel operaator lükkab transporditud makulatuurilehtede paki vastu materjali paki ees olevat pakitõket ning kontrollib, et transporditud paki servad on materjali paki servadega ühel joonel. Seejärel tõstetakse materjali pakk koos makulatuuri lehtedega materjali etteandmise tasapinnale ja transporditakse trükimasinasse.

Pärast makulatuuri etteandeseadme kontseptsionaalse lahenduse kinnitamist loodi esialgne tehniline disain, mille käigus töötati välja seadme tähtsamad sõlmed ja valiti olulisemad ostutooted, koostati ka juhtimisalgoritmi kontseptsioon. Tõstesüsteemis kasutatakse 2000 kg tõstevõimega käärtõstukit AJTooted kataloogist, lehe-tõkestus süsteemis kasutatakse firma Univer teleskoop pneumaatilisi silindreid, etteandmissüsteemina kasutatakse firma Hepco lineaartelge DLS 3, 2200 mm käigupikkuse, 561 N tõmbejõu ja 0,52 m/s kiirusega. Vahelaua konstruktsioonis kasutatakse firma Chambrelan RA7R teleskoopsiine.

Pärast esialgse tehnilise disaini valmimist ja ostutoodete valimist saadi valitud ostutoodete hind edasimüüjate käest ning ülejäänud ostutoodete hind saadi Metaprint AS’i eelnevate sarnaste ostude baasil. Ostutoodete summaarseks maksumuseks saadi 11000 eurot. Üldisest hinnast puudub detailide valmistamise ja juhtimissüsteemi hind.

Järgmiseks sammuks antud projektis on võtta vastu otsus, kas makulatuuri etteandmisprotsessi hakatakse automatiseerima või mitte. Kui jah, siis antud esialgne tehniline disain töötatakse täielikult läbi ning seade valmistatakse.

Magistritööle seatud eesmärgid on loetud täidetuks, kuna töötav lahendus on loodud ning selle hinnanguline maksumus arvutatud. Töö kirjutamise protsess on autorile olnud huvitav ja väljakutseterohke kuna töö kirjutamise käigus tuli teha disainis kompromisse ja esialgseid nõudeid seadmele ümber hinnata.

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APPENDICES

Appendix 1 Price quotes for telescopic cylinders

We can quote these Univer products to you as follows:

1 pc	**RT 2 2 0 032 0300 M**	**459,76 €/pc**
1 pc	**KF-10032A**	**22,34 €/pc**
1 pc	**KF-11032S**	**75,44 €/pc**
2 pc	**RT 2 2 3 032 0200**	**310,80 €/pc**
2 pc	**KF-10032A**	**22,34 €/pc**
2 pc	**KF-11032S**	**75,44 €/pc**

List prices alv 0 %

Discount - 45 % from prices above

Delivery term ex-stock Helsinki Finland

Delivery time 3-5 weeks from order

Payment term to be agreed

If any questions kindly contact me

Best regards

Timo Vakkila
Technics / Department Manager
****
Lektar Oy

Appendix 2 Price quote for linear axis

Hinnad:
DLS 3 2200 L W K .... 2136 EUR
- pikk kelk
- 2 tk piirasendite lülitid, mehhaanilised
- mootori-reduktori valmidus

WG 3 R12 4 M 71 S 2 A 1 ..... 662 EUR
- reduktormootor, tigureduktor i=12

Lugupidamisega
Raul Maripuu

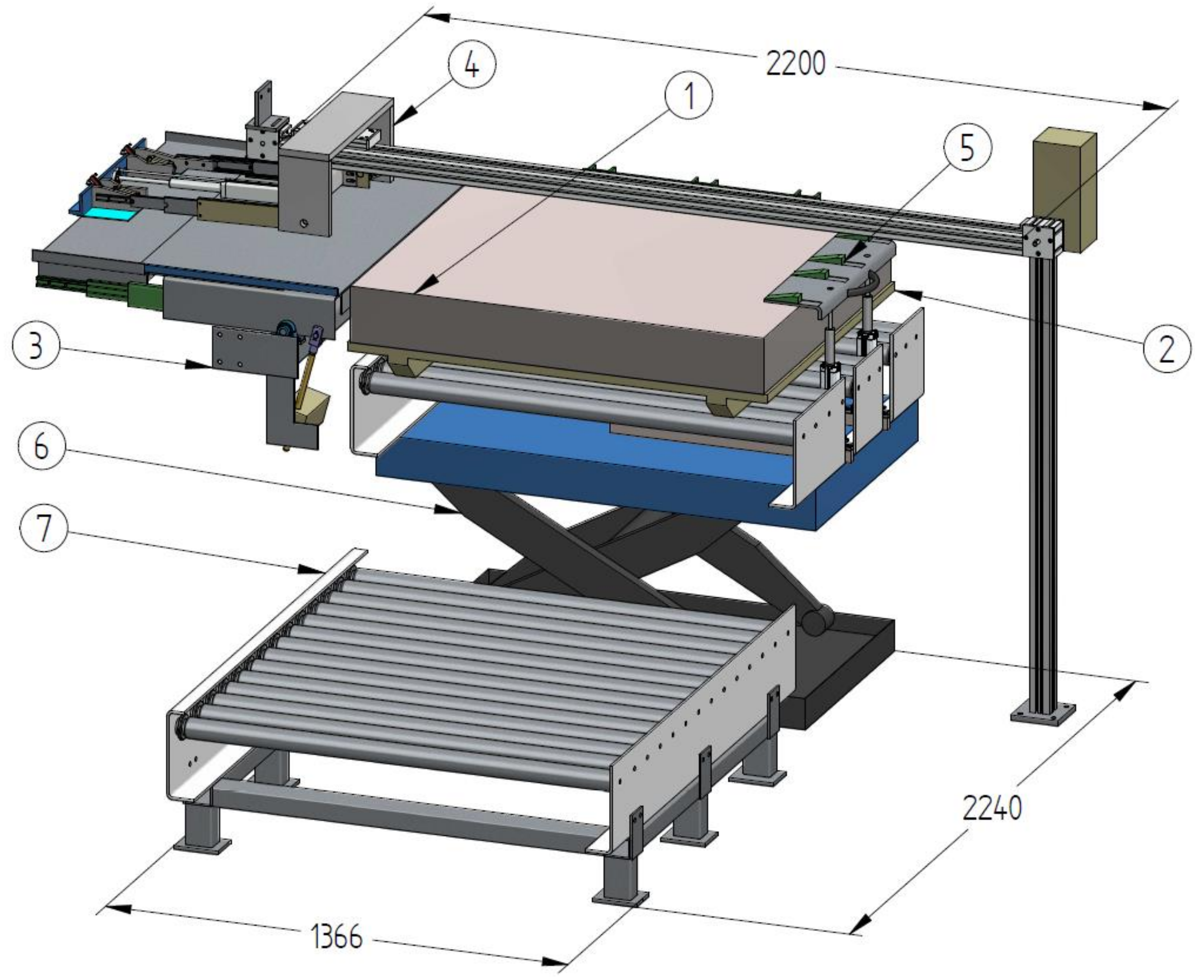
OY MEKANEX AB Eesti filiaal
Peterburi tee 46,
EE11415 TALLINN
ESTONIA
Tel. +372 6139844
Fax. +372 6139866
Mob. +372 54522880
info@mekanex.ee
www.mekanex.ee
www.mekanex.fi

Appendix 3 Price quote for telescopic guides

Tere
Hinnad:
RA774 - 2 tk - 300 mm käik ..... 118 EUR/tk .... 190 kg/paar .... ca 2 nädalat
RA654 - 2 tk - 250 mm käik ..... 144 EUR/tk ...... 47 kg/paar ... ca 5 nädalat

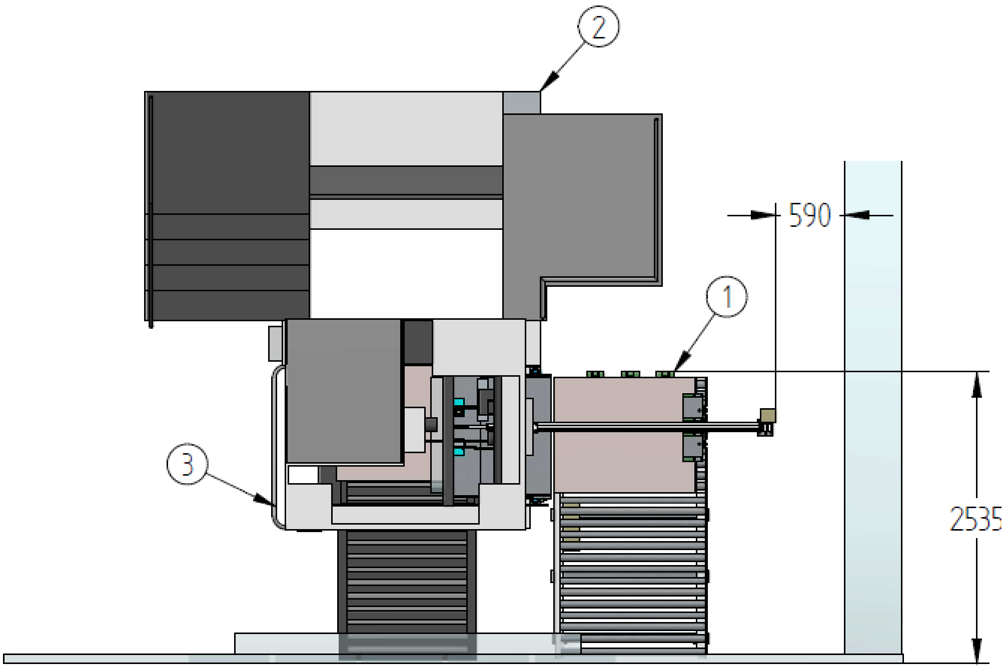
Tervitades
Raul Maripuu
Mekanex

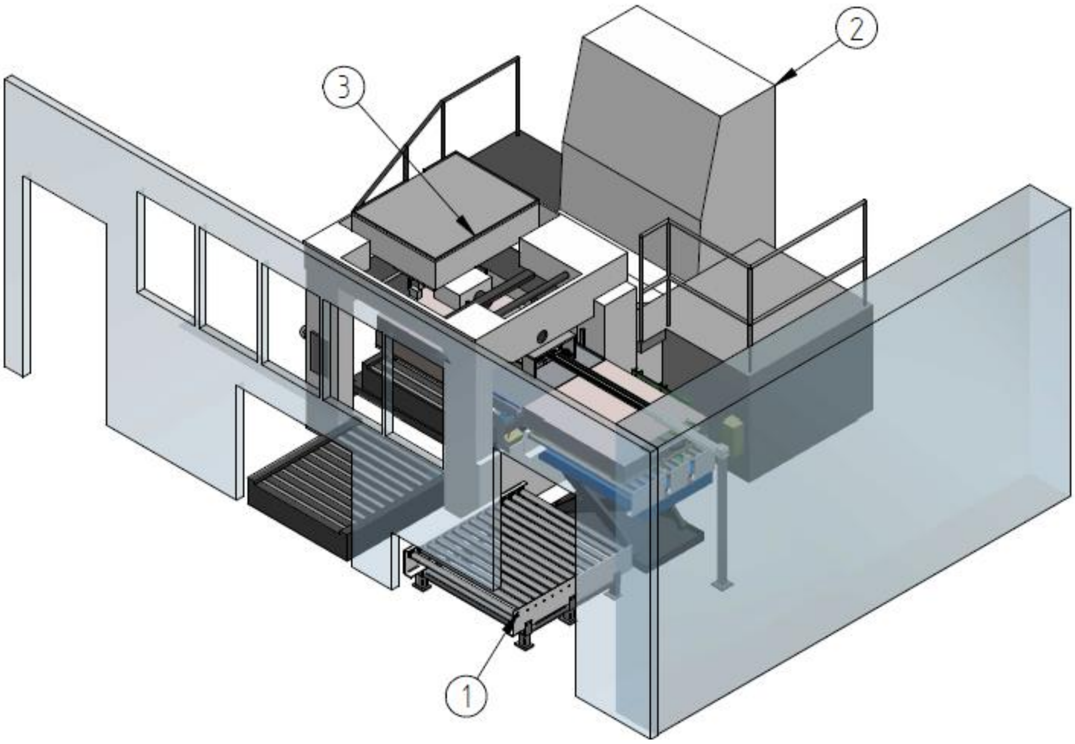
Appendix 4 Maculature feeder



Pos	Code	Title	Qty
1		Mak_pakk	1
2		Wooden_pallet	1
3	MF_01_01_00_00	MF_01_01_00_00_Transfer_table_v3	1
4	MF_01_02_00_00	MF_01_02_00_00_Feeding_system_v1	1
5	MF_01_03_00_00	MF_01_03_00_00_Sheet_holding_system_v1	1
6	MF_01_04_00_00	MF_01_04_00_00_Lifting_system	1
7	MF_01_05_00_00	MF_01_05_00_00_Conveying_system	1

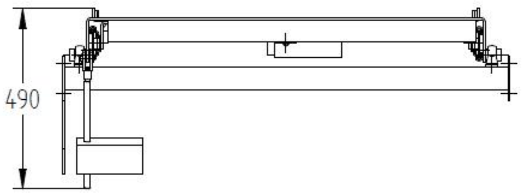
Appendix 5 Maculature feeder location

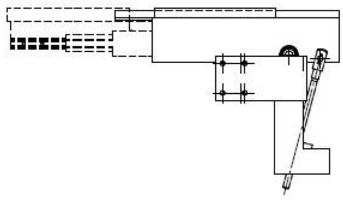


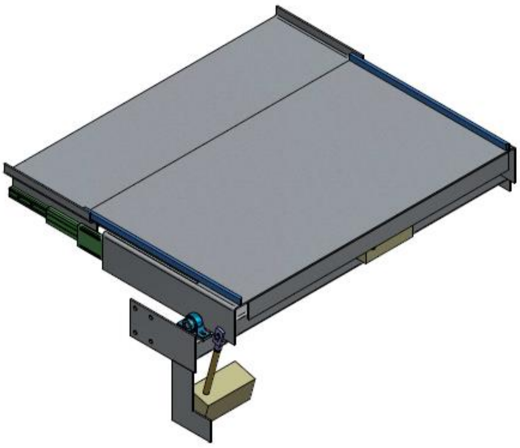


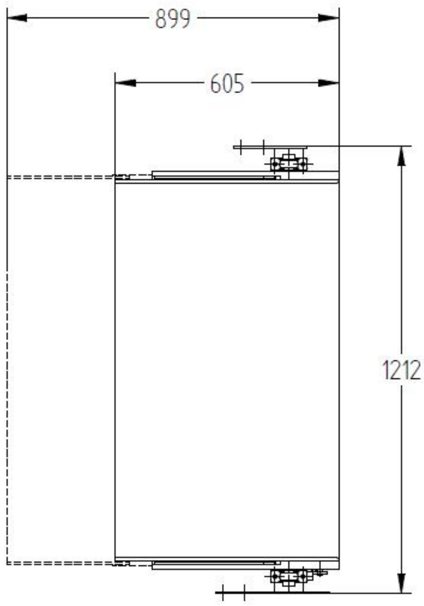
Pos	Title	Qty
1	Maculature feeder	1
2	Printing machine	1
3	Printing machine's feeder	1

Appendix 6 Transfer table

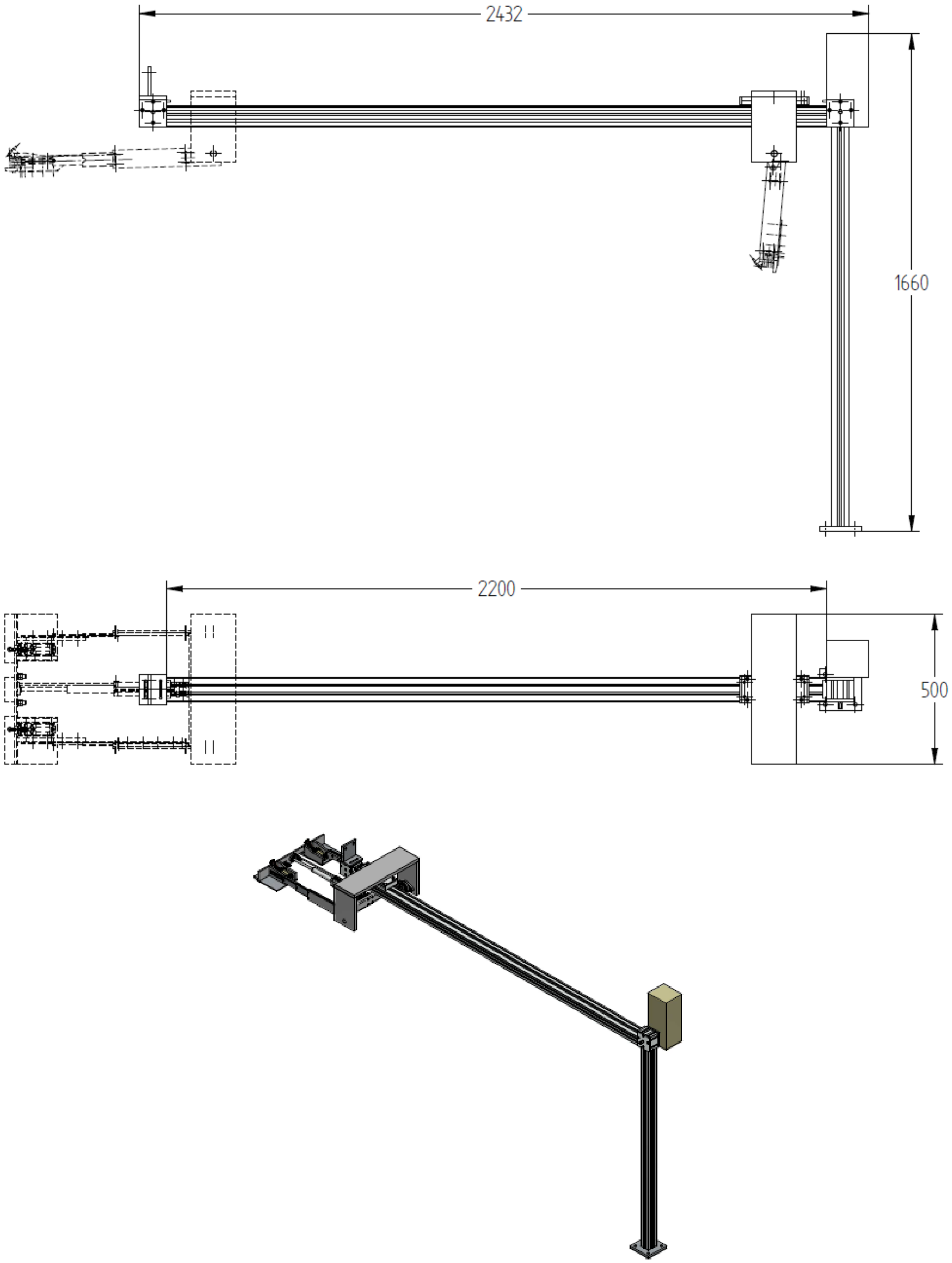








Appendix 7 Feeding system



Appendix 8 Lifting system