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Prototype Design and Manufacture of the New Generation Highly Automated Brushing Machine in Home Textile

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ABSTRACT

Brushing/Raising is one of the important physical process. Raising, which is one of the mechanical finishing processes, is based on the principle of creating a feathered surface by taking out of the fibers from the threads to the fabric surface. It is a process that changes appearance, touch and usage characteristics of the fabric. It gives volume, saturation and soft effect to the fabric. The ability of fabric to be resistant to physical effects is only possible with the high mechanical properties of the fabric. However, it is a sensitive process because it causes weight and strength reduction in the fabric. Desired raising effect can not be obtained with single pass in current brushing machines and, due to process recurrence: Loss of strength, energy and extra labor cost are experienced. Mechanical and electrical components in existing machines are frequently malfunctioning due to inadequate design and material quality and work inefficiently. The quality of the fabric produced on current machines is low and due to the lack of automation, the second quality ratio is high.

The highest quality flannel fabric of the world was produced with the newly designed machine. While the new generation of brushing machine has many innovative aspects compared to existing machines, the most important innovation is to achieve homogeneous, efficient and effective raising effect in a single pass. This superior effect was achieved with the newly constructed brushing wire design. With the new generation brushing machine, the best quality flannel fabric has been produced faster, more efficient, and more energy efficient. It has automation at the top level. It produces a fabric with higher strength in a single step, has superior mechanical design, and at the same time has long-lasting material and less tendency to failure.

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KEYWORDS

Raising, soft touching effect, brushing machine, brushing machine providing a homogenous feather effect, raising wire

1. INTRODUCTION

Raising is a mechanical finishing process based on the pulling of fibers from the yarn with the help of metal wires passed through the surface of the woven or knitted fabric. This process is carried out via pulling out the weft fibers from the fabric with the aid of a plucking and smoothing wires of drums on a raising machine, giving volume, filled, and soft air effect to the fabric. This process can be done at every stage of the production; however, it is usually

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included in the final processes. The reason for this process is to give the desirable handling and appearance properties to the fabric [1-2].

The fabric strength for these forces determines the performance characteristics of the fabrics. For this purpose, performance tests (stiffness, abrasion resistance, pilling, tear strength, bursting strength, etc.) are applied on the fabric. The most important of them are the tensile strength and breaking elongation % tests. Tests are applied on the fabric for warp and weft direction [3].

The effect of drum speed on the raising process in the machine was investigated. upgrade process and number of upgrade passages their effects on various fabric properties [4].

The problems experienced during the current raising process are;

- Due to the wire design, high-strength touch effect fabrics can not be made at high speed and in one go,
- Decrease in strength due to process recurrence,
- Oil stain, insufficient touch effect, low strength, second quality due to damage / wrinkle problems,
- Excess chemical use due to repair process to solve strength problem,
- High amount of process recurrence due to insufficient brush suction system,
- High energy consumption due to double passing,
- Increased energy, maintenance and labor costs resulting from inadequacies in design,
- The high frequency of the faults occurring in the machine depending on the automation and cannot maintain detection,
- High level of ambient dust, formation of contaminant and grease fabric waste, occurrence of fire risk, problems related to environment and occupational health and safety arising from the use of repair chemicals and high waste from maintenance.

The aim of the study is to create a raising machine prototype that has the following features;

- To change the current double-pass production of raising machines to the single pass one,
- Increase the production speed, reduce the amount of second quality,
- Remove completely repairable pile/touch faults caused by conventional raising machines,
- Increasing energy efficiency via reducing electricity consumption during production,
- Reducing maintenance time and cost,
- Reducing the amount of scrap,
- reducing stop times and working area dust during production,
- Prevent contaminant wastes caused by lubrication completely,
- Providing occupational health and safety via high level automation,
- Having technical features that reduce operator-induced errors.

However, the raising process has been investigated on latest technology rasing machines that are owned by our company. Since the desired technology can not be provided with the wire produced by the current technology machine producers, the wire design has been done in our own way. By designing original systems with R & D possibilities, the process of designing according to the requirements of the textile machinery sector, which is mostly dependent on imported, pioneered at the national level at the point of catching the Industrial 4.0 revolution in the textile sector.

2. MATERIAL AND METHOD

2.1 Material

The general view of the raising machine is as in figure 1.

2.1.1. Roller Unwinding

Some problems with the dock wrapping unit were affecting the fuzzing effect. It also caused balance and runout problems in the dock roller. The main problems of this section are cloth breakage and the cloth getting dirty when it touches the ground. With using Dancer scales and infinite round pots, dock release unit with automation control and brake system was built.

2.1.2. Pre-Drying Unit

The amount of moisture on the fabric affects the homogeneous fuzzing effect. Due to the fact that the exit humidity could not be kept constant, the desired hair growth effect could not be achieved. That is why, by controlling the condensate temperature in the drum with the steam drum cylinder and using less steam, the humidity in the outlet drum was controlled more precisely and a steam drying unit was installed to provide moisture control by resistance measurement method.

2.1.3. First and Second Drum Units

Manually controlling the tension on the cloth surface at the drum exit by the operator causes some errors. These errors are in the form of unwanted pilling effect, oil stain, loss of strength, belt breakage. In this section, we aimed to eliminate the problems experienced with the raising wire, the design of which belongs to us. A needle / wire system was made to provide the pilling effect with homogenous desired weight and strength. This system is configurated by figure 2.

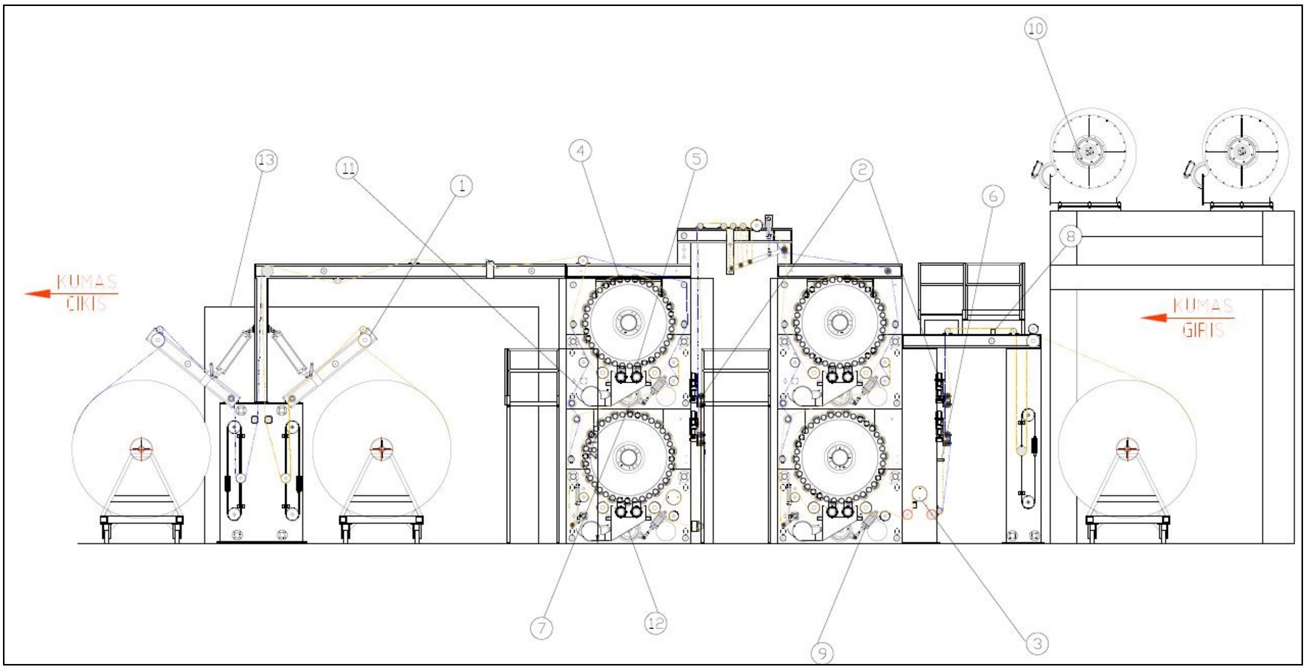

Figure 1. Brushing Machine Design

1. Draft Roller Units, 2. Vertical Scale, 3. Heating Drum, 4. First and Second Drum Wire Design, 5. First and Second Drum Reducers, 6. Sewing Sensor, 7. Drum Drive Belt, 8. Static Bar, 9. Belt Tensioner System, 10. Pressure Prostate, 11. Roller Winding Unit, 12. Closed Loop Communication System, 13. Electric Panel

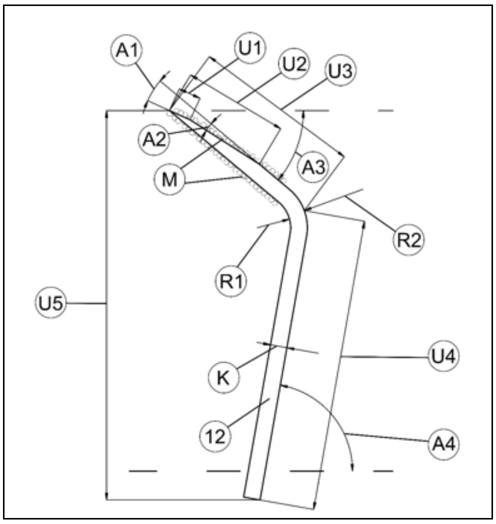

Figure 2. Raising Wire Design

Raising wire; Thickness (K), 1st angle (A1), 2nd angle (A2), 3rd angle (A3), 4th angle (A4), 1st length (U1), 2nd length (U2), 3rd length (U3), 4th length (U4), 5th length (U5), 1st diameter (R1), 2nd diameter (R2) is included.

Thickness (K) measure is between 0,35 mm and 0,5 mm, 1st angle (A1) is between 14° and 17°, 2nd angle (A2) is between 6° and 8°, 3rd angle (A3) is between 42° and 47°, 4th angle (A4) is between 75° and 82°. 1st length (U1) is between 0,51 mm and 0,58 mm, 2nd length (U2) is between 2,48 mm and 2,54 mm, 3rd length (U3) is between 3,98 mm and 4,03 mm, 4 th length (U4) is between 6,8 mm and 7,2 mm, 5th length (U5) is between 8,7 mm and 9,25 mm. 1st diameter (R1) is between 0,76 mm and 0,82 mm, 2nd diameter (R2) is between 1,18 mm and 1,22 mm designed as in Figure 1. Thanks to the special design that this range of values reveals, the homogeneous pilling effect that can be achieved in the fabric with single pass instead of double pass.

A motor with a torque capacity that will provide the desired fuzzing effect on the fabric in a single pass of the plucker and scanner drive reducers on the drum has been selected and it has been carried out in closed loop. This engine is shown in figure 3. In addition, the sharp tip of the raising wire can be sprayed with metal dust (M) to meet different needs.

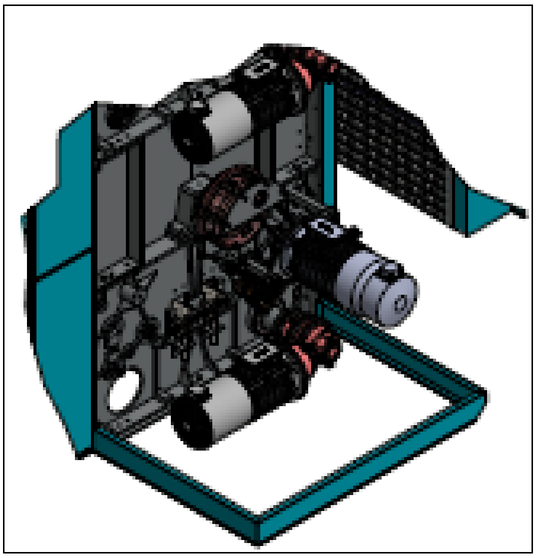

Figure 3. Technical Drawing of motor in drum unit

2.1.4. Dedusting (Dust Suction) System

The main problem in this section was the escaping of the broken cloth or machine parts into the dust suction line. In order to eliminate this problem, the appropriate design of the suction duct and fan propellers has been made. This design is shown in figure 4. Since the cleaning of the brush is more effective, the vacuum system with brush was performed as shown in figure 4.

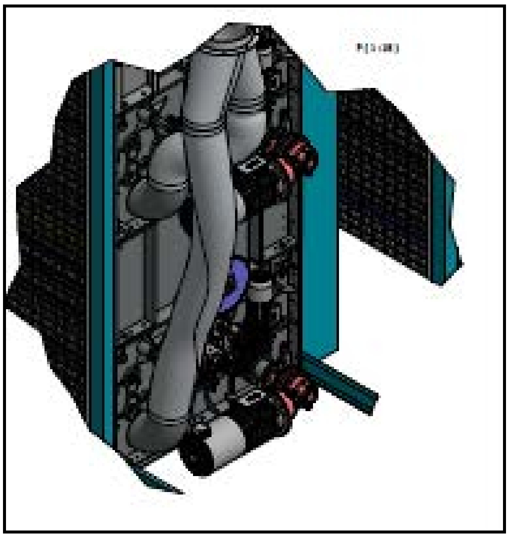

Figure 4. Dedusting System (Brush Vacuumed System)

2.1.5. Roller Winding Unit

The problem encountered in this section is the slippage of the fabric over the draft roller during the dock wrapping process. As a solution to this problem, it has been suggested that the surface of the drafting roller should be covered with suitable rubber so that the fabric does not slip, and that appropriate opening systems should be made to wrap the fabric properly in the dock. It is synchronized with the vertical scale roll to ensure optimum tension operation at high speed.

2.1.6. Automation

An innovative machine design was made in order to achieve the desired pile height in one go. In this study, the raising process can be monitored by measuring the height and density of the fibers emerging from a raised fabric (pile) [5]. In order to reach a more effective solution to the above-mentioned mechanical problems, an automated approach was required. For this reason, it was planned to make the rollers on the drum through automation with the help of belt tension air I/P regulator. For the dust extraction system, it was aimed to prevent malfunctions that may occur through the vacuum malfunction sensor. It is envisaged that a fast and convenient communication system between PLC and driver can eliminate these problems.

2.2 Method

Today, the desired fuzzing effect cannot be achieved at once in raising machines. Due to process repetitions, the fabric shows low strength, energy and labor loss. There is an increase in the number of second quality products resulting from repetitive processes. The draft roller is covered with rubber material to prevent the fabric from slipping during production. In the dock unloading and wrapping units, a vertical scale system, which compensates the fabric more, is used instead of the dancer scale system. Fabric at the exit of the inlet heating drum with the help of automation humidity was controlled. With the specially designed raising wire, homogeneous fuzzing effect provided in double pass is provided in one pass. By choosing the most suitable geared and asynchronous closed-loop motor for the raising machine, motor burns were prevented and optimum fuzzing effect was achieved. The machine works independently from the operator with the seam sensing sensor placed at the fabric entrance. The belt tension air of the cylinders is controlled via automation with the help of I/P. With the pressure prostate attached to the dust collection pipeline, waste pieces of cloth or dust are prevented from escaping into the pipeline during production. With the special design made to the dust collection line, escaping of dust is prevented. Belt pulley resistant to rupture and deformation has been selected.

Today, failure to detect malfunctions in raising machines causes second quality production. Downtime is increasing. Owning to automations, fault detection times are shortened. The compressed air supplied to the brake system is given to the PLC control via the I/P converter. Humidity is measured with a moisture measuring device placed on the cloth heating drum. The steam is proportionally controlled according to the desired humidity. Moisture measurement is made by measuring resistance with two cylinders insulated from the body of the raising machine. The new raising machine design has the ability to save and recall recipe runs for different fabrics. This provides speed and convenience to the operator. The belt tension system air of the scanner and plucker drum cylinders is done by automation over I/P.Current and new generation PLC system is used. The information exchange between the PLC and the driver is done via the Profinet communication system. Thus, electrical noise is prevented.

3. RESULTS AND DISCUSSION

3.1. Engineering Calculations and Analysis

3.1.1. Dust Measurement

Machine dust was detected in an independent laboratory with a dust measurement device called Dustmate via providing ambient conditions of 35.2 ° C, 1.011 mbar, 47% humidity. The device measures with the scattering principle of light. The device contains a diaphragm pump. The device samples the air with a constant and controlled flow rate by means of this pump. The measuring range of the device is 0-65.00 mg/m^3. The device can simultaneously measure and store TSP, PM 10, PM 2,5 and PM 1 measurements.
Dust measurements were made in 4 different regions in the working area of the Raising Machine. Dust in the determined areas was made in two different ways at the beginning and at the end of the project. It was found that the machine-borne dust reduced by 10% with more efficient dust collection through dust extraction system made in our prototype raising machine. The measurement results are given in Table 1.

3.1.2. Estimation of Production and Productivity

After the machine was switched on, it was seen that the production with the targeted 24 m / min was made and at the same time the desired napping effect was provided at one time. It was found that the amount of second quality was reduced by providing a homogeneous napping effect in one go.

3.1.3. Energy Estimation

EFF 3 engine efficiency average 85%, IE2 engine efficiency 92% average A minimum of 8% energy saving will be achieved with the IE2 class motor to be used in the Menderes Raising machine instead of the EFF3 class low efficiency motor used in the existing machines. In our prototype raising machine, it has been observed that the annual electricity consumption is reduced by 55.95% due to the use of high-efficiency motors and feathering in a single pass, and the desired target is achieved.

Table 2 shows that, instead of the low EFF3 class motor used in the current system, 10% energy savings are achieved with the IE2 class motor, resulting in 55.92% savings in annual energy consumption.

3.1.4. Humidity Control

In the dryer section, the vapor pressure on the drums is 3 bar. The specific enthalpy of steam at 3 bar pressure is 2738 kJ / kg [5].

Hfg = H2 -H1
Hfg = 2738-427 = 2311 kj/kg =552 kcal/kg
Q = m×(H2-H1)
Q =50 kg/h × (552 kcal/kg)
m = 27600 kcal/h

Q = Q1 + Q2
Q = m×c×Δt +m×Lb
27600 kcal/h = m×1kcal/kg°C × (100-20) °C+m×540 kcal/kg
m = 44,51 kg/h
m = 741,833 g/min
Machine speed = 20 m/min
Fabric width = 2700 mm
Amount of water to evaporate over fabric =b (g/m^2)
741.83 (g/min) = 20 (m/min) ×2.7 (m)×b (g/ m^2)
b = 13.73gr/ m^2

3.1.5. Steam Consumption

The inlet steam line of the steam drum is 3/4" in diameter. Accordingly, the amount of steam; There is approximately 50 kg of steam consumption per hour in the drying drum of the raising machine with 1 steam drum and 5/4 " steam feed.

a. Mechanical Analysis

3.2.1. Strength Analysis

Structural strength and fatigue analyze of the drums and cones in the drums area under the loads that were applied during the operation of the raising machine were performed.

Table 1. Dust Measurement Results

	PM10 (μg/m3)		PM2,5 (μg/m3)		PM1 (μg/m3)	
Measure Zone	**First**	**Second**	**First**	**Second**	**First**	**Second**
Brushing Mac. Zone 1	116,3	101,6	38,4	34,5	12,30	11,0
Brushing Mac. Zone 2	120,1	107,9	37,5	33,7	12,10	10,9
Brushing Mac. Zone 3	123,1	111,6	36,1	32,8	12,13	10,8
Brushing Mac. Zone 4	128,2	115,8	39,2	36,4	12,20	11,2

Table 2. Energy Measurement

Measure Number	Engine Name	Pcs	Power kW	Work Hour	Current Consumption kWh	Single Pass Consumption kWh
1	Roller Unwinding	1	3	406	1218	609
2	Draft	8	1,5	406	4872	2436
3	Intermediate Draft	2	0,75	406	609	305
4	Drum	4	18,5	406	30044	15022
5	Plucker-Smoother	8	15	406	48720	24360
6	Roller Winding	2	1,5	406	1218	609
7	Dust Suction	2	22	406	17864	8932

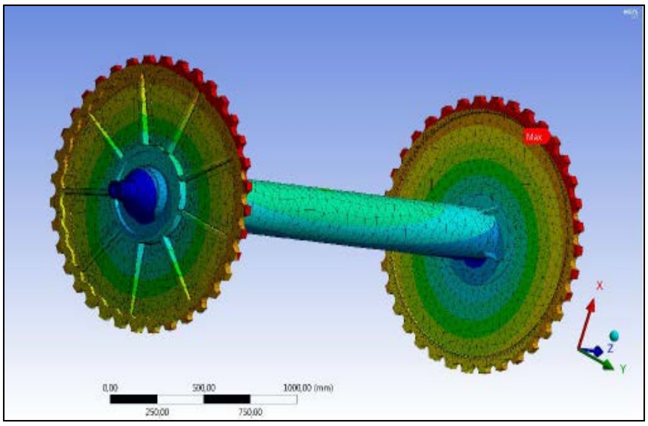

Figure 5. Modelling of ANSYS

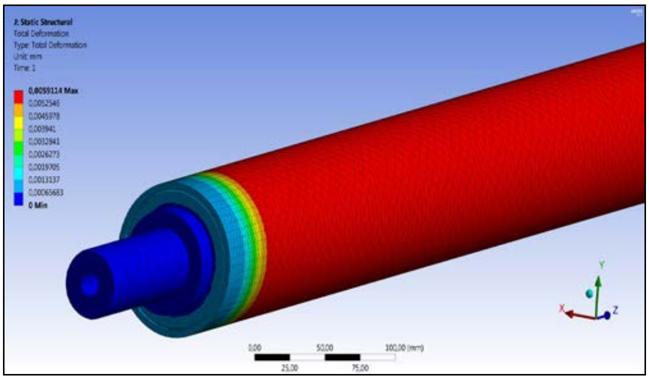

Figure 6. Modelling of ANSYS

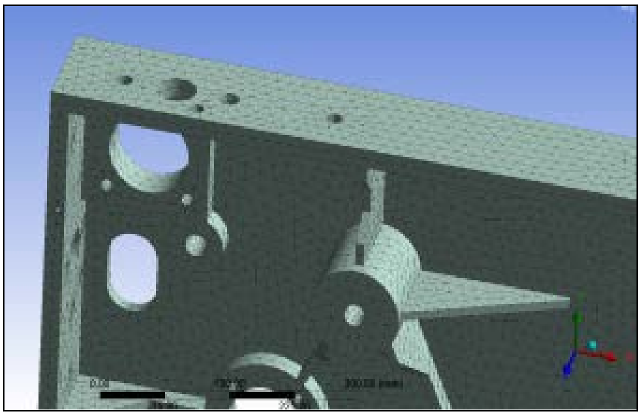

Figure 7. Modelling of ANSYS

The model CAD data was transferred to the Ansys Workbench environment. Static strength analysis of position and loading conditions was carried out by an independent firm and evaluated as equivalent stress (Von-misses stress) and deformation. The system also calculated the critical buckling load on the profiles under the pressurized load. Plates, panels and so on. a higher theoretical approach was targeted using "shell modeling" methods. Links of low significance level were modeled with "beam elements". The parts that cannot be adapted in the model are connected with "bonded contact". The plates between the bolts and the surfaces between the parts were also defined as "no-separation contact". The bolts are defined as beam elements in the ANSYS Workbench environment. The total deformation on the system was found to be a maximum of 0.67 mm. The red regions in figures 4, 5, and 6 show that where sinkage is highest [6].

3.2.2. Physical Tests for Fabric

Physical tests (strength, shrinkage, feather-touch) were applied on the surface of raised and non-raised woven fabrics. The mechanical properties of the fabric were evaluated statistically [7-8].

3.2.3. Tensile Strength Analysis

The tensile strength of raised and non-raised woven fabrics was investigated for both warp and weft directions. It is observed that the tensile strength of the raising fabric in the weft and warp direction is lower than the tensile strength of the non-raised fabric in the weft and warp direction [9-10]. However, the tensile strength of our new generation raising machine has been increased by 10-20% than the tensile strength of the existing raising machines with the help of the desired feathering with a single passage.

3.2.4. Shrinkage Analysis

The test results of the shrinkage analysis at the entrance and exit of the raised and non-raised fabrics were examined. It is seen that the shrinkage test of the raising fabric in the weft and warp direction is lower than the shrinkage test in the weft and warp direction of the non-raised fabric. Shrinkage of our new generation raising machine is higher than the shrinkage of the existing raising machines with the help of providing the desired feathering with a single passage.

Table 3. Tensile Strength Analysis

	Current Raising (N)		New Designed Raising (N)		Non-raised (N)	
Test No	Warp	Weft	Warp	Weft	Warp	Weft
1	240	270	265	290	269,8	294,8
2	245,5	269,8	265,6	289	269,7	294,7
3	243	270,4	264,8	289,5	270,5	295
4	244	268,9	264,9	290,1	270,2	295,2
Ort.	243	269,7	265	289,6	269,8	295

Table 4. Shrinkage Analysis

	Current Raising (%)		New Designed Raising (%)		Non-raised (%)	
Test No	Warp	Weft	Warp	Weft	Warp	Weft
1	-2,6	-0,65	-2,0	-0,65	-2,2	-0,7
2	-2,7	-0,63	-1,95	-0,66	-2,1	-0,69
3	-2,5	-0,66	-1,98	-0,65	-2,0	-0,71
4	-2,2	-0,61	-2,1	-0,64	-2,2	-0,68
Ort.	-2,5	-0,64	-2,0	-0,65	-2,1	-0,7

4. CONCLUSION

- It will be able to apply air comply with brake system according to the diameter of the roller and automatically increase the brake pressure when the machine is stopped while the machine is running. The automation has prevented the problems such as creasing and shrinkage in the fabric.
- The problem of creasing in the fabric was eliminated with proper material selection, design and also preventing the spin and unwinding of scale cylinders.
- At the output of the heating drum, the moisture on the fabric was controlled to achieve the desired pilling effect.
- By controlling the humidity on the fabric, energy is saved by controlling the steam entering the heating drum.
- A raising machine wire was designed to provide homogenous pilling effect.
- An automation system was built that controls the plucking-smoothing cone wire cleaning brush settings and provides operator notification.
- A suitable drive belt has been identified and production losses have been reduced with the choice of belts to work without breaking and deforming for longer.
- The new fan impeller design increases the capacity of the suction fan and avoids the risk of fire due to fan failure.
- A vacuum sensor was installed to create failure notice when the vacuum line is not sufficiently vacuumed, cylinder contamination was prevented via on time notice of insufficient vacuum.
- With proper brush and material design, dead fibers are prevented from blocking between brushes and the cleaning period is extended.
- It has been prevented that the broken piece of fabric or machine parts escapes into the dust suction line.
- The surface of the drafting cylinder is covered with a proper material so that the fabric does not slip.
- Instead of the dancer scales system, a suitable vertical scales system was made to balance the fabric more conveniently.
- A proper opening system was made to ensure that the fabric was properly wrapped around the roller.
- The infeed roller brake tension was adjusted with automation control.
- The steam was controlled via automation with the aid of proportional valve and a humidity sensor at the exit of the cloth heater.
- Belt tension air flow of plucking and smoothing cylinders was performed with I/P automation.
- Electricity and steam consumption were tracked via automation.
- Certain amounts of energy have been saved with using a new generation of proper engine reducers and drivers.
- The number of faults derived from PLC system has been reduced with current and new generation PLC system.
- While the production was done at the speed of 20 m/min in the past, now 24m / min production is realized with

20% speed, 21% production and 137% product increase in raising machines.

- The amount of second quality decreased by 80-100% thanks to single pass technology instead of double pass technology to provide desired napping and soft touch effect.
- A 20% speed increase on the machine resulted in more homogenous and more effective pilling.
- It has been observed that the shrinkage problems caused by raising the yarns, homogeneous feathering and the reduction of deformations on the yarn surface during feathering, decreased from 2.5% to 2.2% in the weft direction and from 3.5% in the warp direction to 3.0%.
- Since the repair process due to the strength problem has been abolished, 3800 kg of chemicals have not been used, in other words, 16500 TL worth of chemicals have been used less.
- A 100% reduction has been achieved in repairable napping-soft touch based defects caused by the raising machine.
- The reduction in strength was reduced by 10-20% as the desired pilling effect was achieved in a single pass.
- As the use of high-efficiency motors and obtaining desired napping in a single pass have been achieved, annual electricity consumption has decreased by 54%.
- In the case of roller changes and short stoppages, the energy consumed was reduced by 8.7% due to the fact that the dust extraction fan was not connected to automation.
- In addition to providing homogeneous napping effect with total machine humidity control, steam consumption is also reduced by 13%.
- Annual maintenance time decreased by 10% and cost by 48%.
- Because of the more efficient dust collection with the newly constructed dust extraction system, the dust originating from the machine given to environment has decreased by 8-10%.

In addition to the innovative technological developments in our work, the prototype raising machine's digitalization and digitization work was also carried out as the first step in the process of going to the dark factories during the Industrial 4.0 revolution. In addition to text, design and production of raising machine is shown in figure 7.

Acknowledgement

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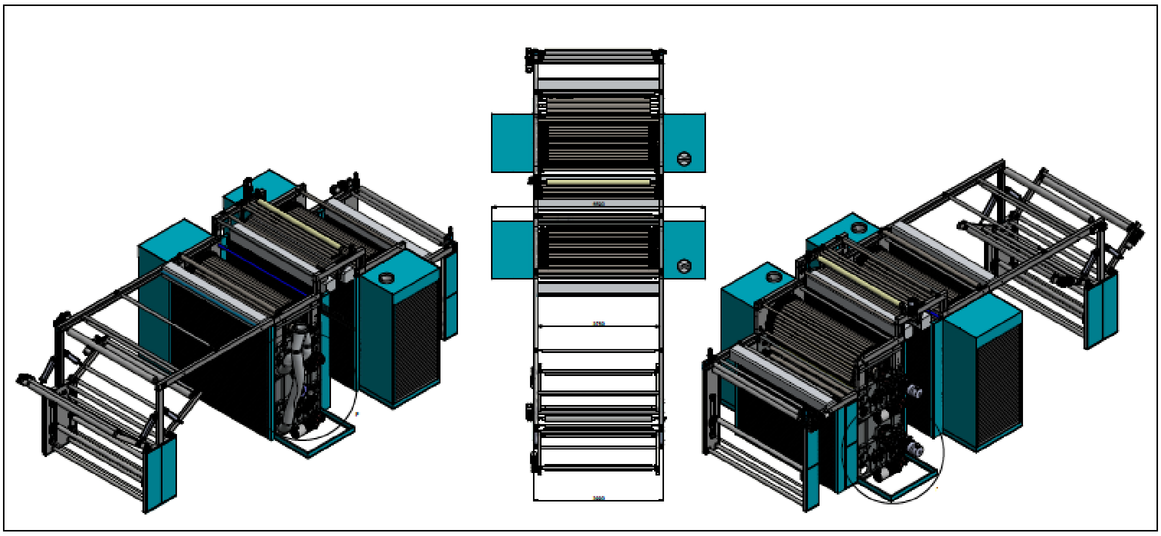

Figure 8. Design and Production of Raising Machine

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