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Linear blower automation on jacquard looms in the textile industry: an experience report

Automação de soprador linear em teares jacquard da indústria têxtil

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Abstract

Through a mechatronic system, the project of the linear blower was born from the difficulty found by the textile industry (which uses cotton as raw material) in keeping their machines and equipment in proper working conditions and without cotton residue accumulation, causing several problems and damaging the final product. To avoid this problem, the solution used until then was a manual cleaning process, which demanded a qualified labor force because there are places of difficult access for cleaning and a certain daily downtime for this reason. The objective of this article was to report the experience of developing an automatic cleaning system, the "linear blower.

Keywords: linear blower; mechatronics; textile industry.

Resumo

Através de um sistema mecatrônico, o projeto do Soprador Linear nasceu da dificuldade encontrada pela indústria têxtil (que utiliza o algodão como matéria prima), em manter suas máquinas e equipamentos em condições apropriadas de trabalho, sem acúmulo de resíduos de algodão, que ocasiona alguns problemas, com isto causa danos ao produto final. Para não ocorrer este problema, a solução utilizada até então era um processo de limpeza realizado manualmente, que demandava uma mão de obra qualificada, pois existem locais de difícil acesso para realizar a limpeza, e um determinado tempo diário de máquina parada por este motivo. O objetivo deste artigo foi relatar a experiência de desenvolvimento de um sistema de limpeza automática, o "Soprador Linear".

Palavras-chave: Soprador Linear; Mecatrônica; Indústria Têxtil.

1. INTRODUCTION

This paper presents an improvement project in a productive system that uses looms in the textile industry, automating the cleaning procedure. The project aims to reduce downtime and the need for skilled labor for the procedure. There are jobs where human action is difficult, risky, or even impossible. For this, the presence of mechatronic devices is necessary, which perform activities aimed at safety, agility, and quality. Using automated and programmed systems increases the flexibility and ability of an unlimited variety of scenarios and movements, facilitating the entire process. In the mechanical structure, the quality and durability of the materials used must be analyzed, always bearing in mind the ease and practicality of maintenance.

To stand out among the countless competitors, one must focus on quality and productive capacity, cost reduction, and strategies that add value to one's products. Increasing production capacity while reducing costs and failures is a constant search in industries. Quality control eliminates the risks of errors and failures that paralyze production or demand time to be corrected.

To solve and reduce downtime, a pneumatic system controlled by a Delta clp was developed so that it would be possible to clean the looms at predetermined time intervals and consequently increase the company's productivity. Lastly, great advances have been conquered in the last decades concerning the production system, and for sure, industrial automation has great importance for this advance (ROSÁRIO, 2005).

2. THE NEED TO AUTOMATE THE BLOWER

The first textile mills that appeared in Brazil in the early decades of the nineteenth century were small-scale establishments. Their production of fabrics in the early years of colonization. Cotton was already known and used by the indigenous people, and it continued to be cultivated by the Portuguese in certain captaincies, starting domestic textile production with importance for the time (STEIN, 1974). The textile industry was a pioneer in the process of industrialization in Brazil, and the presence of automation coincided with the industrial revolution, where machines and equipment were still driven by human or animal strength; then, they started to run on steam and, later on, electric motors. In the mid-twentieth century, the process of industrial automation gathered pace, and the textile sector also began to undergo major transformations. With the use of electricity in the textile industry, manufacturing productivity was boosted, initiating large-scale production. In the 1990s, the automation segment began in search of safety, quality, productivity, materials control, and the optimization of procedures and labor. Today with this increased production, the use of mechatronic equipment with robotic systems is gradually increasing in processes that do not depend on human presence to be performed (PETRUZELLA, 2019).

Skilled labor in this day and age cannot be wasted, as it is becoming increasingly scarce. Avoiding unnecessary labor from human presence is a point that will be explored more and more.

> The lack of **qualified labor** in Brazil compromises not only each company individually but part of the national economy's development. The reality is quite concerning: Brazilian companies produce a lot and have an even greater demand for rework. It is possible to state that this reality is common to almost all market niches. Therefore, betting on new technologies, with a willingness to meet and availability of people and make the best use of opportunities, is unavoidable (GAMBETA, 2021).

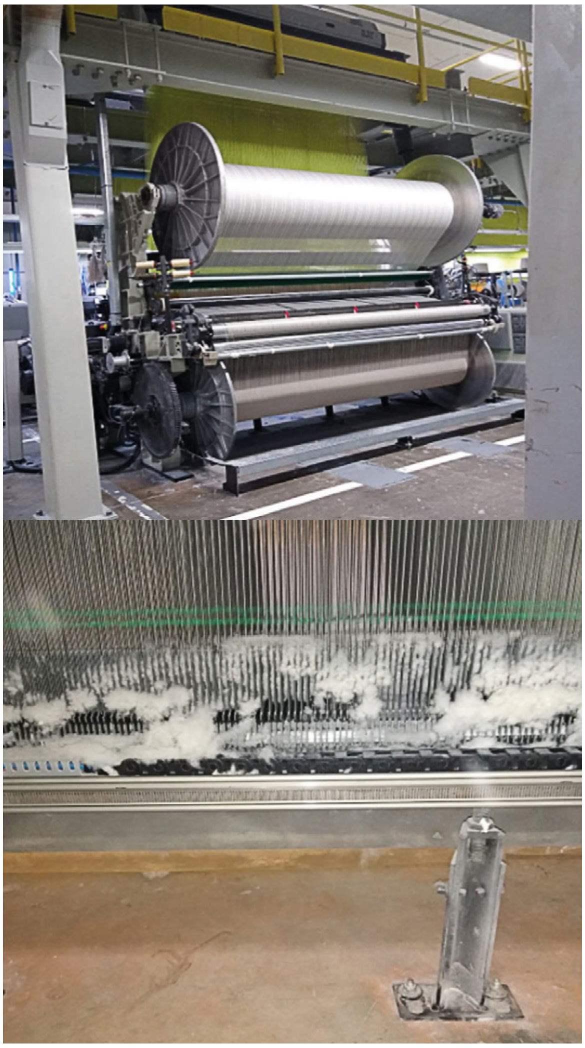
According to CNI (2016), the need to expand the quantity and quality of professional training and expand the effort of qualification and empowerment of human resources in companies given new technologies, retraining, and relocation of the workforce displaced by disruptive innovations (e.g., artificial intelligence). The risk of not keeping up with the technological evolution due to a lack of human resources consists of eventual gaps that may disarticulate part of the industrial production, besides creating obstacles to the leap in the productivity of the sectors and resulting in the loss of new business opportunities for Brazilian companies.

2.1 Difficulties with the process of cleaning the looms

The raw material of the textile industry is cotton, a fiber of plant origin that has great growing possibilities practically all over the planet. However, when the residues of this material are dispersed in the atmosphere through the machines and equipment in operation, they are harmful to their operation. The textile industry has various interesting processes, and the weaving part is crucial because it relies on it to develop the desired designs and shapes using the Jacquard looms.

The looms under study have 384 modules in the upper part, each composed of 8 electromagnetic coils and a series of 3,072 springs in the lower part that pull the stranding down, making a continuous movement (Figure 1). A problem identified is that when these springs get locked due to cotton accumulation, they lose their function and cause poor quality or even the loss of the product. To avoid this problem, the operator must request the manual cleaning process, which requires a skilled labor force, because there are places of difficult access and a certain daily downtime for this reason.

Figure 1 - Jacquard Loom and Springs



Source: From the authors (2021)

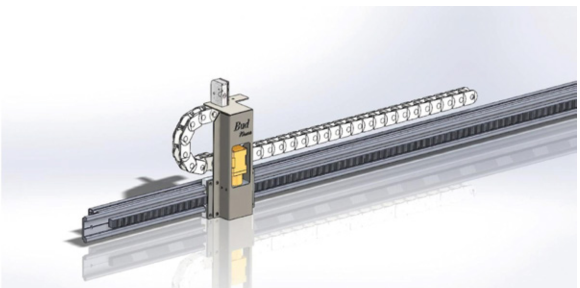
2.2 Proposal for the automation of loom cleaning

By analyzing the downtime of the machine and the waste of labor time for a job that can be automated, the automatic cleaning system was developed. The “Linear Blower,” a mechatronic device with a transmission and control system, performs this fully automatic process without interrupting the production cycle of the machines (Figure 2). In this case, it will not be necessary to intervene in manual cleaning, thus reducing the costs generated by this task and increasing productivity.

> Industrial automation optimizes an operation’s processes by applying various software and hardware technologies. However, it can also be considered the replacing of manual work with mechanical tasks (SALES, 2022).

According to KOSLOSKY (2015), the insertion of industrial automation refers to replacing cheap labor in large quantities that is responsible for competition in Brazil. From the moment technology intensifies, investments and the need to hire specialized labor increase. Despite these challenges, the gain in productivity and the development of new products open doors for professional growth and better opportunities.

Figure 2 - Linear Blower design



Source: From the authors (2021)

3. PROJECT DEVELOPMENT

The choice of materials is one of the most critical steps to be checked, and must analyze each element to be used there will always be a financial impact when it comes to the industry; it will be necessary to do field research to find more resistant materials that meet the project needs. With this, one of the factors that most impact is the issue of material prices, thus seeking the best quality and quantity with the lowest possible price so that a serial assembly line of the project can be made.

For this project, it was used the Linear guide responsible for moving the linear blower; with its concept based on the principles of the bearing, they can guarantee the cleaning process from one end of the machine to the other. The Linear guide can move large parts of a machine’s equipment, thus reducing friction and noise during operation. By supporting considerable loads, it is also highly accurate in positioning with speed and torque on the given rail where its working area will be.

Figure 3 - Linear Guides

Source: BATISTA (2020)

To facilitate the movement of the linear guides, a gear system coupled to a DC electric motor was designed. The gear is driven by the DC motor with a planetary gearbox and is engaged by the rack, causing the entire assembly to move along the linear guide.

Figure 4 - Straight gear and rack

Source: BATISTA (2020)

To control the system, a Delta CLP was programmed (model DVP14SS211R) with the programming language Ladder. In this system, a logic by time was implemented to prevent the blowers from entering simultaneously, reducing the pressure drop in the system. The program comprises the action of 6 machines simultaneously, with cleaning cycles every 5 minutes and a duration of 1 minute. A CLP is like an industrial computer that can be programmed according to the desired execution and can work offline. These controllers significantly reduce the wiring associated with conventional control circuits, besides presenting other benefits such as ease of programming, various controls, defect verification, and high reliability. With a large number of CLP types and manufacturers, it is up to the programmer to define the model to be used according to the project's needs and target the cost-benefit (PETRUZELLA, 2014).

Figure 5 - DVP14SS211R PLC

Source: CRAVO (2020)

Inductive sensors were used as end-of-stroke indicators for the linear blower to send the positioning signals to the CLP. To ensure the efficiency of the process, inductive sensors were installed to ensure the exclusive detection of the metallic object of the blower.

After the CLP monitored and received signals at its inputs, a DC motor was applied to drive the mechanical system composed of linear guides and gears. The DC motor that was applied requires a driver to perform the speed control and thus ensure the movement within the desired speed. Because the driver commands the motor through digital signals, the signal from the clp's digital outputs was used to command the drive logic.

Figure 6 - ST10-PLUS drive and stepper motor

Source: From the authors (2022)

To comply with the proposal of this project, the size of the power supply network for the linear blower project was calculated. Below is some data collected in the field and necessary for correct operation:

Q = Flow rate in m^3/h (compressed air intake $16 m^3/h$).

L = Line length 5 m (air inlet from loom to diffuser).

P = Network pressure of 9 Kgf/cm^2 (8.8 bar).

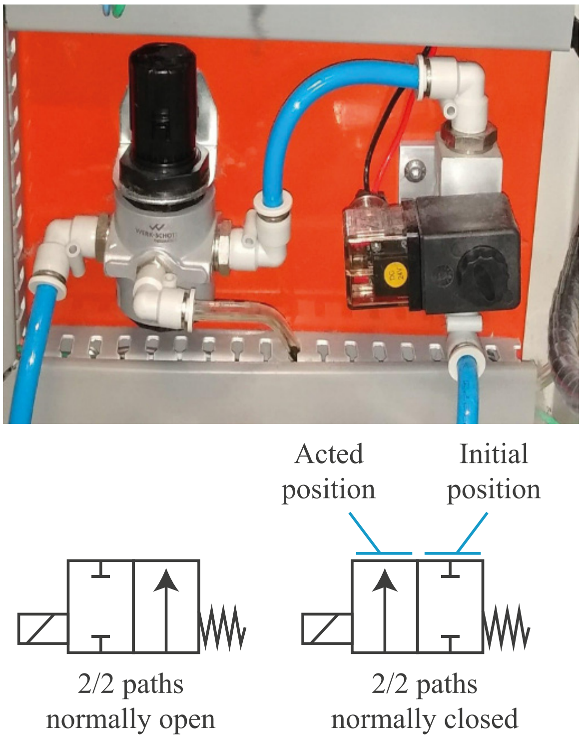
AP = Allowable pressure drop 0.3 Kgf/cm^2 (0.29 bar).

D = Hose diameter (?).

We arrived at a commercial value of 8 mm pneumatic hose according to the calculations performed, and we considered the pneumatic network works at approximately 8 bar pressure, so as not to decrease the pressure if all the linear blowers were activated at the same time. Hence, it was necessary to perform alternate activations of the equipment, with groups of six machines, performing an activation every 5 min, which are called staggered groups.

To apply cleaning system and drive required the installation of a pneumatic pressure regulator; given the calculations of flow sizing, we found the need for only two bars of pressure for each cleaning device. The pneumatic valve responsible for driving the cleaning system through the manufacturing concept was purchased commercially as a 2/2 way spring return valve with a solenoid drive, as shown below.

Figure 7 - Pressure regulating valve

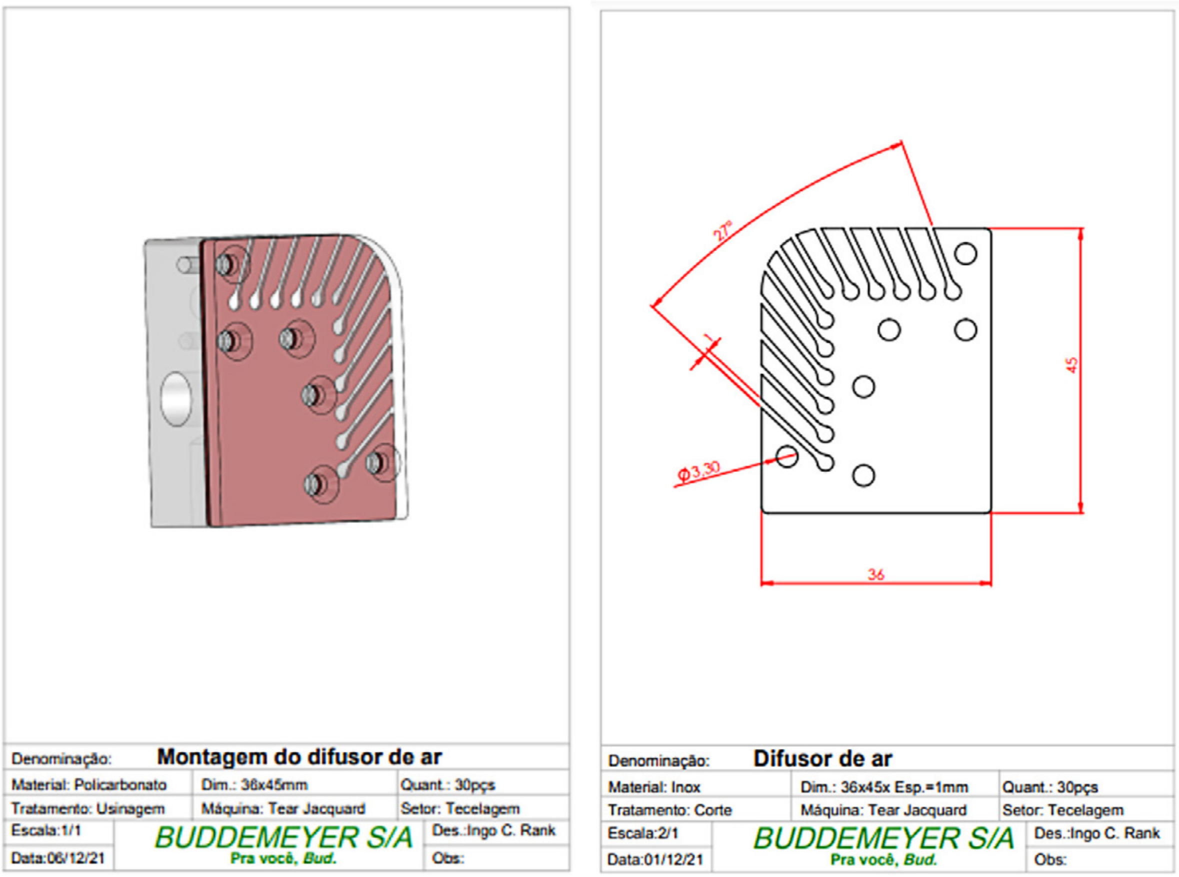


Source: From the Authors (2022)

To ensure the cleaning of the looms' spring assembly, a diffuser was designed; it is made of polycarbonate with a format that provides efficiency in the process. Its design and the degree of its slots through which the compressed air passed to form a fan was calculated by data collected on the machine considering the size of the springs and distance, with the following data:

- Opposite square = 400 mm (length of the springs)
- Adjacent catheter = 15 mm (distance from diffuser to springs)
- Tangent = 27° (fan diffuser opening angle)
- $TG = \frac{\text{opposite measure}}{\text{adjacent measure}}$
- $TG = \frac{400}{15}$
- Tangent = 26.66° (rounding to 27°)

Figure 8 - Diffuser



Source: From the authors (2022)

With the Linear Blower in activity for 3 months, no longer having the machine stop to perform manual cleaning, we gain an average of one hour of production per day. Based on this and the daily production per machine of 266.66 Kg, we obtain predicted calculations of productivity increase:

Table 1 - Predicted calculation for the daily productivity gain in Kg.

SHIFT	GROUP 1 12 LOOMS	GROUP 2 12 LOOMS	GROUP 3 6 LOOMS.
1	45 Kg	45 Kg	22 Kg
2	45 Kg	45 Kg	22 Kg
3	44 Kg	44 Kg	21 Kg

Source: From the authors (2021)

Having an average increase of 333.3 kg daily in 30 machines, and depending on the article that is weaving varies the value, but on average, we have:

Table 2 - Predicted calculation for the daily productivity gain in BRL.

TOWEL	WEIGHT PER PIECE	UNIT VALUE	TOTAL DAILY INCREASE IN 30 MACHINES
Floor	0.422 Kg	BRL 30.00	789 pc BRL 23,670.00
Bath	0.406 Kg	BRL 52.00	820 pc BRL 42,640.00
Face	0.165 Kg	BRL 25.00	2.020 pc BRL 50,500.00

Source: From the authors (2021)

4. CONCLUSIONS

This project made it possible to obtain a dynamic model of a mechatronic drive system in an industrial automation application that relates to functionality in practice. The mechanical study of discrete automated systems, transfer functions such as DC motor, planetary gear reducer, gear and rack, control systems, and references. The optimized choice of materials to be used was aimed at low application costs and to meet the needs foreseen at the beginning of the project. This way, the expected result can be reached with cost savings and efficiency in cleaning the looms' mechanical components, which are fundamental to the design and quality of the final product. Thus, it will not be necessary to have a professional to do the scheduled cleaning.

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