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Design and Implementation of an Automated System for Clothing Manufacturing in Mexico

Román Bravo-Cadena[1], Juan Carlos Monter-Olvera[1], Juan Carlos Cruz-Vazquez[1], Yosihandy Martínez-Martínez[1], Yaneth A. Bustos-Terrones[2,*]

[1]Programa Educativo de Mecatrónica y Energías Renovables. Universidad Tecnológica del Valle del Mezquital, Carretera Ixmiquilpan-Capula km.4 Col. El Nith, Ixmiquilpan, CP. 42300 Hidalgo, México.
[2]CONACYT-División de Estudios de Posgrado e Investigación - Instituto Tecnológico de Culiacán, Juan de Dios Batiz 310, Col. Guadalupe, Culiacán, Sinaloa C.P. 80220
*Corresponding author: yabustoste@conacyt.mx

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Abstract The present work shows how the design and implementation of an automation system was carried out for the line of strap of a women's clothing factory, taking into consideration the time it takes to make the product and the people who work in each production line. The company produces different styles of bra straps; but this work only focused only on 1 style, which was the simple strap. The development consisted of inserting a slide at the end of the elastic and performing the embroidery. This automation is composed of a base, an elastic slider, main base of the slide holder, clamp and rotary module, cutting piece, slide and slide fastener. Once the machine that automates this process was designed and implemented, it was found that it performs twice as much assemblies as those that are done manually, so it saves 50% in assembly time which allows to generate more products.

Keywords: *automation, sewing machines, bra strap*

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1. Introduction

Clothing is the second most important need for humans. This need is increasing throughout the world due to the increase in population and changes in consumer behavior towards fast fashion [1]. Since its inception, humanity has had the need to make its garments and different utensils, people joined pieces of different materials (skins, natural fibers, etc) through manual seams, but over time, this procedure evolved until the first sewing machines appeared. Clothing production requires a lot of labor, but often there is a great demand of quality of the product. Therefore, to meet the high quality requirements, it is necessary that labor-intensive processes become automated processes that are performed through the use of computerized tools. Figure 1 describes several steps followed during the garment manufacturing process [1,2].

Automation is the process or technique of performing certain jobs by using automatic equipment instead of human operators during the manufacture of a product; and it is achieved through the use of automatic tools and equipment integrated with electronic devices [3]. Automation reduces human intervention to a minimum, saves labor and energy; improved precision, accuracy and quality of the products; and high productivity [1,4]. Only in this way can the high demands of lean manufacturing be fulfilled in an optimum way. Nowadays automation is widely used in areas such as manufacturing industries. Several studies have been carried out on automation in the manufacture of garments [1,5,6].

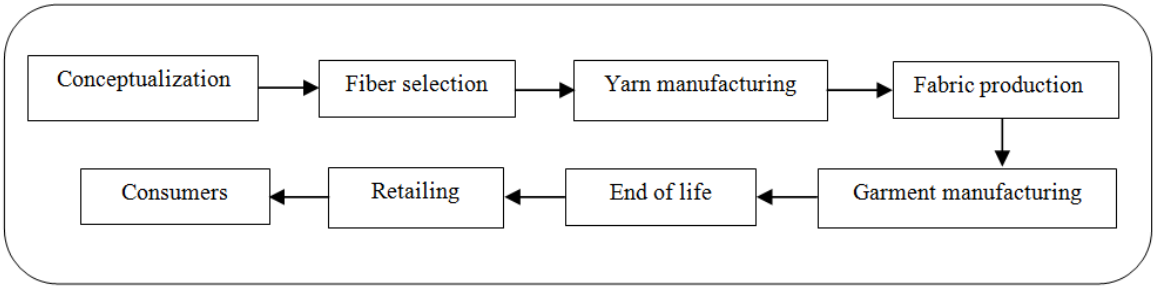

Figure 1. Sequence of the garment manufacturing process

Modern modular construction requires high-quality, cost-effective and efficient production of components. These requirements have led to the emergence of the use of automated machines. Automation is currently gaining popularity due to the performance limitations of the conventional construction methodology [7]. Automation has not been widely adopted due to reasons such as high cost, process complexity and the availability of cheap labor. The competitive advantage of a garment industry in the global market depends on the level of advanced technologies and automatic tools, and equipment used in their design, production planning, manufacturing, supply chain and sales [1,8]. The intense global competition and the rapid development of the technologies make it essential to take new steps in terms of automation [9]. That is why in this research, an automation system was designed for a machine and implemented in a women's clothing manufacturing industry, the main objective was to automate the process of elastic bonding of women's intimate clothing suspenders (BRA). Since automation solutions increase productivity and will always be one step ahead of the competition.

2. Materials and Methods

Currently, there is a need for agile and reconfigurable production systems to cope with various products [7]. Because most manufacturing industries do not have automation systems for the line of bra straps, in this study, a small analysis of the procedure was carried out to assemble the bra strap (single strap) since It was the main base to be able to give continuity to the prototype and to be able to perform it in several stages so that we could make all the styles that the manufacturing company manages.

One of the main problems faced by manufacturing industries is the insufficient personnel (Labor) to carry out all the processes. That is why the project is important. When performing an analysis, it was obtained that the machine would produce roughly twice what a person normally does a day. In addition, this automatic system seeks to achieve greater production, as well as to ensure safety for personnel and avoid any type of accident. Employee safety is a primary concern in industries [10].

2.1. Process Time

The process time plays a very important role in the strap assembly in female clothing, as the main purpose of the design automation is to reduce the time. It was hypothesized that the manual assembly of the female clothing strap represent more time and higher cost. By automating the machinery by inserting a slide at the end of the elastic and performing the embroidery, higher productivity and quality will be obtained [11].

2.2. Establishment of Parameters

In this work, TMU (Time Measurement Unit) units were used. It was firstly determined the time in which the process of assembling the feminine garments was done manually. Labor is counted by batches. One fact is that one person can make approximately 15 lots a day, lots have 48 pairs of suspenders, that is 96 pieces in total. The number of people working on each line and the average time they perform their work is shown in Table 1.

Table 1. Description of the batches made in each production line

Job characteristics	Approximate data	Units
Hours of work per production line	118	Hours
Number of people working in production lines	17	People
Estimated production time per batch	35	min/lot
Production lots per person	15	lots/day
Production lots per day	113-115	lots/day

In Analyst Manual [12], it is mentioned that the methods and times are a system of control of predetermined times, that is used mainly in industrial environments to analyze the steps used to carry out some manual operation or task, and as a result of this analysis, set the standard time of manufacturing, that is to say, the standard time in which a worker must complete a task. With respect to the time required in manual assembly of the bra strap, a piece equals to 11.38 TMU and a lot, equals to 1,115.24 TMU.

The time to make a piece is considerable, because there are times lost from taking the elastic to putting the slide in it. To address this problem, it was decided to make an automation system for the operation of the line of the bra strap, so then the next step was the elaboration of a robot, which consisted of a base, an elastic slider, main base of the bra slides, clamp and swivel module, piece for cutting, sliding and slide fastener.

The sewing machine used is a semi-industrial machine Juki brand clip, which has a typical sewing style (called crochet). This type of seam is carried out when the needles are pushed through tissues and removed, leaving a loop of thread, it passes through the first loop while creating another loop for the next point, this activity resembles a chain.

2.3. Proposed Design

The design begins with a horizontal central plate and a vertical base that will serve as a guide for the elastic roll. The tip of the elastic is taken by an SMC clamps coupled to a SMC DM2KB25-400 piston that pulls the tape 30 cm to the sewing machine, the utility clamp have an adjustable design for different sizes of strap and they were designed so that inside, the clasp or slide is hooked with the strap it is attached, the clamp will be placed in a rotating pneumatic module, with a turn of 180 degrees towards the hands of the clock and vice versa, the mechanism of the clamp is to make a route from the center towards the ends by means of a small sliding track, which is attached to the clamp by means of a bolt mounted in the middle part of the clamp, which allows by means of a simple screw to hold the clamp and the slide, the bolt in turn makes the stop function so that the slide stops. With a single clamping screw, the bolt is adjustable and provides the option of being manipulated to achieve the width required in the slide.

When the slide is inserted into the adjustable clamps, it is held firmly and slid into the swivel module by a small piston fastened on a bolted base, releasing the clasp. The clasps come from a container that allows them to be static.

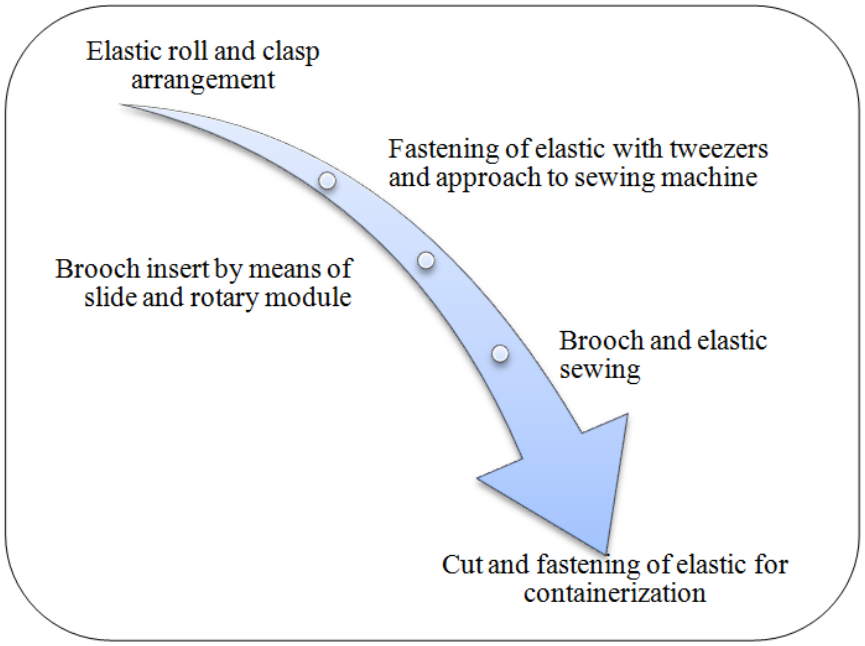

Figure 2. Stages of design

Once the clamp pulls the elastic band towards the sewing machine, the band is fastened by another pneumatic piston that does not allow to return to the elastic, the sewing machine performs the joining of the elastic and the clasp. A blade activated by a pneumatic piston performs the cut of the elastic, then releases the elastic with its clasp in a tank with a slope of 20 ° so that by gravity it goes to the bottom of the container (Figure 2).

The automation system is designed for any female intimate clothing manufacturing company to replace their existing manual system in the strap assembly. The system in addition to being functional and fast, also allows to reduce work accidents since the operator does not need to intervene at the time of the assembly, it is only limited to administer the raw material in their respective containers.

2.4. Automation Requirements

The quality control of the final garment is of a more subjective nature, based on a non-numerical description of the quality and understanding of the garment's style and design requirements. There is no doubt that automation can increase production efficiency, reduce the number of flaws, and reduce overall manufacturing cost. The global demand for quality garments, low production cost and competitive advantages can be achieved by adopting automation [1].

3. Results

For manufacturing and assembling women's clothing, this automated design will reduce the costs and times handled. For the realization of the design figures of the automated system, the software inventor 2015 was used.

3.1. Description of the Design

The automated machine has a cylindrical wheel where the elastic is housed, the protruding end of the elastic is taken by a plier that is held inside the slide, the plier pulls the elastic band towards the sewing machine, the plier joins the band and the slide by a turn, then the sewing machine performs the seam joining the elastic with the slide inside, once the union is made, a piston with a special press holds the elastic, and a blade makes the cut. When making the cut, the elastic attached to the slide is deposited by gravity in its respective container. Following describes. The development of the design is described below.

3.2. Design Development

The automation system contains a vertical base that has a horizontal aluminum plate located in the central part, which will facilitate the elastic travel. This base also has a piece located at the top of the base, facilitating the elastic travel that will serve as a guide.

Figure 3 (a) shows the design and dimensions of the part, and Figure 3 (b) shows the view of the assembly where it may be observed the piece in which the elastic band roll is attached, and the plate where the elastic slides in a faster way. Having the base, an SMC DM2KB25-400 piston is used which will aim to pull the band from the other end approximately 30 cm.

To be able to slide the elastic (which will become the strap) the piston is docked with an SMC clamp that is responsible for securing the band and sliding it to the other end. Considering the dimensions of the different types of slides that are needed in the plant, a base was designed that is fastened by a rotating module. In Figure 4 an image of the CMC clamp and the design of the rotating module is shown.

The base is made up of two small clamps that attach to the right and left part of the piece. The clamps were designed with the aim of attaching the clasps to the elastic (strap) operation. In addition, this base has an extrusion of 6mm diameter and a drilling depth of 12mm, which is placed in a bolt of the rotating module with a diameter of 5.8 mm. The base is coupled to the Rotary module resulting in a 180 degree turn clockwise and vice versa.

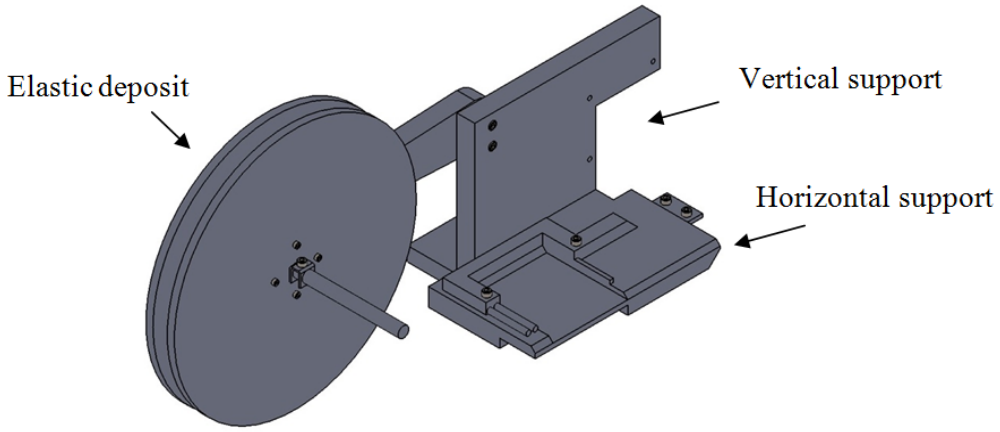

Figure 3. Design of the vertical base part of the automation system

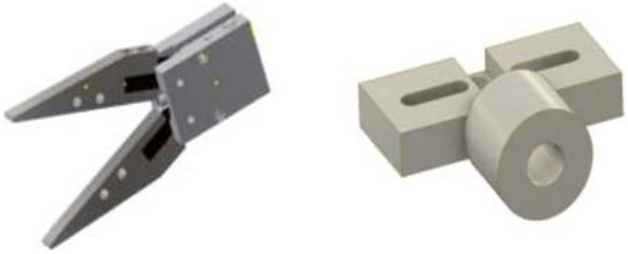

Figure 4. SMC clamp and base with rotating module

Each operation carried out by the strap system is different depending on the styles of intimate feminine clothing (BRA) that are handled. The styles handle different types of slides, which give the dimensions of the slides and are considered from the smallest to the largest, in the same way the thickness of each clasp, as well as the width and length of each slide. One of the important aspects of this piece is that it is only fastened with a screw of 3mm (1/8) being an easy piece to be placed at the base and most importantly adjustable, Figure 5 shows a frontal view of the clamp, as well as the base that is attached to the slide by a custom-designed bolt, as well as final assembly of the clamps, base, screws and bolts.

Figure 5. Adjustable clamps, front view of the bolt and its placement to the base and final assembly of the clamps

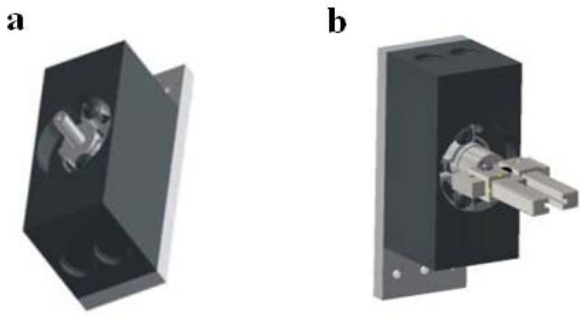

Figure 6. View of the rotating module: (a) previous and (b) later

The assembly is intended to be coupled to a rotating pneumatic module with 180 degrees of rotation and vice versa. Figure 6 shows the Rotary module that was designed, both in front and back view. With the structure that the elastic takes, it was proceeded to the design of the cutter, which has a standard measure blade and that will be mounted on its respective cutting piece.

On the other hand, a piece for the positioning of the slide that allows to slide it easily was designed and implemented, the base was made in order to place a small piston that easily ejects the slides. A small container was added, which serves as storage of the slides. The cutter's design and the container with the slides can be seen in Figure 7. Once the slide is inserted into the adjustable clamps, it is held firmly and slid into the rotary module by a piston fastened on a bolted base, thus moving the slide towards the rotary module (see Figure 8).

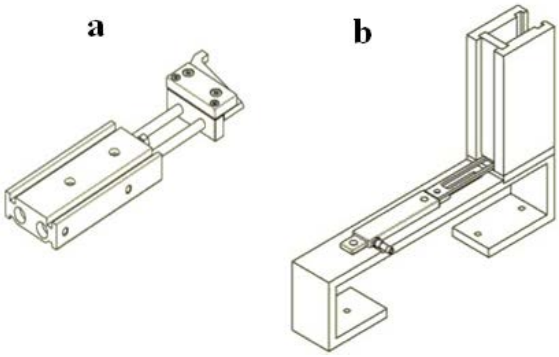

Figure 7. Cutter design and container assembly with slide: a) cutter and b) container with slide

Figure 8. Rotating base that moves the slide towards the rotating module

The elastic strips that are needed for the different production styles are elastic strips with 1.5 cm wide, for this reason a piece that works as a holder was designed, once the cut is made, a piston is activated to work as a press on the strap, this way it will not scroll. Figure 9 shows the elastic clip and the strap fastener assembly.

Figure 9. Elastic bra and bra strap assembly

For the cutting operation, two pneumatic pistons were placed to a base, with the aim of pressing the strap while the cut is made. The cut is done with the dimensions that the operator selects. After the automatic cut has been made, a piston attached to the base is activated to pull the elastic with a pneumatic clip placed on the piston rod.

The next process is to move the elastic so that the route is towards the sewing machine. With the elastic already fitted in the sewing machine, the machine joins the elastic and the slide by sewing. The dimensions for the assembly of the parts were considered according to the dimension of the sewing machine, which will sew the strap along with the slide, once the strap is slid, with a pair of pneumatic clamps will be carried towards the needle of the machine.

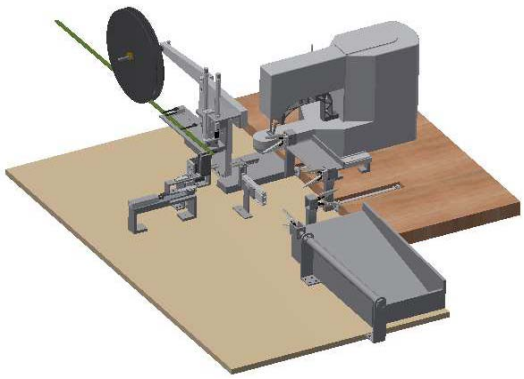

Figure 10. Complete system designed for tie rod cutting

Figure 11. Complete system implemented for tie rod cutting

Finally, the elastic is deposited in a container which consists of a slope that provides a ramp to facilitate the deposit of the elastic. Figure 10 shows the cutter and sewing machine. Once the design was completed, the assembly was carried out, resulting in a functional system (see Figure 11).

3.3. Design System

The automated machine has 7 pneumatic actuators, 6 pistons and a rotating module. A programmable Logic controller (PLC) SIMATICS7-1200 takes care of the activation and deactivation of the Pistons, the PLC is the central process unit and changes the status of the outputs according to the logic of the user program, which includes Boolean logic, counting instructions and timing. Although the PLC can be programmed using STEP 7 Basic v13, the TIA Portal V13 for PLC program was used because it is a platform that provides a great extension to perform different processes. The automatic system is easy to use and low risk, because you only have to ensure the power supply, air with the appropriate pressure for the pistons, the elastic and the slides. The operator does not participate in the direct assembly of the elastic with the slide so it decreases the possibility of an accident at this stage of the process.

3.4. Design Evaluation

Once the machine that joins the elastic to the slides was implemented, tests were carried out to measure the time in which it performs an operation, that is to say an assembly, measuring the time allows getting the information contained in Table 2, where it can be observed that the times of assembly are reduced to almost half by the automatic machine assemblies being compared against the manual assembly, which means that twice the work can be produced at the same time.

Table 2. Tensile assembly busy times measured in TMU

Description	Equivalence (TMU)
Manual assembly	
1 piece	11.38
1 lot	1,115.24
15 lots	16,728.6
Automatic assembly	
1 piece	5.6 TMU
1 lot	557 TMU
15 lots	8364 TMU

4. Conclusions

In this study, a design and implementation of an automation system was carried out for the line of interior feminine clothing (BRA). This automation consisted of a base, an elastic slider, main base of the slide holder, clamp and rotary module, cutting piece, slide and slide fastener. The automated machine cuts, joins and attaches the elastic (strap) which results in an efficient and precise operation, the machine operator will only make sure that the production is adequate, and to supply the materials to the machine in a timely manner. When comparing the automated system

against the manual system, it was observed a savings of 50% in assembly time, meaning that the automated system performs twice as many cuts as when doing it manually. With this implementation of the automated system there is a decrease in manufacturing time of the garments, which allows to generate more products. This automation brings competitive advantages with it.

Acknowledgements

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