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Semi-automatic CNC crimping press design for cable assembly

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ABSTRACT : *This paper presents the integration design for a semi-automatic machine for crimping dielectric material and contacts to coaxial connectors. To this end, this strategy proposes integrating different technologies using a pneumatic piston adapted to a commercially available CNC milling machine and a corresponding instrumentation and control scheme. The proposed solution seeks to reduce assembly times and waste during the coaxial cable crimping production process in a regional company in the state of Sonora.*
KEYWORDS *Semi-automatic crimping press, integration design, CNC milling machine, coaxial cable.*

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I. INTRODUCTION

Crimps have been used throughout history for the manufacture of different objects, designed for both hot and cold work on a variety of materials, and have been used for all processes requiring intense pressure, such as laminating, deep drawing, forging, packaging, etc. Nowadays, the more complex crimping processes are carried out manually, as they require advanced and costly machines, as presented in [2, 6]. This is due to current automatic crimping systems being based on a single hydraulic movement requiring a high-power system, and consequently, the design of high precision mechanical components, which raises the cost, as described in [1]. In [5], a milling machine with a CNC system is used during the manufacturing process for scrap removal; this machine operates on the principle of a tool's rotary motion through the machine's operating space [1].

This paper proposes amethod for reducing waste during the manual coaxial cable crimping process by applying an integrative design approach to commercially available systems, generating a semi-automatic CNC crimping system.

II. PNEUMATIC CRIMPING PRESS

This type of pressurized air powered pressis quite effective for medium-high compression tasks and offers the advantage of faster actuators than those in hydraulic systems. This is because pneumatic presses are powered by an air compressor, which requires less energy than hydraulic presses to move the piston. This compression effect is due to air being compressed and conducted through a hose to the crimping press'piston assembly, which pushes the piston towards the support bench or table. Once piston travel is complete, the air is evacuated through valves, andthe piston is returned to its initial position by means of mechanical springs. This type of crimping press can be seen in Fig. 1.

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Fig.1.Commercially available pneumatic crimping press

Some characteristics of this type of crimping press are listed in [3], such as:.

- Pneumatic crimping presses are faster than manual and hydraulic presses and can be stopped by opening the air exhaust valve.
- Due to this higher speed, greater care must be taken when placing parts to be crimped, as operator reaction time may be shorter than the time required for the press to reach the end of the stroke.
- These kinds of crimping presses are remarkably versatile and can be placed in different positions according to their design.
- They are operator friendly.
- They have few moving parts and are low maintenance.

III. CNC MILLING MACHINE

A milling machine is considered a special type of lathe with a small rotating spindle to which a cutting tool can be attached. These types of milling operations allow users to create round parts with milled or drilled patterns on them, without the need to mount them on a different machine. A commercially available example of such a device can be found in Fig. 2.

Fig. 2. Commercially available CNC milling machine

This device is programmed to mechanically follow a series of coordinates within a plane. According to ISO (International Organization for Standardization) 6983 for CNC, a code derived from the G&M code is used for programming in the operational space of the machine. G code commands describe the machine's movement (cycles, forward steps, radial and rectilinear movements, etc.) and are mathematical calculation and motor control operations, while the M code commands describe the special functions required for machining the part, referring to more complex routines such as on/off and auxiliary functions, among many others.

IV. PNEUMATIC PISTON

This mechanical element can be defined as a device capable of transforming the potential energy in compressed air to mechanical energy by generating linear back-and-forth displacement of a piston, as shown in Fig. 3.

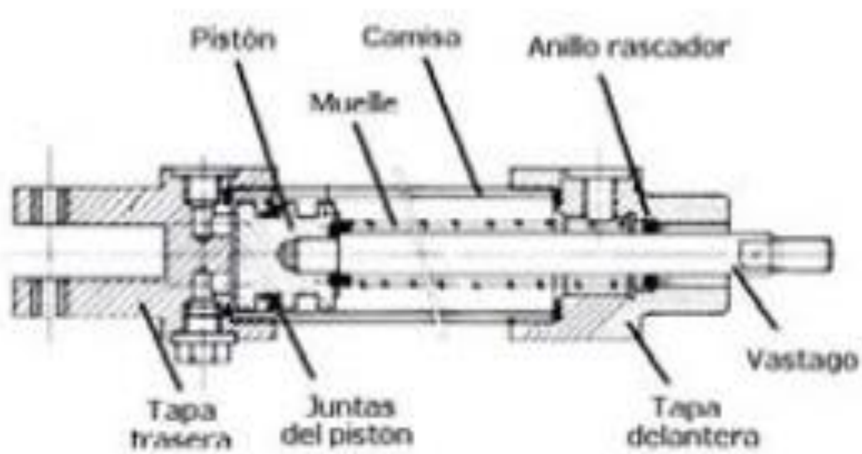


Fig. 3.Pneumatic piston components [4]

This consists mainly of the rod, bushing, front and rear cover, scraper rings, and gaskets. Among the existing types are double-acting pistons, whose two orifices can be used as air inlets to move the piston rod forward or backward as needed. Cylinder force is given by the following equation:.

$$F = P * A \tag{1}$$

where $P(Pa)$ is the air pressure and $A(m^2)$ is the area of the cylinder.

Another particularly relevant variable for commercially available piston selection is the buckling generated in the piston rod, and therefore, the output length is corrected taking the buckling factor into account, as shown in Fig. 4.

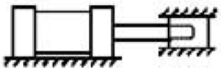
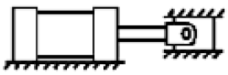
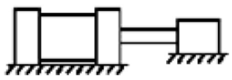
Tipos de montaje	Conexión del extremo del vástago	Tipo de conexión	Factor de pandeo
Grupos 1 o 3 - Los cilindros de gran longitud de carrera deben montarse usando en un extremo una base rígida y alineada para soportar la fuerza principal y en el extremo opuesto un soporte parecido. Se aconseja un soporte intermedio para el caso de carreras muy largas	Fijo y guiado rígido	I 	0,5
	Pivote y guiado rígido	II 	0,7
	Soporte sin guiado rígido	III 	2

Fig. 4.Buckling factor by installation type. [4]

Fig. 4 shows a cross-section, which allows determining the basic rod length using the following equation:

$$L_B = L_C * FP \tag{2}$$

where L_C is the required stroke length (mm) and FP is the buckling factor presented in Fig. 3. Minimum rod diameter is determined from the known variables and from Equation (1) and Equation (2) to avoid buckling, as shown in Figure 2.12 in[4].

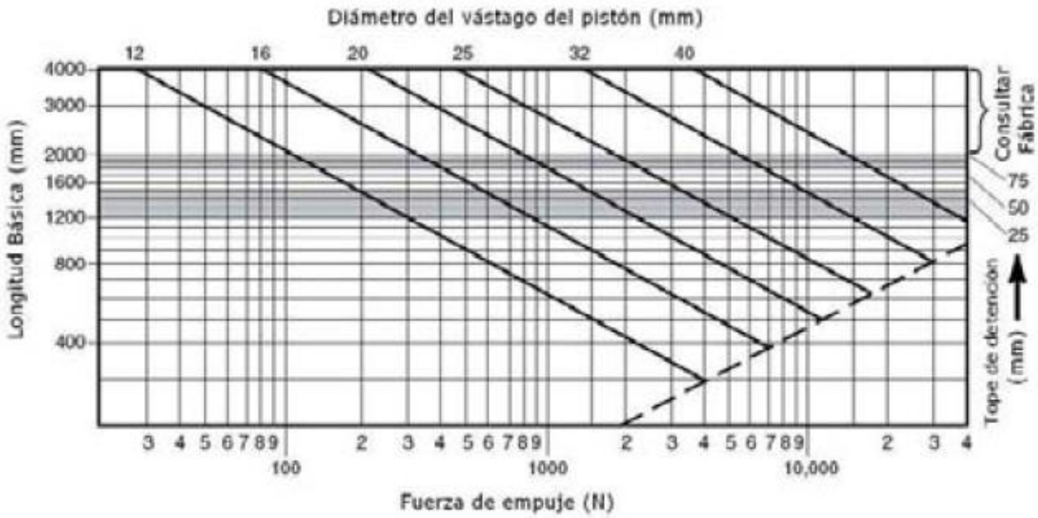


Fig. 5.Unbuckled shaft diameter

Finally, it is necessary to calculate the air required from the airflow consumption required for the piston to operate for a given amount of time, and according to [4], this is determined using the following equation:

$$Q = 2 * \frac{0.987 + P(bar)}{0.987} * \frac{\pi D^2 L_C}{4,000,000} * n \quad (3)$$

where D is the cylinderdiameter (mm) and n is the number of cycles per minute.

V. INTEGRATION DESIGN PROPOSAL

This integration design,based onseveral technologies for improving the coaxial cable crimping process,is shown in the flowchart presented in Fig. 6.

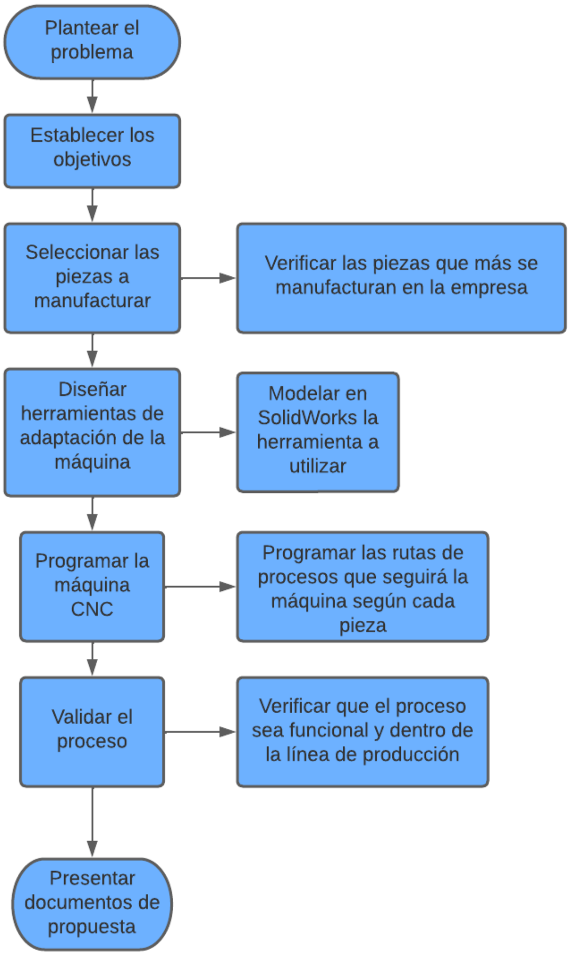


Fig. 6.Project flowchart

Each stage is described below.

- State the problem: Formulated based on the need to improve crimping process cycle time and reduce cable assembly waste.
- Establish objectives: the machine's specific objectives were defined for the purpose of substantiating the scope of the project.
- Select the parts to be manufactured: A two-year company sales projection study was carried out, as well as an analysis of the most requested parts, the complexity of the crimping processes, and adaptations of the machine process.
- Design adaptive machine tools: Every adaptation tool, the connector base, and the stabilizer table were designed and drafted to ensure that the piston remains perpendicular to the parts being crimped.
- Program the CNC machine: A mapped path was programmed, with the piston activated according to the tolerances and calibration required for each connector.
- Validate the process: An analysis was carried out based on production line process tests, verifying its usefulness.

- Present the proposal: The requested document was prepared to present the information gathered pertaining to the project.

The integration design is carried out iteratively, starting with the analysis of a small commercially available piston, and assuming a cylinder diameter of $D=32mm$ anda rod diameter of $d=12mm$, with $n=10$ workcyclesand a maximum pressure of $P=7.3bar$,which generates a force of $F=587.1N$ in the cylinder.

Considering a stroke length of $L_C=50mm$ and a buckling factor of $FP=2$, the minimum rod diameter to avoid buckling is approximately 5 mm when using Fig. 5. The FESTO ADNGF-32 piston, therefore, meets the necessary requirements as well as being commercially available.

Air consumption can be determined using Eq. (3), resulting in a required air flow rate of $Q=6.75\,dm^3/\min$. The existing industrial compressor presents no difficulties for the amount of air required.

A commercially available stamping machine with characteristics similar to those illustrated in Fig. 2, fitted with the previously selected pneumatic piston,was selected. The proposed geometrical design was carried out in the SolidWorks tool, with the resulting proposal shown in Fig. 7.

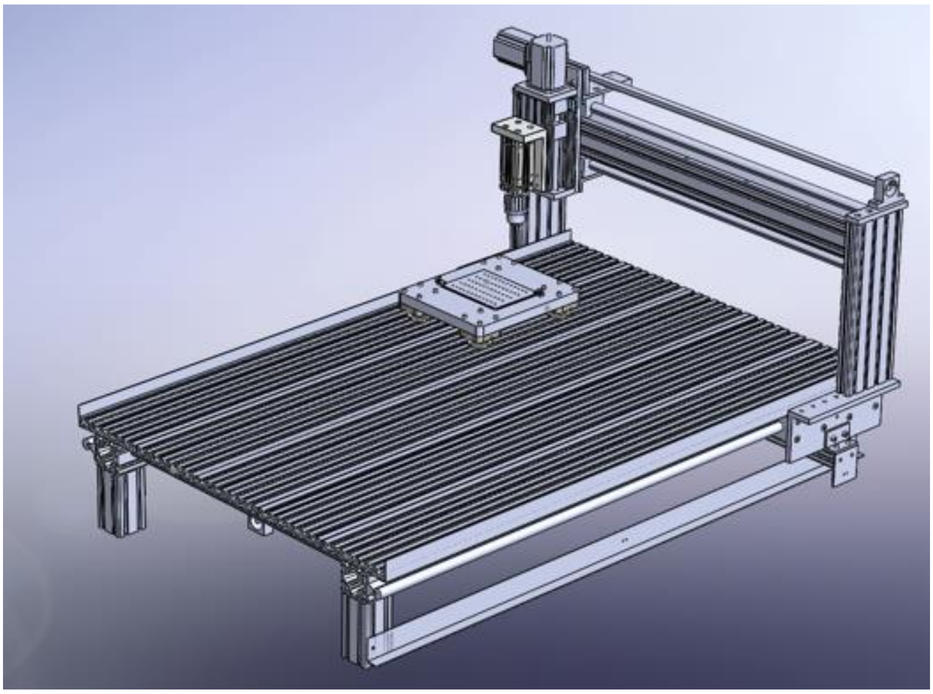


Fig. 7. Mechanical integration proposal

Fig. 7 shows a commercially available chuck at the end to eliminate concentricity errorsproduced during the manual axial cable crimping process.

Likewise, a control system is required to limit piston position, as shown in the following picture.

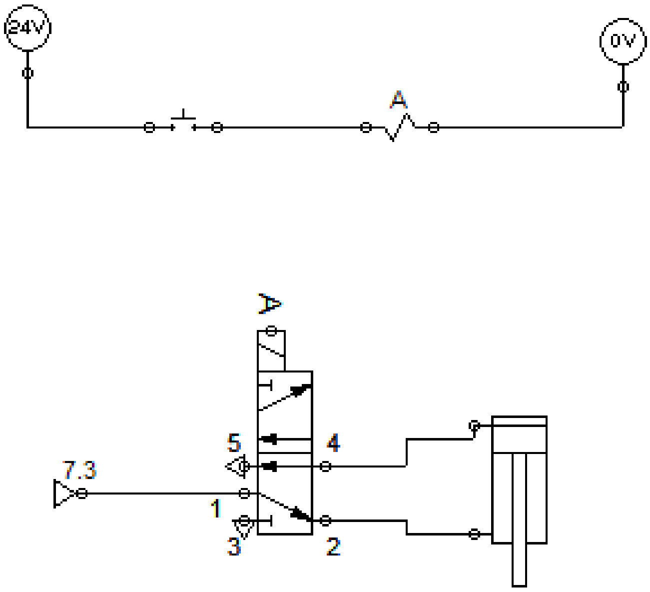


Fig. 8. Pneumatic crimping press circuit

Integration of the components above enabled the development of a semiautomatic CNC crimping press, which, using a pneumatic system, provided the elements necessary to carry out field tests to verify its operation and evaluate its impact on the initial requirements.

Field tests were carried out on a sample of 120 crimping elements, resulting in a 44% reduction in calibration time and a 65% reduction in crimping time, facilitating the corresponding production increase. With the tests run and the new mechanical elements, 0% of defective parts were generated during testing.

VI. CONCLUSION

The machine design process is complicated, especially when there are limitations on the machines or components to be used. This may require certain machines and tools to be adapted, which opens the way to technological integration methods in the industry, such as the design process for a semiautomatic crimping press utilizing a milling machine with a highly developed linear motion system and its own programming language in the manufacturing industry. Errors during coaxial cable crimping are mainly due to the lack of parallelism between tools and the connectors to be assembled, centering errors during tool replacement, misalignment of the stabilizing table to the worktable (now bench), and mechanical vibrations generated by the pneumatic actuator, which results in a number of defective parts being scrapped or requiring machining. These errors were isolated individually and solved by reworking the machined parts for the project. A stabilizing table wasdesigned to align the work piece surface parallel to the face of the crimping tool, and the stabilizing table was secured with torque adjusting tools. Piston speed was adjusted to reduce the impact generated by the internal piston movement, and the adaptation of a pusher-centering tool led to the development of the geometrical design of the prototypes, the calculations, and the design of the pneumatic circuit, allowing the overall objective of decreased cycle time to be met. The corresponding primary objective was met by reducing calibration time by 44.67% and process time by 64.94%. Finally, the piston's end-of-stroke error was reduced to 0%.

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