



ELECTRONIC WINDING MACHINE FOR THE CONSTRUCTION OF TRANSFORMERS

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ABSTRACT

This project shows an application of engineering in the automation of a workshop process such as the winding of transformers, using for this the use of microcontrollers, analog electronics and basic mechanics, for this is done a prior study of the most relevant needs. In the winding process, the most efficient and low cost technologies are used, resulting in the prototype of a machine able to perform a precise, clean and fast work, improving not only the quality of the product, but also the quality of life of the operators.

Keywords: automation, microcontroller, transformers, winding.

1. INTRODUCTION

The construction of transformers and the repair of medium and low voltage motors are processes that are carried out artistically in most of the companies and workshops of the region in the municipality of Neiva due to the lack of application of technological processes in these fields.

It is not that these machines do not exist, since the big industries possess this kind of tools and they have the economic power of investment, when one thinks about the creation of prototypes that help in these processes, it is possible to consult mathematical models like systems of control of Winding of a rotor (Dorf & Bishop, 2005), this being a beginning in the work of automation and improvement of the winding process.

A transformer is a device that changes alternating electrical power from one level of voltage to alternating electrical power to another voltage level by the action of a magnetic field (Chapman, 2000). For the construction of the transformers, the voltage, current and electrical power levels, which is the product of the voltage with the current (Dorf, 1995), must be taken into account and can be taken from any winding since in theory the two consider the same.

The basic principle to perform a winding is the use of an axis which must rotate and on which the core of the transformer is placed, for it is used motors of different classes, one of easy access and cost is the universal motor that allows a reversal of rotation by only changing the polarity of its brushes (Enríquez, 2004).

For the control of all the operations a microcontroller is required, in this application will be used the Arduino Uno R3, which provides all the services that are needed in connectivity, programming being this open source and low cost (Arduino Uno R3, 2016).

2. METHODOLOGY

To achieve project development, the following steps are taken, taking into account the needs of the region, the most appropriate technology, and the application of engineering processes and the cost to make it accessible to small companies.

3. BACKGROUND

A study was carried out in the different workshops for the manufacture and repair of transformers (90% in the area of the center), and found that this process is carried out almost manually, where the operator, through a machine, which transmits the movement to an axis where the enameled wire is wound for the construction of the coil, often resulting in poor counting and uneven winding of the same.

In the best case, you can find a single-phase squirrel-cage motor, used to create the spin and a mechanical counter for counting the turns, although it improves the system a little, it has the disadvantage that being very fast it is possible to stop the motor in time and the tension of the wire causes the operator to warm hands, having to wear gloves to avoid burns. An example of the mechanisms used in the workshop is shown in Figure-1.



Figure-1. Manual assembly in repair shops.

These and many other craft systems, have great shortcomings that make the process time consuming and of poor quality.

3.1 Technical requirements

They correspond to the request of the operators, the tasks that must be performed by the machine for optimum performance in the workshop, not only to fill the



aforementioned failures in manual and electromechanical systems, but also to go further, offering the Possibility of other functions that simplify the tasks in the workshop, in the repair of motors and in the elaboration of coils.

Once the specific area has been identified to improve in the production and repair of transformers, the aspects that need to be improved and the components required for such functions are indicated, all this being advised by the small entrepreneurs who define their own needs, among which are:

- Make the coils independently.
- Programming the number of turns.
- Variation of the speed of rotation.
- Manual and automatic way of working.
- Inverting rotation in the motor.
- Start and stop system in the engine.
- Uniform tension system on the wire.
- Possibility of programming new functions in the future.

3.2 Distribution of work area

The criterion for this distribution is based on two relevant aspects:

The first one corresponds to the size of the machine, which will be designed 55 cm high by 80 cm wide and 40 cm long, these measures are those that will be used to take into account in the workbench or table on which will be located.

The second criterion is given by the interaction of the programmer on the machine, which must have a free area, to install the reels, align the wire and configure the machine for its correct operation, all this is already covered by the statute Industrial safety, resolution 02400 of 1979 (May 22), Articles 7, 8, 9 and 12.

For the installation of the machine, a workbench or table is required, minimum of 1 meter wide by 50 cm long, with a height from the ground of approximately 80 cm depending on the operator. A voltage connection at 110 volts A.C. In addition, a good lighting system.

Since the presence of the operator is not necessary during the whole process of winding, a fixed work point is not required accompanied by a chair or other, the free area around the machine must be minimum of 2 m², according to the security statute Industrial, in its title II, article 9, sufficient space to carry out the operations of installation and configuration of the machine.

3.3 Control panel

From here, the operator will program the machine for the realization of the coils. Among the options that will be available, you will have:

- Turning the machine on.
- Work manually or automatically.
- Speed control.
- Keypad to program number of turns.
- Display to confirm the setting.
- Spin reversing control for the engine.

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The objective will be to design and build a control panel, which will perform the functions indicated by the winding workshop operators. For this, the following diagram was shown in Figure-2, which is the result of several sketches, suitable for size and comfort for the user.

To have a clearer idea of the elements that are installed on the panel, you can see Figure-6, where it is shown by a block diagram the structure that is intended to be realized, it must be taken into account that the microcontroller, or the Arduino card, is behind and not in front of the panel.

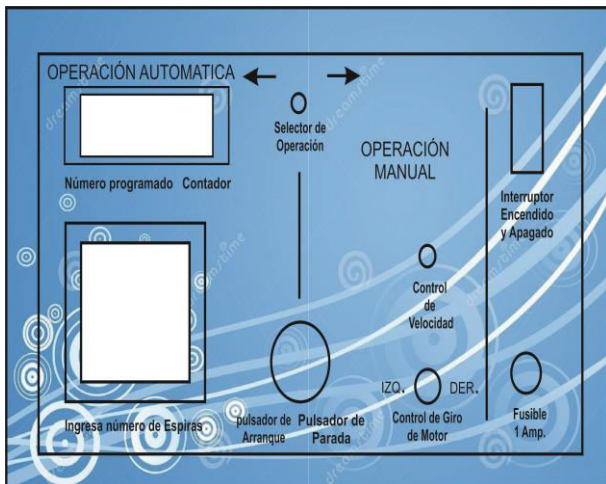


Figure-2. Control front panel diagram.

4. DESIGN

Once you have the parameters to perform, you proceed to make the respective designs, to comply with the required parameters, the modules to be designed taking into account the technical requirements are:

- **Structural design:** responsible for all structural requirements for the support and the different functions, measures and couplings between the control and mechanical modules.
- **Electrical design:** takes into account the connections from the power supply to the motor supply and control elements, the stop system is implemented in the same way as the three-phase motors with a power diagram and a control diagram (Hps SystemTechnik, 2016).
- **Electronic design:** it is the most relevant, it is responsible for the operation on all cards that carry electronic components, the most important being the microcontroller, which is implemented with an Arduino module, which not only requires hardware but also software. Which is responsible for doing the scheduled tasks, this section includes the speed control performed through a TRIAC by the phase control method (Muhammand, 1993) and the card in charge count the number of turns (revolutions) necessary to. In this block, calculations are performed to couple the sensor signal through an integrated circuit 555 and transistor in switching mode (Sedra & Smith, 2014).
- **Mechanical design:** it has as main objective, everything related to the motor to be used, its connections, turning investment and adaptations with pulleys, belt and axle (Wildi, 2013).

Figure-3 illustrates the connection of the Arduino microcontroller, with its peripherals made in fritzing (Fritzing website, 2014); you can notice the simplicity of its connections without the need for complex interfaces.

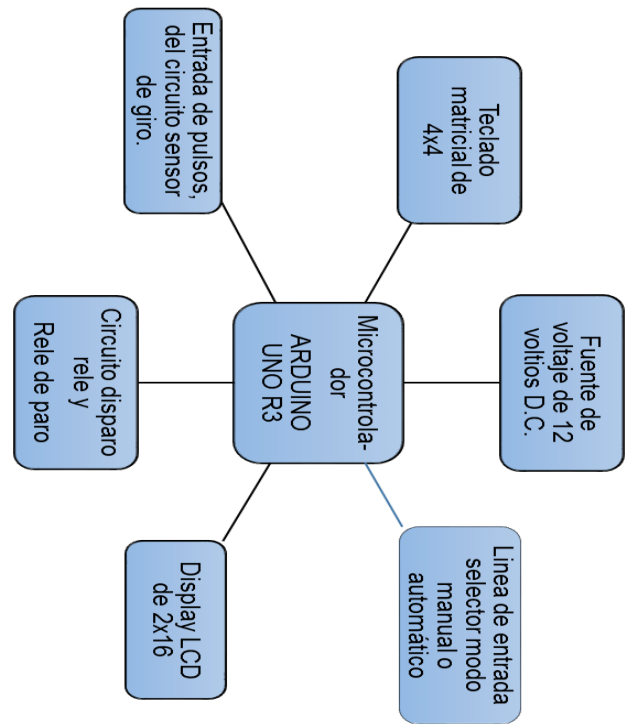


Figure-3. Design with Arduino 1 R3 and peripheral input output.

In Figure-4, a general diagram is shown where the blocks are located and their corresponding operation; this is the result of adding all the partial designs.

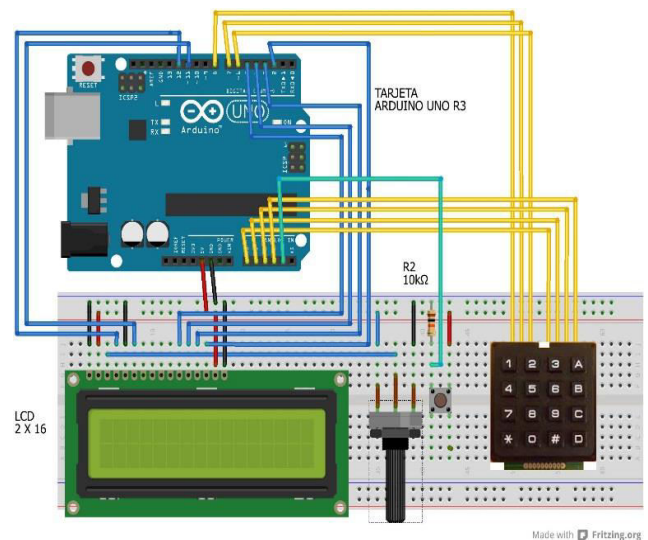


Figure-4. General diagram of the electronic winding prototype.

5. IMPLEMENTATION

Once the construction of the structure is completed, the electrical, electronic and mechanical



circuitry is installed, and then proceeds to perform the necessary tests and adjustments in accordance with the parameters required in the technical prescriptions.

In Figure-5, the prototype of the finished machine can be observed, with its respective control panel and all the accessories that compose it.



Figure-5. Imagen prototype terminator.

5.1 Mechanical system

It is composed mainly of the motor, the central element of this machine, then the pulleys, the belt and finally an axis that goes on bearings so that the corresponding winding can be realized.

In this section, the elements used to implement the mechanical system are described.

5.1.2 Engine. For the engine to meet the objectives of the prototype, it must meet at least five conditions:

- Allow the investment of rotation in an easy and safe way.
- Comply with the minimum torque force to tension and wind the wire, which allows the coils to be made (maximum 18 gauges, with a torque of 0.5 Nm).
- Drive as low as possible (RPM).
- Complies with the voltage conditions (110 volts AC) and frequency of the domestic electrical network (60 Hertz), this for the workshops in non-industrial zones.
- That it is not expensive, since it is aimed at small and medium-sized enterprises.

Within the wide range of known motors, it was chosen to work with a universal low-power type, as this is easy to install, lightweight and feasible to perform turning reversal, the reference of this is Sewing Machine Motor, the which has the following characteristics:

- Operating voltage: 110 volts A.C.

- Frequency of operation: 60 Hertz.
- Rated current: 0.9 Amperes.
- Power: 90 watts.
- Revolutions per minute: 7500 rpm.
- Motor type: universal, asynchronous.

In the engine specifications the power in watts is found, however, for many applications the units are used in horsepower, to make this change, the following expression is used:

$$hp = 90 w * 0,00136 = 0,12 hp$$

Another of the data necessary to know if the engine meets the conditions, is the torque or torque, a value that is not within the specifications given by the manufacturer because it is a Chinese engine, in this case the following formula is used:

$$T = \frac{\text{potencia (vatios)}}{Rpm * \frac{2 * \pi}{60}}$$

$$T = \frac{90 w}{7500 * \frac{2 * 3.1416}{60}} = 0.1146 Nm$$

The only aspects that should be improved, as can be seen, are very high revs and very low torque, to make the motor useful, it develops in the motor-shaft coupling stage, a pulley arrangement, to reduce speed and Increase the force, by using a strap.

Torque increase: how to comply with the torque parameters so that the motor can make the coils, taking into account that the minimum working torque is 0.5 Nm, the value is cleared to know the diameter of the second pulley, which complies with this parameter.

Diameter of the first commercial pulley for this type of motors D1 = 15 mm, motor torque T1 = 0.1146 Nm, minimum torque required to operate 0.5 Nm, but taking into account factors such as friction (effort to use balinera) and Entrainment of the wire spool is taken T2 with increase of 30% to ensure a good operation, T2 = 0.65 Nm.

$$D1 * T2 = D2 * T1$$

Where:

D1 Conductor Pulley Diameter

D2 Diameter of driven pulley

T1 Driver's Pulley Torque

N2 Driven Pulley Torque

$$D2 = \frac{D1 * T2}{T1} = \frac{15 mm * 0.65 Nm}{0.1146 mm} = 85.07 mm$$

Commercially there are 85 mm pulleys, which is necessary to meet the requirements of the machine.



Speed reduction: to make this speed change, a smaller pulley attached to the engine and a larger one is used on the working axis, the pulley measures are:

Pulley attached to the engine 15 mm in diameter.

Pulley attached to the working shaft 85 mm in diameter.

The speed ratio is obtained as follows:

$$N1 * D1 = N2 * D2$$

Where:

D1 Conductor Pulley Diameter
D2 Diameter of driven pulley
N1 Rotation Speed of the Driving Pulley
N2 Driving Speed of Driven Pulley

$$N2 = \frac{N1 * D1}{D2} = \frac{7500 \text{ RPM} * 15 \text{ mm}}{85 \text{ mm}} = 1324 \text{ RPM}$$

Once the calculations have been completed, the pulleys can be purchased with commercial measures, Figure-6 shows how to connect them through the same belt that the motor kit brings

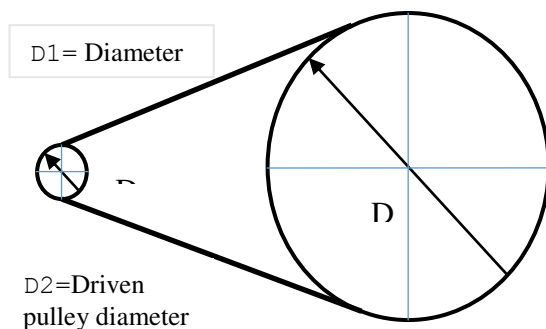


Figure-6. Attaching pulleys and measuring their diameters.

Although the speed has been greatly reduced with this arrangement, it still has a very high speed for winding up. For this reason, a speed regulator with TRIAC, control of the number of turns. This allows the speed to be reduced to the stopping point of the motor.

5.1.3 Feeding. It contains the proper energy elements for a circuit, ranging from the 110-volt AC outlet, the plug, through the duplex cable, entering the machine and coming directly to the protections.

In this section the most important thing is that the elements are selected above the own characteristics of consumption of the machine, that is to say when summing the currents of the different circuits, it must pass through the input cable, which, by norm of Protection (RETIE) will have 25% more ampere rating to prevent damage from heating.

5.1.4 Protections. Basically, the protection of all electrical circuit of low power and electronic is a fuse with its respective fuse holder. Here, a 3 Amp fuse will be used, which will be installed in a 5 x 20 mm panel fuse holder, as shown in Figure 21, which will make it easy to replace in case of over voltage and short circuit damage in the workshop.

However, at the request of the users, a stop button is also implemented, which when the machine suffers damage, can allow the engine to stop without having to shut down the entire prototype and thus be able to store the number of turns that are carried to the Shown on the display.

5.1.5 Electronic design. The electronic design consists of three parts.

Part 1. The circuit in charge of converting the rotation of the axis into square wave pulses, determining the turns of the core that builds the coils, which consists of an optocoupler and an integrated circuit NE556N (integrated that includes two 555 integrated circuits and ideal to deliver A square wave well defined by each rotation of the axis), the card and configuration is shown in Figure 6, this is mounted on a metal base and then on the frame of the machine near the axis, which will have a pin which will pass through The optical sensor.

Part 2. An Arduino card in charge of performing four main functions:

- Receive from a keyboard the number of turns (turns) that the coil must have.
- Receive from the sensor card and signal conditioner, the square wave pulses, which will be counted by the microcontroller.
- Display a 2 x 16 LCD display, the number of turns and during the process the increase of the same.

Send a stop pulse, to end the rewinding once the programmed number is reached.

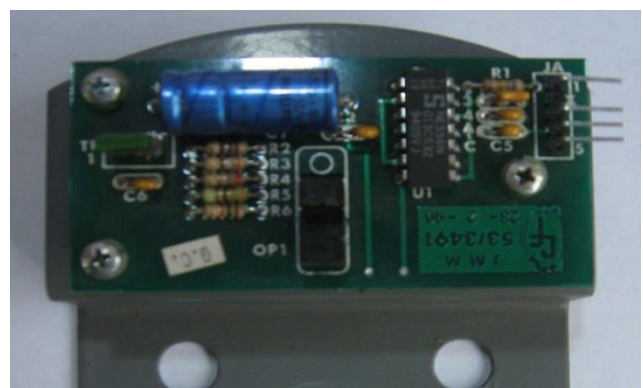


Figure-7. Assembly diagram for the Arduino one R3 card and its connections.

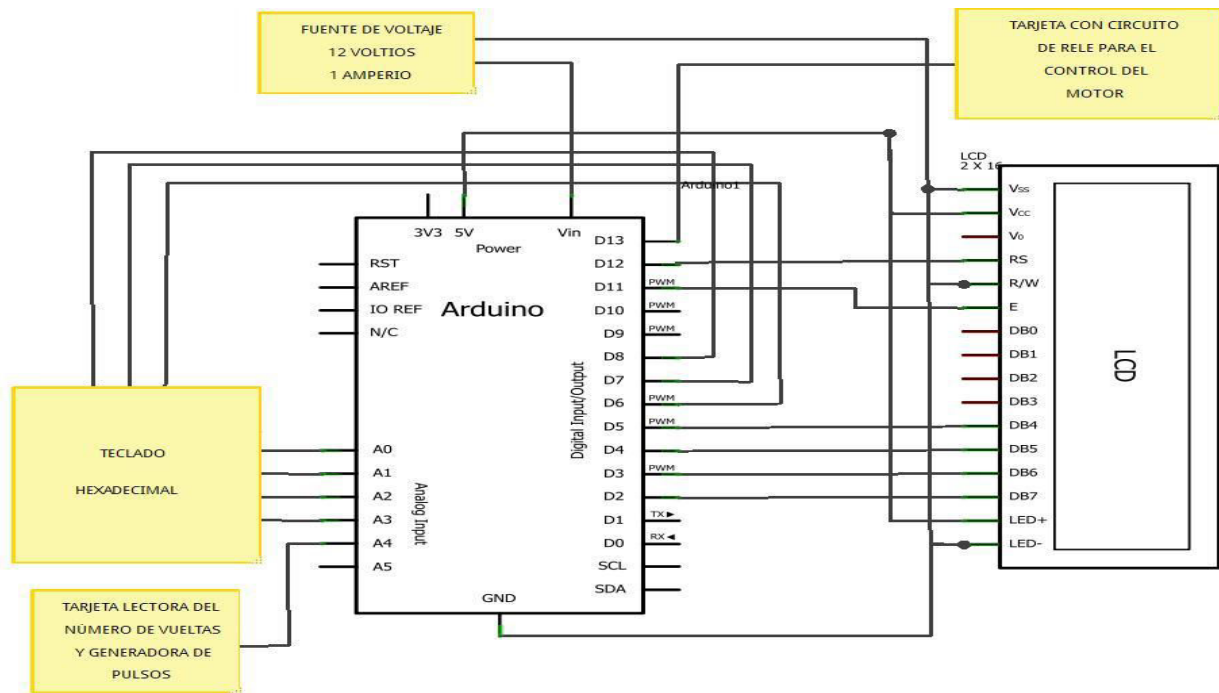


Figure-8. Pulse sensor circuit and signal conditioning.

As can be seen in Figure 7, the physical connections are shown, for:

- A. LCD which uses 4 data transmission lines, two for configuration, two for 5 volts and 3 for negative.
- B. The connection to the 4x4 matrix keyboard, as it is seen, only 7 data lines are used, since the column of the letters is not used for now, however, it leaves the possibility of improving the services and that they are applied in a future.
- C. A small control circuit consisting of a relay, which will cut the supply of the current to the motor once the number of turns assigned.

Finally, the output connection that will go to a transistor and relay in charge of suspending the rotation of the motor, once the number of laps programmed is completed, in this case an LED connected to pin number 13 of the Arduino card is used.

5.1.6 Engine control. (On, off), this will have several fronts, once the machine is turned on, the working method is chosen and the number of turns are programmed; here are several forms of control:

A. The front panel will enter the number of turns to be made and the process starts when the operator presses the start button (green color), the microcontroller compares the number of turns and sends a pulse that will turn the machine off the two values are equal.

B. An emergency stop button (red color) will be installed, which will cut off the power supply to the motor, stopping it immediately, in case of a fault or error in programming the same.

5.1.7 Speed control. The speed control is done through a very common circuit used in motors of AC, which is simply a variator of signal through a TRIAC.

It has been decided to leave a manual control through a potentiometer, by direct recommendation of the operators, leaving the advantage to realize any type of winding, according to the caliber of the wire (the thinner the wire the slower the rotation must be), Because there is a large range of the gauge used in transformers and motors and designing a table with each analog value, would not only make it expensive, but more time consuming. For the realization of this assembly, the diagram shown in Figure 8 was taken into account.

5.1.8 Control number of turns. This is done in the Arduino module, by means of software recorded in the same one, once finished; it sends a pulse to a control circuit, which by means of a relay deactivates the passage of voltage to the motor. For clarity on the carried out programming, Refer to Annex F, where the code for Arduino one R3 is shown in detail.

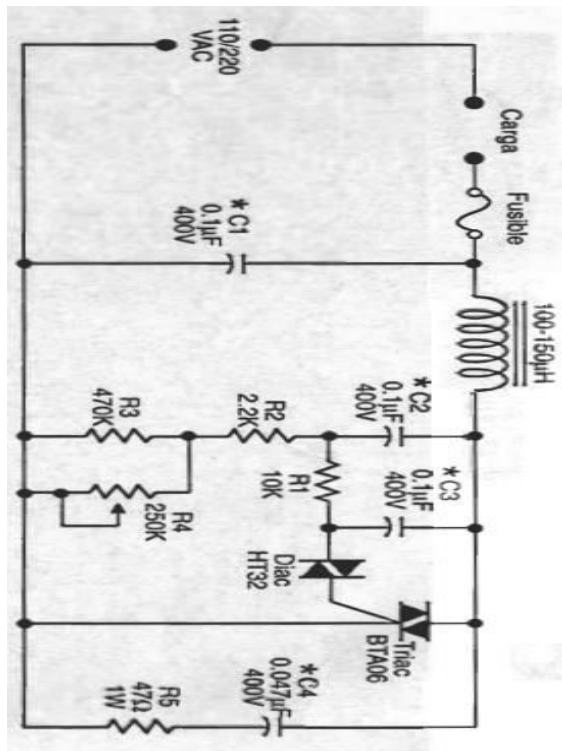


Figure-9. Speed control for the engine.

5.2 Front panel design

Here the measurements of all the elements already described in the section of technical prescriptions will be given, for greater ease they are shown in Figure-9.



Figure-10. Front Panel Design.

This panel will be installed on the frame of the machine, centered and with a space of 26 cm of width; 15 cm of height and 20 cm of length, its structure will be implemented in aluminum angles, for not requiring greater efforts.

Its outer faces will be covered with the same zinc sheet as the frame, but taking into account that on the front

(front panel), a special design is made that clearly indicates the devices and their application.

5.3 Working manual winder machine

Basically the machine has two main operating modes (manual and automatic), however, thanks to its flexibility it provides other services that help in the repair of motors and transformers (counting of coils, elaboration of coils with multiple windings, elaboration of group of Coils, inclusion of modules for coils of different sizes). This manual describes the operation of the main modes of operation in the specific case for winding in a transformer:

First: prepare the machine, before turning it on, no matter which mode is chosen, the feeding reels (where the enameled wire comes), and the reel or form where the winding is required (transformer base or coil), Then the wire is passed through the pulleys and the tensioner, to the transformer securing the first turn.

Second: configuration according to the orientation of the winding is chosen the direction of rotation for the motor (right, left). The velocity must also be graduated taking into account the caliber required to make the coil.

Third: selection of the form of operation, here defines what type of work the machine will perform, whether manual or automatic, this is done with a selector located on the control panel.

5.3.1 Manual operation: it is used when you want to make coils with bypass, this means that the machine must be stopped and a connection must be drawn according to the turns required. Steps to follow:

Step one: start the winding process by using the start button (green color), here you can see the number of turns that are performed in the Display, but there is no control over how many will be done.

Step two: When approaching the number of turns, you can manually reduce the speed, then stop the count with the red button.

Step three: the connection is made for the bypass and the wire is adjusted to continue with the missing turns, here you can reverse the motor rotation if necessary and change the speed in case of changing the gauge of the second coil.

Four passes: steps one and two are repeated until the winding is completed and the machine is turned off once the work is finished.

5.3.2 Automatic operation: used when you want to make a single coil, this is not necessary to change the wire gauge and there are no leads. Steps to follow:

Step one: Enter the number of turns required on the keyboard, be sure to enter the correct number, so you do not have to manually brake the machine.

Step two: start the winding by pressing the start button (green color); here the process starts without operator intervention.

Step three: Wait for the machine to finish the coil, turn off the machine and remove the mold from the transformer.



5.4 Improvements with the new production system

Minor time in the processing of transformers and coils for the repair of motors. With the same number of turns in a transformer manually, the operator can take up to fifty minutes, with the machine the time is reduced to only fifteen minutes.

Quality in terms of precision refers to one hundred percent, since the counting is done in digital form and does not depend on mental accounts that by fatigue or distraction can incur large errors and alter the values of expected voltages.

Presentation on the body of the coils, since the system of tension of the wire is included in the machine, this tends to be constant and therefore the coils are made evenly, in the manual system, as the time increases Operator expresses muscle fatigue and the tension increases or decreases according to the strength and particular resistance in each operator.

Application of the industrial safety statutes, taking into account the physical, ergonomic, mechanical and electrical risks, this is reflected in the parameters of technical prescriptions and calculations, as is the case of the choice of type of cable according to the amperage Circulates through it, seen in tables designed for this purpose, machine operator distance.

6. CONCLUSIONS

- With the construction of this prototype, it is possible to improve the quality in the process of repair and manufacture of transformers, achieving a technological advance at the level of small and medium enterprises.
- This machine is only a prototype, with the ability to make windings for different uses; a serious improvement would be to use a motor with more power to achieve much thicker gauge windings.
- There are different modules that can be designed to use the shaft and thus make windings of specific machines, as is the case of universal motors.
- When expanding in so many functions, it was not necessary in some designs that can be improved, like the one of linear speed control, since, not being an exact process, the prototype works very well.
- The possibilities of these machines are many, centralize these functions more in a microcontrolled system, and offers a greater automation of the same.
- In the manual work mode, speed control could also be implemented, not with a potentiometer on the board, but with a controlled extension with the foot, as is done with industrial sewing machines.
- This prototype could be further automated, if the way of automatically feeding the reels and guiding the position of the wire was designed, reaching the point of not requiring an operator in the whole process.
- A practical application of the engineering in the use of microcontroller technologies with Arduino cards, of easy handling and low cost

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