

INDUSTRIAL AUTOMATION USING PLC FOR SPOOL HEAT SEALING PROCESS

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Abstract—Programmable Logic Controller (PLC) based spool heat sealing automation ensures efficient process control over massive production of vehicle horns. The basic componential structure of vehicle horn consists of a copper coil being fixed inside a metal case with a diaphragm. The coil is excited by the electric supply due to which it vibrates. This tends to vibrate the diaphragm which leads to the production of sound that gets amplified before it gets through the speaker. In some cases there are chances of the copper coil to escape from the position due to its vibration. This may lead to improper working of the horn and also it may cause damage to the coil. This type of coil damage can be reduced by fixing the coil in position. For this purpose the process of fixing and sealing of the coil are being done in industries. The existing system of coil sealing is done manually. In the present system, this process is done with maximum human interference. It is a time consuming process. In order to reduce this drawback of high time consumption this project proposed the system of automation. The proposed system consists of an automation unit for sealing the coil. This system can be implemented by using Programmable Logic Controller. The automation system developed using PLC leads to efficient manpower utilization in the industry.

Keywords— PLC; diaphragm; coil damage; vibration; sealing; automation; effective manpower utilization

I. INTRODUCTION

Industrial automation is the use of control systems, such as computers or robots, and information technologies for handling different processes and machineries in an industry to replace a human being. It is the second step beyond mechanization in the scope of industrialization. Earlier the purpose of automation was to increase productivity, and to reduce the cost associated with human operators. However, today, the focus of automation has shifted to increasing quality and flexibility in a manufacturing process. In the automobile industry, processes are done with automated machinery with an error rate of 0.00001%. Industrial automation eliminates healthcare costs and paid leave and holidays associated with a human operator. associated with machinery used for industrial automation is less because it does not often fail. If it fails, only computer and maintenance engineers are required to repair it. [1]

Industrial automation leads to a significant Improvement in the productivity of the company. Automation alleviates the error associated with a human being. Further, unlike human beings, robots do not involve any fatigue, which results in products with uniform quality manufactured at different times. Adding a new task in the assembly line requires training with a human operator, however, robots can be programmed to do any task. This makes the manufacturing process more flexible. Adding automated data collection, can allow you to collect key production information, improve data accuracy, and reduce your data collection costs. Industrial automation can make the production line safe for the employees by deploying robots to handle hazardous conditions. Industrial automation has recently found more and more acceptance from various industries because of its huge benefits, such as, increased productivity, quality and safety at low costs.

II. EXISTING SYSTEM

The initial process in the making of vehicle horn, consists of pressing unit. In this unit the outer case of the horn is given required shape for the coil to be fixed. The pressing unit consists of

hydraulic presses. The system is semi-automated, which requires manpower to some extent, in order to control and check the process of pressing the metal plate. Once the initial shape of the plate is given, then it is sent for the process of marking, punching etc. In order to get the complete required shape the horn. When the finished product of pressing unit is obtained, it is tested for harmonics before it reaches the assembly line unit. The process of testing is also done in an automated system, where the discarded products are used for some other purposes. Followed by the pressing unit is the coil winding unit. Coil of desired thickness is properly insulated and wound with required no of turns. [2]

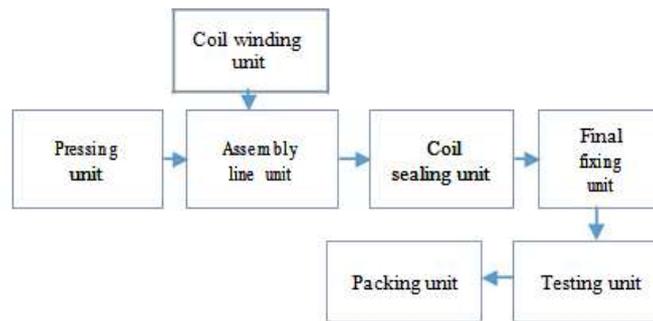


Fig 1 Block diagram for overview of Industrial process

The entire process is done manually. Before these coils being sent to the assembly unit, they are checked and tested for any damage or cut in the middle. After the testing process is done, the wound coils are sent to the assembly line unit for being fixed inside the diaphragm. Assembly line unit is the major unit in the manufacturing process of horns consisting of a large number of workers being employed. Since it is a tedious process of horn production it is done with great monitoring attention. Here the output of the pressing unit and the wounded coil, from the coil winding unit, are brought together where the coil is placed inside the metal plate. The coil is also covered with a metal diaphragm. This unit consists of semi-automated system, which requires the work involvement of employees for the process of placing the metal piece in position, in the field of the pressing unit and taking it off once the process is done. Followed by the assembly line unit is the Sealing unit.

The existing system of sealing process in the industry is a manual one. Workers seal the coil manually. After the coil has been sealed, the horn product is sent for final fixing unit where it is sealed and fixed finally. Testing is done to check the power output, harmonic detection, noise elimination etc. After the products are being tested, they are finally packed and sent to the market for sale. The existing system of horn production in industry, the metal sheet of aluminum is pressed to give the required shape for coil fixing. Copper coil from the coil winding section is being brought into the assembly line unit where it is fixed inside the diaphragm. This unit is followed by the manual sealing unit. Here the coil after being fixed inside the diaphragm, reaches the sealing unit where the workers seal it manually, by means of pressing machine. The outcome of this unit is about one piece per 36 seconds. It is actually a time consuming process. The time taken at this unit largely increases the overall time consumed for the whole manufacturing process in the industry.[6]

The overall product outcome of the industry is less in number that is too low to meet the increasing market demand. The actual outcome of the industry is 1500 pieces per day. The reliability and durability of the product is low due to manual sealing, as the possibility of coil misalignment is greater. This may eventually reduce the quality of the products. Hence the introduction of automation in the process of manufacturing is highly appreciated. The automation system that comprises the process of coil fixing and sealing can replace the existing manual system of coil sealing unit in-order to fasten up the industrial process of manufacturing.

The manual sealing unit when replaced by the automation unit, the output of one piece per 36 seconds can be increased to six pieces per 36 seconds. It is roughly six times the outcome of the existing system. It is highly advantageous to meet the existing increasing demands of the customers.

III. PROPOSED METHODOLOGY

This paper proposed the idea of introducing automation in the process of horn production. Here the manual sealing unit is replaced by an automated unit. And also the two units of coil fixing and coil sealing are combined into a single unit, where the output of the former unit is fed as the input to the sealing unit. This reduces the overall time consumed by the units. For the Implementation of this automation system we have used Programmable Logic Controllers.

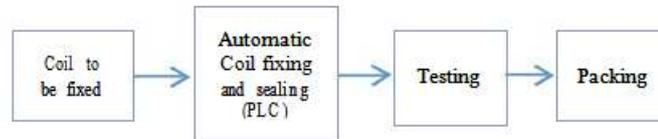


Fig 2 Block diagram of proposed system

Here the process of sealing to fix the coil in position is done with the help of automatically controlled heaters, pneumatic presses, thermostat, conveyor controlled by induction motors and the other necessary elements required for the process of sealing the coil. The proposed system block diagram consists of the pressing unit where the metal sheet is given the required shape for placing the coil inside the diaphragm. The coil is wound by in the coil winding unit. This unit is followed by the existing system of assembly line unit. In this unit the coil is placed inside the diaphragm. This unit is followed by an automated unit of fixing and sealing, where the coil is fixed initially using an automation system. Following this unit is the sealing unit which gets the input from the fixing unit directly. Here the process is done with equipment that are controlled by programmable logic controller.

IV. FUNCTIONAL BLOCK OF PROPOSED SYSTEM

Initially the coil to be fixed is sent to the heat sealing unit in a conveyor. The conveyor is run by an induction motor which is controlled by a variable frequency drive fed by programmable logic controller. The conveyor can carry six pieces of coil at a stroke. The heat sealing unit is an automated system controlled by the programmable logic controller. The heat sealing unit consists of heaters, pneumatic press, and thermocouple with sensors. A temperature controller module is also present in this unit. This module controls the temperature range of operation. It limits the temperature between 158° C-160°C. The temperature range of operation is being determined by the material used for sealing. Here the material used for sealing is plastic. Since the melting point of plastic used is 160°C which is within the limit of operation of the module. The plastic is heated to be melted to seal the coil in position.

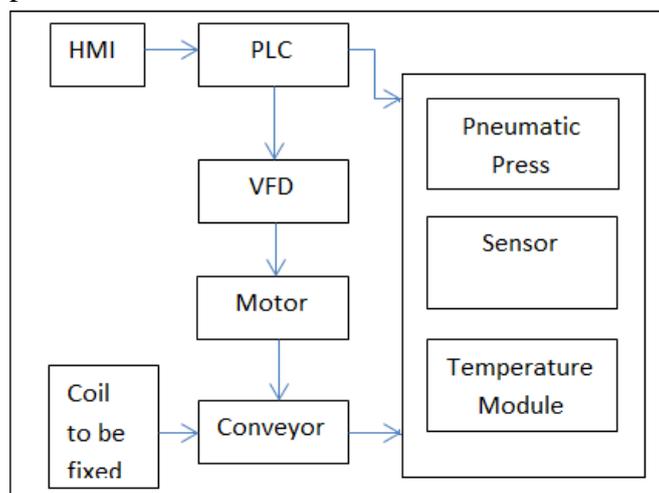


Fig 3 Functional block diagram

The complete operation of the heat sealing unit is controlled by the programmable logic controller. The movement of pneumatic press is also controlled by the programmable logic

controller. The position of the incoming coil is detected by the sensors present. There a total number of twelve heaters in the sealing unit. Once the process of sealing has been completed, the sealed coil is taken back towards the collecting chamber by the backward movement of the conveyor, where the sealed coiled pieces get collected. This gives place for the new incoming coil to be sealed. The overall process is monitored by a Human Machine interfacing unit, which displays the temperature of operation, speed of the variable frequency drive, number of units being processed per minute. The entire process of the Human machine Interface unit is also controlled by the Programmable logic controller. This PLC unit is fed with required program for controlling the operation of the entire unit consisting of VFD, Heat sealing unit and HMI.

V. HARDWARE REQUIREMENTS

The main components required are Programmable Logic Controller, Temperature control module, Human Machine Interface, Ultra slim Photo Electric Sensor, Electromagnetic brake motor, Variable frequency drive, Heater, Thermocouple, AC Synchronous motor, Diffused sensor, Proximity sensor, Switched mode power supply, MCBs, Relays, RR cables, PVC channel, Heat resistance wire.

5.1. Programmable Logic Controller

A programmable logic controller, PLC, or programmable controller is a digital computer used for automation of typically industrial electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or light fixtures. PLCs are used in many machines, in many industries. PLCs are designed for multiple arrangements of digital and analog inputs and outputs, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed-up or non-volatile memory. A PLC is an example of a "hard" real-time system since output results must be produced in response to input conditions within a limited time, otherwise unintended operation will result.

A PLC program is generally executed repeatedly as long as the controlled system is running. The status of physical input points is copied to an area of memory accessible to the processor, sometimes called the "I/O Image Table". The program is then run from its first instruction rung down to the last rung. It takes some time for the processor of the PLC to evaluate all the rungs and update the I/O image table with the status of outputs. This scan time may be a few milliseconds for a small program or on a fast processor, but older PLCs running very large programs could take much longer (say, up to 100 ms) to execute the program. If the scan time were too long, the response of the PLC to process conditions would be too slow to be useful. This simplified programming could be used to save scan time for high-speed processes; for example, parts of the program used only for setting up the machine could be segregated from those parts required to operate at higher speed. Special-purpose I/O modules may be used where the scan time of the PLC is too long to allow predictable performance. Precision timing modules, or counter modules for use with shaft encoders, are used where the scan time would be too long to reliably count pulses or detect the sense of rotation of an encoder. The relatively slow PLC can still interpret the counted values to control a machine, but the PLCs may need to interact with people for the purpose of configuration, alarm reporting, or everyday control. [3]

Under the IEC 61131-3 standard, PLCs can be programmed using standards-based programming languages. A graphical programming notation called Sequential Function Charts is available on certain programmable controllers. Initially most PLCs utilized Ladder Logic Diagram Programming, a model which emulated electromechanical control panel which PLCs replace. While the fundamental concepts of PLC programming are common to all manufacturers, differences in I/O addressing, memory organization, and instruction sets mean that PLC programs are never perfectly interchangeable between different makers. PLCs are well adapted to a range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where

changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations. [7]

5.2 Temperature Controller Module

FBs-TC6 is one of the temperature input modules of FATEK FBs series PLC. It provides 6 channels of thermo-couple temperature measurement input with 0.1 °C or 1 °C resolution. The scan rate for 0.1 °C resolution is 4 seconds, while the scan rate for 1 °C resolution is 2 seconds. The cold junction compensation is carried out inside the module, also it provides wire broken detection feature. To give the user more choices for the selection of thermo-couple type and in order to enhance the noise immunity, the isolation scheme is per channel basis. All the optional features of this module are software configurable; there are no hardware jumpers or switches for user to setup.[4]

5.3 Human Machine Interface

The user interface, in the industrial design field of human– machine interaction, is the space where interactions between humans and machines occur. The goal of this interaction is to allow effective operation and control of the machine from the human end, whilst the machine simultaneously feeds back information that aids the operators' decision making process. Examples of this broad concept of user interfaces include the interactive aspects of computer operating systems, hand tools, heavy machinery operator controls, and process controls. This generally means that the operator needs to provide minimal input to achieve the desired output, and also that the machine minimizes undesired outputs to the human. With the increased use of personal computers and the relative decline in societal awareness of heavy machinery, the term user interface is generally assumed to mean the graphical user interface, while industrial control panel and machinery control design discussions more commonly refer to human-machine interfaces. The user interface or human–machine interface is the part of the machine that handles the human–machine interaction. In complex systems, the human–machine interface is typically computerized. The term human–computer interface refers to this kind of system. In the context of computing the term typically extends as well to the software dedicated to control the physical elements used for human-computer interaction. The engineering of the human–machine interfaces is enhanced by considering ergonomics (Human Factors). The corresponding disciplines are Human Factors Engineering (HFE) and Usability Engineering (UE), which is part of Systems Engineering. Tools used for incorporating human factors in the interface design are developed based on knowledge of computer science, such as computer graphics, operating systems, programming languages. [8] An HMI is typically local to one machine or piece of equipment, and is the interface method between the human and the equipment/machine. An Operator interface is the interface method by which multiple equipment that are linked by a host control system is accessed or controlled. The system may expose several user interfaces to serve different kinds of users. HMI is a modification of the original term MMI (man-machine interface).

5.4 Variable Frequency Drive

A variable-frequency drive (VFD) (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) is a type of adjustable-speed drive used in electro-mechanical drive systems to control AC motor speed and torque by varying motor input frequency and voltage. VFDs are used in applications ranging from small appliances to the largest of mine mill drives and compressors. However, around 25% of the world's electrical energy is consumed by electric motors in industrial applications, which are especially conducive for energy savings using VFDs in centrifugal load service, and VFDs' global market penetration for all applications is still relatively small. That lack of penetration highlights significant energy efficiency improvement opportunities for retrofitted and new VFD installations. Over the last four decades, power electronics technology has reduced VFD cost and size and has improved performance through advances in semiconductor switching devices, drive topologies, simulation and control techniques, and control

hardware and software. VFDs are available in a number of different low- and medium-voltage AC-AC and DC-AC topologies.[9] A variable-frequency drive is a device used in a drive system consisting of the following three main sub-systems: AC motor, Main drive controller assembly, Drive/operator interface

5.5 AC Motor

The AC electric motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but three-phase induction motors are suitable for most purposes and are generally the most economical motor choice. Motors that are designed for fixed-speed operation are often used. Elevated-voltage stresses imposed on induction motors that are supplied by VFDs require that such motors be designed for definite-purpose inverter-duty in accordance with the requirements. In variable-torque applications suited for Volts-per-Hertz (V/Hz) drive control,

AC motor characteristics require that the voltage magnitude of the inverter's output to the motor be adjusted to match the required load torque in a linear V/Hz relationship. While suitable in wide-ranging applications, V/Hz control is sub-optimal in high-performance applications involving low speed or demanding, dynamic speed regulation, positioning, and reversing load requirements. Some V/Hz control drives can also operate in quadratic V/Hz mode or can even be programmed to suit special multi-point V/Hz paths. The two other drive control platforms, vector control and direct torque control (DTC), adjust the motor voltage magnitude, angle from reference, and frequency so as to precisely control the motor's magnetic flux and mechanical torque. Although space vector pulse-width modulation (SVPWM) is becoming increasingly popular, sinusoidal PWM (SPWM) is the most straightforward method used to vary drives' motor voltage (or current) and frequency. With SPWM control, quasi-sinusoidal, variable-pulse-width output is constructed from intersections of a saw-toothed carrier frequency signal with a modulating sinusoidal signal which is variable in operating frequency as well as in voltage. Operation of the motors above rated nameplate speed (base speed) is possible, but is limited to conditions that do not require more power than the nameplate rating of the motor. This is sometimes called "field weakening" and, for AC motors, means operating at less than rated V/Hz and above rated nameplate speed. Permanent magnet synchronous motors have quite limited field-weakening speed range due to the constant magnet flux linkage. Wound-rotor synchronous motors and induction motors have much wider speed range. An embedded microprocessor governs the overall operation of the VFD controller.[12] Basic programming of the microprocessor is provided as user-inaccessible firmware. User programming of display, variable, and function block parameters is provided to control, protect, and monitor the VFD, motor, and driven equipment. The basic drive controller can be configured to selectively include such optional power components and accessories as follows: Connected upstream of converter -- circuit breaker or fuses, isolation contactor, EMC filter, line reactor, passive filter, Connected to DC link -- braking chopper, braking resistor, Connected downstream of inverter -- output reactor, sine wave filter, dv/dt filter.

5.6 Thermocouple

A thermocouple is a device consisting of two dissimilar conductors or semiconductors that contact each other at one or more points. A thermocouple produces a voltage when the temperature of one of the contact points differs from the temperature of another, in a process known as the thermoelectric effect. Thermocouples are a widely used type of temperature sensor for measurement and control, and can also convert a temperature gradient into electricity. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self-powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (°C) can be difficult to achieve. Any junction of dissimilar metals will produce an electric potential related to temperature.

Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage. Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Where the measurement point is far from the measuring instrument, the intermediate connection can be made by extension wires which are less costly than the materials used to make the sensor. Thermocouples are usually standardized against a reference temperature of 0 degrees Celsius; practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals. [5]

5.7 Ultra slim Photoelectric Sensor

A photoelectric sensor, or photo eye, is a device used to detect the distance, absence, or presence of an object by using a light transmitter, often infrared, and a photoelectric receiver. They are used extensively in industrial manufacturing. There are three different functional types: opposed (through beam), retro-reflective, and proximity-sensing (diffused). A self-contained photoelectric sensor contains the optics, along with the electronics. It requires only a power source. The sensor performs its own modulation, demodulation, amplification, and output switching. Some self-contained sensors provide such options as built-in control timers or counters. Because of technological progress, self-contained photoelectric sensors have become increasingly smaller. Remote photoelectric sensors used for remote sensing contain only the optical components of a sensor. The circuitry for power input, amplification, and output switching are located elsewhere, typically in a control panel. This allows the sensor, itself, to be very small. Also, the controls for the sensor are more accessible, since they may be bigger. When space is restricted or the environment too hostile even for remote sensors, fiber optics may be used. Fiber optics are passive mechanical sensing components. They may be used with either remote or self-contained sensors. They have no electrical circuitry and no moving parts, and can safely pipe light into and out of hostile environments.[4] A proximity-sensing (diffused) arrangement is one in which the transmitted radiation must reflect off the object in order to reach the receiver. In this mode, an object is detected when the receiver sees the transmitted source rather than when it fails to see it. Some photo eyes have two different operational types, light operate and dark operate. Light operate photo eyes become operational when the receiver "receives" the transmitter signal. Dark operate photo eyes become operational when the receiver "does not receive" the transmitter signal. The detecting range of a photoelectric sensor is its "field of view", or the maximum distance from which the sensor can retrieve information, minus the minimum distance.[10]

VI. RESULT AND DISCUSSION

Thus by the proposed system of automation, the process of spool heat sealing has been done in a phase, much faster than the existing system. The result of this unit installed, is observed when the output of the overall production has been increased roughly six times the existing output of the manual system. This is a notable advancement in the production process, hence it is highly welcomeable in the industries and can be replaced for the manual system. This system of automation is highly reliable since it is equipped with a continuous monitoring module of Human machine interface (HMI). Each and every process in the automated sealing unit can be easily controlled by the interface module with a high accuracy. This existing unit of sealing is capable of processing six pieces at a time. Also a study to increase the units processed per cycle, is being done by our team. If the constraints in increasing the number of units is achieved, then the production rate can be increased much more. A further development in this heat sealing unit can be done, with the implementation of a counter, which is to keep an account of the number of units sealed for a particular period of time. A few more input channels unutilized in this project can be used in future for the automation of the electrical equipment associated with the unit. A study to reduce the power utilized by the automated unit is also being done by our team. It is done by the regulation of variable frequency drives, and the associated modules of temperature control. Hence though the existing system of automation unit is designed to meet the increasing demand of electric horns, a little

advancement in this system can also be done in the future to follow the advancement in the automobile industries. A system with increased productivity with much reduced power consumption is the need of the hour in the market of automobiles. Our system of automation will contribute its maximum to the current scenario of increasing demand of electric horns.



Fig.4 Hardware PLC Implementation Panel

Table 1. Comparison of Existing System with Proposed System

PARAMETERS	EXISTING SYSTEM	PROPOSED SYSTEM
No. of shifts	2	2
Working days	25	25
No. of workers	6(units)*3	6(units)*1
No. of pieces/second	1 piece/36 sec	6 pieces/36 sec
Production /shift	2500	3800 (estimated)
Overall production / Year	1,25,000	1,90,000
Manpower utilization/shift	18	6

VII. CONCLUSION

Spool heat sealing automation system, when installed in industry greatly contributes towards the overall production of the firm. Earlier system of manual sealing system which produces an output of one unit per 36 seconds can be replaced by an automation system with an output of 6 units per 36 seconds. Thus it increases the number of finished products that is being produced per day in the industry. This system is far better for its high accuracy since the system is completely automated. Further this system can be enhanced in the future by increasing the number of unit being processed within the given time limit. In the first phase of the project, block diagram and circuit has been designed based on the proposed idea. Hardware installation will be focused on the following phase.

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