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A Microcontroller-Based Automatic Coil Winding Machine for Electric Motor

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Abstract

This research aims to design and manufacture an automatic electric motor coil winding machine based on microcontroller for replacing the manual system. The main reasons are reducing the fault risk that could be made by the operator using manual machine, increasing efficiency of machine as well as productivity of work. Methodology of this research based on experimental research that consist of several stages i.e. planning, design and manufacture, trial and analysis, and finalization. Planning stage involves design draft, working drawing, and also tools and material preparation. Then, design and manufacture stage covers making of mechanic parts, electric and electronic circuit, and design of controller program. The testing was conducted on rolling speed test and accuracy test of coil winder. This machine is driven by stepper motor, using keypad as entry data number of windings, LCD to show the progress of coil winder and opto-coupler as a counter of windings. Data obtained from the test shows that the level of accuracy of rpm control is about 99%, average time to roll up a winding is 0,58 second, speed of coil winder is 1,72 windings/second.

Keywords: *coil winder, automatic system, microcontroller, optocoupler*

1. Background

The speed and accuracy of the work is very necessary in the process of maintenance or maintenance and repair of industrial machines. For example, in the process of repairing an electric motor, it is often necessary to replace the motor coil. This requires winding process of a new electric motor coil. The accuracy of the number of windings of the motor becomes one of the important things in the replacement of this motor coil.

In conventional coil winding, the winding process is done manually by turning the handle as many times as the desired number of windings. Constraints that may occur in this manual winding process include inconsistent work speed, winding continuity that depends on the operator, the results of winding can not be as desired, and require supervision during the winding process. This manual mechanism can be optimized by changing the work system to become automatic. The winding process by turning the handle can be replaced with an electric motor, controlling the speed and the winding result can be controlled through a controlling device such as a microcontroller. The process can take place automatically so that the dependence on the operator to supervise fully can be reduced.

Studies or research on the manufacturing of microcontroller-based coil winder machines have been carried out. Gapita, Hamzah, and Nurhalim (2015) have designed an ATMega8535 microcontroller-based transformer winder. The roller machine is made using an AC motor with a magnetic sensor to detect the number of windings, the microcontroller ATMega8535

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as the main controller, and the keypad and LCD as the interface. Engine accuracy testing gives error results below 5%.

Yandri and Desmiwarman (2016) have also made an email wire rewinding machine for motor coils using an ATMega328 microcontroller as a control unit, the resulting winding machine is driven by a DC motor with speed regulation using a potentiometer, and using a limit switch as a count of rotation. Fast and accurate winding results are obtained in PWM settings below 210.

Ahyar and Irdam (2015) have made a prototype of a coil winding machine which is done with the help of students in the D3 Final Project Maintenance and Machine Repair at Akademi Teknik Soroako. The driving and controlling components contained in this coil winding machine are Arduino Mega 2560 microcontroller, stepper motor, 4x4 keypad, 20X4 LCD, and limit switch. The engine performance test has produced a high accuracy of around 99%. The disadvantage that needs to be optimized on this machine is the slow winding process, which requires 1.9 seconds for every 1 winding, or a rolling speed of about 0.53 windings / second.

2. Method

Research Stages

The research design of this microcontroller-based coil rolling machine uses experimental research methods.

The research method was carried out with the following experimental stages: 1). the planning stage which included the identification of problems, field studies, literature studies, draft preparation and alternative designs; 2). the stage of designing and manufacturing tools which include mechanical and electrical system design drawings, material and parts preparation, manufacturing processes, control program design; 3) the testing and analysis phase which includes hardware testing, software testing, machine testing and analysis. The stages of the design of a microcontroller-based coil winder can be seen in Figure 1.

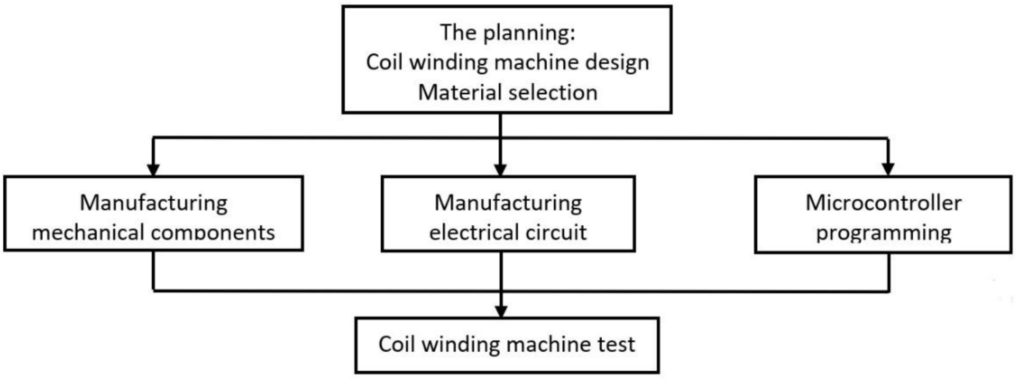

Figure 1. Stages of coil winding machine design

Design Demands

The list of demands will be the basis for consideration in determining the design. Demands are made based on several aspects such as design, cost, time, construction, manufacturing processes, operations, functions, safety factors, maintenance and aesthetics. Table 1 shows the list of demands and demand criteria that became a consideration in the planning and design of electric motor coil winding machine.

Table 1. List of design requirements

No.	Demands	Demand Criteria
1	Design	1. Simple form. 2. The size of the machine is not too big. 3. Easy Mobilization. 4. Spare parts are easily obtained. 5. Material is easy to obtain.
2	Cost and Time	1. Low cost of manufacturing and purchasing. 2. Maintenance costs. 3. Cheap spare parts. 4. Quick design. 5. Short work time.
3	Construction	1. Simple Construction. 2. Components are easily assembled. 3. Solid. 4. Long service life. 5. Ideal weight.
4	Manufacturing Process	1. Easy Machining Process. 2. Easy fabrication process. 3. Uncomplicated manufacturing flow. 4. Easy assembly. 5. Easy part replacement.
5	Operation process	1. Setup is not complicated 2. Easy to operate. 3. Automatic operation. 4. Fast operation. 5. Power supply can use AC and DC currents
6	Function	1. The number of windings is accurate. 2. Coil tight. 3. Tidy coil. 4. Fast rolling. 5. Easy scrolling.
7	Safety factor	1. Does not have sharp parts. 2. Safe electrical circuits. 3. Does not endanger operators and equipment. 4. Do not pollute the environment. 5. Has no combustible material.
8	Maintenance	1. Easy maintenance. 2. Components are easy to remove. 3. Does not require special maintenance technicians. 4. Does not require routine lubrication. 5. Does not complicate maintenance technicians.
9	Aesthetics	1. Neat construction. 2. Neat electrical / electric circuit. 3. Proportional / symmetrical. 4. Clean components. 5. Attractive colors.

Research Design

The machine optimization design is produced after going through the planning and design stages. This stage includes the inspection and analysis of machines that have been made before. The design includes optimizing the design, determining mechanical and electrical components, and changing the control program.

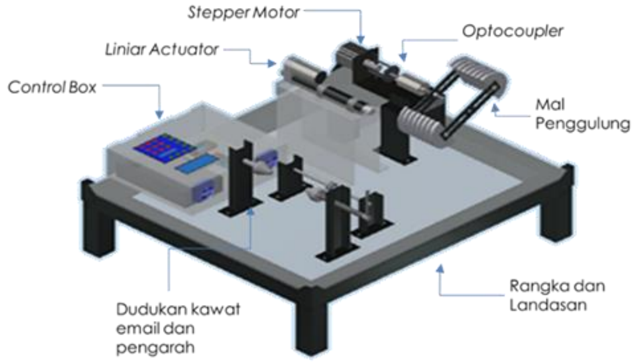

Figure 2. Optimization of coil winding machine design

The planned coil winding machine design includes several aspects, namely:

1. Geometry: the dimensions of the machine made are 800 mm long, 700 mm wide, and 500 mm high.
2. Material: using lightweight and easily formed material, and not easily damaged.
3. Kinematics: rotational motion in the coil winder mall, and translational motion in linear actuators.
4. Force and energy: microcontroller control system with specification of 12 V input voltage, stepper motor and linear actuator with working voltage 5 - 12 V.
5. Signal: using a microcontroller as a process controller, optocoupler as a rotation sensor, and the keypad and LCD as a media interface.
6. Ergonomics: comfortable in operation and easy to move

3. Results & Discussion

Machine Working Mechanism

This research has produced prototypes of microcontroller-based electric motor coil winding machine. The mechanism of action is shown in the control scheme as in Figure 3.

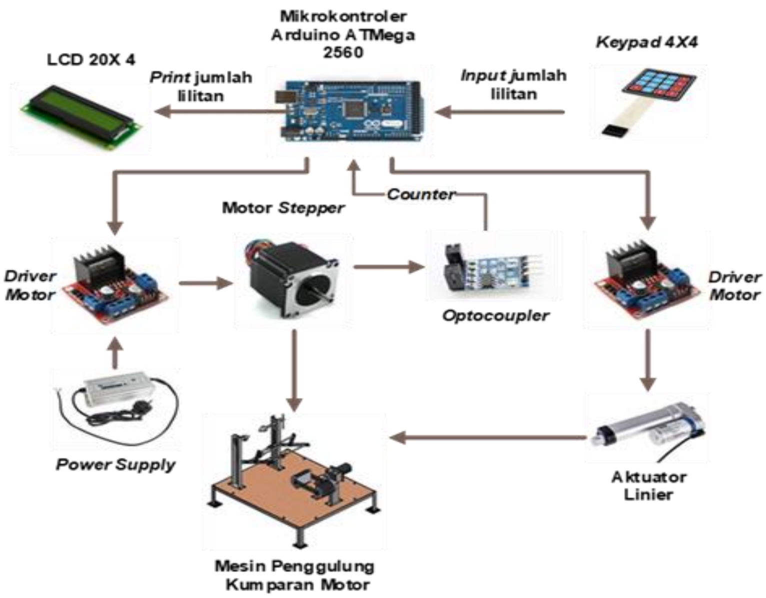

Figure 3. Schematic control of an electric motor coil winder machine

This rolling machine is controlled by input from the keypad and optocoupler which are then processed on the microcontroller, then proceed to the stepper motor driver, linear actuator driver, and LCD. so the stepper motor will rotate according to the input entered on the keypad to be displayed on the LCD. The linear actuator will move back and forth according to the input entered on the keypad. Optocoupler will do the rotation calculation at the rollers mall, so the motor will stop according to the data that has been inputted.

Testing Machine

The testing process is carried out on electrical components such as stepper motors and overall test of coil winder machine performance. This test is carried out to ensure that the components used can function properly, so that the overall testing time can work optimally.

Stepper motor rpm measurement is done to measure motor rotation speed or rpm which is set in the program with the actual rpm. In this measurement, the coil winding mall is removed so that the stepper motor rotates without load. The actual rotational speed of a stepper motor without a load is measured using a tachometer. The measurement results are shown in Table 1.

Table 1. Test results for stepper motor RPM measurements

No	Setting rpm program	Average measurement rpm	Error
1	115	113,9	1,13
2	120	119,3	0,70
3	140	138,8	1,24
4	160	159,1	0,90
5	200	198,7	1,27

From the measurement results obtained data error or the difference between the rpm setting and the actual rpm, and the percentage of accuracy and the percentage of program errors can be calculated. The number of rpm settings is 735 rpm, and the number of errors that occur is 5.24 rpm. The accuracy of the rpm program can be calculated as follows:

Percentage accuracy rpm,

$$= \frac{\sum average\ actual\ rpm}{setting\ rpm} \times 100\%$$

$$= \frac{729{,}8}{735} \times 100\%$$

$$= 99{,}3\%$$

The winding speed test is carried out by winding the 0.8 mm enameled wire coil. The measurement results are shown in Table 2. Measuring the winding time is performed on several variations of the number of windings input 10, 20, 30, 40, and 50 windings.

Table 2. The results of the coil winding speed test

No	Number of windings	Winding time (seconds)
1	10	6,2
2	20	11,5
3	30	17,0
4	40	22,5
5	50	28,9

The test results shown in Table 2 give an average rolling time of 1 winding is 0.56 seconds or a winding speed of about 1.78 windings/sec as shown in the following graph.

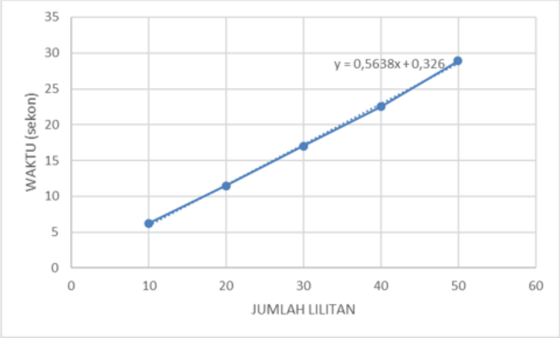

Figure 4. Graph of results of winding speed testing

In terms of winding time, the results of the optimization of the coil rolling machine have been improved from a previously made machine that takes about 1.9 seconds per coil. When compared with conventional coil winding equipment, the winding time obtained is still slower, but the operator can do two jobs simultaneously during the winding process.

4. Conclusion

Based on the design process, testing and analysis of test results it can be concluded that:

1. The automatic motorized coil winder has shown good performance based on tests that have been carried out with an accuracy rate of 99.3% rpm and an average rolling speed of around 1.72 windings per second;
2. The winding time is relatively longer than the manual winding machine but does not have to be continuously monitored during the winding so the operator can do other work simultaneously.

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