Simple Design of Control Motor AC for Rotary Force spinning

R Syam1,*, Kamaruddin1, N Ichzan1, Muhammad MM Munir2,3, Khairurrijal2,3.
1Physics Research Group, Department of Physics, Maros Muslim University, Maros Muslim University, Street Dr. Ratulangi 62, Maros 90511, Indonesia
2Theoretical High Energy Physics and Instrumentation Research Division, Institute of Technology Bandung, Indonesia
3Research Center for Biosciences and Technology, Institute of Technology Bandung

*rahmansyam@umma.ac.id

Abstract. The use of rotary forcespinning in the manufacture of nanofibers should receive special attention because of its ability to produce fibers with high production rates and can be applied to both solution and melt form materials. To produce fiber, this rotary forcespinning technique utilizes centrifugal force emanating from a high-speed, large-torque motor rotation. AC motor is an option in fulfilling the need for fiber manufacturing using this system. The amount of torque and the high maximum rotation speed of the motorbike provides an answer to the needs of the rotary forcespinning system. However, behind the advantages of these motors, controlling the motor rotation speed is a separate problem that needs to be resolved. Therefore the aim of this research is to create a simple system to control AC motors by utilizing a microcontroller system and an AC dimmer circuit that functions to regulate the AC voltage that enters the motor. The results obtained indicate that the simple system design can produce rotation on an AC motor with good linearity, although the error value obtained is still high and needs further refinement.

1. Introduction

Basically, the motor that we use in various electronic devices that use the motor principle is a one-phase motor. The name comes from the fact that this motor works based on the induction of the stator magnetic field to the rotor, where the motor rotor current is not obtained from a specific source, but is the current that is induced as a result of the relative difference between the rotation of the rotor and the resulting rotating magnetic field by the stator current. Induction motor speed control is important to discuss considering the importance of induction motor functions. In [1], the rotor position information can be obtained from the position-dependent voltage phase measurement. This method is advantageous with good characteristics, such as resistance to temperature drift and high velocity for position estimation. Other methods, such as lookup-table based [2], mathematics based models [3], Observer based [4,5], and including externally-circuit based methods [4]. Meanwhile, the method in this research is simple-circuit. Unlike the previous methods which used a rather complicated method for AC motor control, this method is fairly simple in that the information obtained depends on the dimmer circuit used. The dimmer circuit will provide information on the position of the rotor on the rotation counter then the rotation counter will provide feedback back to the dimmer circuit. So that if an error
occurs due to the voltage phase, the dimmer circuit will balance the rotation. Not only that, this model series is more resistant to temperature and humidity.

The disadvantage of the single phase technique lies in the difficulty in controlling the fiber diameter. Meanwhile, meltblowing and biocomponentspinning techniques are limited to a small number of polymers [6]. The high air velocity caused by temperature increases makes the meltblowing technique crucial in fiber formation. This will significantly increase production costs [7]. The manufacture of nanofibers is done by a variety of techniques. One technique that is quite popular is the electric spinner [8]. This technique utilizes the electrostatic force in the electrosprin device to form fibers from a liquid in nano size. The manufacture of materials using the electric spinning technique can produce nanofibers with unique characteristics, but this technique has the limitations of the need for high electric fields for better results, low productivity, and high production costs. A simple electric spinning system, consisting of an atomizer equipped with a hypodermic metal needle to hold the initial solution; a syringe pump as a booster for the solution to get out of the needle by adjusting the flow rate; high voltage source; collectors [9].

Therefore, various efforts and research are continuously carried out to overcome the weaknesses of the electric spinning technique. One alternative to solve problems in the synthesis of nanofiber materials is to use the rotary forcespinning technique. In contrast to electric spinners which utilize electric force, the force spinning technique utilizes centrifugal force [10] which can overcome the disadvantages of electric spinning techniques that can be overcome. In the spinning technique using the rotary forcespinning method, there are several parameters that affect, namely temperature, spinner rotation speed, and collector distance [11].

Rotary forcespinning is a technology tool that uses the motor as the main driving force in forming fiber. Water filter and filter aerosol are the fibers that are applied in filtration technology [12], rotary forcespinning capable of producing fibers with high production rates. This tool has several parts consisting of a high-speed AC motor, a needle, a collector and a heater so that it is able to use quite low energy in its use [13]. To stabilize the rotation speed depends on the shape and construction of the motor and the series of motor rotation speed control system. This study aims to preliminary design a simple control system that we will use for rotary forces spinning with a simple circuit method, namely a microcontroller system and a triac circuit which is incorporated into the dimmer circuit. So that we can adjust the motor speed according to what we want as described above and then tested to produce good fiber.

2. Experimental
The motor control system is one of the main parts of the rotary forcespinning system. The development of a rotary forcespinning tool that has been carried out has a high-speed AC motor specification (maximum speed of up to 25,000 rpm at no load, while when installed the motor speed reservoir becomes 20,000 rpm). The following Figure 1. is an AC motor control circuit.

The block diagram of an AC motor control system in Figure 1 is shown in Figure 2. The system consists of a controller block, rotation counter, dimmer circuit, (triac and digital potentiometer), and AC frequency. As for the overall system for rotary forces pinning is shown in Figure 3. This block system consists of a regulator supply block, AC source, AVR ATMega 328p, AC motor, personal computer, optocoupler, and LCD. In Figure 1, the AC frequency enters the controller then is forwarded to the digital potentiometer which functions to regulate the current and pass the current required by the triac. Triac itself functions to control the current received from the digital potentiometer then connect the system in two directions, namely the positive direction and the negative direction, from the half cycle of alternating current waves. So that the voltage and current output from the triac is smoother. The smoother current is then forwarded to the AC motor, then the motor rotates at the desired speed then the rotation counter calculates the data in serial form which then provides feedback to the controller. But in general the way the overall control system works is designed.
Figure 1. Circuit Schematic

Figure 2. AC Motor Control System as a Whole
Fig 3. Control System

Block 1.
   a. Supply regulator
   The voltage source used in this system comes from PLN 220V and DC 12 V. The main voltage source at this voltage is PLN 220V. While DC 12V is used for AC motor control systems
   b. Microcontroller Unit
   This system uses an Arduino-based microcontroller, the AVR ATmega 328p. This microcontroller functions to regulate the speed of the AC motor
   c. Triac
   The triac here functions to control the AC power load so that the incoming current can be controlled. The Triac connects the system in both positive and negative directions, from a half cycle of alternating current waves. So that the voltage and current output from the triac is smoother
   d. Optocoupler
   The optocoupler functions as a serial data readout of rotation speed on an AC motor.
   e. Comparator
   Compares the input line voltage with a reference voltage.
   f. AC motor
   The AC motor used is a Grass Trimmer type with 350 watts of power.

3. Result and Discussion

The calculation of the motor rotational speed is influenced by a comparator circuit connected to an optical switch mounted on the motor axis as shown in. An optical switch is used to detect the movement of the disc which is mounted on the motor axis. The output from the optical switch will be converted into interrupts with a value of 0 Volts and 5 Volts which are the definition of "high" and "low" of a microcontroller to be able to experience interruptions. However, first we must know how the output characteristics of the optical switch. The reference voltage value given is half of the output voltage of the electric switch when it is open and closed, which is written in equation 1:

\[ V_{\text{eff}} = \frac{V_{\text{max}} + V_{\text{min}}}{2} \]  

(1)
Table 1 represents the data entered using a multimeter at the foot of the optical switch with open and closed. At certain resonance, when the rotor functions in a parallel position it will produce non-identical waves \(^1\). However, in the table below the resulting waves are quite ideal.

| Data | Open Voltage (Volt) | Closed Voltage (Volt) |
|------|-------------------|----------------------|
| 1    | 2.39              | 4.85                 |
| 2    | 2.37              | 4.83                 |
| 3    | 2.35              | 4.79                 |
| 4    | 2.35              | 4.81                 |
| 5    | 2.36              | 4.84                 |
| **Average voltage** | **2.364** | **4.824** |

Thus the value of the reference voltage (Vref) generated is 3.59 V. The value of the voltage is then entered into the comparator. This value is the value that is the reference to be inserted into the inverting leg as illustrated in the figure. by turning the trimpot to get the appropriate tension. Then to get the output signal, an optical switch installed on the motor disc is connected to an oscilloscope. The results of the oscilloscope readings are as in Figure 4 below.

![Figure 4. Optical switch output signal at a given duty cycle of 2.5ms](image)

In this figure, it can be seen that the optical switch output is able to detect when the gap in the disc advances between the slots on the optical switch. After making sure that the optical switch is working properly, the rotation speed data is collected when the motor rotates. The optical switch then gives a signal to the comparator connected to the ATmega 328 minimum system so that the serial monitor on the PC shows the data read as shown in Figure 5.
Figure 5. Graph of stability of rotation speed (rpm)

Figure 5 shows that at speeds of 5,000 rpm, 7,000 rpm, 9,000 rpm, 11,000 rpm, 13,000 rpm and 15,000 rpm, it is still less stable. This is because the single-phase motor has a large slip value so that the speed is difficult to control. At rotational speeds of 5,000, 7,000 and 9,000 rpm the error ranges between 100 and 400 rpm. For a rotational speed of 11,000 rpm the error range that occurs is quite large, namely 100 to 600 rpm. Then at speeds of 13,000 and 15,000 rpm the error range returns to 100 to 400 rpm. From the value of the error range, the speed at 11,000 rpm is quite large. However, the error in a single phase motor is due to the position of the rotor and the quantitative simulation results in several error values\[3\].

4. Conclusions
AC motor control is designed to be good enough to be used for rotary forces pinning with the data obtained as in the discussion above. The results also show that the system used in the AC motor control for rotary forces spinning is quite good. AC motor control was successfully developed but the error value is still high. The error ranges from 200 to 400 rpm. Therefore the motor control system needs to be further developed, namely to reduce the error value in single-phase AC motors.

Acknowledgements
This research was supported financially by the Directorate of Research and Community Service, Ministry of Research, Technology and Higher Education, Republic of Indonesia, under the Hibah Penelitian Dosen Pemula (PDP) for the 2020 fiscal year.

References
[1] K. R. Geldhof, P. Sergent, A. P. M. Van den Bossche, and J. A. Melkebeek, “Analysis of hysteresis in resonance-based position estimation of switched reluctance drives,” IEEE Trans. Magn., vol. 47, no. 5, pp. 1022–1025, May 2011
[2] L. Shen, J. H. Wu, and S. Y. Yang, “Initial position estimation in SRM using bootstrap circuit without predefined inductance parameters,” IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2449–2456, Sep. 2011.
[3] H. Gao, F. R. Salmasi, and M. Ehsani, “Inductance model-based sensorless control of the switched reluctance motor drive at low speed,” IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1568–1573, Nov. 2004
[4] Khalil, A., Underwood, S., Husain, I., Klode, H., Lequesna, B., Gopalakrishnan, S., Omekanda, A. M. “Four quadrant pulse injection and sliding-mode observer-based sensorless operation of a switched reluctance machine over entire speed range including zero speed,” IEEE Trans. Ind. Appl., vol. 43, no. 3, pp. 714–723, May/June 2007.

[5] P. Brandstetter and P. Krna, “Sensorless control of switched reluctance motor using sliding mode observer,” in Proc. Int. Conf. AE, Sep. 10–12, 2013, pp. 1–4.

[6] Nayak, R., Padhye, R., Kyriatzis, I. L., Truong, Y. B., & Arnold, L. Recent Advances in Nanofiber Fabrication Technique. Textile Research Journal, 2011, 82 (2), 129-147.

[7] Schabikowski, M., Tomaszewska, J., Kata, D., & Graule, T. Rotary jet-spinning of hematite fibers. Textile Research Journal, 2015, 85 (3), 316-324.

[8] Zhang, X., & Lu, Y. Centrifugal Spinning: An Alternative Approach to Fabricate Nanofibers at High Speed and Low Cost. Polymer Reviews, 2014, 54, 677-701.

[9] Asy’ari, H., Rakhmadi, A. Pengendalian Kecepatan Putar Motor Induksi Satu Phasa. Teknik Elektro Dan Komputer Emitor. 2004, 4. pp 1

[10] Sarkar K., Gomez C., Zambrano S., Ramirez M., de Hoyos, E., Vasquez H., Lozano K., Mater Today 12, (2010).

[11] Luo, C.J., Stoyanov, S.D., Stride, E., Pelan, E., Edirisinghe, M., Elektrospinning versus fibre production methods: from specifics to technological convergence. Chem. Soc. 2012. 41. 4708-4735

[12] K.M. Yun, A.B. Suryamas, F. Iskandar, L. Baoc, H. Niinuma and K. Okuyama, “Morphology optimization of polymer nanofiber for application in aerosol”, Sep. Purif. Technol. 75 (2010) 340-345.

[13] B. Raghavan, H. Soto, K. Lozano. “Fabrication of melt spun polypropylene nanofiber for forcespinning”. J. Eng. Fibers and Fabrics, 8, (2008) 1