Proceedings of Innovative Research and Industrial Dialogue'18, pp. XXX-XXX (July 2018)

Effect of Driving Signal Waveform to the Motion Characteristics of a Rotary Switched Reluctance Actuator

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Keywords: Rotary angle; switched reluctance; actuator motion characteristic

ABSTRACT – This paper presents the effect of driving signal waveform to the motion characteristics of a rotary switched reluctance actuator (SRA). The motion characterization is conducted on the SRA prototype and the excited current magnitude is fixed at 1A excitation current magnitudes for 6s which includes a 2s delay. Two different driving signals are examine, i.e.: (i) step input signal and; (ii) high frequency pulse signal. The results revealed that the high frequency pulse signal 20Hz, 1:4 duty ratio gave a significantly higher rotary displacement by 72.09^0 compared to the step input signal 65.98^0 by incremental of 10.49%.

1.0 INTRODUCTION

Switched reluctance (SR) actuator is one of the basic types of the stepper motor and it can be categorized as digital actuators, which is a pulse-driven device. Edrington et. al. [1] had proposed a new pattern of the excitation current to maintain the Short Flux Path Excitation (SFPE). In the proposed driver, the current is alternately shifted from positive to negative polarity. The negative polarity were resulted in reversed magnetic flux, thus it may cancel out some of the magnetic flux forms on the second phase excitation. The reason was to avoid heavy saturation conditions which so called as Long Flux Path Excitation (LFPE) that may deteriorate the performance of generated torque. There are various type of driving signals that have been implemented in recent research. Ghazaly et. al. [2] and Nazmin et. al. [3] had shown the effect of different driving signals towards the motion of a multilayer thin electrostatic actuator and a linear switched reluctance motor (LSRM). High frequency pulse signal with different control period of 1:5 duty ratio is presented in the study. The smallest control periods, 0.5ms exhibits significant better response with less than 15nm steady-state error. Through the comparisons, the significant effects are observed although the changes only made at the control period. Therefore, varying control period should be considered in this research to determine the optimize driving signals for wide motion characteristics.

2.0 METHODOLOGY

Figure 1 shows the overview of the experimental setup. It consists of the Host PC, digital signal processing (DSP) system (Micro-box), high current amplifier (PBZ60-6.7) Programmable Bipolar Power Supply, (Kikusui Electronic Corporation) and rotary encoder (Scancon Rotary Incremental Encoder).

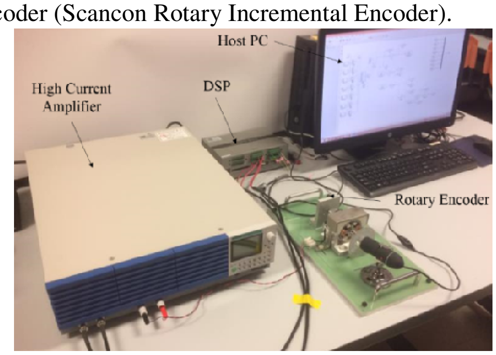


Figure 1 SRA experimental setup for measuring the rotary motion characteristics

The experimentation was carried out by applying an assigned signal to the High Current Amplifier. The connected SR actuator coil winding will be excited and causes motion at the rotor. The attached Incremental Rotary Encoder (IRE) were records the rotary motion and the data of rotary angle and acceleration is obtained. Figure 2 shows the connection diagram of the experimental setup. In addition, the current magnitude is varied from 0 to 2A with the interval of 0.5A for each signal configuration and underwent the 20 repetitions. On each repetition, the rotor was manually adjusted to return at the initial position. The accuracy of initial position were observed through the microscope.

3.0 RESULTS AND DISCUSSION

Two (2) types of driving signal waveforms were evaluated in this research; i.e.: (i) step input signal and; (ii) pulse input signal. All the signals were applied with 1A excitation current magnitudes for 6s including a 2s delay. To evaluate the effects of various input signal to the SR Actuator, the rotor initial position is set to 0°. This initial position is known as a critical self-starting conditions due to its fully unaligned position. For the pulse input signal, the signal were assigned with several different frequency from 1Hz to 20Hz with specific duty ratio as shown in Table 1. Each of the duty ratio determines the pulse on-time period with regards to the frequency. Indeed, increasing the frequency will resulted in reduction of on-time period but it increases the average excitation current.

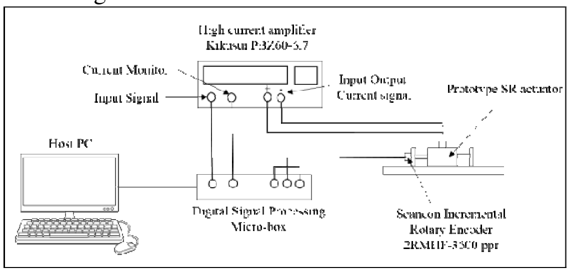
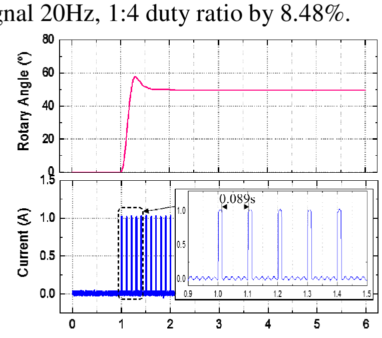


Figure 2 Experimental setup overview

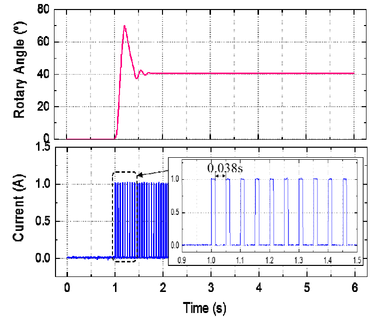
Table 1 High frequency pulse signal parameters

Frequency	On-Time of Duty ratio (s)		
	1:2	1:4	1:8
1	0.5	0.25	0.125
10	0.05	0.025	0.0125
20	0.025	0.0125	0.00625

In this study, the step input signal exhibits high percentage of accumulative magnetic flux. If the applied on-time period is too long, the average current applied will be high which leads to lower rate of demagnetization. As a result, the final rotary angle deviates from the reference position. Therefore, high frequency pulse input signal is opt for the better solution with fast switching between the on/off periods to allow demagnetization. Similar procedure is taken for all respective driving signal types with total of 20 experimental repetition were carried out. The performance of SR actuator is evaluated based on the rotary motion response of each signal configurations. The maximum position driven by the high frequency pulse input signal signals are evaluated further to clarify the optimize signal. Figure 3 presents the rotary motion characteristic of two driving waveform signals at position 0°, respectively. It can be observed that the pulse signal 20Hz, 1:4 duty ratio gave a wider maximum position, 72.09^0 than the pulse signal 10Hz, 1:4 ratio with 53.83^0, respectively. Table 2 tabulates the maximum position response for each driving waveform signals, where the results obtained using step input signal is significantly lower than the high frequency pulse signal 20Hz, 1:4 duty ratio by 8.48%.



(a) Pulse signal 10Hz, 1:4 ratio



(b) Pulse signal 20Hz, 1:4 duty ratio

Figure 3 Experimental work rotary motion responses of different off-time period for configuration.

Table 2 Motion response of different frequency and duty ratio configuration.

Position (°)	Signal	Maximum Position (°)		
		1Hz	10Hz	20 Hz
0	Pulse 1:4	70.16	53.83	72.09
	Pulse 1:8	77.34	16.96	17.18
	Step		65.98	

4.0 CONCLUSION

In conclusion, the rotary motion non-linearity SRA can be improved by exciting suitable driving signal and configurations. In order to decrease the accumulated magnetic flux, high frequency pulse signal 20Hz, 1:4 duty ratio gave the better performance in terms of larger working range, in which will improves the reliability of the SRA in terms of motion characteristics; i.e. precision and accuracy.

ACKNOWLEDGEMENT

This research is supported by Universiti Teknikal Malaysia Melaka grant no. JURNAL/2018/FKE/Q00006, Centre for Robotics and Industrial Automation (CeRIA) and Centre for Research and Innovation Management (CRIM).

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