Performance of Magnetostrictive Amorphous Wire Sensor in Motor Speed Measurement

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Abstract

This paper presents the performance analysis of magnetostrictive amorphous wire in motor speed measurement. The principle of the operation of the sensor is based on Large Barkhausen Jump (LBJ), a unique feature of the wire. A dc motor is used due to the linear relationship between applied voltage and speed. The supply voltage of the dc motor is varied and motor speed measured. The frequency of the signal obtained from the magnetostrictive amorphous wire sensor is measured using an oscilloscope and the motor speed calculated from this frequency. Results obtained from amorphous wire sensor show quite good agreement with that of the digital tachometer.

Keywords: Large Barkhausen Jump (LBJ), Magnetostrictive Amorphous Wire, Speed sensor

Introduction

The use of speed sensors for motor speed control is of great concern in speed control of motors due to its implication on the motor drive size, cost and complexity (M. Boussak and K. Jarry 2006). It is therefore desired that the sensor so chosen will contribute into the reduction of the mentioned motor drive features. Sensorless approach, where speed is estimated rather than measured, has been developed (M. B. Mohamed Jemli and Hechmi Ben Azza 2009). However, this approach has its own shortcomings due to its dependence on the motor model equation which is complex, temperature dependent motor parameters, and introduction of errors due to the estimation process. The search for a speed sensor which will overcome these shortcomings is therefore inevitable. In (P. K. Kihato et.al 2007) and (J. N. Nderu et.al 2009) a motor speed measurement approach, based on the magnetostrictive amorphous wire is presented. Using the amorphous wire, the authors achieved speed measurement of induction motor at the rated motor speed.

1.1 *Operation of the sensor*

The sensor is a magnetostrictive amorphous wire with the composition $(Fe_{50}Co_{50})_{78}Si_9B_{13}$, 7cm in length and 125μm diameter, placed in a pick-up coil. The operation of the sensor is based on Large Barkhausen Jump (J. N.

Nderu et.al 2009). Large Barkhausen Jump is an inherent property of rapidly quenched magnetostrictive amorphous wire. If a pick-up coil is around the wire, sharp voltage pulses will be induced in the coil due to sudden magnetic flux reversal of the amorphous wire. The sudden magnetic flux reversal of the wire is termed Large Barkhausen Jump. Due to LBJ, magnetostrictive amorphous wires generate very sharp and stable voltage spikes in ac fields. This is illustrated in Figure 1.

When a permanent magnet is attached on the rotor and a pick-up coil placed near the rotor with the amorphous wire inside the coil, voltage spikes are induced in the coil as the rotor rotates due to the sudden reversal (change) in magnetic flux in the amorphous wire core. The voltage spikes are induced every time the north pole of the magnet comes close to the wire. The frequency of the induced voltage spikes is equivalent to the number of times the North Pole passes close to the wire per second, hence the rotor speed in revolutions per second. The rotor speed in revolutions per second is converted into revolutions per minute by multiplying by sixty.

1.2 Experimental Procedure

In the present work, a dc motor is used due to the linear relationship that exists between the supply voltage and speed. It is, therefore, easy to vary the speed of the motor by varying the supply voltage. It is connected as a separately excited motor with the field winding fixed at 220 V, while the stator winding is connected to a variable supply and a voltmeter connected across it. A permanent magnet is attached on one end of the rotor, well secured to prevent it from flying away as the rotor rotates. A pick-up coil of 3000 turns, with the amorphous wire placed inside, is then placed about 7 cm from the rotor. The end the coils are connected to a digital oscilloscope. Four experiments were conducted; (i) without any wire in the pick-up coil, (ii) with a copper wire in the pick-up coil, (iii) with the amorphous wire in the pick-up coil and one magnet and (iv) with the amorphous wire in the coil and two magnets. The frequency of the signal from the pick-up coil is measured with the oscilloscope at varying values of the supply voltage. The values of frequency obtained are then used to calculate the speed of the motor. The speed of the motor is also measured with a digital tachometer for comparison purposes. The measured and calculated values of speed are shown in tables 1 and 2.

Results and Discussion

Figures 2 and 3 show the signal waveform without any wire and with the copper wire respectively. The small pulse signals seen can be thought to be noise signals and cannot be used for speed measurement.

Figure 4 shows the signal waveform when using one magnet and the amorphous wire. The waveform is uniform and appears on the negative half cycle and a signal of low amplitude appears on the positive half. This is because the magnet is closer to one side of the wire than the other and therefore effects of magnetic fields are strong on one side and weak on the other.

Figure 5 shows the signal waveform when using two magnets and the amorphous wire. The signal is uniform and appears on both the positive and negative half cycles. This is because the two magnets are connected with the unlike poles facing each other forming one magnet whose magnetic fields are strong enough to be experienced on both sides of the wire, with opposite voltage spikes being induced due to change in direction of the magnetic fields as the rotor rotates with the attached magnets.

Calculation of Speed from amorphous wire pulse voltage

Since frequency is the number of cycles per second, and a voltage spike is induced each time a North Pole comes close to the wire, then the frequency is equivalent to the number of revolutions of the rotor per second i.e. motor speed in revolutions per second. We therefore multiply the frequency by sixty to convert the speed in revolutions per second to revolutions per minute (rpm).

$$\text{Motor speed (rpm)} = \text{frequency (Hz)} \times 60$$

Tables 1 and 2 show the measured and calculated values of the speed for the motor using one magnet and two magnets respectively.

Figures 6 and 7 show the graphical representation of the motor excitation voltage versus speed, with the triangular shaped one being for the digital tachometer while the circular shaped one for the magnetostrictive amorphous wire sensor.

Conclusion

Using the magnetostrictive amorphous wire, we were able to measure the speed of the motor at different values of motor excitation voltage.

The results of the measured speed using the magnetostrictive amorphous wire sensor compare well with those obtained using a digital tachometer.

References

J. N. Nderu, P. K. Kihato, and G. M. Hinga, (2009), “Effect of motor-cage temperature on motor speed sensing characteristic of magnetostrictive amorphous wire,” IEEE Africon

M. B. Mohamed Jemli and Hechmi Ben Azza, (2009.), “Sensorless indirect stator field orientation speed control of single phase induction motor drive,” IEEE Transactions on Power Electronics, 24, 1618–1627.

M. Boussak and K. Jarry, (2006), “High-performance Sensorless Indirect Stator Flux Orientation Control of Induction Motor Drive,” IEEE Transactions on Industrial Electronics, 5, 41–49.

P. K. Kihato, J. N. Nderu, and G. M. Hinga, (2007), “Motor speed measurement using magnetostrictive amorphous wire,” Proceedings of 2007 JKUAT Scientific, Technological and Industrialization Conference, 315–319.

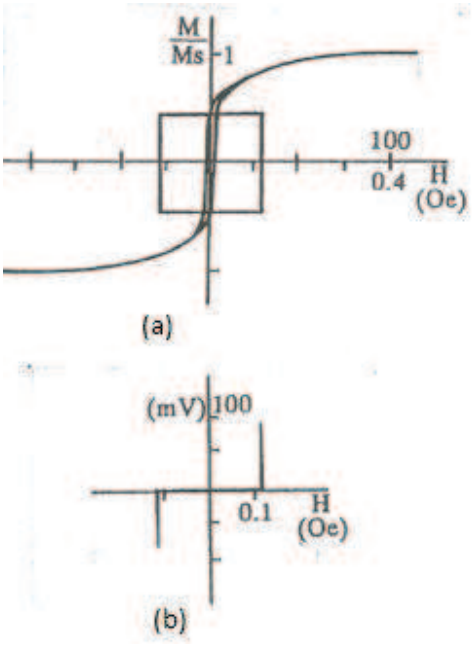


Figure 1: (a) Low and high field M-H loops for $(Fe_{50}Co_{50})_{78}Si_7B_{15}$ wire (b) Voltage pulse induced in a pick-up coil around the wire during LBJ

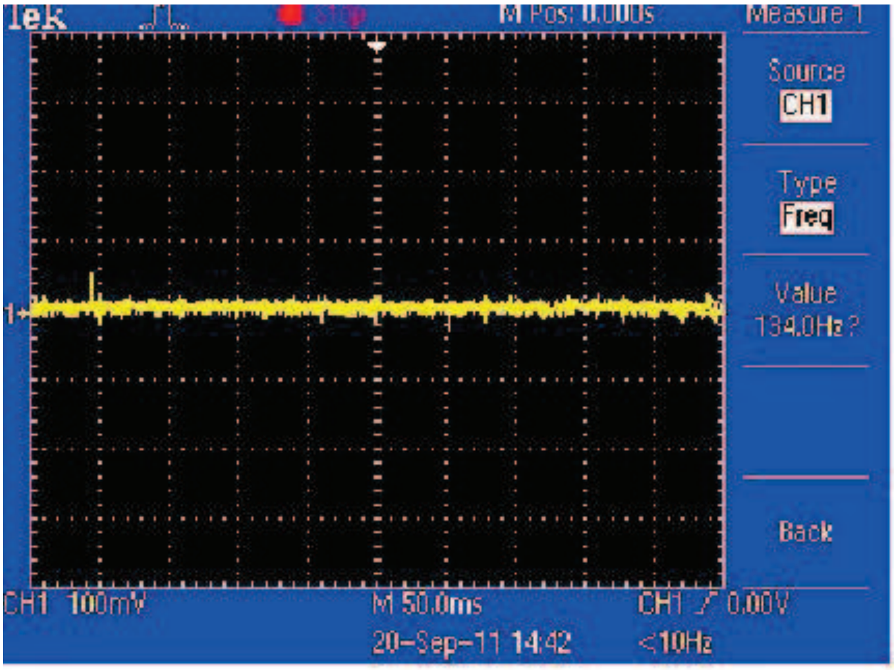


Figure 2: Signal waveform without wire

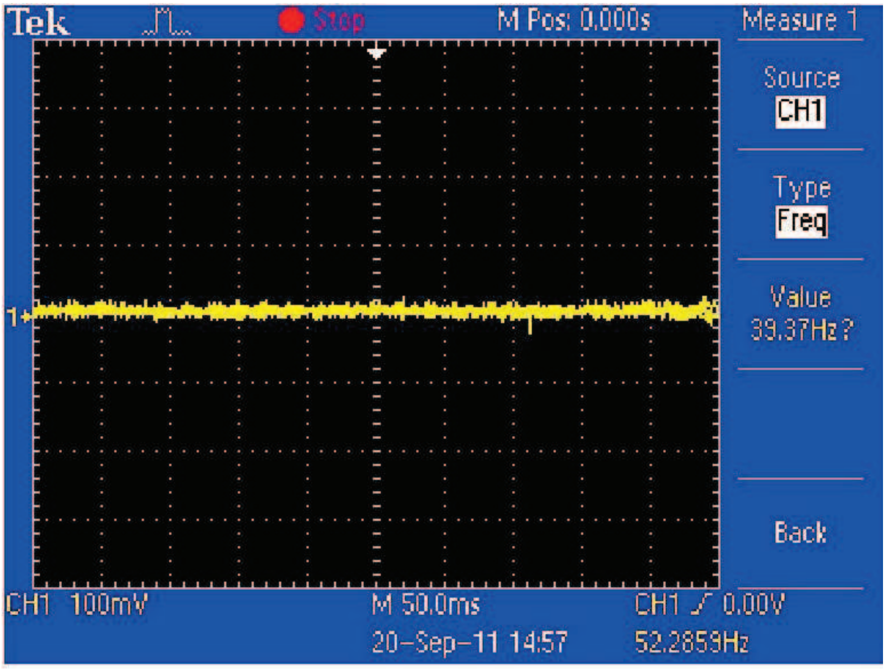


Figure 3: Signal waveform with copper wire

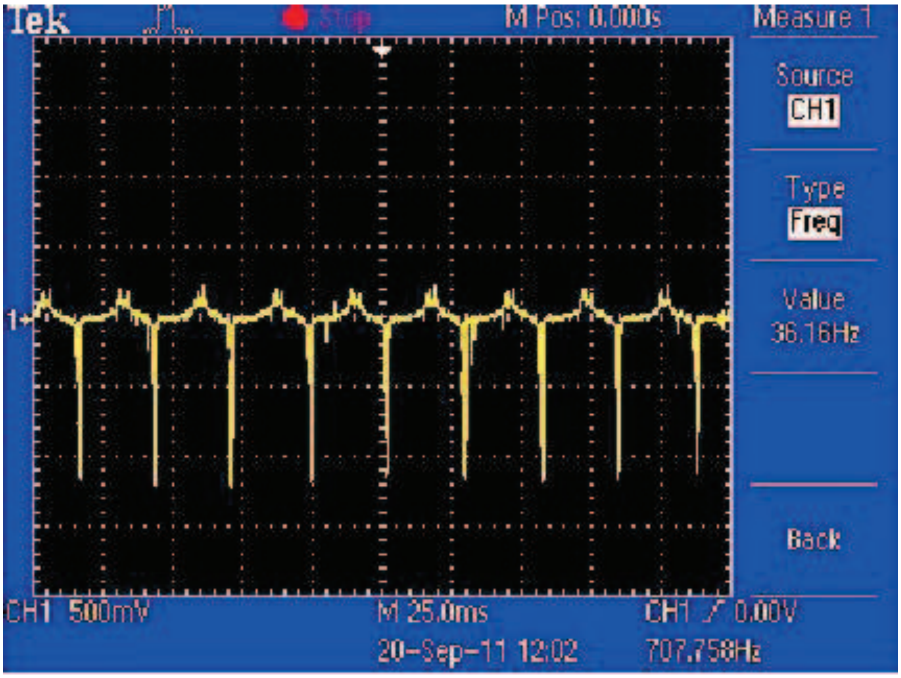


Figure 4: Signal waveform with one magnet amorphous wire

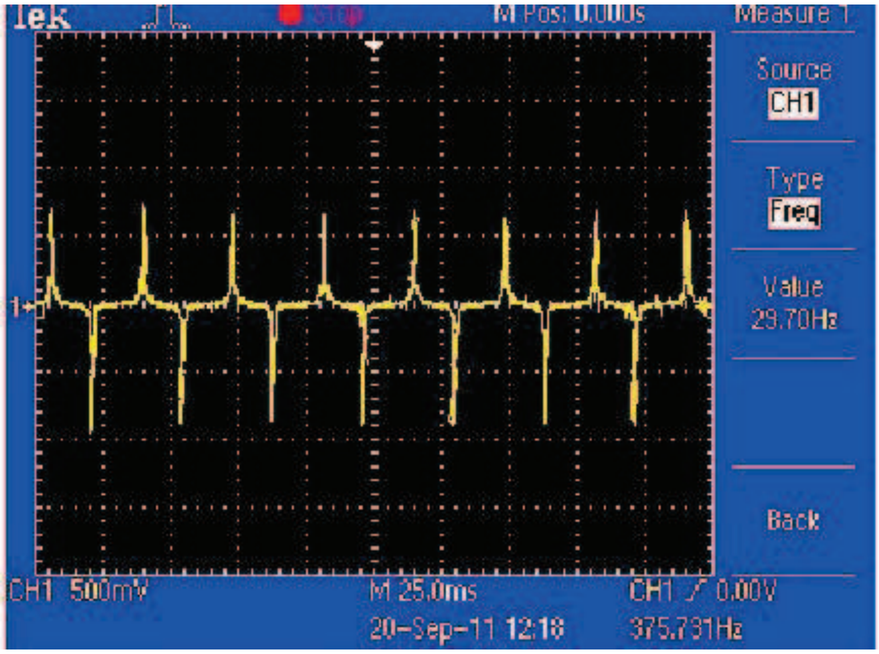
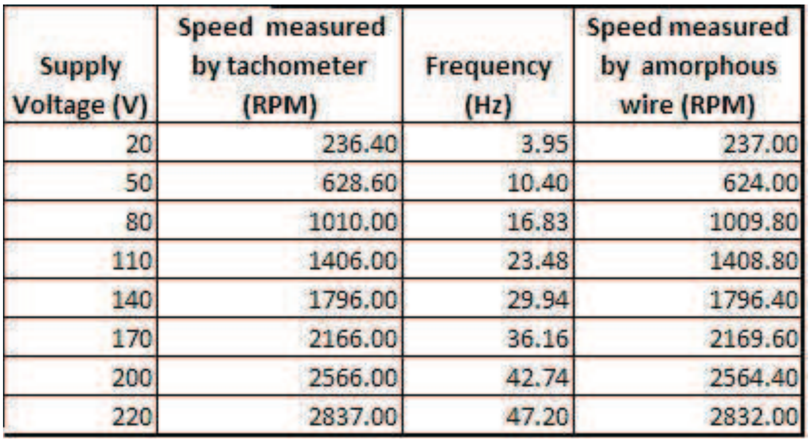
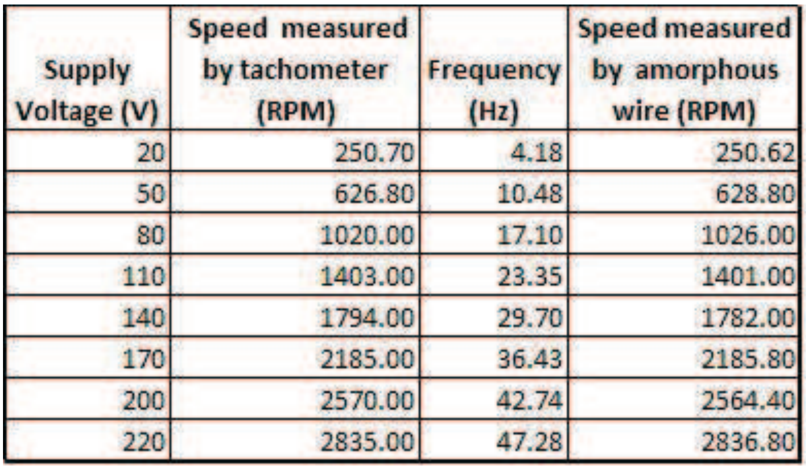


Figure 5: Signal waveform with two magnets amorphous wire



Supply Voltage (V)	Speed measured by tachometer (RPM)	Frequency (Hz)	Speed measured by amorphous wire (RPM)
20	236.40	3.95	237.00
50	628.60	10.40	624.00
80	1010.00	16.83	1009.80
110	1406.00	23.48	1408.80
140	1796.00	29.94	1796.40
170	2166.00	36.16	2169.60
200	2566.00	42.74	2564.40
220	2837.00	47.20	2832.00

Table 1: Results obtained with one magnet and amorphous wire



Supply Voltage (V)	Speed measured by tachometer (RPM)	Frequency (Hz)	Speed measured by amorphous wire (RPM)
20	250.70	4.18	250.62
50	626.80	10.48	628.80
80	1020.00	17.10	1026.00
110	1403.00	23.35	1401.00
140	1794.00	29.70	1782.00
170	2185.00	36.43	2185.80
200	2570.00	42.74	2564.40
220	2835.00	47.28	2836.80

Table 2: Results obtained with two magnets and amorphous wire

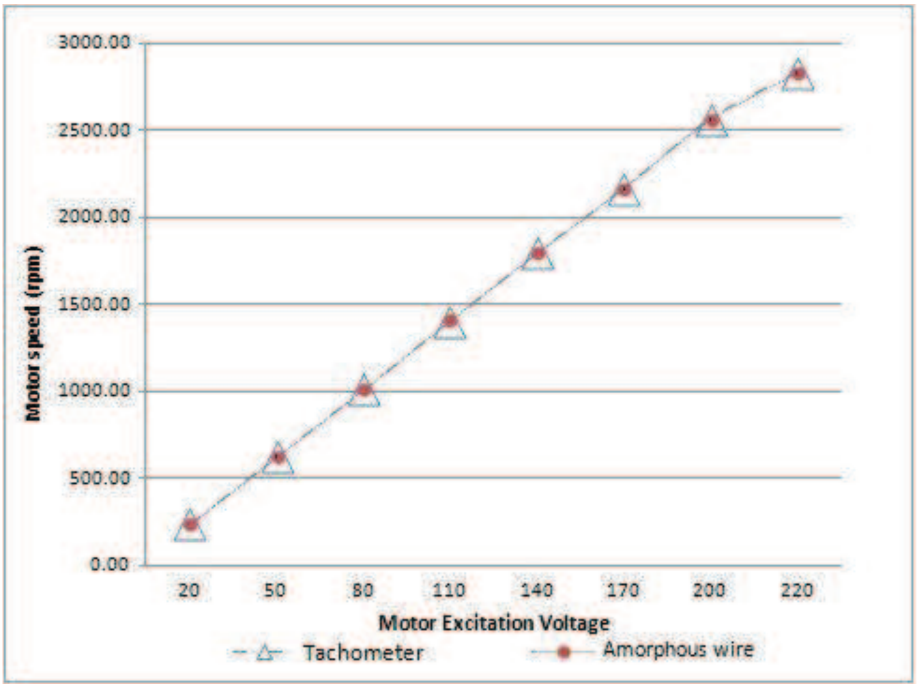


Figure 6: Motor Excitation Voltage versus speed with one magnet and amorphous wire

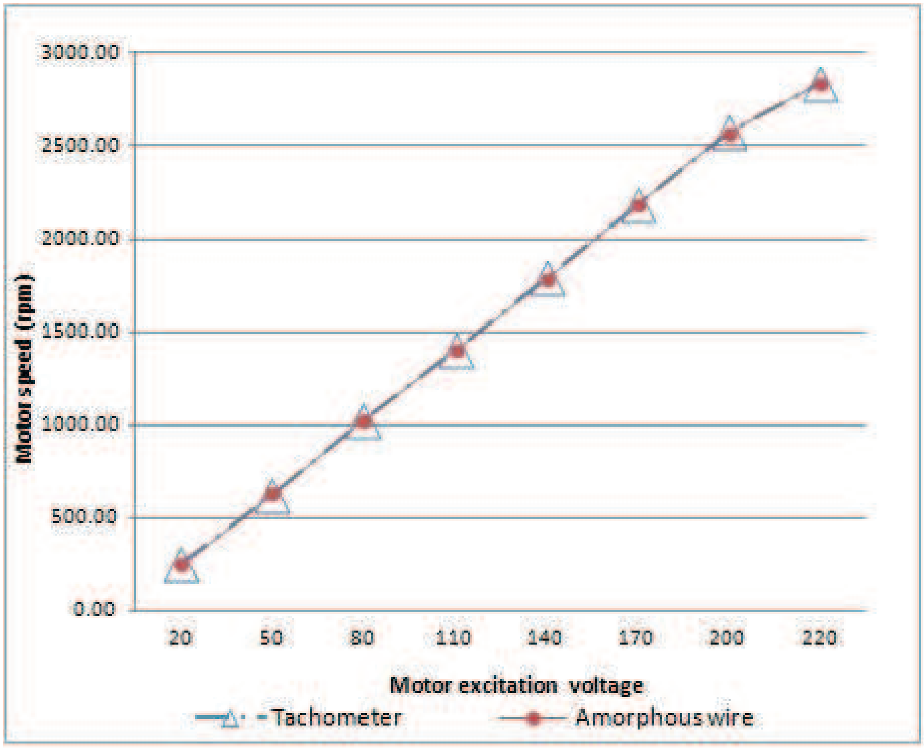


Figure 7: Motor Excitation Voltage versus speed with two magnets and amorphous wire

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