Microcontroller Based Magnetostrictive Amorphous Wire Motor Speed Sensor

J. N. Nderu, A. M. Muhia, P. K. Kihato and C. K. Kitur

***Abstract*—This paper presents a microcontroller based motor speed sensing approach using magnetostrictive amorphous wire. The principle operation of the sensor is based on Large Barkhausen Jump, a unique feature of the wire. The wire generates stable voltage pulses in alternating fields. These pulses correlate well with the rotary speed of the motor hence can be used to measure the speed of the motor. The pulses are signal conditioned and fed into a microcontroller for measurement of frequency. The speed of the motor is calculated from this frequency. A graphic user interface is designed where the frequency and the speed of the motor is observed on a personal computer. The design presents a motor speed sensing mechanism with desirable accuracy.**

***Index Terms*—Large Barkhausen Jump (LBJ), Magnetostrictive Amorphous Wire, Microcontroller, Speed sensor**

I. INTRODUCTION

Our previous research [1] employed Large Barkhausen Jump, a unique feature of magnetostrictive amorphous wire in motor speed sensing. The result of the research was a speed sensor that compares well to conventional speed sensors such as tachometer. In [2], we obtained the critical length and optimal position of the wire relative to the rotor for optimal operation of the sensor. This research extends the same principle of speed sensing and incorporates a microcontroller for fast and efficient frequency reading and display of motor speed. The wire generates stable voltage pulses in alternating fields. These pulses are signal conditioned for interfacing with microcontroller. A graphic user interface is developed in Visual Basic 6.0 where the frequency of the pulses and speed of the motor is displayed.

A. Principle of speed sensing

The sensor is a magnetostrictive amorphous wire with the composition $(Fe_{50}Co_{50})_{78}Si_9B_{13}$, 7cm in length and 125$\mu$m diameter, placed in a pick-up coil. The operation of the sensor is based on Large Barkhausen Jump; sudden magnetic flux reversal [3]. Large Barkhausen Jump is an inherent property of rapidly quenched magnetostrictive amorphous wire. When a permanent magnet is attached on the rotor and a pick-up coil with the magnetostrictive amorphous wire inside is placed near the rotor, as the permanent magnet rotates due to rotation of the rotor, sharp voltage spikes are induced in the coil due to the sudden reversal (change) in magnetic flux in the amorphous wire core. These sharp voltage spikes are induced every time the North pole of the magnet comes close to the wire [4] and [5] . 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.

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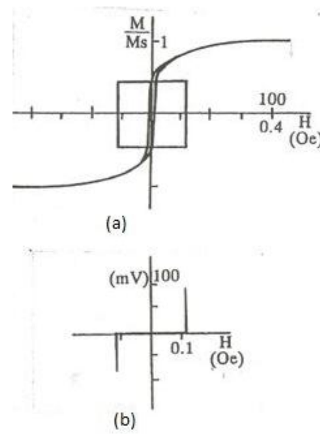

Fig. 1: (a)Low and High field M-H loops for $(Fe_{50}Co_{50})_{78}Si_7B_{15}$ wire (b) Voltage pulse induced in a pick-up coil around the wire during LBJ

B. Experimental Procedure

Two permanent magnets are attached on either sides of the rotor, well secured to prevent them from flying away as the rotor rotates as shown in Fig 2. A pick-up coil of 3000 turns, with the amorphous wire placed inside, is then placed about 7 cm from the rotor. The output from the ends of the pickup coil is fed into the amplifier circuit of Fig 3 for amplification of the signal. The output of the amplifier circuit is fed into the circuit of Fig 4 for conversion into TTL logic. The output from this circuit is fed to a microcontroller so as to read the frequency. Atmega 328 on arduino board is used in this case. The frequency is read into the computer via the USB port. Speed is calculated from this frequency and the results displayed on a graphic user interface developed in Visual Basic 6.0.

(i) Sensor Positioning

Two magnets are used to increase the magnitude of the signal from the pick-up coil. The two magnets are placed with their unlike poles facing and the outcome is a stronger magnetic field formed by the two magnets.

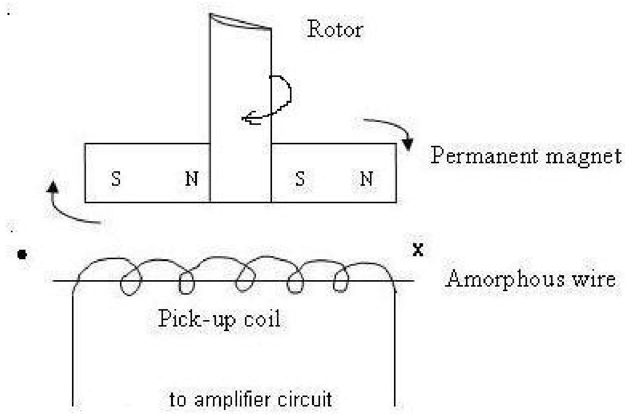

Fig. 2: Illustration of Principle of speed sensing

(ii) Amplifier Circuit

The signal obtained from the pick-up coil is in the order of milli volts (generally between 80mV and 200mV peak voltage)and is first amplified to suitable levels in order to be able to drive logic circuits. A gain of at least 40 is therefore required to ensure the signal is logic HIGH. A two-stage inverting amplifier using the operational amplifier is employed. The first stage amplifies the signal while the second stage has a gain of one and serves to invert the signal back to its initial form.

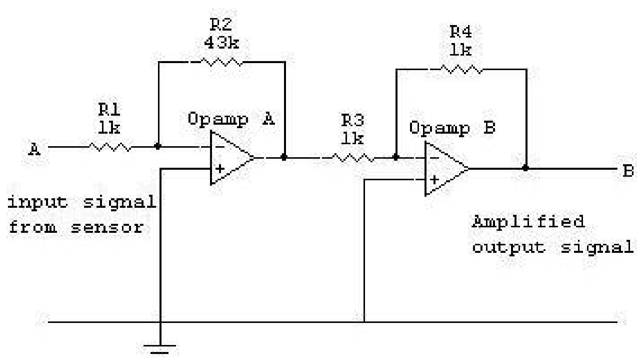

Fig. 3: Amplifier circuit

The gain of the amplifier circuit is given by

$$G = \frac{R_2}{R_1} = 43$$

(iii) TTL Logic Conversion Circuit

The peak voltage of the signal obtained after amplification may be greater than 5V depending on the speed of the motor. This has to be regulated to not more than 5V before feeding to the microcontroller. The circuit of Fig 4 is used to convert the signal to TTL logic levels (0V or 5V). When the input signal is HIGH, the transistor is biased and the input to the NOT gate is almost 0 since most of the drop is across R_6. In this case the output is HIGH. When the input signal is LOW the transistor is not biased and therefore the input to the NOT gate is HIGH since no drop occurs on R_6. In this case the output is LOW.

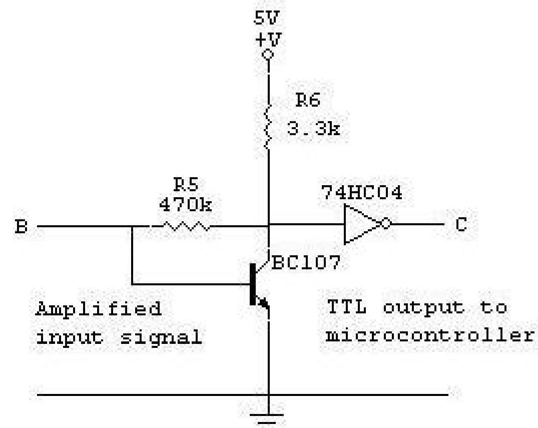

Fig. 4: TTL Logic conversion circuit

II. Results and Discussion

(i) Signal from the pick-up coil

The signal waveform from the ends of the pick-p coil is as shown in Fig 5. The magnitude of the signal is in millivolts (124mV peak or 278 mV peak to peak). The frequency is noted to be 45.38 Hz.

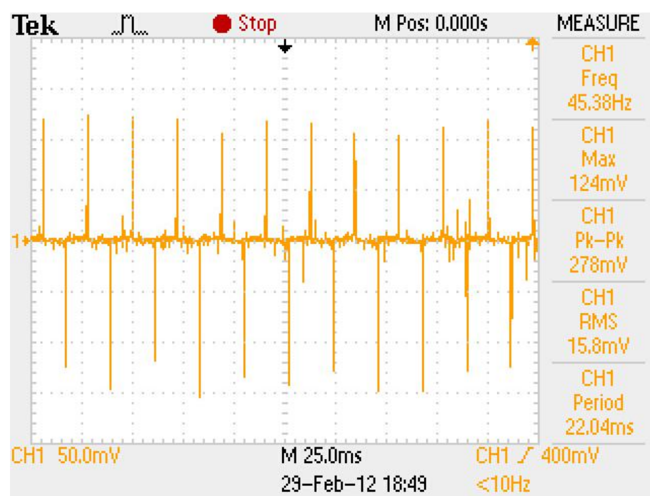

Fig. 5: Signal waveform from the pick-up coil

(ii) Signal from the amplifying circuit

The signal waveform from the amplifying circuit is as shown in Fig 6. The magnitude of the signal is 5.6V peak voltage or 12.5V peak to peak voltage. From this the gain is calculated as

$$G = \frac{12.5}{0.278} \simeq 45$$

This compares well with our theoretical value of 43. The frequency is 45.40 Hz which compares with that of the initial signal at 45.38 Hz.

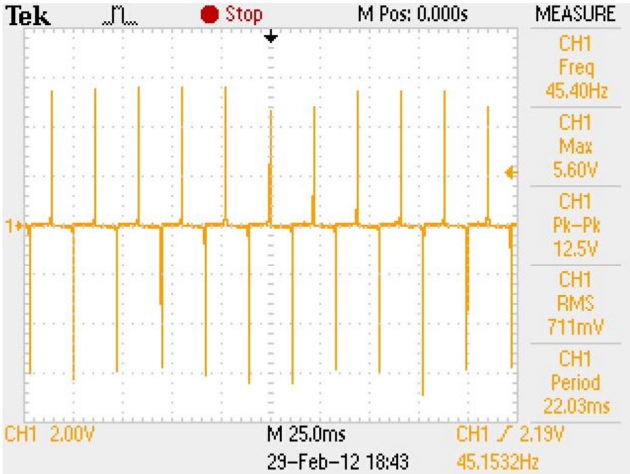

Fig. 6: Amplified signal waveform

(iii) Signal from TTL logic conversion circuit

The signal waveform from the TTL logic conversion circuit is as shown in Fig 7. The signal appears only on the positive cycle and has a magnitude of 5.12V (TTL logic). The frequency is 45.45 Hz which is within the initial range of 45.38 Hz, with a tolerable error.

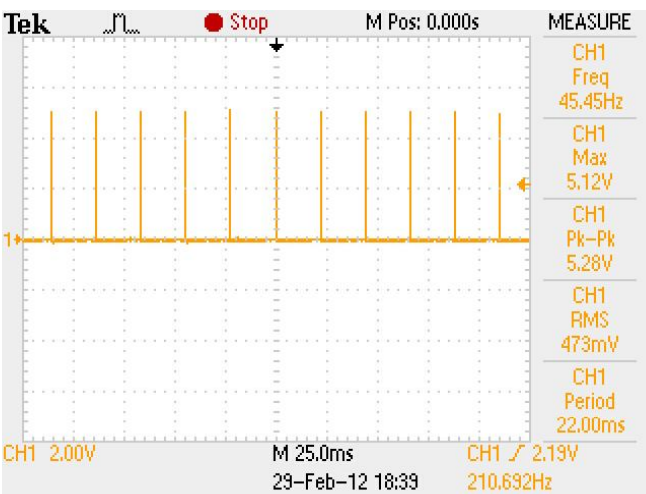

Fig. 7: TTL logic conditioned signal waveform

(iv) Graphic user interface

The frequency and speed of the motor is displayed on the graphic user interface shown in Fig 8. The frequency is 45.39 Hz which compares well with the initial value of 45.38 Hz. The speed is calculated as frequency x 60 giving a value of 2723.4 RPM which again compares well with the measured value of 2722.9 RPM using digital tachometer.

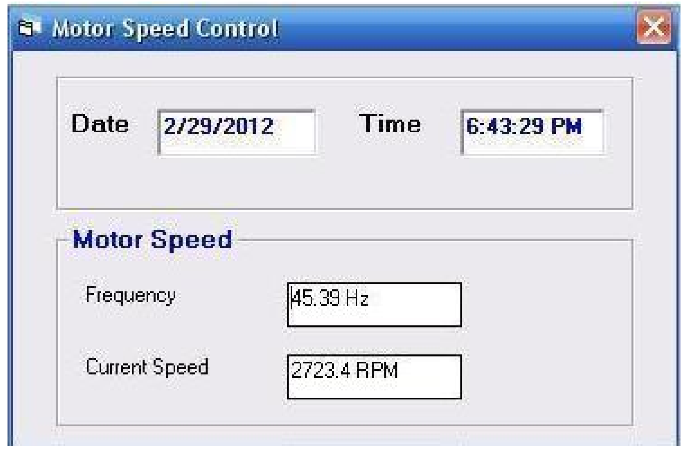

Fig. 8: Graphic user interface

III. Conclusion

1) In this work, we were able to design a motor speed sensor using magnetostrictive amorphous wire and the microcontroller.
2) Using the microcontroller based magnetostrictive amorphous wire sensor, we were able to measure the speed of the motor and display it on the computer.
3) The measured speed using the this sensor compares well with that obtained using digital tachometer.
4) The sensor can be useful in motor speed control

References

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