Automobile Speed Measurement System based on Microcontroller and Magnetostrictive Amorphous Wire Sensor

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Abstract

This paper discusses a vehicle speed measurement and display/recording system using Magnetostrictive amorphous wire as speed sensor. The system basically consists of two parts namely vehicle speed sensor based on amorphous wire and recording/display system based on Atmega 32 microcontroller. The Magnetostrictive Amorphous Wire (MAW) sensor operation is based on Large Barkhausen Jump, a unique feature of the wire. Voltage pulses from the sensor, which correlate well to the vehicle speed are fed to a microcontroller for measurement of frequency. Vehicle speed is calculated from this frequency and displayed via LCD. The data (speed) is stored in a memory for future retrieval. From the tests performed, it is observed that the pulse frequency measured by the sensor can be used to compute the vehicle speed giving results that compare well with the speedometer readings. In addition it is shown that the MAW sensor has several advantages compared to conventional vehicle speed measurement methods.

Keywords: Microcontroller, Magnetostrictive Amorphous Wire, LCD (Liquid Crystal Display), Vehicle speed recording.

1. INTRODUCTION

Sensors comprise an essential part of automotive electronic control systems (William J. Fleming, 2001). Traditionally, rotational motion sensors comprise most of the vehicle speed measurement sensors. Such sensors include the variable reluctance, Hall effect, and magnetoresistor among others. The output voltage amplitude of most of these sensors is totally dependent on excitation field strength and its orientation, i.e the voltage amplitude depends on the rotational speed of the vehicle shaft. Moreover the voltage signals generated by these sensors are normally of low magnitude and hence affected by noise. This paper discusses the use of magnetostrictive amorphous wire (MAW) in vehicle speed measurement. Microcontroller is employed to enhance the processing of the sensor output and enable speed display via Liquid Crystal Display (LCD). Magnetostrictive amorphous wires possess unique soft magnetic properties that enable them to be used for a large number of technological applications (M. Vazquez et al 1997). The operating
principle of MAW sensor offers several advantages compared with Hall Effect sensors or inductive sensors such as low speed measurements and superior signal to noise ratio. Magnetostrictive amorphous wires also have a high -level voltage- pulse signal at low rotational speeds. Moreover the signal level does not depend on the wheel speed which is among the important aspect in low speed measurements. Vehicle speed recording is also an important aspect in the field of automobiles often referred to as Event Data Recorders (EDR). Some of the benefits for vehicle speed recording include helping the driver and fleet owners to monitor vehicle and driver performance to ensure safety and efficient movement of people and freight. The data recorded can also be of help for monitoring driver behavior and other research related fields.

1.1 Sensor structure and basic operating principle
The proposed sensor is a magnetostrictive amorphous wire with composition \( \text{Fe}_{50}\text{Co}_{50}\text{Si}_{9}\text{B}_{13} \), 7cm long and 125µm diameter. The wire is placed in a pick-up coil (A. M. Muhia et al 2011). The preparation of MAW sensor is discussed in [C. K. Kitur et al, 2012]). Operation of the sensor is based on Large Barkhausen Jump (LBJ), an effect which is a discussed in (A. M. Muhia et al 2011).

1.2 Speed measuring principle
Vehicle speed information is obtained from a rotational motion sensor. The rotational frequency of the shaft is directly proportional to the vehicle speed and thus with the wheels specification it is used to compute vehicle’s speed in Km/h. The vehicle uses 15 inch wheels and 195/65 tyres. The wheel diameter \( D \) is determined using equation (1).

\[
D = (R \times 25.4) + \left( \frac{A}{100} \times W \times 2 \right)
\]  

(1)

Where

\( D \) - Wheel diameter; \( R \) - Rim diameter; \( A \) - Ratio of the height of the tires cross-section to its width;  
\( W \) - Tyre width

With the frequency obtained from the MAW speed sensor, the vehicle speed \( V \) is thus computed using equation (2)

\[
V = 3.6\pi D f
\]

(2)

Where

\( V \) - Vehicle speed in Kilometers per hour; \( D \) - Wheel diameter; \( f \) - Rotational frequency in Hertz (Hz)

2. EXPERIMENTAL SET UP
The rotational speed measurement was carried out on a vehicle rotating shaft. Two permanent magnets were attached on the rotating shaft with the unlike poles facing each other as shown in Figure 1. The permanent magnets rotate at the speed of the vehicle’s rotational shaft. With the magnetostrictive amorphous wire placed inside a pick-up coil of 3000 turns, it was placed 4.5 cm from the rotating shaft. Ends of the coil were connected to a digital oscilloscope for frequency measurement of the output pulses. The output of the sensor is a series of voltage pulses whose frequencies are correlative with the vehicle’s speed. The voltage pulses are induced in the MAW wire each time a magnetic pole comes close to the wire. As the vehicle speed increases, the rotation speed of the shaft increases and consequently the measured pulse frequency increases. The frequency obtained is directly proportional to the vehicle’s speed and hence is used for vehicle speed
calculation. Frequency measurements were taken in two scenarios, first with one wheel stationary and secondly with both wheels spinning freely. The speed indicated by the speedometer is tabulated hereafter for comparison purposes.

Figure 1: Sensor arrangement

The output signal from the sensor is fed in to a signal conditioning circuit as shown in Figure 2 for amplification of the signal before being input to a microcontroller for frequency reading.

Figure 2: Signal amplification circuit

Microcontroller is used in this case for speed calculation while display of speed is done via liquid crystal display. The speed is directly stored in the microcontroller’s EEPROM, where it is possible to retrieve the information for any subsequent use.

3. RESULTS AND DISCUSSION

The results of experiment using amorphous wire sensor and digital oscilloscope to read the frequency are as follows. In both cases, frequency is observed between vehicle speeds of 20 Km/h and 80 Km/h. In the first case with one of the vehicle wheels stationary, the frequency ranges from 6.45Hz in Figure 3(a) to 23.24Hz as shown in Figure 3(b). In the second scenario with both wheels spinning freely, Figures 4(a) and 4(b) show the frequency ranging from 3.14Hz to 11.73Hz. The increase in frequency in both cases is due to the increase in vehicle speed, which results in the shaft rotating at a higher frequency. The frequency is directly proportional to the speed as evident from the graph of speed versus frequency as shown in Figures 5 and 6.
The signal obtained in figure 3(a), 3(b), 4(a) and 4(b) show that magnetostrictive amorphous wire is not affected by mechanical vibrations as the signal obtained is very distinct and stable. Compared to other sensors commonly used, the magnitude of the signal obtained is quite high (in order of millivolts) and requires little amplification. The signal obtained is also in form of pulses as opposed to other sensor methods which generate a continuous signal, hence the advantage of interfacing with microcontrollers in the case of magnetostrictive amorphous wire.
Table 1 shows the results obtained using the magnetostRICTive amorphous wire and the vehicle’s speedometer values for comparison. Using equation (1), (2) and the frequency measured by the sensor, the vehicle speed is calculated and tabulated in kilometres per hour as shown in Table 1. The frequency measured by the MAW sensor increases as the vehicle speed is increased. This is because at high speeds the vehicle shaft rotates faster and hence the linear increment in speed. The frequency increase is observed in both scenarios of the experiment. As seen from Table 1, if one wheel is held stationary, the counterpart wheel turns at twice the normal speed or the speedometer indicated speed. This is attributed to the automobile differential locking system.
Table 1: Speedometer reading versus calculated speed

<table>
<thead>
<tr>
<th>Speedometer Reading (Km/h)</th>
<th>Both wheels spinning freely</th>
<th>One wheel held stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (Hz)</td>
<td>Calculated Speed (Km/h)</td>
</tr>
<tr>
<td>20</td>
<td>3.15</td>
<td>21.4</td>
</tr>
<tr>
<td>30</td>
<td>4.12</td>
<td>27.9</td>
</tr>
<tr>
<td>40</td>
<td>5.74</td>
<td>38.9</td>
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<tr>
<td>50</td>
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<td>70.4</td>
</tr>
<tr>
<td>80</td>
<td>11.73</td>
<td>79.6</td>
</tr>
</tbody>
</table>

Figure 5: Speed versus frequency (one wheel stationary)

Figure 6: Speed versus frequency (both wheels spinning freely)

Figure 5 shows the variation of speed as frequency increases. It is observed that the speed is twice the recorded speedometer reading when one wheel is held stationary. This is attributed to non-locked
automotive differential system which transfers all power to the rotating wheel. Figure 6 shows that the speed calculated using the measured frequency compares well with the speedometer speed. In both Figure 5 and 6, the frequency is seen to increase linearly with the increase in vehicle speed. As the vehicle speed increases, the shaft rotates faster hence the increase in frequency. The signal obtained using the MAW sensor is in form of pulses and hence would give advantage when interfacing with the microcontroller. The pulses are fed into the microcontroller using the interrupt function and speed calculated from the pulse frequency. A snapshot of the LCD display is shown in Figure 7. The Microcontroller’s EEPROM memory stores the displayed speed and frequency values. The stored data can be retrieved later via the USB port.

![Image of LCD display showing speed and frequency readings](image1.png)

**Figure 7: Snapshot of speed display (LCD) using ATMEGA 32 microcontroller.**

4. Conclusions

- In this work it has been shown that magnetostrictive amorphous wire can be used to accurately measure the speed of a motor vehicle.

- Based on the sensor signal obtained, it is deduced that amorphous wire possesses several advantages as compared to other methods of vehicle speed measurement. Such advantages include non-contact, high signal to noise ratio, small size, excellent digital output signal properties and insensitivity to mechanical vibrations.

- It was observed that with only one drive wheel spinning freely, the speed measured is twice the actual speedometer reading which was attributed to the differential lock system. When the two wheels were freely spinning, the measured speed compared well with the actual speedometer reading.

- With MAW sensor, interfacing with microcontrollers is possible, hence, speed measurement may be displayed via LCD and the measured speed can be stored in memory for future use.
REFERENCES

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