Remote measurement of speed using fiber optic technique

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A simple non-contact type technique is presented for the remote as well as precise and accurate measurement of speed in the presence of axial and radial motions of the rotating members. Fiber optic system, based on intensity modulation is designed in such a way that radial and axial motions do not hamper the accuracy as well as the precision of measurement, with the passage of time. LED with stable light output is used to transmit light through optical fiber and reflected light from a properly designed reflecting plate, attached with the axle of the motor, is transmitted to a distant place (20m)through optical fiber to the optical detector. The output of the detector is used, through electronic circuits and microcontroller, to display the speed with high degree of accuracy and precision. It is used for the remote measurement of speed with a precision of 1/90 of a revolution.

1. Introduction

Measurement of speed plays a very important role in mechatronic systems. Optical, magnetic, capacitive techniques have been used for this purpose [1, 2, 3, 4]. Due to the wear and tear of bearings, in most of the cases, radial and axial movements creep in, with the passage of time, and errors are introduced in the measurement of speed. With radial or axial motion capacitive, magnetic, inductive and optical methods give error due to the absence of systematic variation of the quantities like capacitance, flux and light and hence can be used with stable moving systems only. For remote measurement of speed, conventional methods, fail to fulfill the requirements with complete satisfaction. Similarly, at very high speeds, most of the methods have problems due to the time constants of the devices and optical techniques are found to work satisfactorily [1]. Similarly, at very low speeds, measurements become difficult due to low frequency and low output voltage by the capacitive and tachometer method [2]. On the other, fractional horse power motors can not tolerate the loading of the magnetic sensors. Microcontrollers have been used to develop smart sensors [5, 6].

Optical fiber which was initially developed to transmit signals from one place to another is now used as highly successful sensing device and a number of extraordinary applications have been developed, with special features, which were not possible by any another sensor[7]. In this paper, a low cost highly accurate technique has been presented which employs a fiber optic sensor based on intensity modulation together with microcontroller to measure as well as provide some intelligence in it. It neither has the problems related with mechanical or electrical loading nor high speed problems. Although

fabrication requires initial precautions to achieve good sensitivity, overall cost and size of the system is very reasonable. Complete set up is shown in Fig.1. With proper design of electronic circuits; well shaped pulses will be obtained from the sensor which can be easily interfaced with the microcontroller for measurement and control purposes.

2. Methodology

The modified version of the Fotonic sensor [1, 8] has been used to generate pulses whose frequency is directly proportional to the speed of the motor. Instead of a reflecting plate, a plate with reflecting and non-reflecting patches (white and black) on its periphery is used. In front of the plate is placed a stationary probe which contains only two optical fibers(multimode plastic fiber), one of them carries the light up to the plate and other collects the reflected light from the reflecting portions and transmits it to the remote receiver as shown in figure 1(a). The changes in intensity of light due to the nature of the surface are shown in figure 1(b). Due to this variation of intensity of light the output of the receiver will have pulses proportional to the number of the reflecting and non-reflecting portions. A well designed analog comparator converts them in to sharp pulses which are fed to the micro controller which measures the frequency and displays the speed on the hyper terminal. Complete schematic diagram of the system is shown in figure 1 and reflecting plate is shown in Fig. 2.
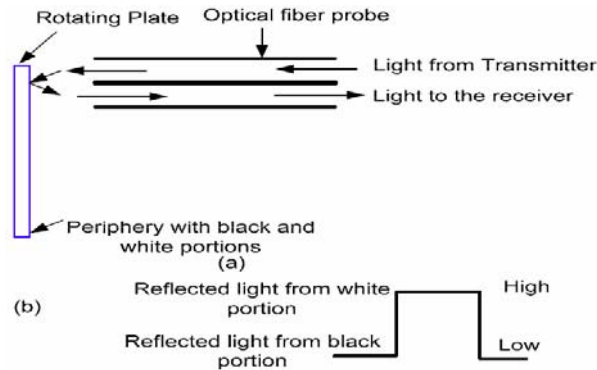
Fig.1. (a) Process of light intensity modulation (b) Pulse of light intensity generated (ideal)

2.1 Design of Reflecting Plate

Side view of the plate is shown in Fig. 2. Depending upon the requirements, reflecting patches may be made on the surface of the plate as far as possible near the diameter of the plate or on the thickness of the plate. If there are chances of axial motion in future then reflecting and nonreflecting portions will be made on the thickness of the plate. If radial motion is more prominent then reflecting portions will be made on the flat surface of the plate and radial width of the reflecting surface will be made more than the radial motion. This construction may take care of axial as well as radial motions. The plate, with reflecting and non reflecting segments is shown in figure 2. The distance between the plate and probe may vary and will change the height of the generated pulse and it will be taken care off by the analog comparator.
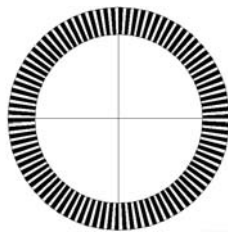

Fig. 2. Reflecting plate attached with the motor shaft.

2.2 Description of the Hardware and software of the scheme

The electronic circuit of the proposed system is composed of the following components:

a) Transmitter composed of LED with constant supply of DC voltage.

b) Receiver circuit composed of photo diode as detector, current to voltage converter, amplifier and comparator.

c) Microcontroller based speed and acceleration / retardation display system.

The microcontroller is programmed to measure the speed as well as to determine the acceleration in the speed which is an important parameter with respect to automobile industry. All programming is done with the help of PIC Basic Pro and the flow chart shown in figure 3, is drawn for the measurement of speed only. Axial and radial motions of the motor can be taken care off by proper design of the reflecting plate as discussed in the above section.
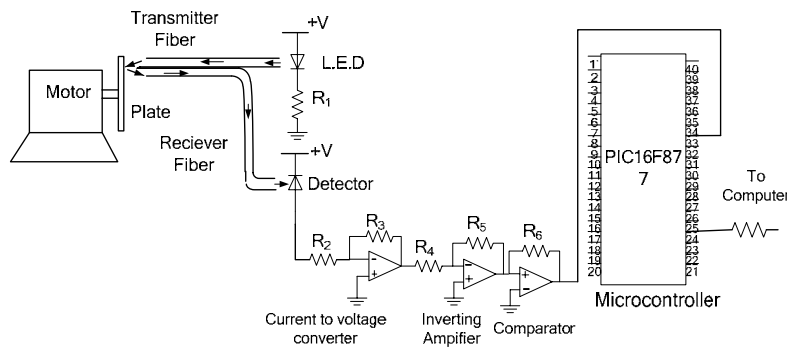

Fig. 3. Schematic circuit diagram of the Speed measuring system.

2.3 Experimental Methods and Results

Initially, the LED source is switched on and output of the transmitter is seen on the screen of CRO with motor running at slow speed. If well spaced pulses are seen on the screen then system is working satisfactorily otherwise we have to vary the gain of the amplifiers/adjust the distance between the plate surface and fiber probe. After checking the magnitude of the pulses, the out put is interfaced with the microcontroller port. The program of the microcontroller is written in PicBasic Pro language.

* To count the number of pulses passed at input port of the microcontroller (PORTB.1), command COUNT is used. This command will count number of LOW to HIGH transitions in the pulses applied at the input port. The counting will be repeated for every period as stated in the command (it is 500ms). The result of counting will be then saved as a variable that should be defined earlier (it is variable w_1).
* Calculation of speed in RPM:
–   Numbers of transition sensed by the microcontroller are w_1.
–   The plate attached to motor shaft has 90 pairs of silver and black stripes. This will produces 90 LOW to HIGH transitions in the output pulses of the receiver in one revolution. Hence the revolutions made by motor shaft are

$$revolutions = \frac{w_1}{90} \qquad (1)$$

–   We are counting the number of transitions at input port at the interval of 0.5s. So
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$$Speed = \frac{revolutions}{0.5} \, rps \qquad (2)$$

$$Speed = \frac{2w_1}{90} \, rps \qquad (3)$$

* The calculated value of speed is stored in a variable named *speed.* The value of *speed* is then displayed in Hyper Terminal program through serial port.
* Since the value of *speed* can be 1 or 2 digits, so some algorithm should be there in order to display the number properly.
* To do so, the number is checked first. If it is <10 (which means only 1 digit), then 1 'space' will be displayed first followed by the *speed* value. Then 2 'backspace' is displayed to force the cursor back to initial position (so the displayed number will remain in the same location each time it is updated).
* In the case of *speed* with 2 digits, above action is not needed.
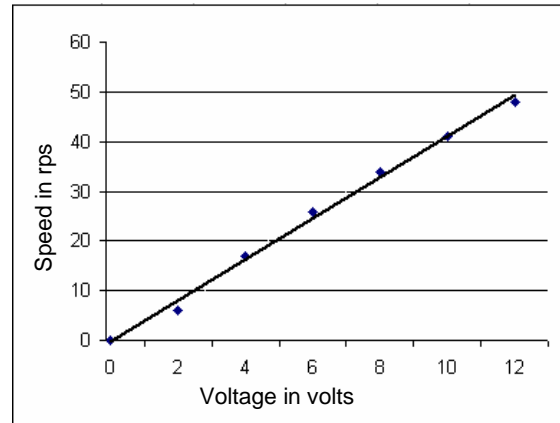

Fig. 4. Display of Hyper Terminal at computer screen.

After displaying the value, the program will loop back to count number of pulses at input port again. And this will continue as long as the microcontroller is ON. To shows the results on PC, serial port communication is used. The serial connection is done through the PORTC.6 of the microcontroller. This port has the serial transmit function as stated in the datasheet. A 1000ohm resistor is connected in series for protection purpose.

To test the working of the sensor, a dc motor is selected and its speed is varied by varying the applied voltage. It is varied in steps of two volts and corresponding speed, with voltage is drawn in the hyper terminal as shown in Fig. 4.

3. Conclusions

A low cost, simple non-contact type scheme which can also be used for remote measurement of speed is described in this paper. The light intensity modulation technique is successfully developed for the measurement of high speeds with good order of accuracy. Errors due to radial and axial motions are taken care of by the design of reflecting plate attached on the axis of the motor. Out put of the sensor is successfully interfaced with the microcontroller to measure as well display the speed with high order of precision. A number of features can be added in the measurement by further programming of the microcontroller i.e., measurement of acceleration/retardation, warnings under the condition of over speeding of the device under control etc. To increase the precision as well as the distance of transmission, glass fiber may be employed.

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