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Design and Construction of a Digital Anemometer

Niaz Ahmad[1], Hari Krishna Kumar Sah[1], Md. Saddam Hossain[1], Mohammad Ariful Islam[2]
[1] Undergraduate Student, Department of Mechanical Engineering,
Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH
[2] Professor, Department of Mechanical Engineering,
Khulna University of Engineering & Technology, Khulna-9203, BANGLADESH

ABSTRACT

Anemometer is a measuring device used for measuring wind speed. Since the beginning of its invention, it has been modified several times. Many types of new generation of Anemometers are available nowadays. But these anemometers complicated and very high in price. Our objective was to develop an anemometer of simple design and construction with ease of use. In this paper, design, construction and testing of a three cup anemometer has been described. A three cup anemometer was designed as three cup anemometers are simpler and yet has less errors. Microcontroller was used to make it digitalized. It was tasted with a standard anemometer to perform necessary calibration. After calibration, it was tested again on various wind speeds and the errors were found to be 3.04% and the minimum air that it can measure is 3km/hour.

Keywords: Wind Speed, Anemometer, Digital anemometer, microcontroller, cup anemometer.

1. Introduction

An anemometer is a device used for measuring wind speed, and is a common weather station instrument. The term is derived from the Greek word ''*anemos"*, meaning wind, and is used to describe any airspeed measurement instrument used in meteorology or aerodynamics. It was first invented by Leon Battista Alberti around 1450 [1]. Anemometers are commonly used in weather recording and forecasting. It is also used in mines, tunnels and ventilation systems; in aircraft testing and other experimental work; and in aerial navigation. Sailors also use the anemometer as wind speed is a great factor on sea. Different kinds of anemometers are present now. But among all those types of anemometer, it is best to use a three cup anemometer as it has less error than a four cup anemometer, it does need to face the wind and no need to give any additional effort or parts to make sure that it faces the wind continuously as the wind from any direction will force the cups to rotate and an angular acceleration will be created.

Modern anemometers are too much costly to purchase. Objective of this project is mainly developing an anemometer with better calibration and better performance which will give instant and continuous results digitally. By using a digital anemometer, time can be consumed, data can be stored for further uses and a better understanding of weather can be gained. So, design and use of a three cup digital anemometer is very useful and cost effective in perspectives of our country.

The objectives of this project are to:

a) Design a three cup anemometer.
b) Construct a three cup anemometer.
c) Testing and improving the anemometer.

2. Literature Review

2.1 Working Procedure

When the anemometer faces the wind, concave surfaces of the cup create more resistance than it's convex surfaces and hence an unbalanced moment is produced which causes rotational motion with respect to its center axis. Under steady flow condition, the rotational speed of the anemometer is directly related to the wind speed.

One of the fan blades have tiny magnets mounted on it and each time when the arms make a single rotation, the magnet move past a magnetic detector called a reed switch. When the magnet is nearby, the reed switch closes and generates a brief pulse of electric current, before opening again when the magnet goes away. This kind of anemometer effectively makes a series of electric pulses at a rate that is proportional to the wind speed. Counting how often the pulses come in and the wind speed can be measured from that.

* Corresponding author. Tel.: +88-01677413281
E-mail address: niazahmad065@gmail.com

2.2 Magnetic Sensor

Magnetic sensors are most commonly used nowadays. When brought into a magnetic field the reeds, which are ferromagnetic will close, creating a switching function. The orientation and direction of the permanent magnet determine when and how many times the switch will open and close.

When a magnetic force is generated parallel to the reed switch, the reeds become flux carriers in the magnetic circuit. The overlapping ends of the reeds become opposite magnetic poles, which attract each other. If the magnetic force between the poles is strong enough to overcome the restoring force of the reeds, the reeds will be drawn together [1].

Figure 2.1: Magnetic Reed Switch [1]

2.3 Arduino Board

Arduino board is a microcontroller embedded control system. In general an arduino board has a microcontroller, external power supply, usb interface, reset button, power led, digital and analog pins, I2C, ICSP Header embedded on it [3].

Figure 2.4: Arduino Board (UNO)

Arduino started in 2005 as a project for students at the Interaction Design Institute Ivrea in Ivrea, Italy. At that time program students used a "BASIC Stamp" at a cost of $100, considered expensive for students. Massimo Banzi, one of the founders, taught at Ivrea [1].

A hardware thesis was contributed for a wiring design by Colombian student Hernando Barragan. After the wiring platform was complete, researchers worked to make it lighter, less expensive, and available to the open source community. The school eventually closed down, so these researchers, one of them David Cuartielles, promoted the idea [1].

There are different types of Arduino board. Such as Arduino Diecimila, Arduino Duemilanove, Arduino UNO, Arduino Leonardo, Arduino Mega, Arduino Nano, LilyPad Arduino [3].

2.3.1 Features of Arduino

- It has an ATmega328 microcontroller integrated with it.
- It’s operating voltage is 5V. Recommended input voltage for Arduino is 7V to 12V. It’s highest limit is 20V.
- It has 14 digital I/O pins (Of which 6 provide PWM output).
- It has 6 analog input pins
- It has a flash memory of 32 KB of which 0.5 KB is used for boot loader.
- It has a clock speed of 16 MHz
- It has SCRAM of 2 KB.
- It has EEPROM of 1 KB.

3. Design and Construction

Among the different types of anemometers that are discussed before in this report, a three cup anemometer was chosen for this project. The reasons for choosing a three cup anemometer are as followed:

- It has less error than a four cup anemometer [1].
- Its construction is simple than others.
- It does not need to manually faced to the wind or to add any other medium to do this job like vane anemometer. It can give reading from any direction of the wind.
- It is cheaper than other anemometers like Hot Wire type or Laser Doppler type anemometer.

As for the above cases, designing a three cup anemometer and making it digital is more effective.

3.1 Design Assumptions

The anemometer was designed based on the above stated design assumptions.

- The design was based on appropriate sensing of wind flow.
- Designed is assumed to work under a sufficient range of wind velocity. The range was assumed to be from 2 km/hour to 35 km / hour.
- Inertia and frictional loss is assumed to be minimum.
- Torque produced by the minimum wind force is assumed to overcome the inertia of the body.
- Full contact of air to the cups was assumed.

3.2 Construction

Construction was completed regarding the assumptions. First the mechanical part of the connection was completed, then the electrical parts were connected to the anemometer and then the code was prepared to obtain desired result.

Fig.3.1 Constructed Anemometer

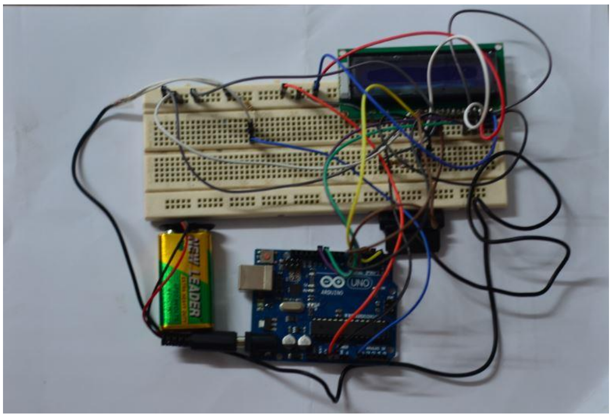

Fig.3.2 Circuit Of the calculation unit

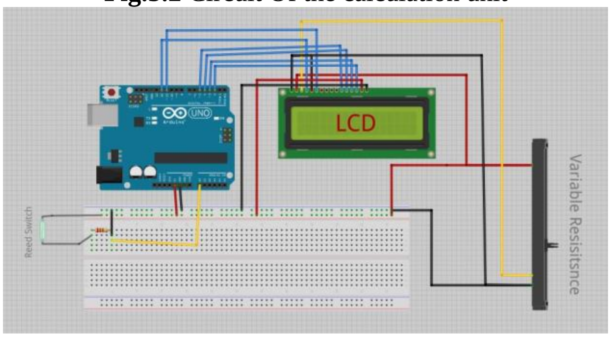

Fig.3.3 Circuit Diagram of Microcontroller Unit

3.3 Code Development

Code for the microcontroller was developed using Arduino IDE. Code for the microcontroller unit is given below:

```
#include <LiquidCrystal.h> // Including Library For
LCD
// Variables to Display on LCD Screen
LiquidCrystal lcd(12, 11, 5, 4, 3, 2);
//Magnatic contact Sonsor pin diclaration
int reedPin = 0;    //analog input, but could also be
digital

// Other variables to calculate speed and read time
float wheelDiameter = 37;   // THE DIA OF WHEEL IN
CENTIMETER(CM)
float wheelC = 3.14 * wheelDiameter;
int circleNum = 0;
int Time=0;
float RPM=0;
float speedometer = 0;
float MPH = 0;
float KPH = 0;
float km=0;
int reedTime;
int reedTimeDelta;
boolean reedOn = false;
```

```
// Setting the pins input and output and setting the LCD
void setup(){
  // set up the LCD's number of columns and rows:
  lcd.begin(16, 2);
  // Print a message to the LCD.

  Serial.begin(9600);//Starting the serial monitor
  reedTime = millis();
}

// Main working function or main loop
void loop(){
  checkReed(); // Calling the checkReed Function
  getSpeed(); // Calling the getSpeed Function
   //RPM=km/(2*3.1416*18.5);
  //Printing Speed in Kilometer per hour
    lcd.setCursor(0, 0);
    lcd.print("KPH: ");
    lcd.setCursor(5, 0);
    lcd.print(km,2);
  //Printing no of revolution
    lcd.setCursor(0, 1);
    lcd.print("RPM:");
    lcd.setCursor(5, 1);
    lcd.print(RPM,2);
    }
// The checkReed Function
void checkReed(){
  //int Time=0;
  Time = millis()/1000;

  int r = analogRead(reedPin);
  if(r > 10 && reedOn == false){
    reedOn = true;
    reedTimeDelta = millis() - reedTime;
    reedTime = millis();
    circleNum++;


   //prints all metrics when magnet passes switch
    printAll();
  }

  else if (r < 10 && reedOn){
    reedOn = false;
  }
}

//Speed Caculation Function
void getSpeed(){
  speedometer = wheelC/reedTimeDelta;
  MPH = speedometer * 22.369;
  KPH = speedometer * 36;
  km=1.8*pow(KPH,1.063);
  RPM= 14.348*KPH;

}

// Printing the values on serial monitor Function
void printAll(){
  Serial.print("KPH: ");
  Serial.println(km, 2);
  Serial.print("MPH: ");
  Serial.println(KPH, 2);
}
```

4. Performance Test of Anemometer

To check the efficiency of the constructed anemometer, we checked its performance with a standard and calibrated anemometer on different wind speed.

Table 4.1:- Data taken from the experimental setup.

No. of Observation	Value from Standard Anemometer (KM/ Hour)	Value From Constructed Anemometer (KM/ Hour)
01	4.4	2.32
02	5.8	2.63
03	6.3	3.11
04	6.7	3.5
05	7.3	3.85
06	8.5	4.19
07	9.5	4.35
08	9.7	4.66
09	10.6	5.41
10	11.5	5.89
11	12.5	5.97
12	13.5	6.46
13	17.5	8.3
14	19.5	8.45

From the above data, a standard vs constructed graph was plotted and relation was determined.

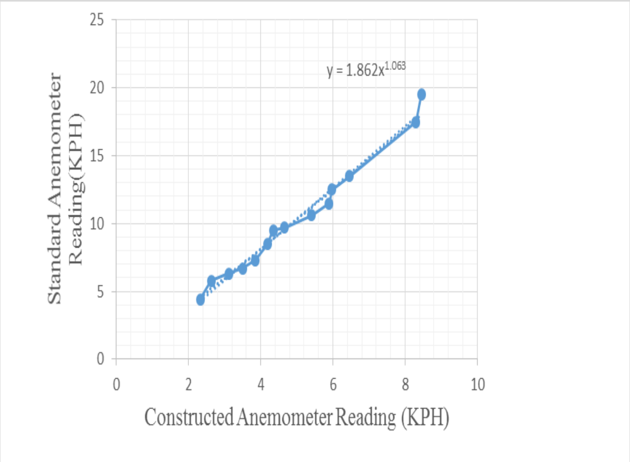

Figure 4.1: Value from standard anemometer vs Value from constructed anemometer

From the above graph, the best fit curve was drawn and the best suited curve was the power series. The Equation of the of the relation between the Actual value and the given value by the constructed anemometer is,

$$y = 1.862x^{1.063}$$

Here,
y= standard anemometer reading
x= constructed anemometer reading
After calibration, anemometer was tasted again with the actual value. Data of the test are given below:

Table 4.2: Data taken after calibration

No. of Observation	Value from Standard Anemometer (KM/ Hour)	Value From Constructed Anemometer (KM/ Hour)
01	23.2	22.85
02	18.55	18.4
03	16.90	17.4
04	14.46	14.9
05	12.55	12.7
06	11.33	11.6

From the above data, a graph of standard anemometer vs constructed anemometer was plotted:

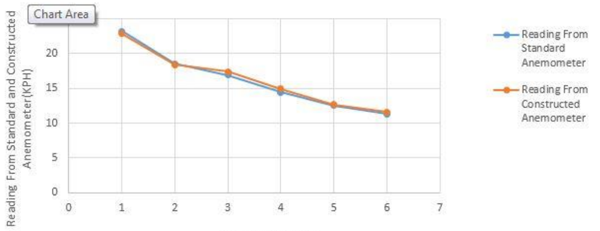

Figure 4.2: Reading from standard and constructed anemometer vs no. of observation

Above graph can be used to calculate the final error and the obtained graph showed that after calibration, the constructed Anemometer gives almost the same reading with the standard Anemometer.

From the above calculated data and graph, error was calculated by the following formula:

$$Error = \frac{SAR - CAR}{SAR} \times 100\%$$

Here,
SAR= Standard Anemometer Reading
CAR= Constructed Anemometer Reading

By using the above formula, error was calculated for each set of data and summing and by calculating the average value of errors, the average error was found to be 1.7732%(+ or -), maximum error was 3.04% and the minimum error was .8% .

6 Conclusion

An anemometer is an essential part weather forecasting. Wind speed can give certain information of weather which are necessary in the field of aviation, shipping, agricultural field and many more industrial and experimental works. On the basis of design assumption and keeping in mind the objectives of the design, a three cup digital anemometer was constructed. It was tested with other ideal instruments and further evaluation and calibration was done to lessen the error. After calibration, the anemometer was again tested and the results were compared. An average error of more or less 1.7732% was found. The maximum error was found about -3.04% and the minimum error was .8%. The anemometer does not give a reading if the wind velocity is less than about 3 KM/Hour.

Recommendation

- Better use of material which are a bit costly but will give a better result.
- Additional parts can be added to determine the wind direction also.
- Sensor can be added to the cups to determine the Humidity of the wind.
- A memory card can be added to the Arduino board in order to store the data.

REFFARANCE

[1] http://www.en.wikipedia.org
[2] http://www.explainthatstuff.com
[3] http://www.arduino.cc
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[5] http://www.azosensors.com
[6] http://www.sparkfun.com