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Development of Low Wind Speed Anemometer

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***Abstract*— Anemometer is a measuring device used to measure the wind speed of an area. Before design or installing a wind turbine, it is important to determine the average wind speed of that particular area throughout the year. But it is illogically to purchase anemometer to measure the wind velocity for a year period. The purpose of this project is to design and fabricate a small scale of anemometer which will able to give the wind velocity with an acceptable range of uncertainty. The fabrication of the anemometer is developed using design methodology and simulation to obtain the optimized design. The designed anemometer has the mean absolute percentage error (MAPE) of 3.23 % when compared with Dwyer series 471 thermo-anemometer.**

***Keywords*— Anemometer; low wind speed; energy conversion system.**

I. Introduction

Anemometers can be divided into two classes which measure the wind speed, and measure the wind pressure. Between wind speed and wind pressure, there is a close connection. There are several type of anemometer used to measure the wind speed, eg: cup anemometer [1-2], hot wire anemometer [3-4], thermal anemometer [5-6], sonic anemometer [7-8] and etc.

When narrowed the angle to low wind speed measurement, there are few types of anemometer design is suitable to be used to obtain an accurate result. The accuracy of an anemometer is independent of the anemometer design only but also affected by other factors. The factors that can affect the accuracy of an anemometer might be the electronic component used in the system, the height of the anemometer placed while measurement is taken and also the environment conditions [9].

In Malaysia, wind energy conversion is a serious consideration. The potential for wind energy generation in Malaysia depends on the availability of the wind resource that varies with location. Understanding the site-specific nature of wind is a crucial step in planning a wind energy project. Detailed knowledge of wind on-site is needed to estimate the performance of a wind energy project.

The availability of wind resource varies at different location at Perlis. It is necessary to first carry out a general assessment of the wind energy potential at Perlis climate. This step is taken before installing wind turbine to decide a proper wind turbine to be installed at the desired location in Perlis. In order to carry out general assessment to study on wind speed at Perlis, an anemometer has to be designed and fabricated to measure small scale of wind velocity with an acceptable range of uncertainty for short term usage.

This project only considers measuring the wind speed of the range of 2 m/s to 6 m/s at permanent campus Ulu Pauh of University Malaysia Perlis. The design only consider of non-continuous measurement. The error occurs for the low wind speed anemometer being set in order not to exist 20% when compared with the pilot tube or available anemometer.

II. Morphological Chart

Several morphology chart being proposed after a brain-storming session.

A. Cup and recorder design

Several designs of cup, shaft, bearing and encoder being consider which shown in Table I. Morphological chart for combination of parts for whole anemometer system is given in Table II. The suggested solutions in Table II are compared with standard anemometer which given in Figure 1 and the result is given in Table III.

TABLE I
MORPHOLOGY CHART FOR PART

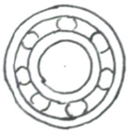
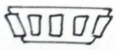
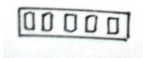
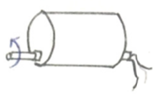
Sub-function	Solution 1	Solution 2	Solution 3
Drag force	 Cone	 Hemisphere	 Combination
Sensitivity	 110 mm	 85 mm	 50 mm
Low Friction	 Ball bearing	 Tapered bearing	 Roller bearing
Rotary reading	 Rotary encoder	 DC-geared encoder	 Absolute encoder

TABLE III
MORPHOLOGY CHART FOR ANEMOMETER SYSTEM

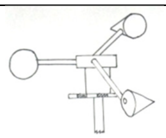
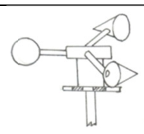
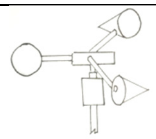
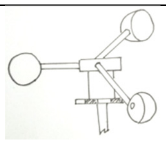
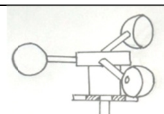
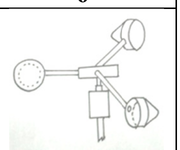
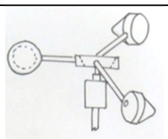
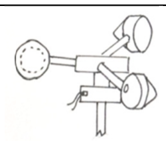
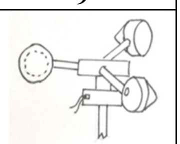
Sub-function	Solution		
	1	2	3
Concept			
Parts	Cone cup 110mm shaft Ball bearing Plate encoder	Cone cup 50mm shaft Roller bearing Plate encoder	Cone cup 85mm shaft Ball bearing DC-geared encoder
	4	5	6
Concept			
Parts	Hemisphere cup 110mm shaft Ball bearing Plate encoder	Hemisphere cup 85mm shaft Roller bearing Plate encoder	Hemisphere cup 110mm shaft Roller bearing DC-geared encoder
	7	8	9
Concept			
Parts	Combination cup 110mm shaft Tapered bearing DC-geared encoder	Combination cup 85mm shaft Roller bearing Absolute encoder	Combination cup 50mm shaft Ball bearing Plate encoder

Fig. 1 Standard cup shape anemometer used for comparison in morphological chart [10]

TABLE IIII
MORPHOLOGY CHART FOR PART

Criteria	Solution (Conceptual design)								
	1	2	3	4	5	6	7	8	9
Resolution	1	0	0	1	0	1	1	0	0
Material	1	1	1	1	1	1	1	1	1
Maintenance	1	1	0	1	1	0	0	-1	1
Durability	0	0	0	0	0	0	0	0	0
Price	1	1	1	0	0	0	0	-1	1
Accuracy	0	-1	0	0	-1	0	0	0	0
Quality	0	0	0	0	0	0	0	0	0
Sum	**4**	**2**	**2**	**3**	**2**	**2**	**2**	**-1**	**3**
Continue	**Y**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**

Indicator : 1 = Better; 0 = Same; -1 = Worst; Y = Yes; N = No

As a result from morphology chart in Table III, solution 1 which consists of cone cup, 110 mm long shaft, ball bearing and plate encoder was chosen to be further analysed by using House of Quality (HOQ).

III. HOUSE OF QUALITY

In order to knowing the demand of the criteria and determine the weight for fabrication, house of quality (HOQ) being used to evaluate the design in solution 1. Figure 2 shows the importance weight (%) versus quality characteristic for House of Quality (HOQ) result based on the analysis done onto the cup shape anemometer as decided as a sequence from Table III. The detail analysis of House of Quality (HOQ) for solution 1 in Table III is given in Figure 3. From this analysis shown that the design of the cup size and design of the arm will be the most importance criteria to be considered compared to other identified parameters.

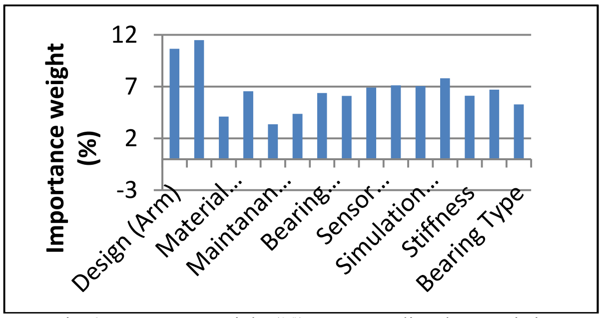


Fig. 2 Importance weight (%) versus quality characteristic

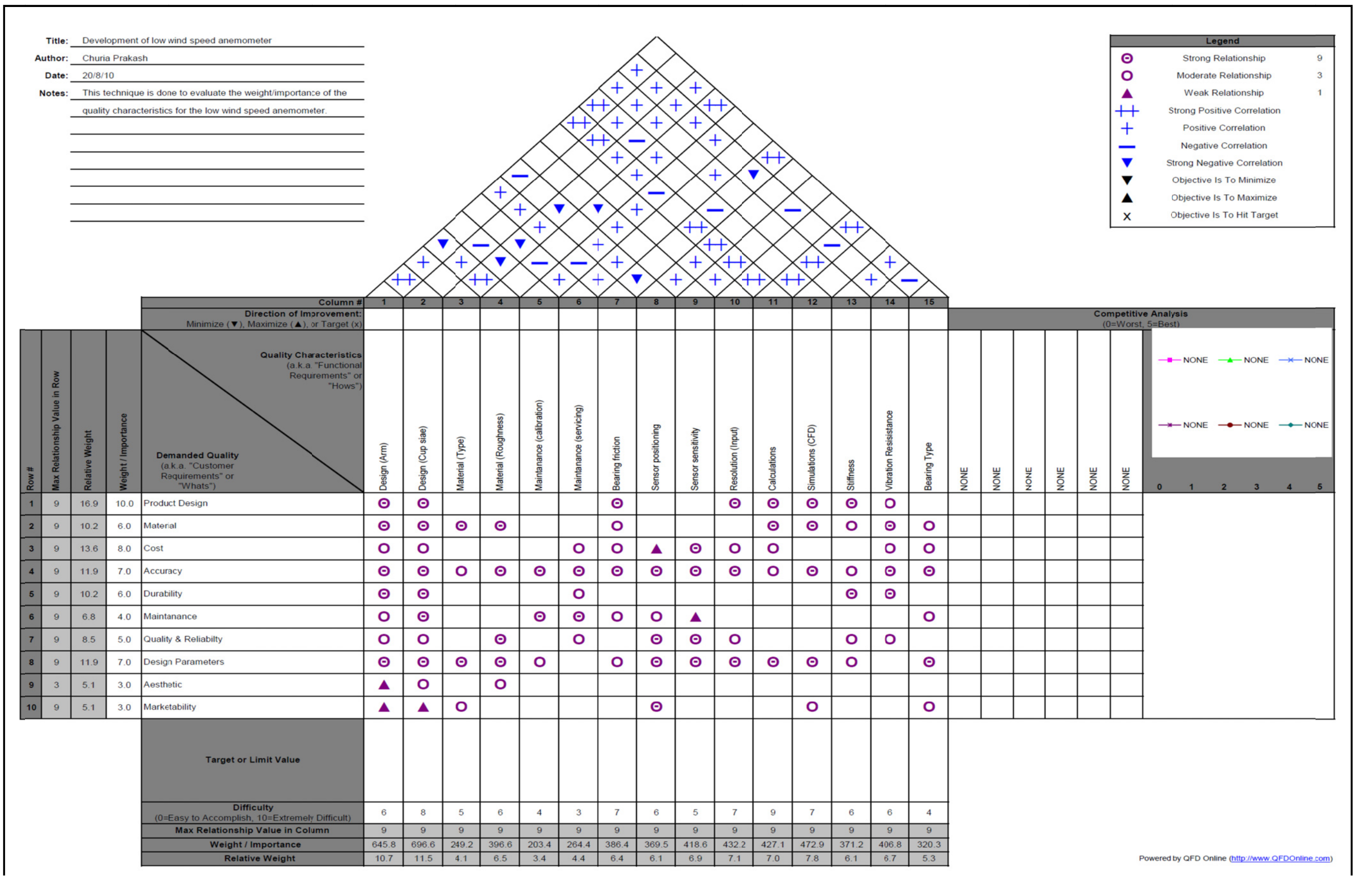


Fig. 3 Result of House of Quality (HOQ) analysis for anemometer [11]

IV. Computational Fluid Dynamics (CFD) Analysis

In order to obtain the optimum design for cup size as observed in House of Quality (HOQ), Computational Fluid Dynamics (CFD) analysis being implemented. COSMOFloWorks being used to simulated the design shape and size for the cup of anemometer. Three designs of cup being considered which shown in Table IV. Sample of simulation using COSMOFloWorks is shown in Figure 4 where the wind flows along Y-axis (negative-to-positive).

TABLE IV
Designs of Anemometer Cup

parameter	Design		
	A	B	C
diameter	40 mm	65 mm	80 mm
depth	30 mm	30 mm	30 mm

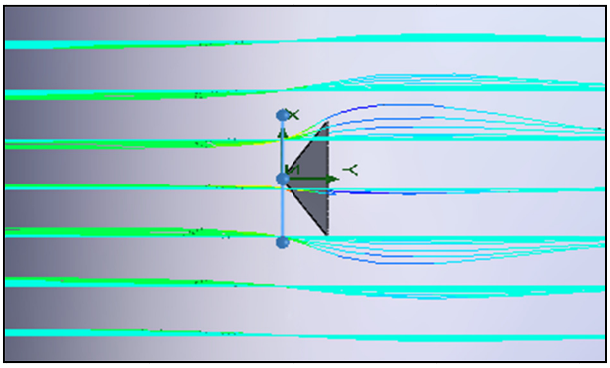


Fig. 4 Computational Fluid Dynamics (CFD) analysis for cone cup of anemometer.

Based on the Computational Fluid Dynamics analysis, it is found that design C having the best performance in term of drag coefficient and torque generated among three designs. The final design of the anemometer is given in Figure 5.

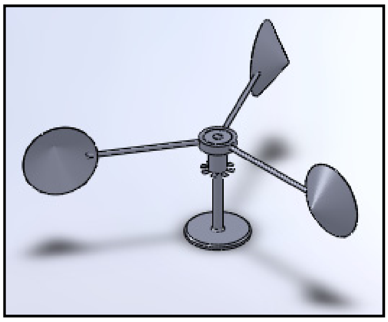


Fig. 5 Final design of low wind speed anemometer.

V. Error determination of anemometer system

After fabrication of whole cup shape anemometer, the system being tested and measure the wind velocity sample with the help of wind tunnel which almost similar with the methodology used other researchers [12]. The reading of wind speed measured by designed anemometer is then compared with the Dwyer series 471 thermo-anemometer which available in Heat Transfer and Thermodynamics Laboratory in School of Mechatronic Engineering, Universiti Malaysia Perlis.

The results from both measuring equipments are shown in Table V. From Table V, the designed anemometer not only able to be fabricate in any workshop but also within an acceptable accuracy ranges with the operation environment of 2 m/s – 6 m/s which is 3.23 % for mean absolute percentage error.

TABLE V
Mean absolute percentage error analysis

No	Vane anemometer	Designed anemometer	Absolute Percentage Error (%)
1	2.0	2.0	0.00
2	2.2	2.1	4.55
3	2.4	2.5	4.17
4	2.6	2.7	3.85
5	2.8	3.0	7.14
6	3.0	2.9	3.33
7	3.2	3.0	6.25
8	3.4	3.3	2.94
9	3.6	3.9	8.33
10	3.8	4.0	5.26
11	4.0	4.2	5.00
12	4.2	4.3	2.38
13	4.4	4.6	4.55
14	4.6	4.8	4.35
15	4.8	4.8	0.00
16	5.0	5.1	2.00
17	5.2	5.1	1.92
18	5.4	5.4	0.00
19	5.6	5.5	1.79
20	5.8	5.8	0.00
21	6.0	6.0	0.00
Mean Absolute Percentage Error (%)			3.23

VI. Conclusions

This paper success presented a development of low speed anemometer in order to meet the demand of having a easy to fabricate and yet reasonable accuracy range of anemometer for measuring wind speed velocity with range from 2 m/s to 6 m/s as an initial step for analyze wind velocity before installing any wind turbine for renewable energy generation in a small scale application like home-used.

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