



## MODIFICATION OF OPEN CIRCUIT WIND TUNNEL

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### ABSTRACT

A modification of the wind tunnel is important to overcome existing problems in order to provide deeper research development. This method of modification is conducted by varying some design contraction sections, test sections and diffuser section by using the simulation CFD (Computational Fluid Dynamic) using *software* SolidWorks 2014. Then, the most optimal result is realized on existing wind tunnel. The results obtained from optimization are a combination of the 2<sup>nd</sup> contraction section design, a test section design and 2<sup>nd</sup> diffuser section design which are the most optimal results. The results of these modifications open circuit wind tunnels can generate wind flow on the scope of an average wind speed up to 15 m/s in the test section with an average turbulence intensity up to 1%.

**Keywords:** modification, wind tunnel, open circuit, CFD.

### INTRODUCTION

The implementation of wind energy technology in Indonesia is still low. The total wind power generation installed in Indonesia is around 1.6 MW in non-commercial scales [1]. This step of course requires the adequate research medium and supports. Various research which have been done and also various other research result [2-4] indicate that requirement of wind tunnel is capable of operating in full scale; further, supporting equipment for adequate measurement instruments in order to conduct performance test for a wind turbine building for its development is absolutely important.

Wind tunnel is equipment which is used to investigate aerodynamic properties from an object by flowing the air which has controlled at the object [5]. The Wright Brother, the pioneers on air transport, comprehensively built wind tunnel in 1901. Since then, various wind tunnels in many types, sizes and purposes have been developed [6]. In generic, main parts of wind tunnel, specifically open circuit type, which are designed and made at this research consist of: (i) wind activator in the form of fan or fan arrangement is designed to meet the requirement of power scale capacities, (ii) test section where test object is placed, dimension of this test section also determine the dimension of object to be tested. In principle, greater test section will yield the phenomenon or properties of the emerging from test object more comprehensive and accurate, but it requires the high expense, (iii) recovery stream is air stream location after passing the test section, (iv) calming section is the air stream controller according to required variation, and (v) display board which shows the variable of the emerging properties.

Laboratory heat transfer and mass and mechanics fluid Department of Mechanical Engineering, Universitas Gadjah Mada has a wind tunnel with a small scale and

medium-sized enterprises that needs modification to support deep and adequate research activity in the field of wind energy utilization.

This modification was done because a wind tunnel which has considerable dimensions can generate the wind stream at range minimum and maximum in test section (mean of 2.8 ~ 6.4 m/s) [7]. Further, turbulence intensity is expected to be smaller than before. The condition of the wind tunnel which will be modified is shown in Figure-1.



(a) Inside wind tunnel



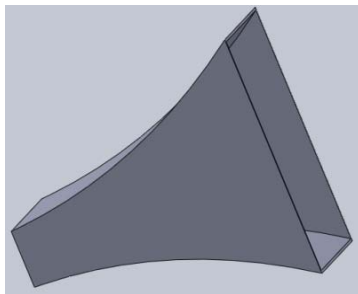
(b) Outside wind tunnel

**Figure-1.** The condition of the wind tunnel before modified.

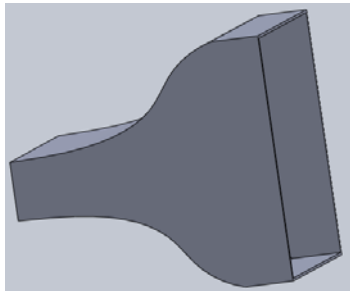


## METHOD

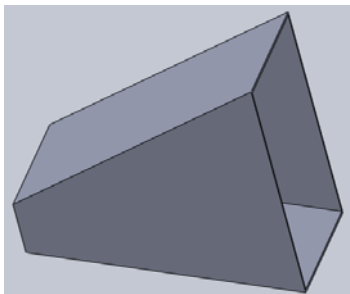
Wind tunnel design modifications consist of contraction section, test section and diffuser section. This method of modification is conducted in varying some design contraction sections, test section and diffuser section by using the simulation CFD (Computational Fluid Dynamic) using software SolidWorks 2014. Then, the most optimal results are realized on existing wind tunnel. Contraction section consists of three designs, a test section design and three diffuser section designs. Therefore, this modification has 9 form variations which will be simulated. The three contraction section design is shown in Figure-2, a test section design is shown in Figure-3, and the three diffuser section designs are shown in Figure-4.



(a) 1<sup>st</sup> contraction section design

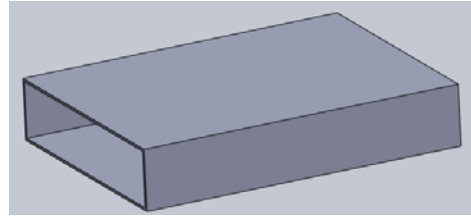


(b) 2<sup>nd</sup> contraction section design

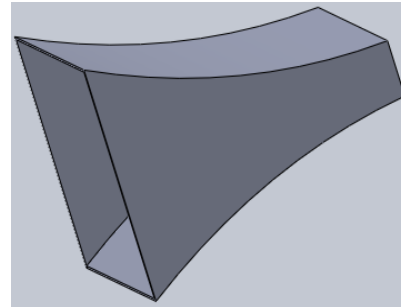


(c) 3<sup>rd</sup> contraction section design

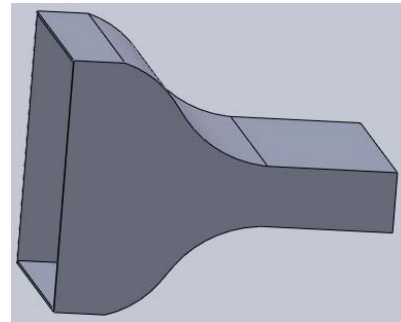
**Figure-2.** Three contraction section design.



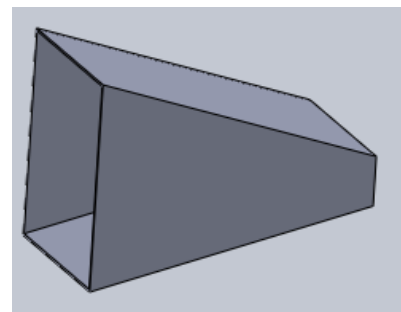
**Figure-3.** A test section design.



(a) 1<sup>st</sup> diffuser section design



(b) 2<sup>nd</sup> diffuser section design

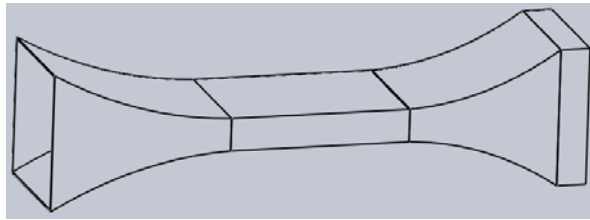


(c) 3<sup>rd</sup> diffuser section design

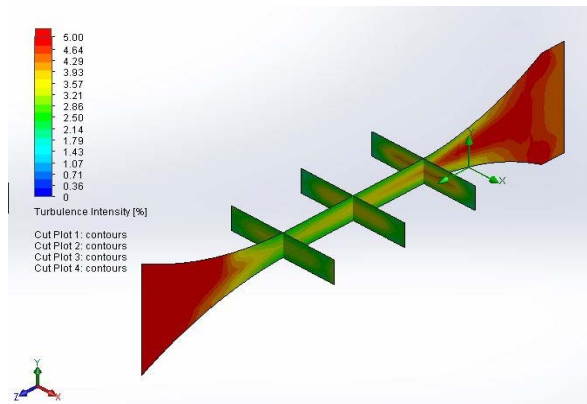
**Figure-4.** Three diffuser section designs.

## RESULT AND DISCUSSIONS

Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design as shown in Figure-5 and result of simulation are based on turbulence intensity as shown in Figure-6.

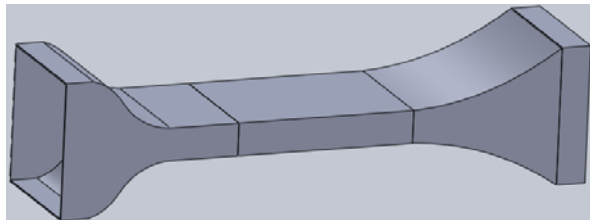


**Figure-5.** Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design.

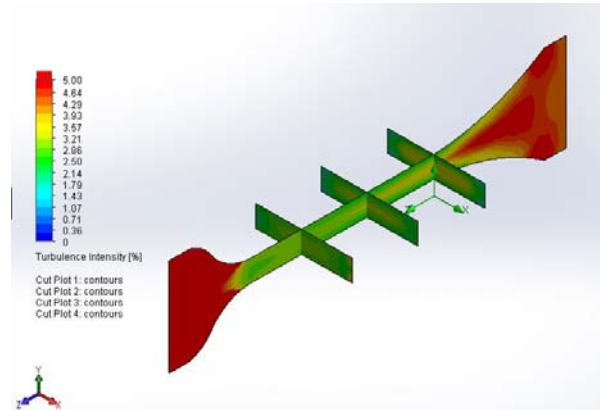


**Figure-6.** Result of simulation based on turbulence intensity from Figure-5.

Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design as shown in Figure-7 and result of simulation are based on turbulence intensity as shown in Figure-8.

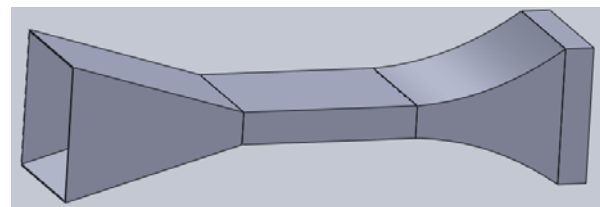


**Figure-7.** Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design.

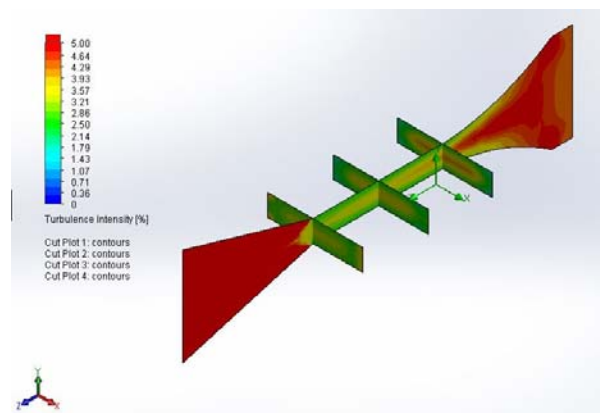


**Figure-8.** Result of simulation based on turbulence intensity from Figure-7.

Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design as shown in Figure-9 and result of simulation are based on turbulence intensity as shown in Figure-10.

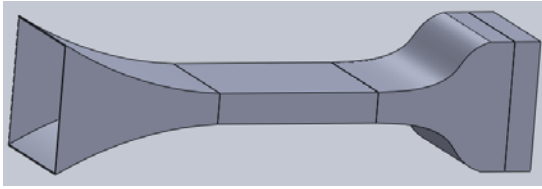


**Figure-9.** Combination of wind tunnel of the 1<sup>st</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design.

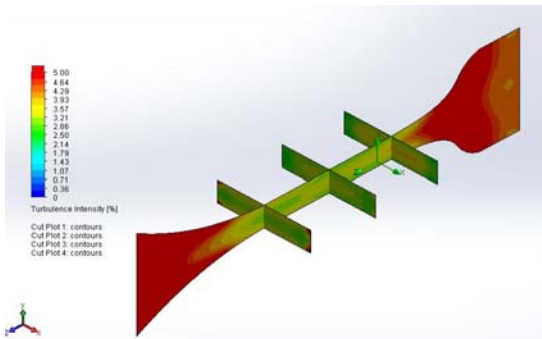


**Figure-10.** Result of simulation based on turbulence intensity from Figure-9.

Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design as shown in Figure-11 and result of simulation are based on turbulence intensity as shown in Figure-12.

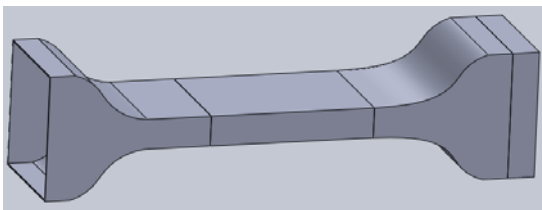


**Figure-11.** Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design.

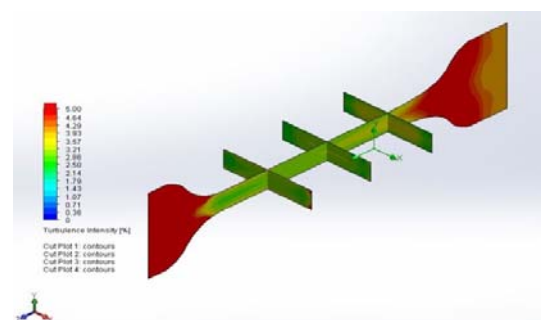


**Figure-12.** Result of simulation based on turbulence intensity from Figure-11.

Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design as shown in Figure-13 and result of simulation are based on turbulence intensity as shown in Figure-14.

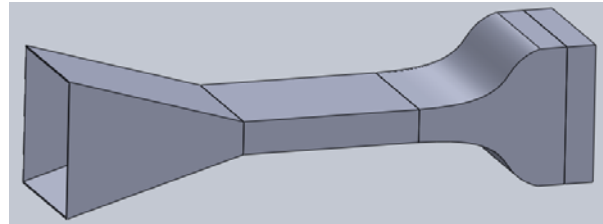


**Figure-13.** Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design.

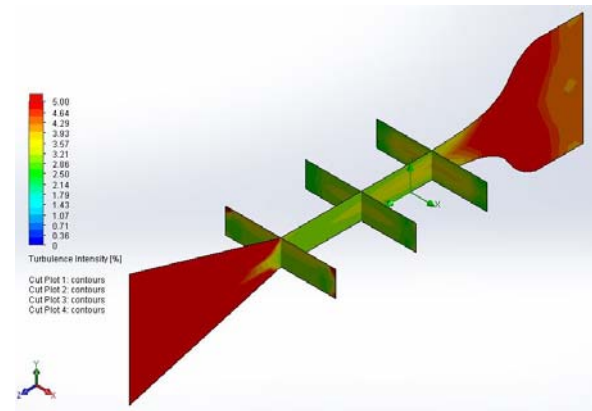


**Figure-14.** Result of simulation based on turbulence intensity from Figure-13.

Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design as shown in Figure-15 and result of simulation are based on turbulence intensity as shown in Figure-16.

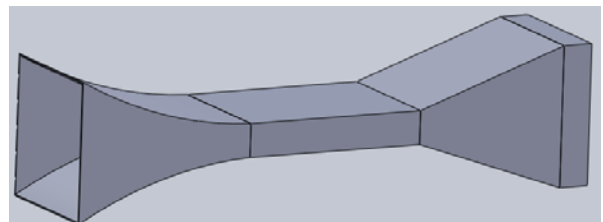


**Figure-15.** Combination of wind tunnel of the 2<sup>nd</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design.

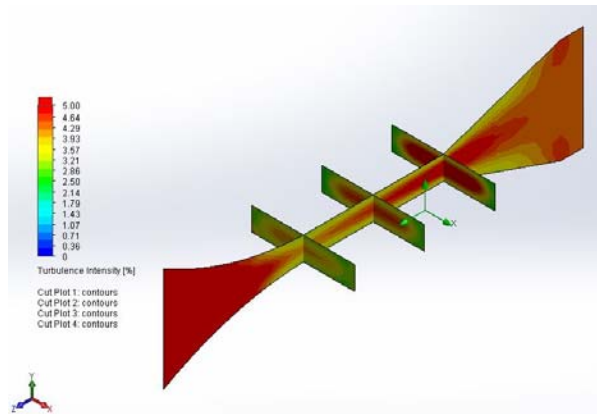


**Figure-16.** Result of simulation based on turbulence intensity from Figure-15.

Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design as shown in Figure-17 and result of simulation are based on turbulence intensity as shown in Figure-18.

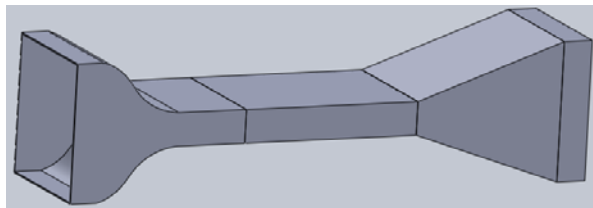


**Figure-17.** Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 1<sup>st</sup> diffuser section design.

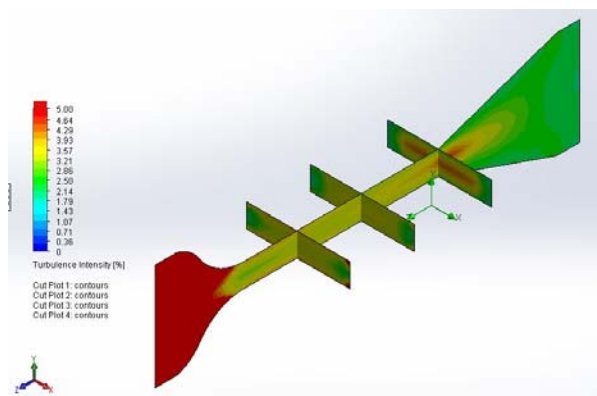


**Figure-18.** Result of simulation based on turbulence intensity from Figure-17.

Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design as shown in Figure-19 and result of simulation are based on turbulence intensity as shown in Figure-20.

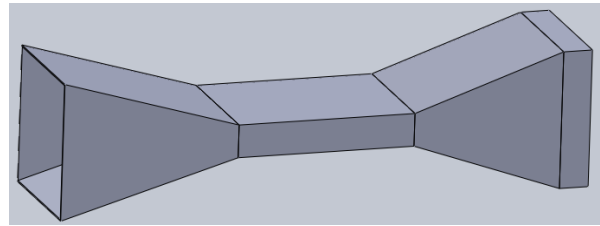


**Figure-19.** Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 2<sup>nd</sup> diffuser section design.

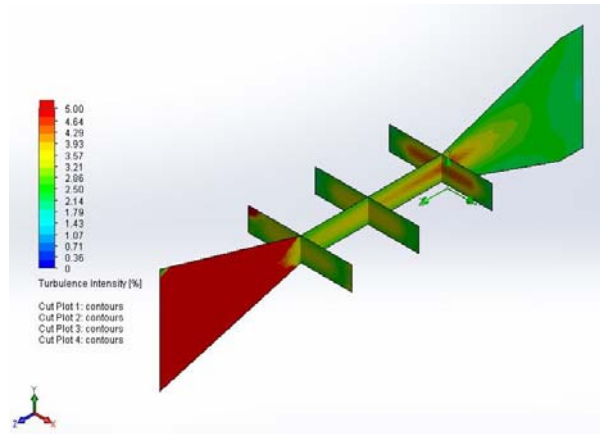


**Figure-20.** Result of simulation based on turbulence intensity from Figure-19.

Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design as shown in Figure-21 and result of simulation are based on turbulence intensity as shown in Figure-22.

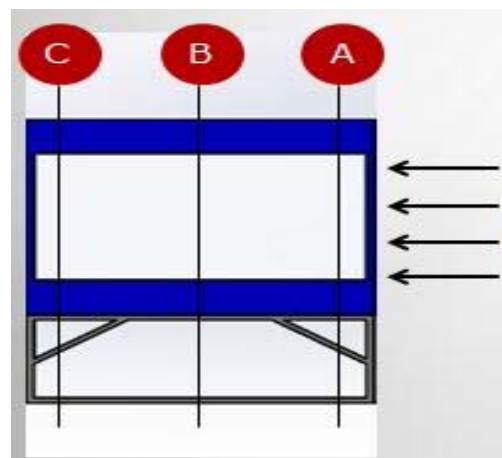


**Figure-21.** Combination of wind tunnel of the 3<sup>rd</sup> contraction section design, test section design, and 3<sup>rd</sup> diffuser section design.



**Figure-22.** Result of simulation based on turbulence intensity from Figure-21.

Numerical data on the position as shown in Figure-23 are also taken from CFD simulation results. In this simulation, it is assumed that input turbulence intensity is about 2.11%, and input wind speed about 6 m/s. The data assumption is used based on the data before wind tunnel is modified. The data results from CFD simulations are shown in Table-1.



**Figure-23.** Positions in taking numerical data on the CFD simulation.



**Table-1.** Summary results of the simulation.

No	A combination of contraction section design, test section design and diffuser section	Goal plot	The assumption that input turbulence intensity about 2.11%, and input wind speed about 6 m/s
			Turbulence intensity (%)
1	1, 1, 1	A	4.12309
		B	3.56886
		C	3.18449
2	1, 1, 2	A	3.76934
		B	3.30142
		C	3.0088
3	1, 1, 3	A	4.1199
		B	3.55673
		C	3.28913
4	2, 1, 1	A	3.7259
		B	3.222
		C	2.9508
5	2, 1, 2	A	3.7367
		B	3.2179
		C	2.9064
6	2, 1, 3	A	3.8098
		B	3.2803
		C	3.0789
7	3, 1, 1	A	5.8581
		B	4.7025
		C	4.0985
8	3, 1, 2	A	4.2939
		B	3.5201
		C	3.2087
9	3, 1, 3	A	4.5021
		B	3.7333
		C	3.4617

From the above results, it can be concluded that a combination of the 2<sup>nd</sup> contraction section design, a test section design and 2<sup>nd</sup> diffuser section design is the most optimal results with the smallest turbulent intensity. The results of making modifications to the design of wind tunnel with a combination of the 2<sup>nd</sup> contraction section design, a test section design and 2<sup>nd</sup> diffuser section design can be seen in Figure-24. The results of these modifications open circuit wind tunnels can generate wind flow on the scope of an average wind speed up to 15 m/s in the test section with an average turbulence intensity up to 1%.



(a) Test section



(b) Upper contraction/diffuser section



(c) Lower contraction/diffuser section

**Figure-24.** Photos of modification wind tunnel.

## CONCLUSIONS

From result and discussion, it can be concluded that: (a) a combination of the 2<sup>nd</sup> contraction section design, a test section design and 2<sup>nd</sup> diffuser section design is the most optimal results; (b) wind tunnel has good performance because there are relatively homogenous speed of wind stream in tunnel plane; (c) fan speed to generate wind flow on the scope of an average wind speed up to 15 m/s in the test section with an average turbulence intensity up to 1%; (d) transparent wall gives broadness to observe stream through test object; and (e) wind tunnel structure as a whole is rigid enough and can give full flexibility to arrange the test object.

## ACKNOWLEDGEMENTS

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