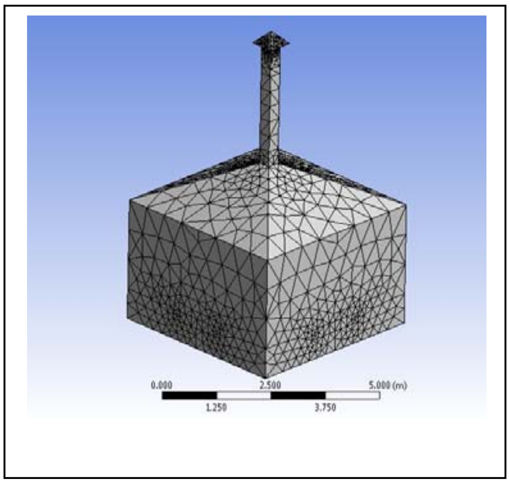
CHAPTER 4

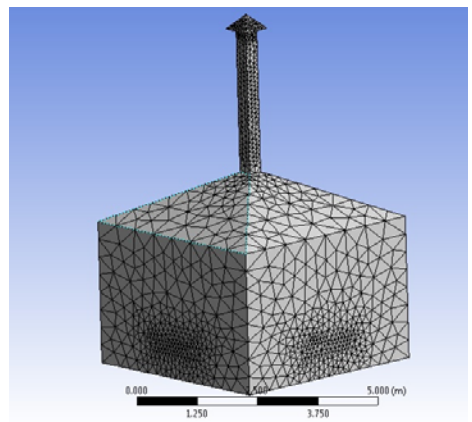
RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

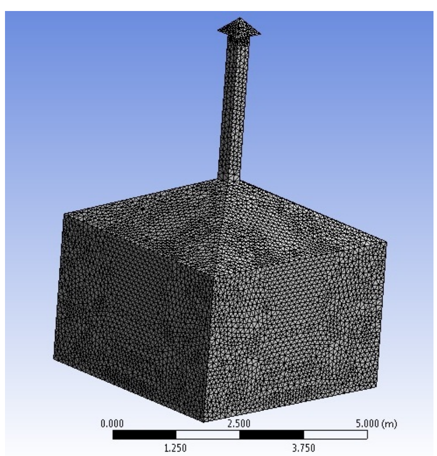
4.1 Mesh sensitivity study

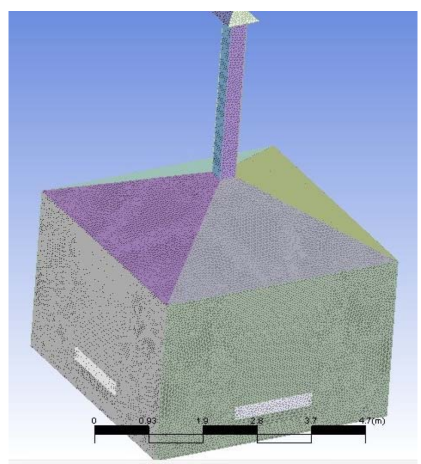
Mesh sensitivity study was done to investigate the effect of mesh size on the accuracy of the result. For this purpose, the model is meshed using different mesh size to produce different number of element and the result is compare. Figure 4.1 shows different numbers of element being used in the study. The result of temperature for selected point in the solar dryer greenhouse model with different number of element is shown in Figure 4.2.





(a) (b)





(c) (d)

Figure 4.1: Solar dryer greenhouse model with different numbers of element (a) 29537 (b) 51155 (c) 241053 and (d) 391163

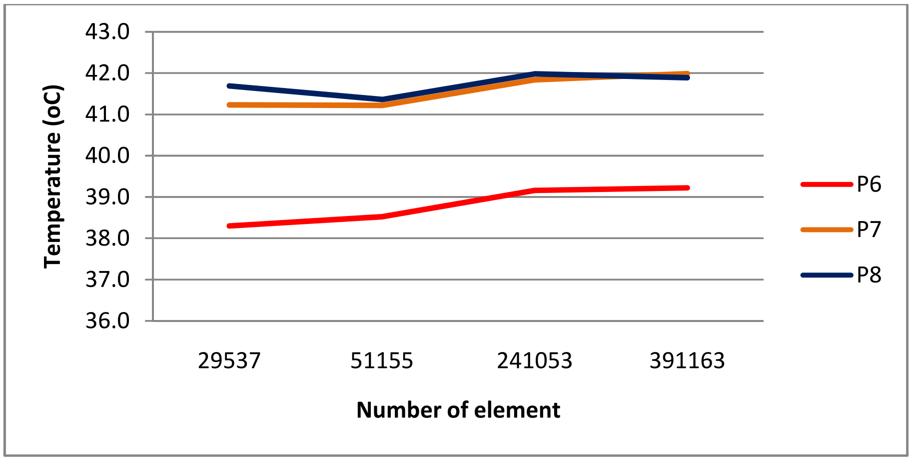


Figure 4.2: Temperature of location P6, P7 and P8 for model with different numbers of element

From Figure 4.2 it is shown the result for 241053 element is the very similar to the result of 391163 element where the percentage different is only within 0.4%. Therefore, the optimum number of element is achieved and further increasing the number of element will have no effect on the accuracy of the result produce.

4.2 Convergence trend

The convergence trend for this simulation is shown in Figure 4.3

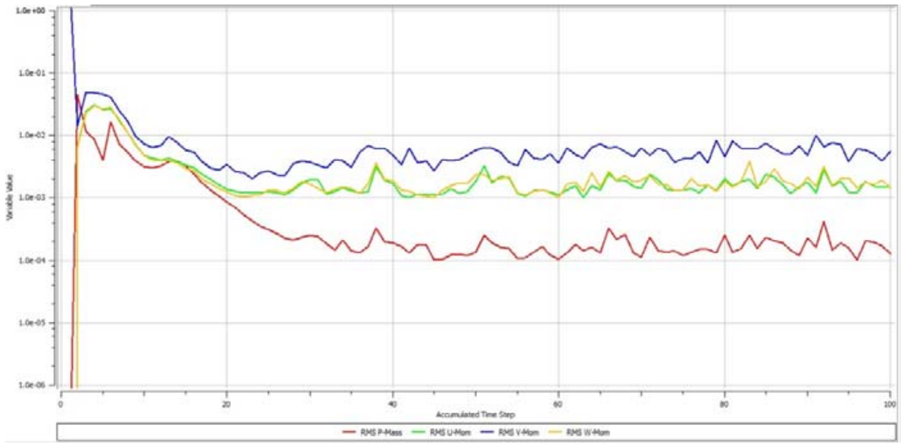


Figure 4.3: Convergence trends of the simulation.

From figure 4.3, it is shown that the RMS residual level is decrease from around 1e-01 to around 1e-04. According to ANSYS-CFX Solve Modelling Guide, this level of residual is acceptable and sufficient for many of engineering application.

4.3 Solar dryer house with roof and side opening open (condition 1).

The results from the CFD simulations were compared with the measured data for:

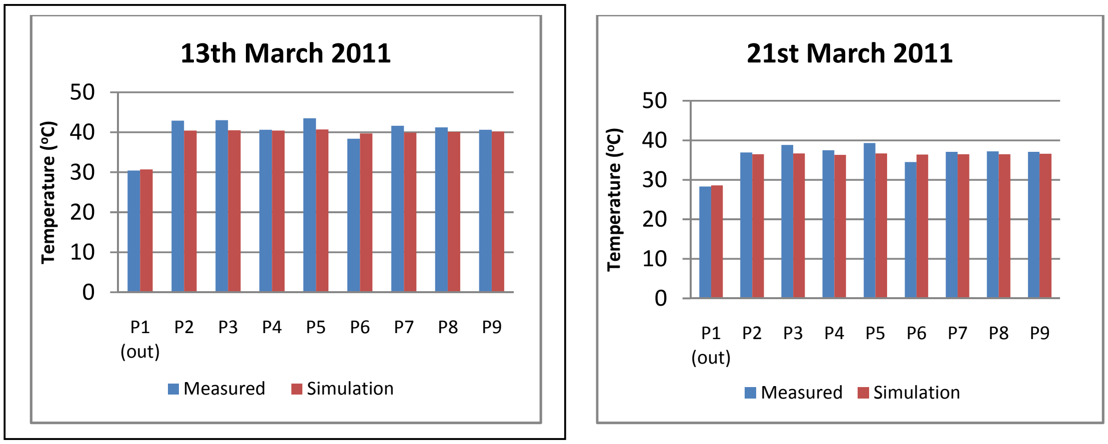
a) Temperature for location P1 to P9.

b) The difference of the outside temperature and inside average temperature.

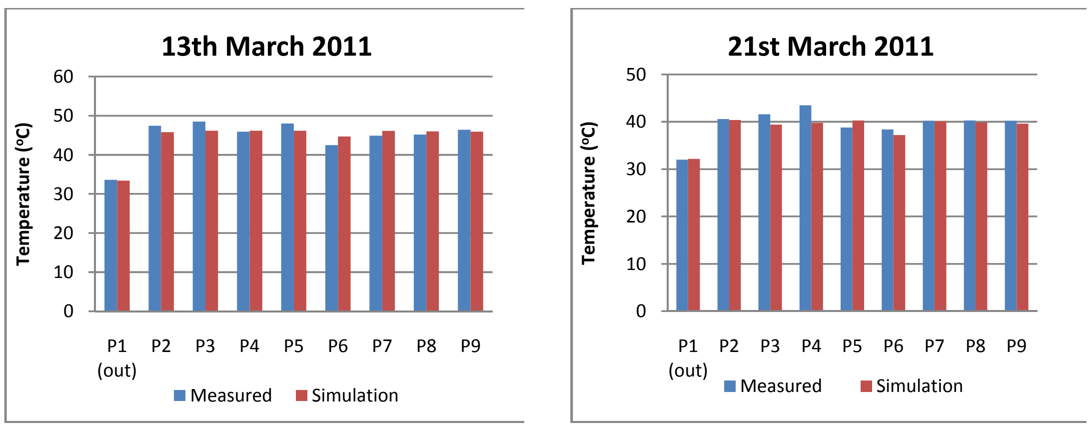
The temperature distributions contour and air flow velocity profiles from the CFD simulation were also produce for the analysis.

The results are as below:

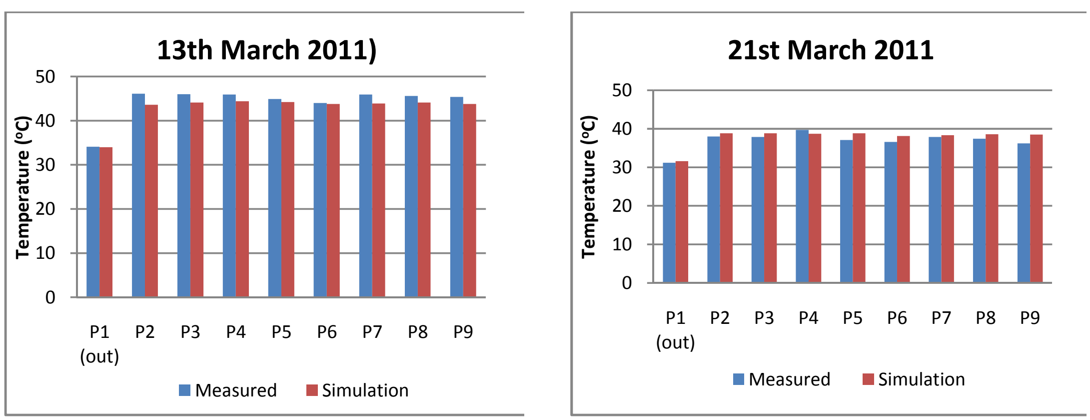
4.3.1 Temperature for location P1 until P9



(a)



(b)



(c)

Figure 4.4: Temperature for each location at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm on 13th March and 21st March 2011

4.3.2) Temperature distribution from CFD simulation

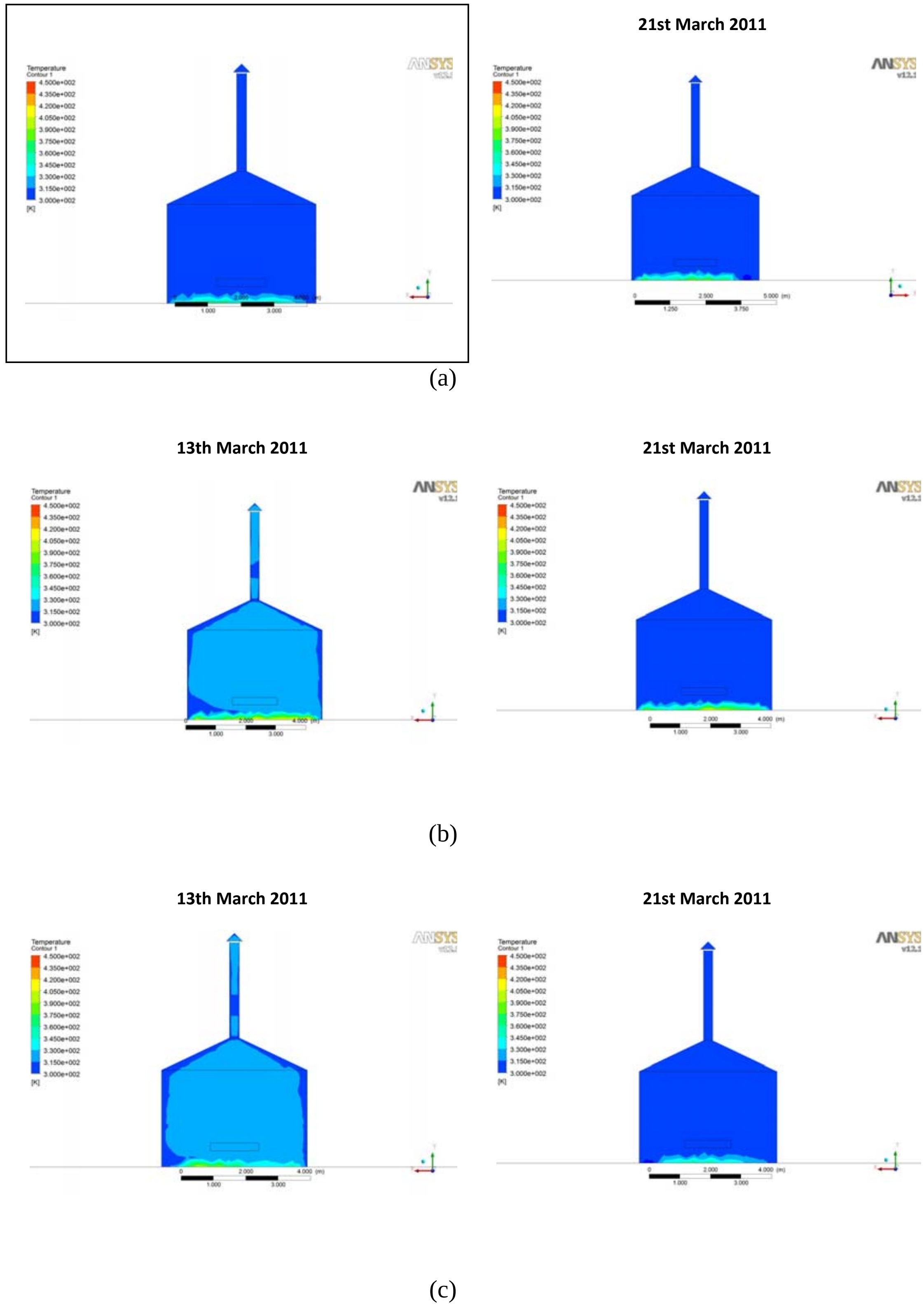
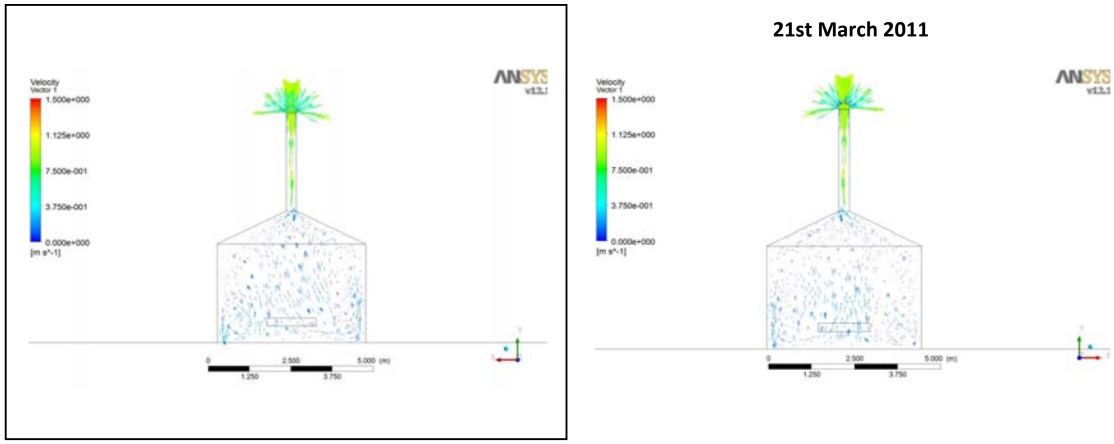
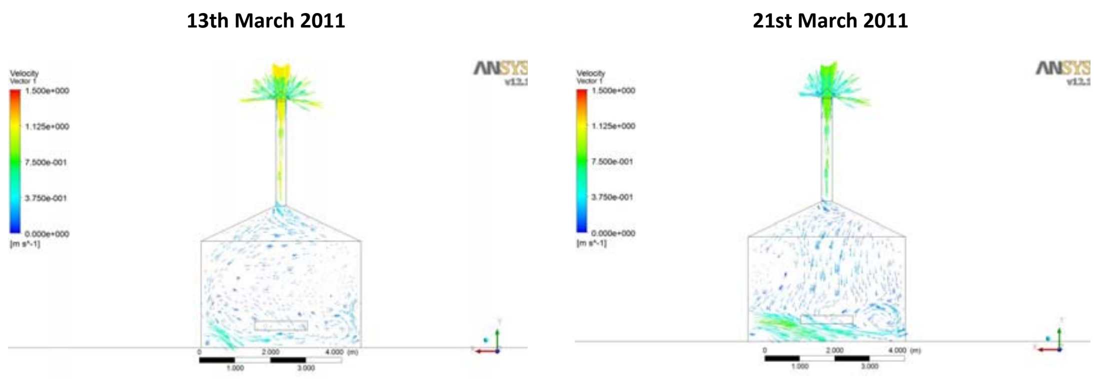


Figure 4.5: Temperature distribution contour at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm on 13th March and 21st March 2011

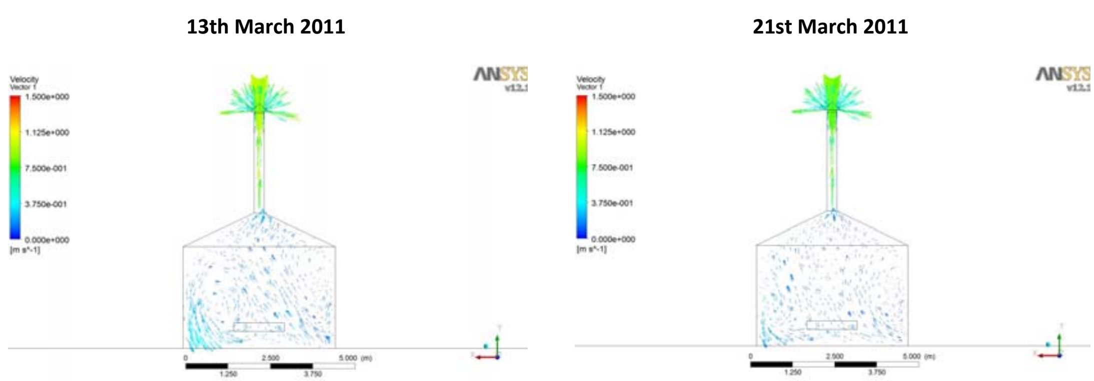
4.3.3) Air flow velocity profile



(a)



(b)



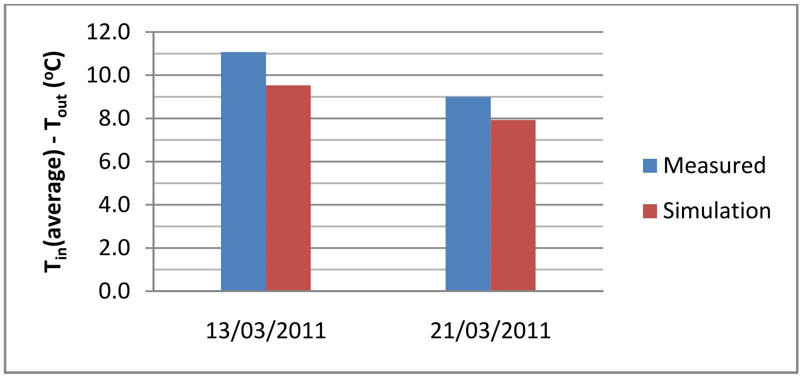
(c)

Figure 4.6: Air flow velocity profile at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm and on 13th March and 21st March 2011

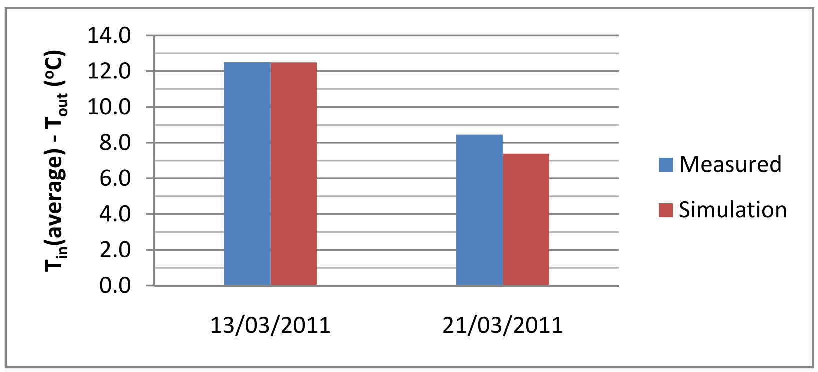
4.3.4 Data analysis and discussion for solar dryer with roof and side opening

For the condition where the side and roof opening was open, two dates were selected for comparison which is on 13th March and 21st March 2011. Observation on both days was a clear sunny day without rain. Measured data on solar radiation shows higher readings on 13th March compare to 21st March. As a result the temperature from measured and simulation on 13th March is more than 40^{o}C at 10.40 am, 1.30 pm and 4.30 pm while on 21st March only at 1.30 pm the temperature is above 40^{o}C. The temperature distributions from the CFD simulation were similar compared to measured data. The temperature average percentage difference between measured and simulation is almost the same for all three times which is 3.5% at 10.30 am, 3.0% at 1.30 pm and 3.3% at 4.30 pm.

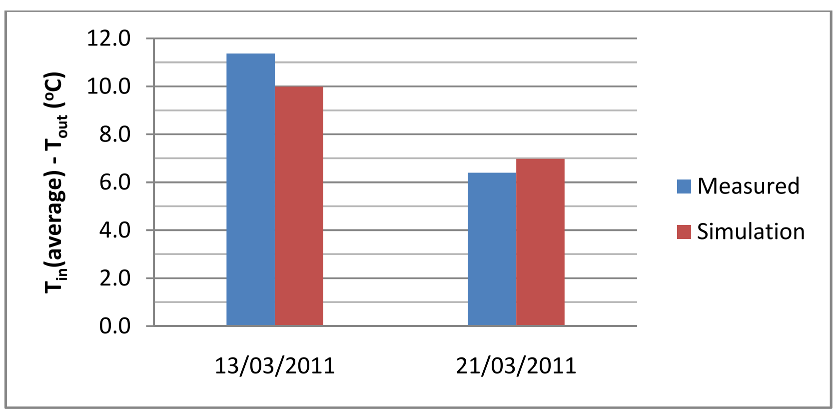
The data for temperature difference between inside the solar dryer greenhouse and the environment is measured by subtracting outside temperature (temperature at point P1) from the average inside temperature (average temperature at point P2 to P9). Figure 4.7 shows the temperature difference between the inside and the outside air of the solar dryer greenhouse. The temperature difference is higher on 13th March compare to 21st March 2011. The maximum data difference between simulation and measured data for the outside and inside temperature difference was 1.5^{o}C at 10.30 am, 1.1^{o}C at 1.30 pm and 1.4^{o}C at 4.30 pm (Table 4.1). The fluctuations of temperature for each location (P1 to P9) from the CFD simulation was smaller compare to measured data. The variations of temperature from the simulation were within 3^{o}C while from measured data the temperature fluctuations were as big as 6^{o}C. This condition may be due to the present of other things inside the solar dryer such as the pillar at the centre of the solar dryer where the sensors were mounting and also the present of the empty cabinet. While in the CFD simulation it was assumed that only air were inside the solar dryer. Therefore the distribution of the heat is more even compare to the actual condition.



(a)



(b)



(c)

Figure 4.7: Measured and CFD-simulated data for differences between inside (T_{in}) (average) and outside (T_{out}) air temperature for solar dryer with side and roof opening open at (a) 10.30 am, (b) 1.30 pm and (c) 4.30 pm.

Table 4.1: Difference of outside temperature (T_{out}) and inside temperature (T_{in}) data between simulation and measured for condition 1.

Date	Time	T_{in}(average) - T_{out}		Difference of (T_{in} - T_{out}) for measure and simulation (^oC)
		Measured (^oC)	Simulation (^oC)	
13/03/2011	10.30 am	11.0	9.5	1.5
13/03/2011	13.30 pm	12.5	12.5	0.0
13/03/2011	16.30 pm	11.4	10.0	1.4
21/03/2011	10.30 am	9.0	7.9	1.1
21/03/2011	13.30 pm	8.5	7.4	1.1
21/03/2011	16.30 pm	6.4	7.0	-0.6

For the air flow velocity profile, its shows the air from the bottom of the solar dryer was flowing to the environment through the roof opening. This was because the hot air inside the solar dryer was having lower density and rises. The cooler air from the environment moved into the solar dryer greenhouse from the side opening to replace the hotter air. This phenomenon is called buoyancy force. The air speed at the chimney was higher compare to the air speed inside the drying chamber. However as the temperature inside the chimney was lower compare to the temperature inside the drying chamber, most of the hot air was circulating inside the drying chamber and less air was able to go out through the roof opening on top of the chimney. As the temperature difference between inside air and outside air is higher on 13th March, the air flow velocity is higher due to higher buoyancy force on this date compare to 21st March. This can be seen at 1.30 pm.

At both dates, the wind speed is low which less than 1.0 ms^{-1} at 10.30 am and 4.30 pm and about 1.0 ms^{-1} at 1.30 pm. As the sensor used only can read wind speed more than 1.0 ms^{-1} the wind speed at 10.30 am and 4.30 pm is assumed to be zero. From the air flow velocity profile it was observed that the wind speed factor has contributes to the higher air flow velocity inside the solar dryer greenhouse at 1.30 pm on both dates.

4.4 Solar dryer house with roof opening open and side opening close (condition 2).

Same as the condition 1, for condition 2 the result from the CFD simulation was compared with the measured data for:

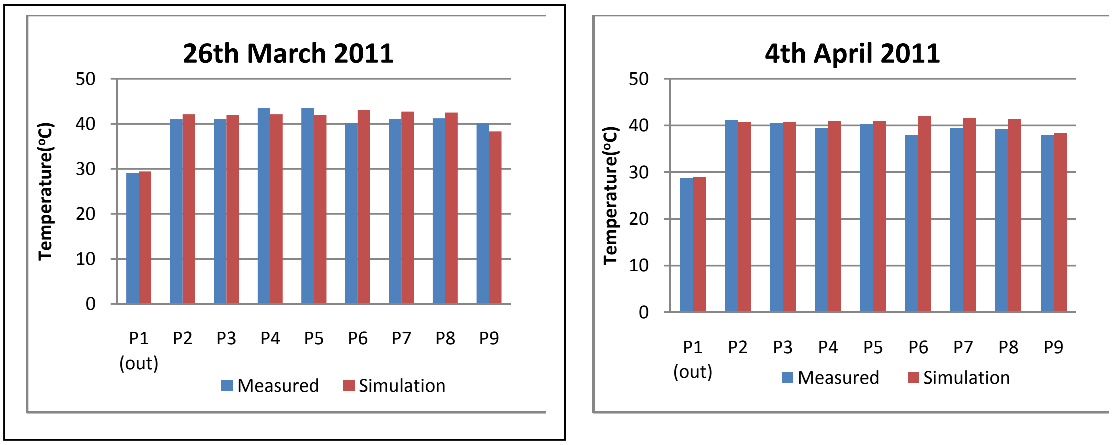
a) Temperature for location P1 to P9.

b) The difference of the outside temperature and inside average temperature.

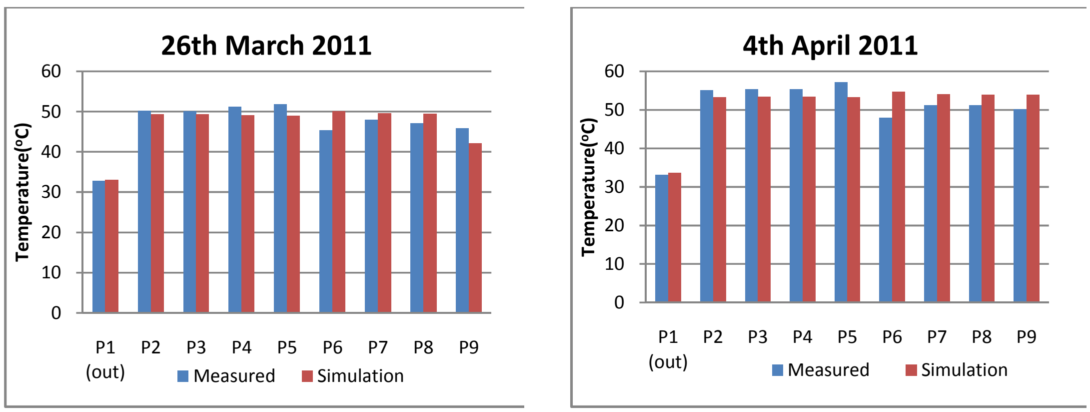
The temperature distributions contour and air flow profiles from the CFD simulation were also produce for the analysis.

The results are as below:

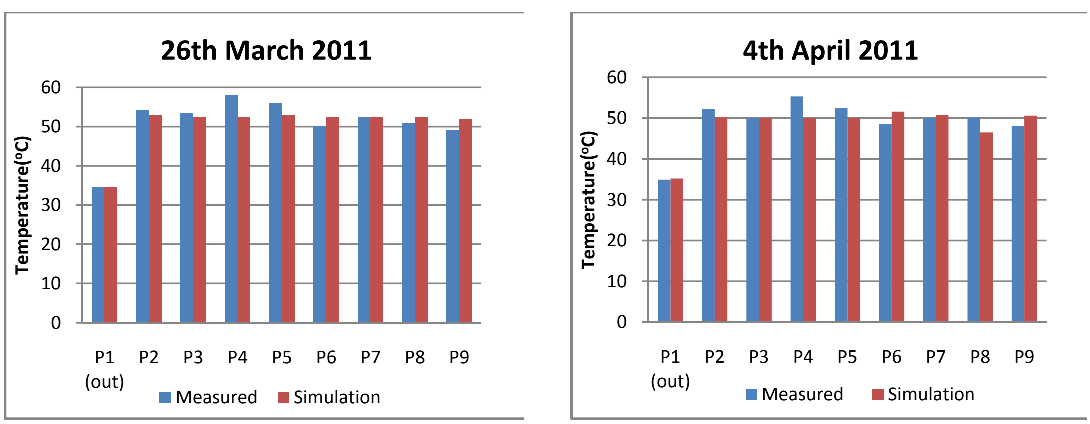
4.4.1 Temperature for location P1 until P9



(a)



(b)



(c)

Figure 4.8: Temperature for each location at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm on 26th March and 4th April 2011

4.4.2) Temperature distributions contour.

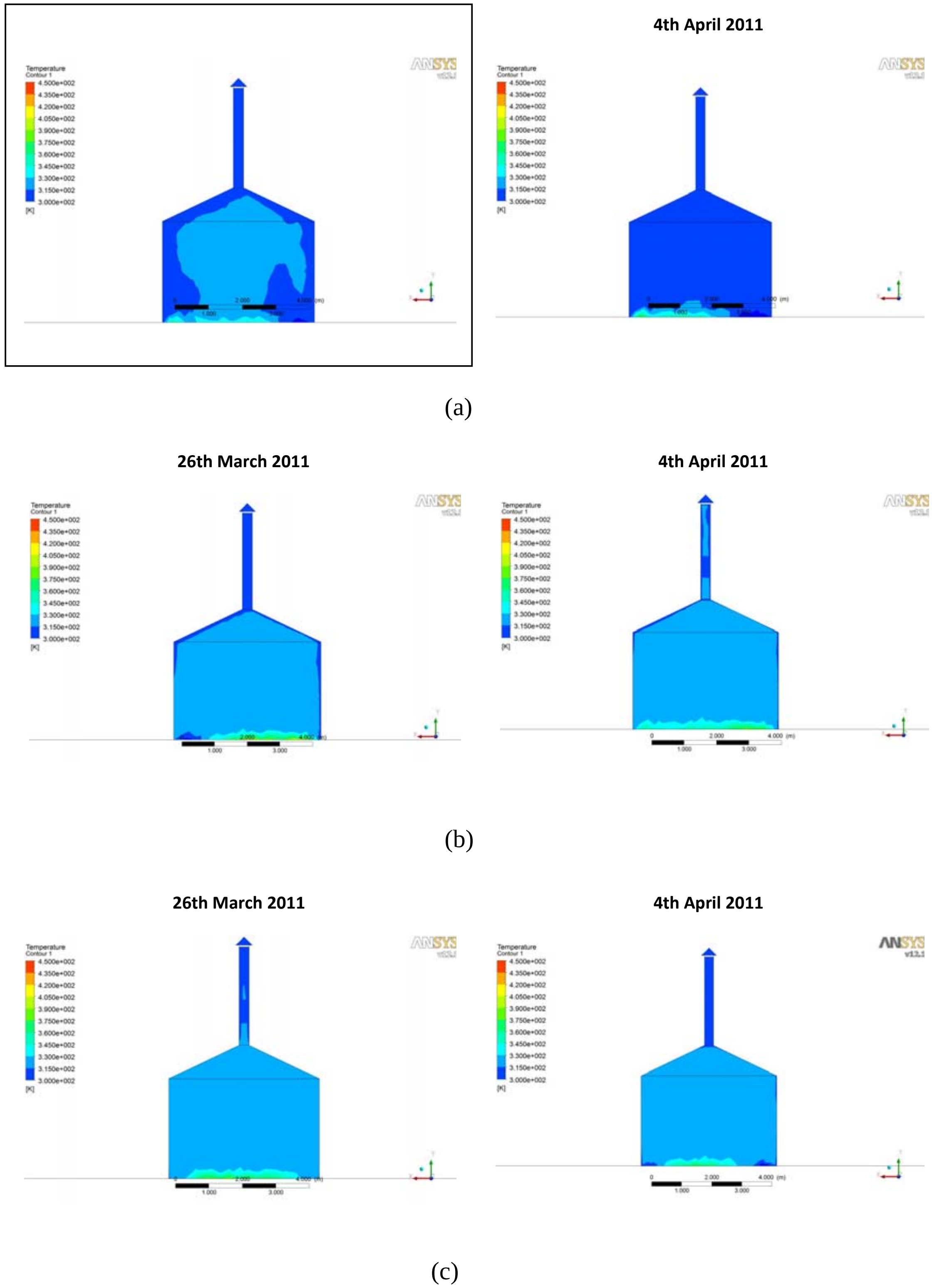


Figure 4.9: Temperature distributions contour at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm on 26th March and 4th April 2011

4.4.3) Air flow velocity profiles

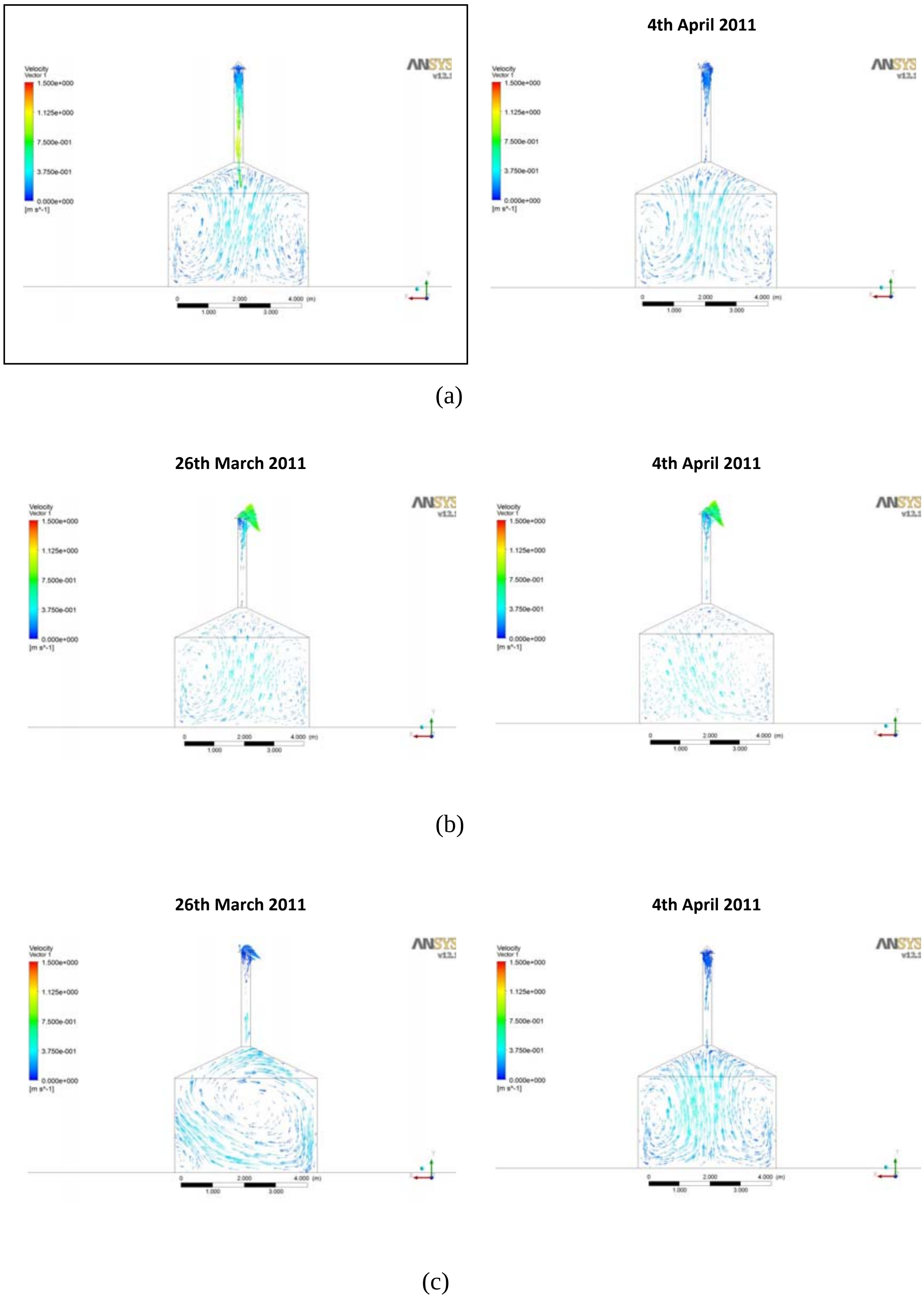
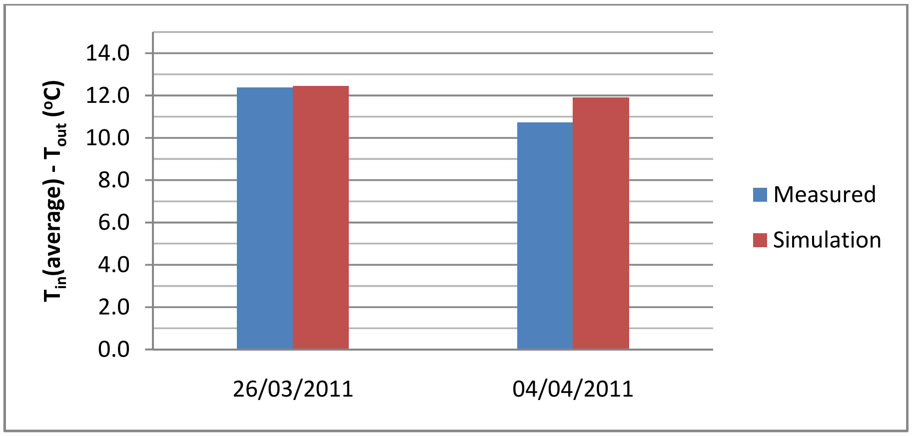


Figure 4.10: Air flow velocity profile at (a) 10.30 am, (b) 1.30 pm, and (c) 4.30 pm on 26th March and 4th April 2011

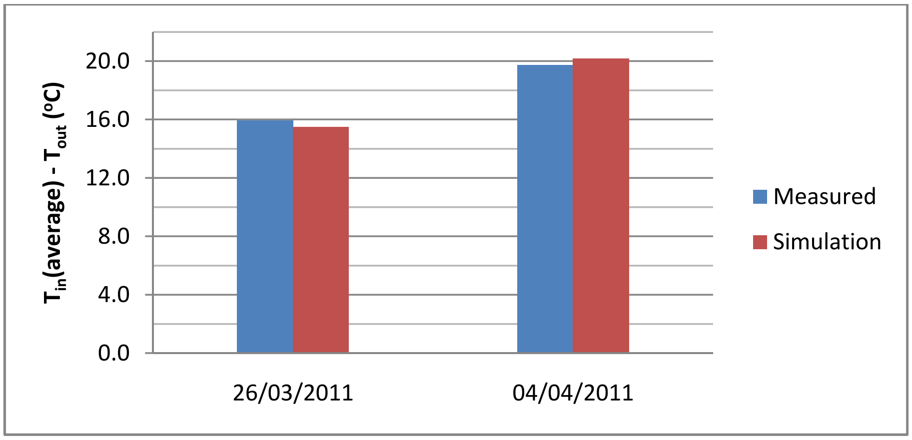
4.4.4 Data analysis and discussion for solar dryer with only roof opening open.

For the condition where only the top opening is open, two dates were selected for comparison which is on 26th March and 4th April 2011. Observation on 26th March was a clear in the morning, cloudy during noon and back to clear in the afternoon. While on 4th April it was a clear sunny day without rain. Measured data on solar radiation shows similar readings at 10.30 am and 4.30 pm for both dates, while at 1.30 pm solar radiation is higher on 4th April compare to 26th March 2011. As a result the temperature from measured and simulation on 4th April is more than 50^{o}C at 1.30 pm and 4.30 pm while on 26th March only at 4.30 pm the temperature is above 50^{o}C. The temperature distributions from the CFD simulation were similar compared to measured data. The temperature average percentage difference between measured and simulation are 3.8% at 10.30 am, 5.5% at 1.30 pm and 4.5% at 4.30 pm.

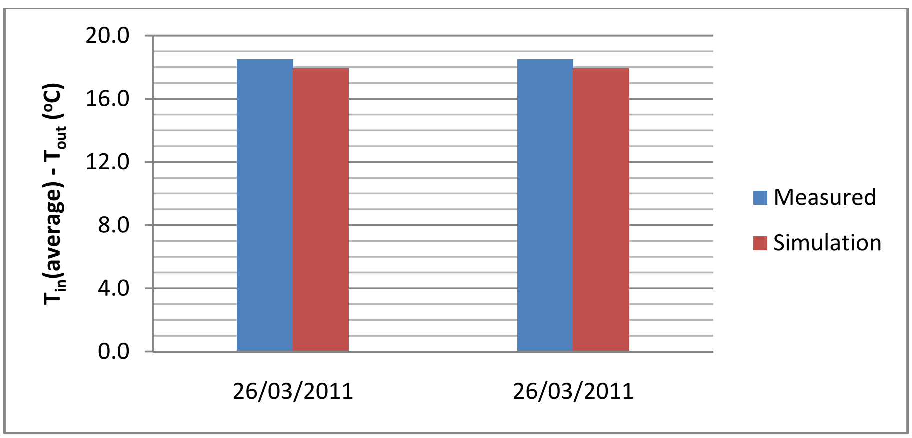
Figure 4.11 shows the temperature differences between the inside and outside air of the solar dryer greenhouse. The temperature difference is similar on both dates at 10.30 am and 4.30 pm and the temperature difference at 1.30 pm is higher on 4th April compare to 26th March. This is because the weather is cloudy at noon on 26th March. The maximum data difference between simulations and measured for the outside and inside temperature difference were 1.2^{o}C at 10.30 am, 0.4^{o}C at 1.30 pm and 1.2^{o}C at 4.30 pm (Table 4.2). The fluctuations of temperature between P1 to P9 for both CFD simulations and measured data were 8 and 9^{o}C. In all times in this condition, the temperature of the chimney was lower compare to the temperature of the drying chamber.



(a)



(b)



(c)

Figure 4.11: Measured and CFD-simulated data for differences between inside (T_{in}) (average) and outside (T_{out}) air temperature for solar dryer with roof opening only at (a) 10.30 am, (b) 1.30 pm and (c) 4.30 pm.

Table 4.2: Difference of outside temperature (T_{out}) and inside temperature (T_{in}) data between simulation and measured for condition 2.

Date	Time	T_{in} - T_{out}		Difference of (T_{in} - T_{out}) for measure and simulation (°C)
		Measured (°C)	Simulation (°C)	
26/03/2011	10.30 am	12.4	12.5	-0.1
26/03/2011	13.30 pm	15.9	15.5	0.4
26/03/2011	16.30 pm	18.5	17.9	0.6
04/04/2011	10.30 am	10.7	11.9	-1.2
04/04/2011	13.30 pm	19.7	20.2	-0.4
04/04/2011	16.30 pm	16.0	14.8	1.2

For the airflow velocity profile, in majority of the situations the hot air was circulating inside the drying chamber. This situation happened because although the hot air inside the drying chamber was less dense compared to the surrounding and tend to rises, the air in the chimney was having higher density because it has lower temperature compare to the air inside the drying chamber. This caused part of the air at the chimney tends to flow back into the drying chamber and another part of the air especially near the top opening is flowing outside. This situation can be seen clearly in figure 4.10(a).

4.5) Overall data analysis and discussions

From the result of both conditions of solar dryer greenhouse, average percentage difference between measured and simulation temperature for condition 2 is higher compare to condition 1. The temperature difference between inside and outside air was higher for condition 2, which was up to 20^{o}C, while in the condition 1 the temperature difference was only up to 12^{o}C. The lower temperature difference in condition 1 was because the cooler air from the outside moved into the solar dryer to replace the hot air through the side opening which was opened. The temperature fluctuation between P1 to P9 was higher in the condition 2. This was because the difference between the drying chamber temperature and the chimney temperature was higher in this condition.

The airflow in condition 1 is better compare to condition 2. Although in both conditions the temperature of the chimney was lower than temperature at the drying chamber, in condition 1 the cooler air from outside through the side opening is moving in and pushing more hot air with lower density up to the chimney area and flowing out to the environment through the roof opening. This situation causes less hot air trapped inside the drying chamber compare to condition 2. In condition 1, the present of wind also affect the temperature and air flow pattern and velocity. The wind will further increase the ventilation rate but at the same time will reduce the temperature inside the solar dryer house. Ventilation here is defined as the movement of air from outside a building to the inside. On the other hand for solar dryer with only roof opening open, the wind does not have any significant effect on the internal climate of the solar dryer.

As a conclusion from the result, solar dryer with only roof opening open was having higher temperature difference between inside and outside air, but have poor ventilation. While for solar dryer with both side wall and roof opening open, the temperature difference is much lower but the ventilation is better compare to previous condition.

To make a drying process efficient, having high temperature different and also good ventilation rate is important, therefore some modifications are needed for the current solar dryer design to ensure both factors are achieve.