Study the effects of Physical Parameters on performance in Solar Chimney

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Abstract - **The solar chimney is also known as solar updraft system that is an economical way to generate ventilation for house or space. The solar chimney has two major parts, which are called solar collectors and chimney or draft. The solar chimney can be also used for cooling space as well as for distilling sea water. In the solar chimney system, the air is heated by suing solar radiations collected by solar collectors. The warm air rises up because of the buoyancy effect as it`s gets less denser and it will exit through the chimney. The main identified problem in the solar chimney is the height to create the sufficient draft. A new type of chimney is designed and tested by the Chu et.al. in the year 2012 that significantly reduced the height of the solar chimney. Circular and square based chimney models are used for the study and found that modified chimney be able to enhance about 60% flow rate and exit air temperature. The effects of the physical parameters are not yet investigated in the new type chimney therefore under this paper it is aimed to investigate the effects of physical parameters on solar chimney air flow rate as well as exit air temperature.**

Keywords: solar updraft chimney; ventilation, solar energy

1.0 INTRODUCTION

Chimney is a structure that is used for ventilation to exile hot flue gases to the outer atmosphere. Mostly, it is found in vertical erected or almost near to vertical shape, the process of exhaling hot gases is known as Stack effect and the this process is known as natural convection process in which air moves due to buoyancy effect. There is no fan or pump is used while these are most essential component of forced convection system. Chimney has been widely used in locomotives, cooling towers in industries for removing waste heat and homes for ventilation and so on. Solar chimney or solar draft natural convection process can be used for home as alternative forced or mechanical cooling system. This passive system doesn`t need any device that is operated electrically as moving component. Moreover it`s work on solar radiation which makes the system environmental friendly and economical. Solar chimney consists of two major parts solar collector and draft or chimney. The working principle of solar chimney is quiet simple, the air is heated by solar radiation absorbed by the solar collectors (heat source). The warm or hot air received more kinetic energy to initiate movement and it`s rises up. This effect is known as buoyancy effect, the less dense air that leads to the draft from which it is exhale. The efficiency of solar chimney depends on the radius of collector, design of collector pattern and quality of material of collectors. Moreover efficiency also depends on the physical shape of the chimney, height and diameter. Solar chimney can be used for power generation, pudding drying and seawater distillation. Therefore, the aim of this project is to develop a different shaped of the chimney and evaluate the performance. In this paper, the simulation results are presented to validate the design of solar chimney.

2.0 LITERATURE REVIEW

Globally, the cooling system mainly air conditioning units are utilizing more power than to heating system. Study showed that alone the United Stated uses the power for cooling appliance (air conditions) are equivalent to power usage by completely entire Africa. Additionally, utilization of power on air-conditioning significantly contributes global warming as vast as fossil fuel have been used to generate power. The leakage of refrigerant is also responsible for global warming and other pollutions that promotes a lot respiratory and cardiac diseases [1][2].

However, the thermal comfort is also necessary which cannot be denied. The best way to achieved it by using sustainable technology. One of the appropriate and valid suitable option is solar chimney that works on the principal of buoyancy effect. As mentioned earlier that the warm air rises due to less dense replaced by the cold air from the house or space. Additionally, the usage of chimney can also reduce the electricity bills significant amount. The history of chimney is not new. The earliest chimney was found at 12^{th} of century during romans period, then a lot of works have been done to increase its efficiency basically for enhancing draft. The application solar chimney is found for power generation. The first prototype of

solar chimney for power generation was constructed in Spain. Conducted a CFD simulation study on Spain prototype model [3]. Another researcher Rajput et.al., in the year 2017 performed simulation by using ANSYS software for the same porotype model in Spain. The solar chimney was modified with throat at inlet and it is found that it significantly enhance the efficiency [4]. Additionally, Sakir et.al., in the year 2014 performed experiment study on solar chimney [5], Ming et.al., in the year 2017 and Zuo et.al., in the year 2011 simulated solar chimney and developed a mathematical model for sea water distillation. The main aim of the work is to use solar power to obtain fresh water[6][7], Klimenta and Peuteman in the year 2014 is introduced the theoretical concept of solar chimney with square based pyramidal shaped [8]. Furthermore, Beneke et.al in the year 2016 introduced the solar chimney octagon shaped [9]. At the same year Ubhale simulated solar chimney which was divergent and convergence shape. From the findings, it can be concluded that divergent is more efficient than to convergent shape of the solar chimney [10]. The convergent shaped chimney can be choked if ratio between surrounding pressure and exit chimney pressure is lower than 0.528. The mass flowrate will be decreased as same as when chocking is present in the nozzle [11].

3.0 METHODOLOGY

Solar chimney technology is combined with solar collector, a heating section and draft chimney. Under this project different shaped solar chimney models are designed by using CAD software. The height and diameter of the chimney are maintain 3 m and 0.4 m respectively, with a vertical inclination angle 2^o at the throat. Study showed that it is the most efficient angle at the throat to increase the efficiency of bell mouth [12]. The software "ANSYS Fluent version 19.0" is used for the air flow simulation in the chimney. The simulation was carried by using very finest mesh and number of iteration to achieve better efficiency. The inlet velocity is calculated from the following differential pressure equation and has been chosen as inlet velocity during simulation.

$$v = \sqrt{2gh\frac{\Delta\rho}{\rho}}$$

$v =$ Velocity, g stands for the acceleration due to gravity, h for height of the chimney and ρ is density of air. While the density can be, calculate using below expression

$$(\rho - \rho_0)g = -\rho(T - To)g$$

Where, ρ_o and T_0 are the air density and ambient temperature. The approximate value of the air density is considered 1.225kg/m^3 on standard temperature 298k and pressure 101325pa, while ρ and T are density and temperature at processes site

In the simulation process, air is considered as working fluid in this paper. At the inlet and exit of the chimney are considered normal temperature 293k and gauge pressure at 0Pa that is equals to 1 atmospheric pressure 101325Pa.The system is considered as isentropic so solar radiations, heat transfer through convection from outside could be neglected. The frictional loss due to wall roughness is also consider negligible and there is no heat loss from the system that makes change of entropy negligible. The bell-mouth radius and height are calculated from the following equation.

$$BM_r = 0.2{\sim}0.4 \times D_h$$

$$BM_h = 0.2{\sim}0.8 \times D_h$$

Where BM_r, BM_h stands for bell-mouth radius and height, while D_h represent the hydraulic diameter of the cylindrical shape chimney. For circulation chimney the hydraulic diameter is same as diameter of the chimney.

Study showed that the divergent chimneys are more efficient than the conventional circular chimneys. In the divergent and convergent chimney the fluid moves due to the pressure difference between inlet and outlet. In the divergent chimneys the air velocity is found higher at throat and that convert into pressure during operation. The flow rate in the chimneys can be calculated by using the following equation

$$\dot{m} = \rho v A$$

Where $\dot{m}$ represent mass flowrate v is velocity and A is area

4.0 RESULTS AND DISCUSSION

A divergent convergent solar chimney was design. Flow simulation was run to understand the velocity and pressure drop in the solar chimney. The maximum velocity is observed at exit of the convergent section which is about 4.4 ms^{-1}. The simulation for velocity is shown in the Figure 1. The velocity drop in the divergent section. In this simulation, it is also noticed that the pressure at the throat is less and the pressure at the exit of the chimney is much higher normal standard pressure as gauge pressure have been used. The sample simulation results for pressure is shown in the Figure 2. In convergent section of the chimney the pressure at the exit decrease due to the venture effects. According the Bernoulli energy equation the velocity increase leads the static pressure drop. If the pressure at exit of the convergent section of chimney is reduced and reached less than atmospheric pressure then reverse follow phenomenon can be observed at the exit of the chimney that is known and chocking or flow reversal or back flow. Which is unexpected and undesired phenomenon in the natural draft chimney. It reduced performance of the chimney significantly [13]. The pressure can be reduce almost 4 times even more compare to the throat depends on the area ratio between convergent section inlet and outlet. In the divergent section of the section chimney the air velocity slows down at the exit, so the static pressure values increased up to greater than 0.5Pa which is gauge pressure that will be 101325.5Pa that is greater than atmospheric pressure and made the flow steadier just like cross ventilation. It is also found from the simulation results that throughout the divergent and convergent section of the chimney the temperature differences are relatively very small in magnitude. Therefore the energy losses depends on the properties of air. This finding can be supported by the Klarin et al., 2009 who published a

simulation work for the improvement of the flow inside the solar chimney [14]. The simulation results are used to determine the physical dimensioned of the solar chimney which is more efficient than conventional circular design,

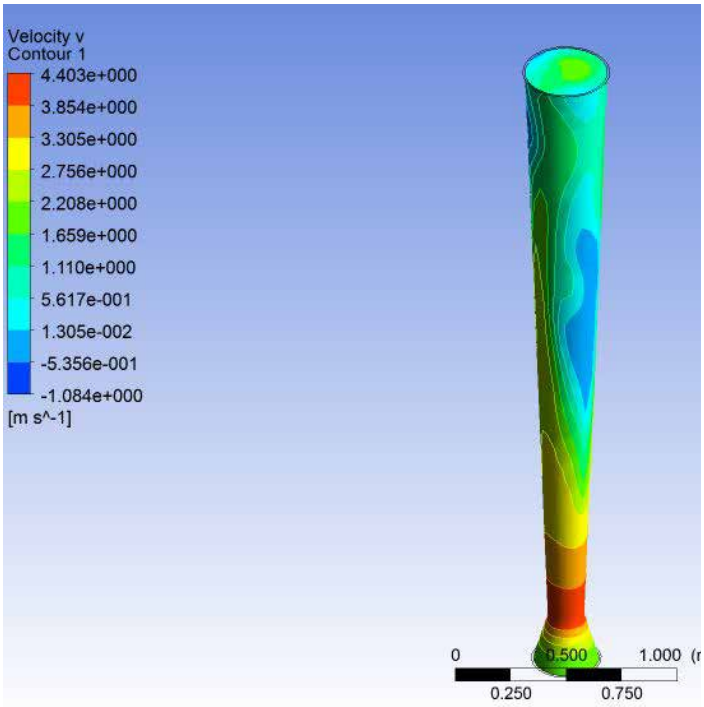

Figure 1: Velocity distribution for Solar Chimney

5.0 CONCLUSION

The demand of air conditioning is increasing day by day, which demands more energy that promotes pollution and global warming as the usage of fossil fuel is extent. The divergent shaped solar chimney is efficient way to achieve the thermal comfort and it cuts electric bills. Solar chimney is also environmental friendly as it works on natural convection unlike forced convection

6.0 ACKNOWLEDGEMENTS

The authors would like to express gratitude thanks to the Ministry of Higher Education of Malaysia and Universiti Malaysia Sabah for their financial and facilities support through Fundamental Research Grant (FRG0429-TK-1/2015). Additionally, the authors would like to thank all the group members for their continuous support to complete this project.

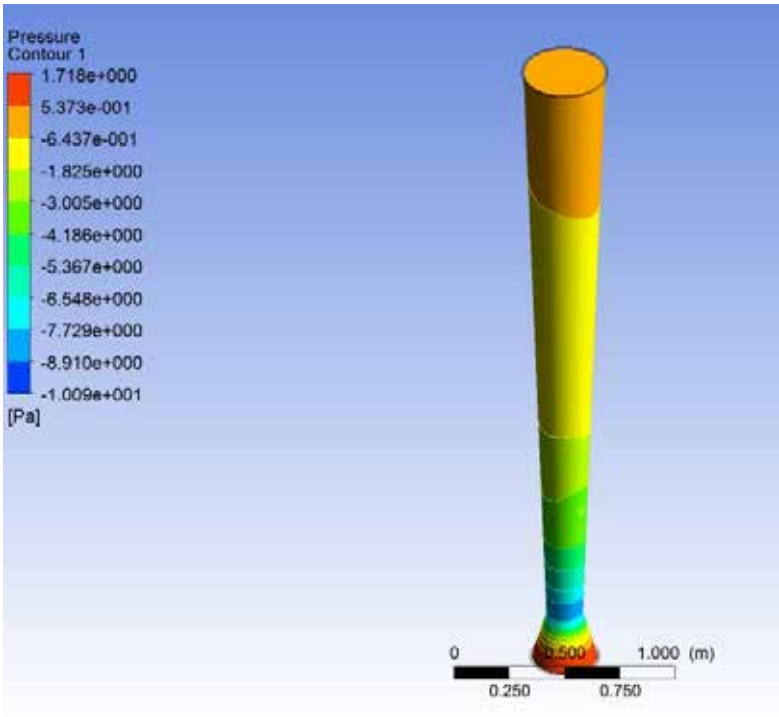

Figure 2: Pressure distribution inside the solar chimney

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