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A RESEARCH PAPER ON SOLAR THERMAL CHIMNEY DESIGN

Engineering

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ABSTRACT

This work aims to focus on the real ground problem power and water the CAD design focused on the power in remote area and clean and drinkable water in coastline area of the world. This is conceptually investigating the solar chimney and designs the energy flow in evaluating the system's feasibility. The piece starts with creating a model of the solar chimney and its comparison to experimental observations, demonstrating that the results. The model represents a steady temperature and velocity inside the chimney, allowing for the development of a basic model of the chimney that provides accurate results. Finally, a modification of solar chimney and other systems put in a structure is simulated the fluid collection and power generation.

KEYWORDS

Renewable Energy, Solar Chimney, declination angle and Local apparent time (LAT)

INTRODUCTION

Solar chimneys are new generation of solar power plants which can absorb both direct and indirect solar radiation and help generate power by aid of the formed hot air flow along with the chimney effect. Common solar chimneys consist of three parts: the solar collector or the greenhouse that absorbs the solar radiation, the chimney that due to providing chimney effect sucks the hot air upward, toward the chimney outlet, and the turbine which is installed in the chimney to generate power from the hot air flow within the chimney. The air content beneath the Collector warms up due to absorption of solar radiation. Then due to buoyancy effects, the warmer air sucked into the chimney, which is located at the center of the collector. A turbine is usually installed in the path of the airflow to generate electricity [1].

Theory

Fluid dynamics

The Navier-Stokes equations describe the motion of a fluid substance:

- Continuity

$$\frac{\partial \rho}{\partial t} + \nabla(\rho \vec{u}) = 0 \qquad (1)$$

- Momentum

$$\rho \frac{\partial \vec{u}}{\partial t} + \rho \vec{u} \nabla(\vec{u}) = -\nabla p + \frac{\mu}{\rho} \nabla^2 \vec{u} + \rho \underline{f}_m \qquad (2)$$

- Energy

$$\rho \frac{\partial c_p T}{\partial t} + \rho \vec{u} \nabla(c_p T) = -p \nabla \vec{u} + \bar{\bar{\tau}} : \nabla \vec{u} + \nabla(k \nabla T) \qquad (3)$$

These equations do not have an analytic solution; therefore, they usually simplify these to achieve an approximate solution [2]. The dimensionless number is used to carry out these simplifications, as the Reynolds number or the Rayleigh number.

The Reynolds number gives a measure of the ratio of inertial forces to viscous forces. Consequently, it quantifies the relative importance of these two types of parties for given flow conditions.

$$Re = \frac{\rho U D}{\mu} \qquad (4)$$

When this number is high (Re>>1), the viscous forces can be neglected. Also, when Re<2300 in ducts, a laminar flow occurs, and for Re>4000, the flow is turbulent.

The Rayleigh measures the importance of buoyancy-driven flow). When the Rayleigh number is below the critical value for that fluid, heat transfer is primarily in the form of conduction; when it exceeds the critical value, heat transfer is mainly in the form of convection.

$$Ra = \frac{g \beta \Delta T c_p \rho^2 L^3}{\mu k} \qquad (5)$$

Besides, in pure natural convection, the Rayleigh number measures the strength of the buoyancy-induced flow. When $Ra<10^8$ indicates an induced laminar flow and a transition to turbulent flow among $10^8<Ra<10^{10}$.

Bernoulli Equation

The Bernoulli equation results from the simplification of the Navier-Stokes equations assuming and inviscid fluid (Re>>1).

$$\frac{1}{2}\rho v^2 + P_s = cte = P_t \qquad (6)$$

This means, if the velocity increases, the static pressure has to decrease.

This equation can be completed by summing the effects of gravity and a turbomachine.

$$\frac{1}{2}\rho v^2 + P_s + \rho g h + \Delta P_{fan} = cte = P_t \qquad (7)$$

Pressure Loss

In every duct system are present pressure losses due to the circulation of a fluid inside a duct (primary pressure loss) and caused by additional components as a valve, contractions or inlets (secondary pressure loss). These pressure losses can be incorporated in the Bernoulli equation:

$$\frac{1}{2}\rho v^2 + P_s + \rho gh + \Delta P_{fan} = P_t + \frac{1}{2}\rho v^2 \sum K_{drop} \quad \textbf{(8)}$$

The total coefficient of pressure drop ($\sum K_{drop}$) is the sum of the primary pressure loss and secondary pressure loss.

Primary pressure loss

$$f\left(Re, \frac{\epsilon}{Dh}\right) \quad \textbf{(9)}$$

$$\frac{L}{Dh} L = length of the duct$$

D_h= hydraulic diameter of the duct

$f = friction coefficient of Darcy$

$\epsilon = rugosity of the duct$

The friction coefficient of Darcy can be estimated with the Moody chart.

- The secondary pressure loss depends on the components of the system. Every detail has its coefficient of pressure loss, and in most cases, can be calculated with charts. In this thesis, the secondary pressure is the inlet, outlet, nozzle and valve. All these components have a constant coefficient of pressure loss.

Buoyancy And Stack Effect

Buoyancy is the force, along with the gravity, involved in the movement to the upper positions of an object or fluid with less density than the fluid surrounding [3].

In ideal gases, when the temperature increases, the density decrease, thus a movement between the cold and warm zones appears. This movement is knowledge as the Stack effect [4]. The pressure difference of the stack effect is the following equation 10.

$$\Delta P_{stack} = gH\Delta\rho$$

$$\Delta P_{stack} = \rho g H \frac{\Delta T}{T_i} \quad \textbf{(10)}$$

The problem of this driven force is that it connects the energy and momentum equations (equations 14 and 11), hindering the solution of the problem.

To get a faster solution, usually is used the Boussinesq Model. This model treats the density as a constant value in all the equations except in the buoyancy term of the momentum equation.

$$\rho = \rho_o(1 - \beta\Delta T) \rightarrow \beta\Delta T \text{"}1 \quad \textbf{(11)}$$

$$\Delta P_{buoyancy} = \rho g H \beta \Delta T \quad \textbf{(12)}$$

Working

The solar radiation is abundant in nature and the radiation energy is used to convert into sustainable energy. The radiant energy is used to heat the fluid (air). The inclined canopy helps the air to move towards the tower having the lift force. The lift force is used to run the turbine to produce electricity. The fluid temperature decreases and moisture in air condensed to water and can be used in various applications such as drinking or in boiler. The area under canopy can be used as green house farming.

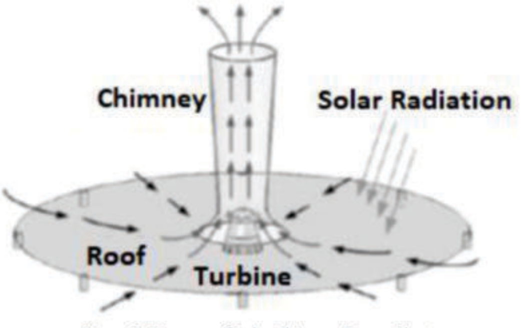

Figure 2: Diagram of Solar Chimney Power Plant

RESULT

The following conclusion could be drawn.

The design of the solar chimney allows using simple physical models, knowing its properties (flow rate and temperature) and modeling the size (height and solar collector area) due to the uniform velocity and temperature appears inside the chimney. Also, these characteristics of the flow make it possible to use all the knowledge of the standard flues in this solar chimney.

The solar chimney can be used in both types of climates (warmer and cold), and for reasonable height, it is the type of solar chimney that gives the highest flow rate. Only in warmer temperatures and in tall buildings the solar chimney will provide better results.

The chimney's solar efficiency depends on the magnitude of solar radiation and the difference in temperatures between the building and the surroundings. Therefore, only when the temperature difference is near zero, the solar chimney makes sense to use it.

A solar chimney with a heat recovery improves solar efficiency but hinders air exchange. For that reason, only hybrid ventilation systems with the support of a fan and enough flexibility to change the course of the flow rate should be used with the solar chimney and heat recovery.

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