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A REVIEW ON SOLAR AIR HEATER DUCT WITH TRANSVERSE VORTEX GENERATORS

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Abstract

Growing energy needs from a thriving global economy, and the damage done by burning fossil fuels, are two of the world's biggest problems. Renewable energy sources provide a solution to both of these issues. Over the last decade, there has been a surge of interest in this area from government officials, financiers, and academics. A solar air heater (SAH) is an appliance that makes use of solar thermal technology to lessen the load on electrical use for tasks like heating, cooling, and drying in homes, businesses, farms, factories, and other settings. Modifying the SAH-duct route and the absorber plate may increase thermal efficiency, which is the main issue with SAH. The SAH-domain has never seen the use of transverse vortex generators (TVGs), despite their widespread use in basic research, gas turbine blades, and micro-channels. This study optimises the smooth rectangular duct of a solar air heater (SAH) geometrically in order to improve the SAH's thermal-hydraulic performance using in-line circular thermo-viscous gradients (TVGs). This work paves the way for further investigations into the use of TVGs to improve heat transmission in the SAH-domain. Some potential directions for further study are listed below. There needs to be a 3D numerical study to see the effect of side-walls, a more advanced experimental study using high-speed cameras and thermal sensors, a fluid-structure-interaction study for vortex-inducedvibrations to further improve heat transfer, and TVGs with a variety of cross-sections (square, rectangle, ellipse, etc.) arranged in a variety of configurations (side-by-side, staggered, etc.).

Keywords: *Transverse vortex generators (TVGs), solar air heater (SAH), 3D numerical investigation. gas turbine blades.*

Introduction

When burning fossil fuels, harmful emissions are released into the air. Air pollution from fossil fuel emissions is responsible for 3 percent of global GDP loss and 5.1 million deaths annually. The greenhouse effect caused by the 35 billion tonnes of carbon dioxide produced year by burning fossil fuels is the primary driver of climate change and global warming. However, since 2015, global energy consumption has increased at a pace of above 2.5%. The long-term goal of the 2016 Paris Agreement is to limit global warming to 2 degrees Celsius over pre-industrial levels. A rapid, large, and coordinated shift away from fossil fuels and towards non-fossil fuels is required to accomplish our Paris accord and SDG7 commitments while also striking a balance between global development and climate change. The world's primary energy sources are broken down into four categories: fossil fuels, nuclear power, hydropower, and renewables. However, India has lately included hydroelectric in the renewables category so that it may take advantage of government regulations favouring renewables. Whether or not hydropower is renewable is contentious owing to its very large environmental baggage. As of 2018, 85% of the world's primary energy consumption came from fossil fuels (specifically, 34% from petroleum, 27% from coal, and 24% from natural gas). While 4.4% comes from nuclear power, 6.8% from hydropower, and 4% from renewables. In terms of capital expenditures and new installations, interest in fossil fuels, nuclear power, and hydropower has been on the wane as of late, while interest in renewable energy sources has been on the rise. Localised sources, such as power plants and cooking, are easier to regulate than non-localized sources, such as traffic, which contribute significantly to air pollution. Economic growth and rising living standards need access to both electricity and a clean cooking fuel (two major contributors to localised air pollution). Having a cleaner option for energy and cooking fuel will significantly reduce pollution levels. Approximately 40 nations have an electrification rate of less than 50%. While the percentage of people with access has climbed from 71% in 1990 to 89% now, there are still almost 840,000,000 individuals who have never been inside a home with electricity. Despite India's recent success in electrifying the whole country (a hamlet is considered electrified if 10% of homes have electrical connection), providing energy for 24 hours a day is still a major problem. More than 2.6 billion people globally, including 670 million in India, lack access to safe cooking fuel, and indoor air pollution is directly responsible for almost 5 million fatalities each year. India must pursue a greener replacement for this massive energy consumer if it wants to continue economic and social development. In this part, we'll examine the current potential, production, consumption, per capita demand, etc., of a wide variety of energy sources. Since these regions include the bulk of the global population, we don't only compare India to the rest of the globe; we also compare Brazil, China, Russia, the United States, Europe, and Africa.

Solar energy

As of December 2019, the world's total installed capacity for renewable energy sources is 2536.8 GW, with solar energy accounting for a total of 586.4 GW of that figure. With a total of 330.1 GW, Asia accounts for the lion's share. The countries with the highest contributions are China (205.7 GW), Japan (61.8 GW), India (34.8 GW), and South Korea (10.5 GW). 138.2 GW, 68.2 GW, 16.23 GW, 15.9 GW, 7.14 GW, 6.46 GW, 6.36 GW, 5.14 GW, and 2.1 GW are the respective totals for Europe, North America, Oceania, Australia, Eurasia, South Aerica, Africa, the Middle East, Central America, and the Caribbean. The United States and Germany each have the biggest percentage on their respective continents, with 60.5% and 49.9%, respectively. Figure 1 illustrates how rapidly the solar energy industry is expanding in comparison to other renewable energy sectors throughout the globe. In 1982, a 1 MW power plant in Lugo, USA, demonstrated the viability of solar energy; by 2020, Badhla Solar Park in Jodhpur, India, with 2245 MW of SPV capacity, would be the biggest in the world. India is also home to the second-largest solar park, the Pavagada Solar Park near Tamkur (2050 MW). In November 2009, India's government established the Jawahar Lal National Solar Mission to accelerate the country's transition to solar power. In 2010, just 161 MW of solar power was in place; by 2015, that number would increase to 3.8 GW, and by 2020, it would reach 46 GW. The 113 GW by 2022 goal has been established. India has set a goal of 450 GW of renewable energy, but it is expected to exceed 500 GW, with solar energy accounting for more than 70% (more than 300 GW) of that total. Only 46% of power is generated privately, but that number is expected to rise in the future years, which will allow for capacity increases in excess of goals. ‘

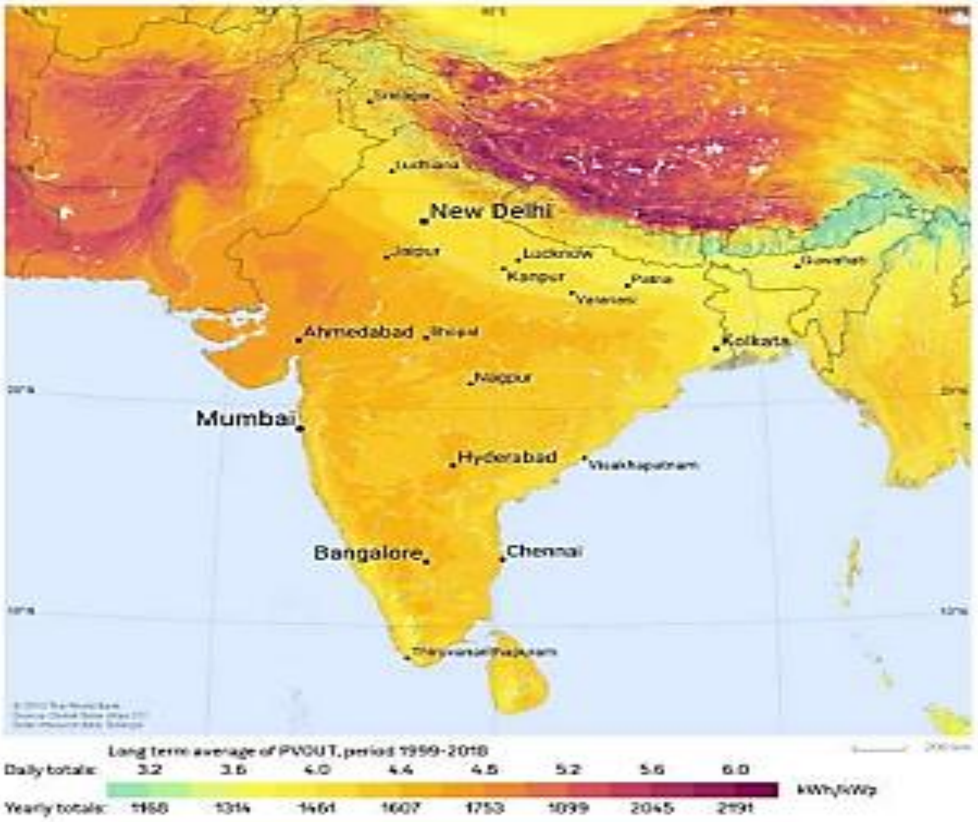


Figure 1. Solar energy potential of India

Solar air heater

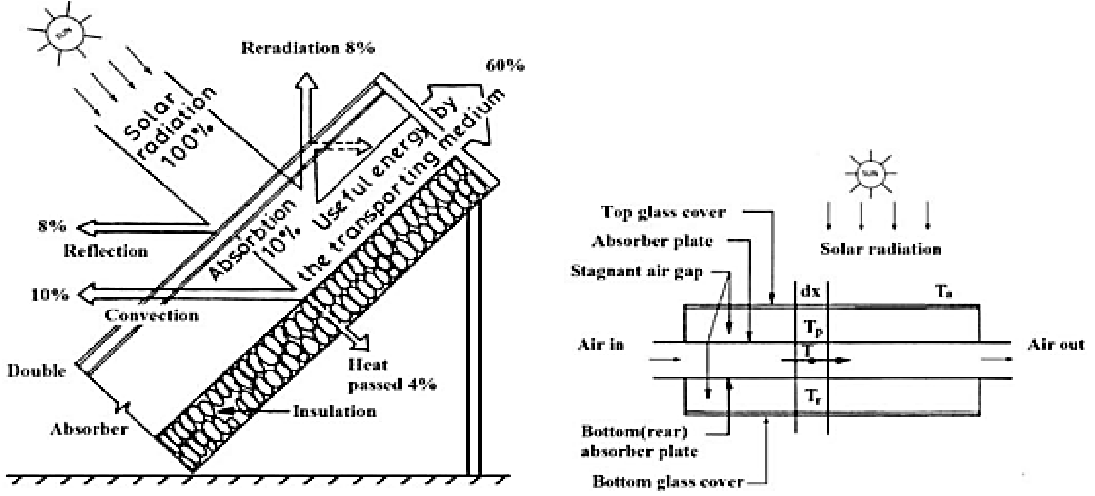
Although renewable energy's primary impact is in the production of electricity, which is the most versatile and adaptable source of energy. The solar PV industry is also the primary focus of solar energy studies. Only 10% of the 586 GW total solar installed capacity is accounted for by CSP (Concentrated Solar Power), the second most common solar harnessing device after PV channels. Solar air heaters (SAH), solar chimneys, solar lights, solar pumps, water heaters, solar cookers, thermal energy storage, water treatment, etc. are all examples of small-scale equipment that may capture solar energy and reduce or eliminate the need for electricity. It's often held that reducing one's energy use is equivalent to producing new power. Not only do these devices have a high solar conversion rate (up to 90% or up to 500-600 peak thermal W/m2), but they also have a low capital cost, use air as a working fluid that is both non-corrosive and non-reactive, and are constructed out of more environmentally friendly and less expensive materials than PV channels. In this paper, we examine one such device, a solar air warmer, that relies on solar thermal technology rather than electricity. The gadget uses solar energy to warm air, which may then be used in a wide range of commercial, agricultural, and residential settings. However, unlike a solar water heater, a considerable quantity of air must be managed, and it has subpar thermal qualities.

Applications

In order to heat a room, air is sucked in from the surrounding area or the building itself, forced through a SAH-duct, and then heated by convection and conduction from an absorber plate.

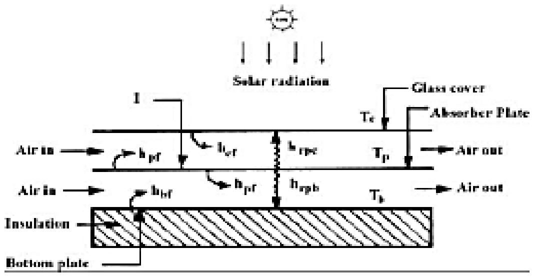
Drying crops in agriculture, drying garments in hotels and hospitals, drying food and packaging it in food companies, etc. all benefit from warm air.

At night, heat is dissipated when long radiation waves from the warmer surface (a roof or metal in this example) travel into the cooler night sky. Cold air may be brought into HVAC equipment to cool any system in the summer by forcing the hot ambient air to flow over a cooler metal surface, where the heat is dissipated into space.



(a) Conventional SAH

(b) Double exposure SAH



(c) Both side flow SAH

Figure 2. Various types of non-porous SAH

Literature Review

The use of dimples and delta winglets (DWs) as a vortex generator in a supersonic aircraft wing (SAH) was computationally explored by Luo et al. [1], who found that the use of these features dramatically enhanced friction loss and heat transmission.

Using a variety of wavy delta-winglet geometric parameters, Sawhney et al. [2] performed an experiment in a SAH duct and found a maximum thermo-hydraulic performance of around 2.09. Skullong et al. [31] presented numerical and experimental work comparing the thermal performance of the P-TWVG and the P-RWVG, two types of perforated trapezoidal- and rectangular-winglet vortex generators used to improve thermal-hydraulic performance in a SAH duct.

Heat transmission may be increased using the slanted projecting winglet pair, as indicated by Oneissi et al. [3].

In an experimental study, Baissi et al. [4] found that the performance boost provided by a perforated delta-shaped vortex generator (VG) on an absorber was greater than that provided by a non-perforated VG. Experimental research by Zhang et al. [5] looked at the effect of V-shaped WVGs on the assessment of flow friction and the improvement of ultrafine particle deposition in an air duct.

Perforated elliptical- and delta-winglets (P-EW and P-DW) on the absorber were used in an experimental investigation of turbulent flow and thermal behaviours in a SAH by Promvonge and Skullong [6]. Both winglets were found to achieve their best thermal performance at a value of 2.1, however the P-DW outperformed the P-EW.

The evaluations cited above demonstrate that the use of VG devices in the shape of winglets results in improved thermal performance throughout a broad range of Reynolds numbers with just a little increase in friction loss. In this way, a well-thought-out VG device, such as a rectangular or delta-shaped winglet, may generate more powerful longitudinal vortices without causing a recirculation zone behind it, resulting in less drag. CFD studies on flow pattern and heat transfer in a SAH duct with punched winglets are extremely rare, especially for the punched delta-winglet (P-DW) and the flapped delta-winglet (F-DW), despite the fact that numerous investigations on the winglet-mounted absorber have been proposed. The primary goal of this work is to use a CFD model to investigate the turbulence and temperature distributions in a SAH duct with varying geometric characteristics. The current calculation is performed for Re = 4000 24,000 and involves a 3D turbulent periodical duct flow across 30° P-DW/F-DW installed on the absorber plate.

The classic solar air heater relies on heat convection from the absorber plate to the surrounding air. The absorber plate's high thermal resistance or the air's poor heat transfer capabilities contribute to this very low value. The thermal efficiency of an air heater may be improved by increasing its heat transfer coefficient. Increasing the flow's turbulence or introducing artificial roughness to the surface are also ways to boost convective heat transfer. The pace at which heat is transferred to the surrounding air by convection may be improved in a number of ways. About 14 different types of heat exchanger improvements were catalogued by Bergles et al. [1]. There are two broad categories into which these various methods of improvement may be placed: active and passive. There are two distinct categories for these approaches. There are two types of approaches: active and passive. The former makes use of an external energy source to disrupt the flow, while the latter makes use of any inserted devices. Solid devices that may be inserted or installed into the flow channel are known as insert devices. Insert devices, which are often employed in channel heat exchangers, include things like ribs, fins, baffles, and winglets. Vortex generators are insertion devices that disrupt flow by creating vortices. When introduced into the flow, these vortex generators generate secondary flow in the form of longitudinal vortices[2,3], which disrupts the thermal boundary layer that forms along the wall. Additionally, this will cause large-scale turbulence, which will move heat form the wall to the centre of the flow. By increasing both heat transfer and pressure drop, vortex generators in channel radiators may boost pumping efficiency. Puncturing holes at strategic locations in vortex generators helps minimise pressure drop.[8]

Classification of SAH

Non-porous SAHs and porous SAHs are the two primary categories of solar air heaters. Additional categorization of these two primary SAH kinds is explained below with appropriate schematic illustrations.

Non-porous SAH

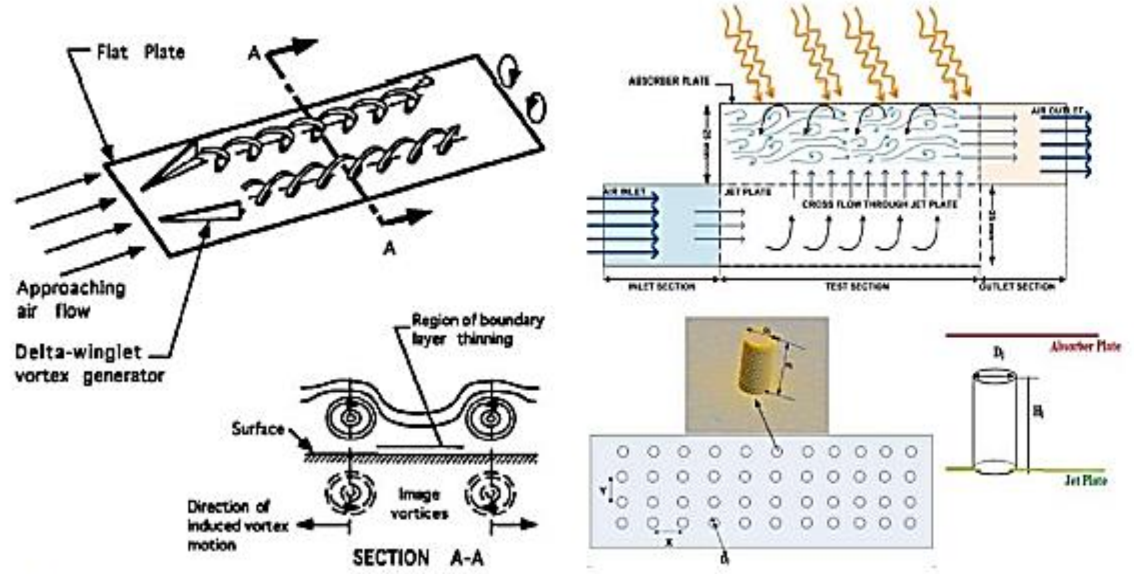
A non-porous solar air heater (SAH) is only a smooth duct without any heat-absorbing components. In addition, there are many varieties of non-porous SAH, delineated by where the air is flowing: (a) above the absorber plate, (b) below the absorber plate, or (c) on both sides of the absorber plate. Case (a) is not advised since the absorber plate is exposed to direct sunlight via a glass cover plate, leading to higher temperatures and more top heat losses than in case (b). The many forms of SAH are discussed in depth below.

SAH with airflow on both sides of absorber plate

See Fig.3 for an illustration of the upper and lower air passages included in this SAH design. Air initially passes over the absorber plate in the top route before descending via the bottom passage. This kind of SAH will have a higher exit air temperature and greater thermal efficiency. Heat will be lost and the air temperature will be lower in the higher air channel than in the lower air passage. Insulation separates the upper and lower tubes, whereas a single absorber plate serves both.

Thermal-hydraulic performance enhancement techniques

The heat transmission is impeded when comparatively cold air flows over the absorber plate, creating a viscous sub-layer inside the turbulent boundary layer. As demonstrated in Fig. 4, the viscous sublayer may be disrupted by mounting artificially repeated rib roughness, or ribs, on top of the overlapping layer. The absorber plate's viscous sub-layer initially detaches above the ribs' head and mixes with the main airflow to dissipate heat; it then reattaches farther downstream with some new, comparatively cool fluid to absorb and dissipate further heat. Staggered ribs in front of these spaces may generate even more of a disruption, and the secondary flow that the ribs create along their length can be manipulated to mix with the primary fluid flow. These ribs may have any number of different cross-sections and orientations, including round, square, rectangular, and arc. In addition, ribs provide the same function as fins by increasing the heat transmission surface; however, ribs are typically just 2-3 mm tall, whereas fins may be as tall as 20-40 mm. The optimal design of ribs is determined by studying their form, size, direction, and cross section.



(d) Longitudinal vortex generators (e) Jet impingenment

Figure 4. Various possible heat transfer enhancement techniques used in SAH

Environmental parameters

When conducting a SAH research in real time, it is important to account for environmental factors such as insolation, ambient and sky temperature, wind velocity, etc. The open real-time research is not as desirable as the controlled setting when heater plates or halogen lights are employed as heat sources. The controlled experiment allows for varying output characteristics, allowing for a more thorough examination of their range. Lower values of insolation need low mass flow rate, and maximum efficiency moves towards lower Re as insolation declines for a fixed e/D after Re > 10000. Air, sky, and solar temperature "Ta, Tsky, and Tsun" Ts might be 10 degrees Celsius higher in polluted areas than those calculated through correlation. At greater TRP, the decrease in top losses caused by the low-temperature gradient of the glass cover with ambient air is more pronounced, therefore th rises as Ta does. For any given TRP, both Tsky and Tsun contribute to an ever-increasing th. Due to a rise in top losses, both th and ef f decrease with increasing Vw, and this fluctuation is most obvious at high TRP or low flow rates.

Conclusion.

We quantitatively investigate the thermal behaviours and flow patterns in a SAH duct with 30° P-DW/F-DW inserted at regular intervals on the absorber. In order to increase the turbulence intensity, particularly for the solid delta-winglet (dR = 0), P-DW/F-DW may be used to create longitudinal counter-spinning vortex pairs (LCVP) throughout the SAH duct. P-DW/F-DW's induction of LCVP flow causes impingement jets of air to strike the absorber surface, which in turn causes a higher increase in heat transfer..

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