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Study for the Irradiance Attenuation on the Cover of Solar Collectors Due To Humidity and Dustfall in Southern Taiwan

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Abstract

Air quality becomes worse in southern Taiwan partly due to two factors; humidity and falling dust, which affect the solar collector performance. Under the indoor experiments in this study, the humidity in the chamber and dustfall on sample glasses are used as parameters, and the temperature and irradiance on the observation plane are recorded and analyzed. The humidity chamber is used to simulate relative humidity in the air and sample glasses representing the cover of solar collectors are used to collect falling dust outdoors for four months. Therefore, we can obtain irradiation attenuations due to effects of humidity or dustfall quantity. Besides, the numerical diffuse fractions, simulating the irradiance reduction due to humidity or dustfall quantity, are tuned in numerical simulations to fit the experimental data for further design purposes. Correlations for the relation of irradiation attenuations versus relative humidity and dustfall quantity respectively are proposed based on experimental data.

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Keywords: humidity; dustfall; solar collector; CFD

1. Introduction

Solar thermal panel is a device that converts optical electromagnetic radiation to thermal energy using heat exchanger [1]. Due to inherent material property of panel and exchanger efficiency, efficiency of the collector can be as high as 40% [2]. However, as solar radiation travels through the atmosphere, a significant amount of it is attenuated. It can be absorbed by particles in the atmosphere, reflected by water vapor, air molecules, dust and other

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pollutants and scattered backward [3]. Scattering dust decreases the direct component of solar radiation, hence increases the diffuse irradiance component. Radiation attenuation depends on the pollutants nature and amount in southern Taiwan, especially when there is from a heavy Asian dust transport phenomenon [4]. We provide this evidence by the real model of a solar thermal heater as shown at the left-hand side (LHS) of Fig. 1 and the dustfall on the flat-plate collector for four months at the right-hand side (RHS) of Fig. 1. Thus, dust become one of the environmental factors that should be considered in optimizing thermal panel efficiency. The effects of dust on solar thermal panel efficiency can be viewed from two different perspectives; effects of dust scattering in the atmosphere and effects of dust deposited on the panel surface [5, 6]. In addition to dust effect, the influence of humidity on the performance of solar thermal systems has not been given much attention. In southern Taiwan, an island with high solar diffuse fraction in the air [7], the average annual relative humidity (RH) is 81.6% and can be considered as the other factor to influence the efficiency of thermal collectors in this study.

Researchers have become more interested in executing indoor experiment in order to be able to control related parameters, e.g., irradiance and temperature. With aid of sun simulator and pyranometer, sample will be irradiated indoor within certain power to satisfactorily simulate the sun. Relative humidity in the air and dust on the cover plate cause efficiency degradation of the collector by attenuating the incoming solar irradiance, reducing the surface transmittance and introducing partial shading effect. Most applications in solar energy, glass was commonly used as surface material for the cover of collectors [8]. In present study, indoor experiments were conducted to study the dust effect under outdoor exposure conditions and to investigate the seasonal variation of dustfall. Simulation of natural dust deposition process is required for indoor experiments. However, different methods in artificial deposition process result in different uniformity and clustering pattern of dust deposition. In this study, we collect dustfall from outdoor for a period of time, and then conduct the experiment to see the dustfall effect on the cover of collectors.

Computational fluid dynamics (CFD) has well been known for more than 20 years as a pragmatic and reliable tool to describe local thermal flow fields in academic and industrial problems [9]. Its modelling has been applied to investigate the transport phenomena in the solar thermal related problems [10, 11]. We use CFD to access the internal numerical information inside the domain of interest and it can be an effective way in design processes. In other words, CFD helps to visualizing and quantifying the simulated thermal flow field for detailed researches. In this study, we depict the methodology, including experiment setup, computational aided design (CAD) and CFD techniques to simulate thermal flow fields with radiation in section 2. Results and discussions are stated in section 3, which includes test results from two cases, humidity and dustfall, by experiments and CFD. Besides, correlations for irradiance attenuation versus humidity and dustfall quantity are proposed respectively in this section. Remarks are concluded in the final section, which includes the present contributions and future works.

Fig. 1. The real model of a solar thermal heater (LHS) and dustfall on the flat-plate collector (RHS) for four months.