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Thermal Performance of Building-integrated Solar Wall during Stagnation

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Abstract

This paper analyzes the thermal performance of a typical building-integrated solar wall (we’ll call it solar wall later in this paper) which integrates flat plate solar thermal collector with building wall. The thermal performance of the solar wall during stagnation, temperature of the absorber plate and heat flow on the inner wall, is studied by space state method in summer and winter respectively. If the collector of solar wall stops running, the maximum absorber plate temperature during summer daytime can reach 92.2 °C, and the total heat flow on the inner wall in one day is 1063 kJ/m\textsuperscript{2} which is about 5 times of the normal operation condition. In winter, the temperature and heat flow of solar wall is higher too, which is beneficial to reduce the space heating load and the room can obtain heat from the outside in some time.

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Keywords: Building-integrated; Solar wall; Stagnation

1. Introduction

The integration of building with solar collectors to reduce building energy consumption has become a tendency in building sector. Many experts and scholars have been attracted on this topic and great achievements have been obtained in recent years. When there is no need of heating load, the collectors stop running while the solar irradiance is very high, that is called “stagnation” in this paper. Stagnation happens commonly. Studying the thermal performance of the solar wall under stagnation condition is important to the safety of collectors. Thorsten Siems [1] developed a standardized stagnation measurement to characterise solar collector modules as they are marketed. Robert Hausner [2] investigated the behavior of combsystems at stagnation and discussed the design practice which

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prevents the activation of safety valve in the collector loop. Guoqing Yu presented a state space model [3] for thermal analysis of an integrated structure of flat plate solar collector and building envelope, and the state space model was verified by FLUENT simulation and experiment [4] respectively. The paper introduces a typical solar wall and analyzes the thermal performance of the solar wall during stagnation by space state method.

2. Description of the solar wall and research method

2.1. Description of the solar wall

The typical structure of the active solar wall is shown in Fig. 1. It is the integration of a flat plate solar thermal collector and building wall, which includes glass cover, absorber plate, tubes, insulation layer, back sheathing and building wall from outside to inside. The heat collected by the absorber plate is delivered to other place for heating by the fluid in tubes when the collector is in normal operation. Compared with separate solar collector or wall, the design of solar wall is intended to improve the thermal insulation of a building while producing heat.

Fig. 1. Schematic of the active solar wall.

The specifications of the flat-plate solar collector and the wall are shown in Table 1 and Table 2 respectively.

<table>
<thead>
<tr>
<th>Table 1. Specifications of the solar collector.</th>
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<tbody>
<tr>
<td><strong>Item</strong></td>
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<td>----------------------</td>
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<tr>
<td><strong>Collector</strong></td>
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<td></td>
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<tr>
<td><strong>Glass cover</strong></td>
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<td></td>
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<td><strong>Air space</strong></td>
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<td><strong>Absorber plate</strong></td>
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<td></td>
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<tr>
<td><strong>Tubes</strong></td>
</tr>
</tbody>
</table>

The paper uses state space model to analyze the thermal performance of the solar wall during stagnation. The variables characterizing time-domain behavior of systems are called state vector, and the space composed of state vectors is called “state space.” The method using state space as a mathematical model to describe and to analyze the system is called state space method. Compared to finite difference method or finite element method, the state space model only needs discretion in space and solution of integration form can be obtained; meanwhile the calculation stability is not affected by the time step if some manners are taken.

The solar wall is divided into many segments from outside to inside surface and heat balance equations are setup for each segment in the paper. By integrating the heat balance equations, we can get the all nodal temperature profiles changing with time and then we can calculate the heat flow of the inner wall in further. Space state method is an effective way to analyze the heat transfer process of building and the specifications of the solar wall used in the thermal analysis are the same as those listed in Table 1 and Table 2.

3. Thermal performance of the integration during stagnation in summer

3.1. Weather conditions for simulation in summer

We take a typical meteorological day in summer in Shanghai as the external interference factors, as shown in Fig. 2. The solar wall towards south direction and we set the indoor air temperature as constant 26°C in summer during calculation. The mass flow rate of the collector is set to 0.02kg/s with the collector inlet fluid temperature at 30°C. Thermal performance of the solar wall in summer is shown in Fig. 3-4 with comparison in different case.
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