AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

EXPERIMENTAL STUDY OF THE THERMO-HYDRAULIC PERFORMANCE OF A SINGLE-PASS SOLAR AIR HEATER WITH POROUS MEDIUM

A Thesis Submitted in Fulfillment of The Requirements of The Degree of Master of Science in Mechanical Engineering

Submitted by

Ashraf Hussien Abd Alhamed Mislem

B. SC Mechanical Engineering, Power dept., 2011

Supervised by

Professor Dr. Gamal Mosaad Hennes

Mechanical Power Engineering Department

Faculty of Engineering, Ain Shams University

Professor Dr. Eldesouki Ibrahim Saleh Eid

Mechanical Engineering Department

Faculty of Industrial Education, Suez University

Dr. Ehab Mouris Mofid Mina

Mechanical Power Engineering Department

Faculty of Engineering, Ain Shams University

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Examiners' Committee

Name and Affiliation	Signature
Professor Dr. Tarek Abdel Malak Mikhail Power Engineering, Aswan University	…………………
Professor Dr. Raouf Nassif Abdel Messih Mechanical Power, Ain Shams University	…………………
Professor Dr. Gamal Mosaad Hennes Mechanical Power, Ain Shams University	…………………
Professor Dr. Eldesouki Ibrahim Saleh Eid Mechanical Engineering Department, Suez University	…………………

Preface

This dissertation is submitted for the degree of master of science in mechanical engineering for the faculty of engineering of Ain shams university, Cairo.

The work distinguished in the dissertation was executed at the Department of Mechanical Power Engineering, Faculty of Engineering, Ain Shams University, Cairo.

No part of this thesis was submitted for an academic degree or qualification at any other university or institution.

Under supervision and guidance of:

- **Professor Dr. Gamal Mosaad Hennes**
- **Professor Dr. Eldesouki Ibrahim Saleh Eid**
- **Dr. Ehab Mouris Mofid Mina**

Name : **Ashraf Hussien Abd Alhamed Mislem**

Signature :

Date : / / 2020

Researcher Data

Name:	Ashraf Hussien Abd Alhamed Mislem
Date of birth:	8/4/1988
Place of birth:	Dammam, Saudi Arabia
Last academic degree:	Bachelor of Engineering
Field of specialization:	Mechanical Power Engineering
University issued the degree:	Higher Technological Institute (10^{th} of Ramadan city)
Date of issued degree:	2011
Current job:	Teaching Assistant at H.T.I

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Abstract

Enhancing the thermo-hydraulic performance of solar air collectors (SACs) can be achieved by various ways, some of which are; fins, ribs, baffles, porous medium and groves. So far, diverse attempts have been established to enquire the effects of these ways on the heater performance. Consequently the performance of a single pass SAC (SPSAH) employing Porous Medium (PM) with various density and porosity has been experimentally investigated. Several porous packings made of compressed aluminum scraps with different packing density and filament size were utilized. A SAC fitted with a solar simulator was designed to apply a uniform heat flux (q”) of about 700 W/m^2, where the solar simulator generates irradiance similar to that coming from the sun. It is utilized to run experiments under constant heat flux conditions without the demand for natural solar radiation. Noting that solar simulator utilized in this study is designed and constructed of scrape which is mentioned in details. The distribution of the flux generated from the constructed solar simulator was measured and reported in the results.

This study aims to improve the temperature lift in an SPSAH with a minimum possible increase in pressure drop (ΔP). Locally available metal packings are used as a PM to accomplish this aim. Two types of packing are employed in experimental work. The first type is made of compressed aluminum

swarf with different wire size and packing density. The porosity in this type ranges from 0.60 to 0.96. The second type is made of packed steel wire mesh with varied mesh density. The porosity of this second type ranges from 0.60 to 0.92.

- The thermal efficiency (η_{th}) is used to evaluate the heater performance. The pressure drops (ΔP) associated with each packing is employed to assess the exergy loss from the solar heater, and the packing is compared accordingly. Additionally, a Computational Fluid Dynamic (CFD) analysis is executed to analyze the SPSAH performance.
- The results illustrate that employing compressed aluminum swarf as a porous medium increases the thermal efficiency (η_{th}) of SPSAH and preserves the temperature inside the heater for longer running periods. Additionally, the results indicate that increasing the air mass flow rate ($\dot{m}$) will decrease the temperature difference (ΔT) between the inlet and the exit sections of the heater, but also, will cause an increasing in η_{th} of the system.
- The packed SPSAH (packed with aluminum swarf) enhanced the η_{th} by 50 - 60% compared to empty SPSAH for the same dimensions and air mass flow rate. The maximum temperature incurred from the packed SPSAH is 62 ^{o}C for a temperature difference of 34 ^{o}C. The experimental data validated the CFD results with a maximum deviation between both results within $\pm$ 2%.

Nomenclature

Symbol	Name	units
A	area	m^2
I	solar radiation intensity	W/m^2
$\dot{m}$	Mass flow rate	kg/s
Pr	Prandtl number	$m^2\ s^{-1}$
ΔP	pressure difference	pa
Q	volume flow rate	m^3/s
q”	Heat flux	W/m^2
Q	useful heat gain	W
S	Absorbed radiation from the sun	W/m^2
T	inlet temperature	K
ΔT	temperature difference	K
U	loss coefficient	$W/m^2.K$
U_L	Heat transfer coefficient	
V	air velocity	m/s
Greek symbols		
α	Absorptivity	
H	Efficiency	
ρ	density of air	kg/m^3
τ	Transmissivity	
Φ	Porosity	
Subscripts		
A	Ambient	
b	Beam	
C	Collector	
d	Diffuser	
F_R	Heat removal factor	
g	Ground	
I	Inlet	

O	Outlet
R	Removal factor
T	Top
th	Thermal
u	Useful

Abbreviations

CFD	Computational Fluid Dynamics
PM	Porous medium
SAC	Solar air collector
SAH	Solar air heater
SPSAH	Single pass solar air heater

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