

# Design of Flue Gas-Air Heat Exchanger for Regeneration of Desiccant System

*Shaymaa H. Abdulmalek<sup>1</sup>, Hussain H. Al-Kayiem<sup>1,\*</sup>, Aklilu T. Baheta and Ali A. Gitan<sup>2</sup>*

<sup>1</sup>Solar Thermal Advanced Research Center, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia.

<sup>2</sup>Tikrit University, Faculty of Engineering, Mechanical Engineering Department, Tikrit.

**Abstract.** Heat recovering from biogas waste energy requires robust heat exchanger design. This paper presents the design of fuel gas-air heat exchanger (FGAHE) for recovering waste heat from biogas burning to regenerate desiccant material. Mathematical model was built to design the FGAHE based on logarithmic mean temperature difference (LMTD) and staggered tube bank heat transfer correlations. MATLAB code was developed to solve the algorithm based on overall heat transfer coefficient iteration technique. The effect on tube diameter on design and thermal characteristics of FGAHE is investigated. The results revealed that the smaller tube diameter leads to smaller heat transfer area and tube. On the other hand, the overall heat transfer coefficient and Nusselt numbers have larger rates at smaller tube diameter. In conclusion, the nominated tube diameter for FGAHE is the smaller diameter of 0.0127 m due to the high thermal performance.

## 1 Introduction

Efficient and economic thermal energy gained from the biomass waste, for drying application, requires specific thermal backup unit (TBU) and robust design of heat exchanger [1-3]. Basically, transferring heat from flue gas (the hot fluid) to air (the cold fluid) needs efficient gas-gas heat exchanger that maximize the utilization of thermal load in the flue gases. Based on previous works, the challenge of designing appropriate flue gas-air heat exchanger (FGAHE) for recovering waste biomass energy used to regenerate desiccant material is still under investigation and development.

Many previous researches had presented different designs of heat exchanger for different applications such as reactivation the silica gel by solar energy [4, 5]. On the other hand, during the absence of solar energy the alternative source of the thermal energy is the biomass in this trend many other researchers investigate the using of waste biomass to introduce hot air [3, 6-8]. In an industrial application, the silica gel is regenerated by using fossil fuel like electrical heater at 140 °C. Solar energy was used to regenerate the silica gel through a heat exchanger during the day time and after the sun hour using the flue gas from the thermal backup unit by using gas to gas heat exchanger [3, 9-12].

\* Corresponding author: [hussain\\_kayiem@utp.edu.my](mailto:hussain_kayiem@utp.edu.my)

# Development of Multi Chamber Technique to Improve the Uniformity in Drying Application

Shaymaa H. Abdulmalek<sup>1, a)</sup>, Hussain H. Al-Kayiem<sup>1, b)</sup>, Morteza K. Assadi<sup>c)</sup>  
and Ali A. Gitan<sup>2, d)</sup>

<sup>1</sup> Solar Thermal Advanced Research Center, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak, Malaysia.

<sup>2</sup> Tikrit University, Faculty of Engineering, Mechanical Engineering Department, Tikrit, Iraq.

<sup>a)</sup> [Shaymaa\\_g03363@utp.edu.my](mailto:Shaymaa_g03363@utp.edu.my),

<sup>b)</sup> [hussain\\_kayiem@utp.edu.my](mailto:hussain_kayiem@utp.edu.my),

Corresponding author: [mkhassadi@yahoo.com](mailto:mkhassadi@yahoo.com)

<sup>d)</sup> [aliagitan@tu.edu.iq](mailto:aliagitan@tu.edu.iq)

**Abstract.** Multi tray solar dryer is commonly used for thin layers drying type due to its ease of manufacturing and economical aspects. However, the drawback of this dryer design is the non-uniformity in the required moisture content of end product. This work presents the development of multi chamber solar drying cabinet using numerical analysis. The main objective is to ensure uniform velocity distribution inside the multi chamber dryer. This aim has been achieved by series of modifications of design concepts based on the aerodynamic behavior of air flow. The results showed that four design phases to come out with optimum design configuration of the multi chamber drying cabinet. The velocity above the splitter has a significant difference of around 0.1 m/s at the end of splitters among the chambers. It is concluded from this result that the cross section flow area has an impact on the uniformity of velocity and a further modification is recommended.

## INTRODUCTION

Product drying is an important industrial process to extend the product life especially in high humidity environment. Although the drying process is commonly used, the drying systems still under developing in aspects of saving energy, increasing drying rate and the uniformity of drying which has a significant impact on product quality. Solar dryers are an old-new promising technology that may achieve performance improvement in all these aspects and others as friendly environment technique. Nowadays, solar drying systems are a wide topic which has been handled by researchers from many perspectives in order to enhance the performance of drying systems. However, the issue of drying uniformity in solar dryers is still not considered extensively in previous works even though its importance in product quality.

The conventional design of solar drying chamber shown in FIGURE 1 has been considered by many researchers and non-uniform drying was recorded due to non-uniform air distribution through each tray [2]. The non-uniformity of air movement inside drying chamber is the main reason of non-uniform product drying [3]. Controlling the air distribution characteristics inside the drying chamber is based on drying chamber design which has a significant effect on the uniformity of drying. Hence, the experimental investigation of air flow uniformity inside the different designs of drying chamber is very expensive and time consuming [2, 4-7]. Therefore, computational fluid dynamics (CFD) simulation has been adopted to investigate different configurations and to optimize drying chamber design for uniform solar drying [8-10]. In order to increase the quantity of dried product, a complex geometry drying chamber having hundreds of trays was presented and studied numerically and experimentally [11]. A way from increasing product quantity, the quality issue represented by the desired moisture content of end product was considered for different drying chamber configurations [12]. Seven different geometries of cabinet dryer were

## Effect of Tube Diameter on The Design of Heat Exchanger in Solar Drying system

Shaymaa Husham Abdulmalek<sup>1</sup>, Morteza Khalaji Assadi<sup>1</sup>, Hussain H. Al-Kayiem<sup>1</sup>, Ali Ahmed Gitan<sup>2</sup>,

<sup>1</sup>Universiti Teknologi PETRONAS, Solar Thermal Advanced Research Center, Bandar Seri Iskandar, Perak, Malaysia.

<sup>2</sup>Tikrit University, Faculty of Engineering, Mechanical Engineering Department, Tikrit, Iraq.

morteza.assadi@utp.edu.my

**Abstract.** The drying of agriculture product consumes a huge fossil fuel rates that demand to find an alternative source of sustainable environmental friendly energy such as solar energy. This work presents the difference between using solar heat source and electrical heater in terms of design aspect. A circular-finned tube bank heat exchanger is considered against an electrical heater used as a heat generator to regenerate silica gel in solar assisted desiccant drying system. The impact of tube diameter on the heat transfer area was investigated for both the heat exchanger and the electrical heater. The fin performance was investigated by determining fin effectiveness and fin efficiency. A mathematical model was developed using MATLAB to describe the forced convection heat transfer between hot water supplied by evacuated solar collector with 70 °C and ambient air flow over heat exchanger finned tubes. The results revealed that the increasing of tube diameter augments the heat transfer area of both heat exchanger and electrical heater. The highest of fin efficiency was around 0.745 and the lowest was around 0.687 while the fin effectiveness was found to be around 0.998.

Keywords: (solar energy, air- water heat exchanger, silica gel, drying)

### 1. Introduction

High thermal energy storages are gained from evacuated tube solar collectors that use water to transfer heat to another system through an energy converter such as heat exchanger [1-4]. Several different types of heat exchangers have been developed for different applications being the shell-and-tube and plate-fin the most commonly utilized configurations. Because many heat exchanger arrangements involve multiple rows of tubes in a fluid cross flow, the heat transfer characteristics for tube banks are of important practical interest. The gas flowing on the outside impinges perpendicularly on these tubes [5]. With constant fluid velocity, this type of flow gives rise to an increase in turbulence compared with the case where the gas flows along the tubes and parallel to them. Heat exchangers are extensively used in diverse industrial processes nowadays. Many previous researches have presented different designs of heat exchanger used in different applications such as reactivation the silica gel as shown in Figure1 by using many sources of heat for example, solar energy [6, 7]. In an industrial application, the silica gel is regenerated by using fossil full like electrical heater at 100 °C. A desiccant system was used to dry crushed oil palm fronds [6, 8]. Solar energy was used to regenerate the silica gel through a heat exchanger. A theoretical analysis was carried out with an optimization of a gas-to-gas heat exchanger with a non-constant cross sectional area [9]. The results obtained from the modeling demonstrate the premise that it is possible to realize designs for heat exchangers that are highly exergy-efficient and very cheap. Some



# Performance Investigation on an Integrated Multi-Stage Cylindrical-Tank Solar Water Heater

Tadahmun A. Yassen<sup>1, b)</sup>, Mousa M. Waes<sup>2</sup>, Omer K. Ahmed<sup>3</sup>, Tahseen Ahmad Tahseen<sup>1</sup>, M.B. Baharom<sup>4,5, a)</sup>

<sup>1</sup>*Department of Mechanical Engineering, College of Engineering, Tikrit University, Tikrit, Iraq*

<sup>2</sup>*Kirkuk Technical College, Northern Technical University, Iraq*

<sup>3</sup>*Technical institute of Hawija, Northern Technical University, Hawija, Kirkuk, Iraq*

<sup>4</sup>*Centre for Automotive Research and Electric Mobility (CAREM), Research and Innovation, Universiti Teknologi Petronas, 32610 Seri Iskandar, Perak, Malaysia*

<sup>5</sup>*Department of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Petronas, 32610 Seri Iskandar, Perak, Malaysia.*

<sup>a)</sup>Corresponding author: masrib@utp.edu.my

<sup>b)</sup>tadahmunahmed@tu.edu.iq

**Abstract.** This research is about performance investigation of a multiple-tank integrated-solar collector storage heater. A prototype of the heater having a capacity of 300 Liter was constructed and experimentally tested outdoors to observe the variation of water temperature in the storage tanks. A Fluent program is used to predict the storage water temperature. The experimental data was verified with the results from the simulation model. In vice versa, the simulation model was validated using the experimental data. Two cases have been studied, namely with and without flow rate. The results show that the maximum water temperature exited from the storage tanks during February month of 2010 was 48°C. The results illustrated that the present integrated solar water heater was a success in providing hot water suitable for day time use by households during the winter in Iraq.

Keywords: Integrated system; performance; solar; water heater.

## INTRODUCTION

The usages of solar energy and their conversion into thermal, electric or chemical energy are common nowadays. Its applications include heating, cooling, water heating, desalination, power generation, cooking, drying of agricultural crops and others. Solar water heaters are one of the simplest and most widespread applications of solar energy in the world today. The Arab countries are among the world's richest areas of solar energy. The sun is available for long periods of time throughout the year. Solar water heaters contain three main parts namely solar collector, storage tank and water distribution pipes. The cost of solar water heaters is the mainstay of its spread and use, hence it needs a lot of attention from researchers to develop and make it less expensive and more efficient to use especially in war-torn country like Iraq. Many researchers tried to reduce this cost using an integrated solar water heater, which incorporates the solar collector and the storage tank in a single unit(1).

A numerical code which was capable of prognosticating the thermal behavior of a double tank integrated collector storage system (ICS) with a compound parabolic concentrator (CPC) had been developed by Kessentini and Bouden(2). A concept design of an ICS device was built and tested in both open and closed area to inspect the variation of water temperature in the storage tanks. The experimental results indicated a significant water temperature increase in the storage tanks during the day and a satisfactory temperature preservation during the night. The bottom tank received more heat as it was better exposed to the sun while the change in the demonstrated temperature in the upper placed tank were smaller due to its better thermal insulation providing a good storage of hot water temperature to the ICS system. Garnier et al.(3) in an Integrated Collector Storage Solar Water Heater (ICS-SWH). Their model design

# Consideration of the use of artificial intelligence methods for determining the friction coefficient of lubricated sliding bearings

**B R Andelković<sup>1</sup>, A Al-Sammarraie<sup>2</sup>, D Milčić<sup>1</sup>, D Stamenković<sup>1</sup>, M Banić<sup>1</sup>, J S Marinović<sup>1</sup>, B Đorđević<sup>1</sup> and N Zdravković<sup>1</sup>**

<sup>1</sup>University of Niš, Faculty of Mechanical Engineering, A. Medvedeva 14, 18000 Niš, Serbia

<sup>2</sup>University of Tikrit, Faculty of Engineering, Department of mechanical engineering, Tikrit, Iraq

E-mail: bandjel@gmail.com

**Abstract.** Sliding bearings' main advantages over the ball bearings are it's load capacity and longevity. If hydrodynamic lubrication conditions are met then the sliding bearings will work forever. This is especially important when dealing with high rotation rate environments, where ball bearings see very limited use due to their inferior load capacity and longevity. The focus of this study is the examination and determination of coefficient of friction values in sliding bearings made of tin based white metal alloys conditioned with hydrodynamic lubrication. A sliding bearing is based on a kinematic pair made of a steel axle and a braided alloy TEGOTENAX V840 made by Ecka Granules. The chemical composition of the this alloy is 88.7% Sn, 7.6% Sb and 3.7% Cu. The examination was performed using one oil lubricant. Experimental data has been used for creating an adaptive neuro-fuzzy inference system model. ANFIS model provides an estimation of coefficient of friction values in function of load. Based on the ANFIS model an analytical expression, used for connecting load values with coefficient of friction values, was defined. This analytical expression is suitable for engineering applications and purposes.

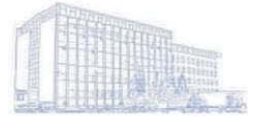
## 1. Introduction

Friction is a physics phenomenon that can have positive and negative effects on the manufacture and functional processes of mechanical construction designs. Sliding bearings are very commonly used as kinematic pairs. Friction coefficient of sliding is one of the basic parameters defining the quality of a sliding bearing. High quality sliding bearings have very low friction coefficients values. Friction is a phenomenon that, in this case, has a negative effect. With regards to both manufacture and design, project developers aim to diminish friction values as much as possible. In full-film lubrication conditions, film thickness should be enough to separate the peaks of rough contact surfaces. Experiments of R Đuriš [1] and Labašová [2] have shown that the friction coefficient values of an aluminum - steel sliding bearing can be much lower than the expected value of 0.8, and that it can even be as low as 0.1.

There are a large number of papers and publications on dealing with the problems of friction coefficient and sliding bearings. Numerous authors [2] and [3] have studied the friction coefficient of graphite notched bronze. Results show that the friction coefficient lowers with perpendicular load







# Study the Effect of Load, Sliding Speed and Sliding time on Dry Sliding Wear Rate and Wear Resistance of Carburized Mild Steels

Adel M. Bash, Amir Alsammarraie, Sulaiman E. AL-BASAQR, Sabah M. SALIH

Tikrit University, Engineering Faculty, Tikrit, Iraq

Adelbash@edu.iq, amircraft.2011@yahoo.com, sulimaninad@gmail.com, sabahmehdi\_69@yahoo.com

**Abstrac** — The purpose of this study is to understand the wear properties of the carburized mild steels at different temperatures by the effects that sliding speed, time and different loads make. The chosen temperature ranges for carburization in this testing are 825°C, 875°C and 925°C, and in order to investigate the requirement of the adhesion wear, the apparatus pin on disc is utilized. The experimentations were executed on a bunch of samplings at specific periods of time (5 to 30 minutes), and at various loads (9.81N to 49.05N), and certain speeds (1.8 to 8m/sec). The findings of these settings illustrated that the method of carburization significantly upgrades wear features, for example wear rate and wear resistance, and also that these characteristics are amplified with raise in the carburization temperature. For the moment, the mild steel carburized at 925°C provides the best outcome for various wear features since it offers the utmost wear resistance at this temperature. Consequently, it must be given a preference for the desired uses and the outcomes will demonstrate direct relations of the rate of adhesion wear with time, sliding speed and load.

**Key words**— wear, sliding speed, carburization, Carburized Mild Steels

## I. INTRODUCTION

The research on the mechanical and wear characteristics of iron and steel constituent under special condition has been conducted by many researchers, but mostly their focus was on analyzing the wear properties only. In fact, only a handful of studies were made that included both the mechanical and wear properties keeping in view the matching parameters and circumstances [1]. As it is reported by literature, a research was conducted by Baldissera and Delprete [2] with the purpose to investigate the effects of deep cryogenic treatment (DCT) on static mechanical properties of 18NiCrMo5 carburized steel. It concluded that, the soaking time parameter establishes a well-built control to increase the hardness and is stimulated by the pre-tempering DCT.

Under the conjecture that the micro structural mechanism engrosses the whole process, additional advancements could be achievable with a prolonged DCT exposure.

The unaffected tensile power of the pre-tempering DCT groups may perhaps be correlated to a returning outcome owing to the failure in lasting stress.

Another research by Khusid et al [3] investigated the wear of carburized high chromium steels and stated that Carburization increases the uncompromising wear resistance and allocates considerable control of the adhesion trends under dry sliding. These outcomes establish that the system of surface hardening of high chromium steels is essential to manufacture the preferred blend of wear resistance and bulk strength characteristics.

Researchers Wang and Lei [4] analyzed the increased wear resistance for the subsequent order of materials: spherodized carbide, martensite, bainite and lamellar pearlite. Their results signified that the discrepancy in wear resistance of diverse microstructures were induced by the variations in their thermal stability, resistance to deformation, resistance to nucleation and propagation of micro-cracks, etc.

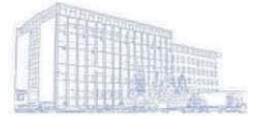
Kumar and Gupta [5, 6] were the two researchers who conducted a series of trials to carry out wide-ranging research on low stress abrasive wear properties of carburized mild steels, and medium carbon and alloy steels examined by heat. They observed that the maximum abrasion resistance was found in the steel specimens carburized in partly burnt charcoal, and the hardness and wear resistance standards of mild steels carburized by the application of coal tar pitch were analogous with those of heat treated high carbon low Cr-steels.

The consequences of microstructure on the abrasive wear behaviour of spheroid cast iron were studied by Luo et al [7]. He accounted that the wear resistance of spheroid grey cast iron was lower than that of steel with a comparable matrix. So, he concluded that, the austempered structures were less resistant to abrasion than the quenched structures, at higher temperature, the wear performance of quenched iron and steel samples were better than austenite ones.

## II. MEASUREMENT METHODS OF WEAR

According to (Rabinowicz,1965), the extensively recognized techniques in analyzing wear depend on: deciding the sliding surfaces, and then calculating, prior to experimenting the removal material, and after that, any occurring variation will be recognised as a resulted wear. Among the many methods to indicate wear, some are as follows:

- Weighing method.



# Predictions of Wear in Hydrodynamic Journal Bearing Using Artificial Neural Networks

Amir ALSAMMARRAIE<sup>1</sup>, Dragan MILČIĆ<sup>2</sup>, Milan BANIC<sup>2</sup>

<sup>1</sup>Tikrit University, Engineering Faculty, Tikrit, Iraq,

<sup>2</sup>Faculty of Mechanical Engineering, University of Niš, Niš,  
amircraft.2011@yahoo.com, dragan.milcic@masfak.ni.ac.rs, banicmilan@hotmail.com

**Abstract** -The present paper investigates the effect of sliding distance, rotation speed of shaft and normal load on wear journal bearing coated by babbitt alloys Tegotenax (V840) under lubrication condition using artificial neural networks (ANNs). An experimental plan was performed on test rig apparatus designed and fabricated for obtaining experimental results under lubricated conditions. Development of ANN models for modeling relationships between the wear of Babbitt and radial normal load and sliding distance was based on the acquired experimental data. The experimental data have been normalized before being used in the ANN model development in order to have same scale. The test results show that non-linear relationships between the radial load, sliding speed and loss material parameters, exist. It has been observed that the well-trained ANN models can exactly predict the wear according to the radial load and sliding distance.

**Key words:** Artificial neural network, Hydrodynamic Journal Bearing, Wear, Babbitt Metal - Tin Based-Tegotenax (V840)

## I. INTRODUCTION

Journal bearings have been used in rotating equipment since the invention of the wheel. In its simplest form, a journal bearing consists of a cylinder built around an axle with a small clearance separating the two. Journal bearings play an important role in the dynamics of rotor-bearings systems, being responsible for supporting the machine and transmit forces between the rotor and the foundation. The operation of a rotor for a long period of time as well as the many starts and stops to which the system is subjected, may result in direct contact between the shaft and the bearing, leading to high friction in the lubricated contact and consequently the wear of the bearings wall. This wear causes discontinuities or geometric changes in the bearing, which influence the bearing radial clearance.

To reduce wear of the surfaces, the clearance is filled with a lubricant which allows the contact to operate in the mixed or hydrodynamic regime.

Study of tribological materials properties dates back to the sixteenth century, almost instantly after the devise of Newton's law of motion. The difference of friction coefficient and wear rate depends on interfacial conditions such as normal load, geometry, relative surface motion, sliding velocity, surface roughness of the rubbing surfaces, type of material, system rigidity,

temperature, stick slip, relative humidity, lubrication and vibration [1]. Among these factors sliding distance, rotation speed and radial load are the two main factors whose play significant role for the difference of friction and wear rate. Friction coefficients of different material pairs are investigated and compared in [1]. Using a pin on disc apparatus, friction coefficients of copper-copper, copper-brass, brass-brass, brass-copper pairs are investigated experimentally. Results showed that friction coefficient varies with duration of rubbing, normal load and sliding velocity. The effect of radial load on the coefficient of friction and loss material of different polymer and composite materials was investigated in [2]. It was found that the amount of coefficient of friction and loss material are different for different materials.

The tribological behaviours of Babbitt alloy 16-16-2 sliding against aluminium bronze ZnCuAl9Mn2 lubricated by sea water were systematically investigated by Wu et al. [3]. The results indicated that the friction coefficient decreased as the load increased to 30N and then remained at a steady level at high loads, but decreased with increase in sliding speed. Zeren et al. [4] studied the tribological behaviour of two different tin-based bearing materials in dry sliding conditions, one of these alloys with low Sb content (7%) is known as SAE 12 and is widely used in the automotive industry and the other with high Sb content (20%) is a Sn-Sb-Cu alloy. Experimental results have proved that WM-2 and WM-5 alloys can be used in dry sliding conditions. It has been shown that performance of WM-5 under heavy service conditions is better than WM-2 due to its alloying elements.

The lose weight of material due to rubbing are not fundamental properties of a material but characteristic of the total engineering system and operating environment. Therefore, it is important to establish a mathematical model for the prediction of wear. Artificial neural network (ANN) has provided an exciting alternative method for solving a variety of problems in different fields of science and engineering. They represent revolutionary computing paradigms that try to mimic the biological brain and are especially useful to address problems where solutions are not clearly formulated or where the relationships between inputs and outputs are not sufficiently known [5]. Many researchers have worked on the use of an ANN to predict the intensity of