PROJECT REPORT

ADVANCE STUDY OF SOLAR ATTIRE DRYER

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My beloved circle of colleagues, friends, family and all who have supported and encourage me through good time and hard time
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ABSTRACT

The traditional practice of drying cloth in open sun, which is considered to be economical but many drawbacks such as exposed to dust, rain and ultraviolet ray which could destroy the fabric structure of some type of cloth and its color. Besides that, in traditional drying, natural ventilation is not always available and heat are not high enough to get cloth dry in a predetermine time resulting in long drying period. The initial design of the solar attire dryer constructed by Mr. Lam Chin Yueh in order to overcome the problem face by traditional drying method has shown some success. However, lack of consideration in the influence of humidity to the drying rate has been a weakness to the initial design. Improper ventilation inside the initial design of the dryer has resulted in high concentration of moisture at the top section of the dryer that leads to slow drying (more than 4 hours in average for nylon cloth). The new design which is a modification of the initial design introduce in this report has been constructed and tested to measure the performance. The result shows that, considering the influence of relative humidity, the new design has a better performance i.e. less than 3 hours average drying for the same specimen. The temperature inside the dryer is always higher than the ambient that is 30°C - 55°C on average at Kuching’s weather condition. Furthermore, the ventilation fans in this project are powered by solar which is relatively cheap and clean. Battery is use as a backup just in case the power supplied from the solar panel is not enough especially during very cloudy day.
ABSTRAK

Cara pengeringan biasa untuk pakaian yang dianggap lebih murah tetapi mempunyai banyak kelemahan seperti terdedah kepada debu, hujan dan sinaran ultraviolet yang boleh merosakkan struktur fabric baju serta boleh melunturkan warnanya. Selain itu, melalui pengeringan biasa, pengudaraan semulajadi jarang ada dan suhu juga tidak mencukupi untuk mengerikan pakaian dalam tempoh yang ditetapkan menyebabkan tempoh pengeringan yang panjang. Rekaan awal pengering pakaian solaryang dibina oleh En. Lam Chin Yueh untuk menyelesaikan masalah yang dihadapi oleh cara pengeringan biasa telah menunjukkan hasil yang memberangsangkan. Tetapi, kurangnya pertimbangan yang diberikan terhadap pengaruh kelembapan terhadap kadar pengeringan menyebabkan rekaan ini mempunyai kelemahan. Pengudaraan yang kurang memuaskan di dalam rekaan awal pengering ini juga menyebabkan wap air berkumpul di bahagian atas pengering pakaian tersebut yang menyebabkan pengeringan yang lambat (lebih daripada 4 jam secara purata untuk pakaian yang diperbuat dari nilon). Rekaan baru yang merupakan pengubahsuaian daripada rekaan awal tersebut yang diterangkan dalam laporan ini telah dibina dan diuji untuk menetukan kecekapannya. Keputusan ujian menunjukkan, dengan mempertimbangkan pengaruh kelembapan, rekaan baru ini mempunyai kecekapan yang lebih baik (kurang dari 3 jam secara purata) untuk specimen yang sama. Suhu di dalam pengering pakaian tersebut juga selalu lebih tinggi dari suhu sekitar iaitu 30°C - 55°C secara purata bagi keadaan cuaca dikawasan kuching. Selain itu kipas-kipas yang digunakan bagi tujuan pengudaraan dalam projek ini juga menggunakan kuasa elektrik yang dijana dari solar yang murah dan bersih. Bateri digunakan sebagai tenaga sokong apabila tenaga yang dijana dari panel solar tersebut kurang mencukupi seperti pada hari mendung.
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NOMENCLATURE

PVC – Polyvinylchloride
EMC – Equilibrium Moisture Content
RH – Relative Humidity
BHP – Brake Horse Power
P – Pressure
V – Volume
HP – horsepower (divide HP by 1.34 (or multiply by 0.75) to convert to KW)
$P_i$ – ideal power consumption (W)
$dp$ – total pressure increase in the fan (Pa)
$q$ – air volume flow delivered by the fan ($m^3/s$)
RPM – Rotation per minute
CFM – cubic feet per minute
vdc – Voltage Direct Current
AC – Alternated Current
DC – Direct Current
PV – Photo Voltaic
US – United States
PCU – power conditioning unit
CHAPTER 1

INTRODUCTION

1.1 General

Drying is a process involving removing of moisture from the interior of the material to the surface and then to remove this moisture from the surface of the drying material. In natural sun drying where product is directly exposed to the sun in the open air, the necessary heat required for moisture removal is supplied from the sun and a little from the ambient air. The wind and natural convection disperse the water vapour. In the convection type of dryer, a stream of preheated air from solar energy supplemented by auxiliary energy is allowed to pass through the product which supplies the necessary heat for moisture removal from inside to outside and also carries the moisture. Drying of a product is a complex heat and mass transfer process which depends on external parameters such as temperature, humidity and velocity of the air stream. Drying processes are also affected by the drying material properties like surface characteristics (rough or smooth surface), chemical composition (sugar, starches, etc.) physical structure (porosity, density, etc.); size and shape of the product.
Therefore, at low humidity and high temperature with enough ventilation, a faster drying time could be achieved. In order to accomplish this, low humidity content and high temperature must first be achieve inside the dryer. This project is name The Advance Study of Solar Attire Dryer because it requires humidity testing which has not yet been done before to the prototype. The next stage of the project will consist of the simulation operation in order to show the concentration of heat inside the dryer when various condition is being applied. Then the specification of the project which involves dimension and material for the project will be finalized.

Using conventional cloth drying, user only consider the use of heat or radiation from the sun to get their cloth dry, this project will consider another factor that affect the drying process that is humidity, besides heat (temperature) and ventilation (natural). The principal applied here is that at less humid air, drying is faster. In this project, the fundamental of Thermodynamic concerning Heat Transfer and most importantly this project requires Engineering Design principal to come out with the prototype as well as making use of solar energy. This project will also expose the student on the principal of psychrometrics which involve terminology such as humidity, comfort and air ventilation. The air ventilation principal is very important nowadays in air conditioning and human comfort.

Drying is perhaps the oldest, most common and most diverse of chemical engineering unit operations. Over four hundred types of dryers have been reported in the literature while over one hundred distinct types are commonly available
1.2 Basic Principal and Terminology

Drying is a complex operation involving transient transfer of heat and mass along with several rate processes, such as physical or chemical transformations, which, in turn, may cause changes in product quality as well as the mechanisms of heat and mass transfer. Physical changes that may occur include: shrinkage, puffing, crystallization, glass transitions. In some cases, desirable or undesirable chemical or biochemical reactions may occur leading to changes in color, texture, odor or other properties of the solid product. In the manufacture of catalysts, for example, drying conditions can yield significant differences in the activity of the catalyst by changing the internal surface area.

Over 85 percent of industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium. Over 99 percent of the applications involve removal of water. All modes except the dielectric (microwave and radio frequency) supply heat at the boundaries of the drying object so that the heat must diffuse into the solid primarily by conduction. The liquid must travel to the boundary of the material before it is transported away by the carrier gas (or by application of vacuum for non-convective dryers).

Transport of moisture within the solid may occur by any one or more of the following mechanisms of mass transfer:

- Liquid diffusion, if the wet solid is at a temperature below the boiling point of the liquid
- Vapor diffusion, if the liquid vaporizes within material
• Knudsen diffusion, if drying takes place at very low temperatures and pressures, e.g., in freeze drying

• Surface diffusion (possible although not proven)

• Hydrostatic pressure differences, when internal vaporization rates exceed the rate of vapor transport through the solid to the surroundings

• Combinations of the above mechanisms

Note that since the physical structure of the drying solid is subject to change during drying the mechanisms of moisture transfer may also change with elapsed time of drying.

The three characteristics of air that are necessary for successful drying in the constant rate period are

a. Moderately high dry-bulb temperature,

b. Low RH and

c. High air velocity.

1.3 Objectives

The former design has not yet been tested for humidity, therefore the main objective is to achieve the drying period less than three hour as well as to decrease the humidity inside the attire dryer to obtain faster rate of drying, instead of just playing around with the temperature and heat.
Basically the experiment work will concentrate on the testing and collecting appropriate data suitable for the evaluation of the cloth drying using solar attire dryer. Certain instrumentation equipment that is suitable for data collection are to be built, installed and applied to ensure sufficient information and data collection for the subsequence analysis. The objectives of this project are as follows:

- Conduct a literature review on psychrometrics principal.
- Construct a psychrometer to determine the humidity inside the dryer.
- To perform humidity test on the solar attire dryer
- Analyze the results obtain from the humidity test
- To decrease the humidity level inside the dryer
- The main objective of this project is to redesign the solar attire dryer to achieve the drying rate less than three hours compare to the three hours drying rate achieve by the previous solar attire dryer. In order to achieve this, the efficiency and performance of the dryer need to be improve wherever possible, for ease of maintenance and assemblability.

The analysis will ensure that the newly constructed solar attire dryer will dry a given cloth at an appropriate temperature and humidity. In addition to determine the range of the drying rate and when the cloth is the cloth is said completely dry. The preparation of the experiment in terms of raw material and others related data collection devices are important to ensure appropriate data is obtained during the trials. The equipment setup, schematic diagram and the installation of the instrumentation will be discussed further in the later chapter of this report.
1.4 Problem Statement

When this project is being completed in the past, it has been tested for temperature related performance, where the result shows that higher temperature promote faster drying rate. The previous project has not been tested for humidity i.e. water vapor content characteristic which is interrelated to temperature. Temperature and humidity of the air play important role in most drying process involving solar dryer. If the humidity is low and the temperature is high inside the attire dryer, the cloth can be dried at a faster rate. Therefore, instead of just increasing the temperature, this project aimed to decrease the internal humidity, thus allow the cloth to dry at a faster rate.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The drying method being applied to dry cloth in the rural areas are normally the conventional type. This is done by exposing the wet cloth in the open sun where no drying condition is taken into consideration. Furthermore, electricity is hardly available in certain places making it hard to apply electrically powered types of dryer to increase the drying process. Therefore, an enclose dryer with better and constant ventilation would be preferable. In order to achieve the constant ventilation, a fan is use and again it needs to be powered up. Therefore, due to no electricity in rural areas, the fan will be powered up by solar energy and yet the solar energy is always abundantly available for free. Beside that, due to it's enclose characteristic, the user never have to afraid that the cloth will get wet when it is raining.

A comprehensive review of the various designs, detail of construction and operational principles of the wide variety of practically-realized design of solar energy drying systems reported previously is presented. Solar energy dryer have been classify into two generic groups, passive or natural-circulation solar energy
dryer and active or forced convection solar energy dryer. Three subgroups of these can also be identified, integral type (direct mode), distribution type (indirect mode) and the mixed mode type.

2.2 Various Types of Solar Drier

The solar dryer concept is not new. But the solar dryers that were designed so far were never commercialized substantially. These work on the principle of natural convection of air, which results in slow drying. However the forced circulation accelerates the drying process. Solar drying is a technique particularly suited to the warmer parts of the world, since:

- There is abundant sunlight.
- The air temperature is high and relatively constant over the whole year.

Solar dryers use a simple construction to more efficiently make use of the sun's heat.

Under the correct climatic conditions they can improve sun drying rate. These include:

i. Higher drying temperatures, which result in shorter drying times and the ability to dry to a lower final moisture content.

ii. Protection from contamination by dust and from rain showers. They are low cost and simple to construct in local workshops. However, this is not so important in the case of tropical climate such as Malaysia.
Solar dryers consist of a transparent panel above a chamber or collector that is painted black to absorb the sun's heat. Polythene, which is very cheap, is commonly used to glaze the panel but it turns yellow and opaque after a few months and needs to be replaced. Plastic films that are not damaged by sunlight are now increasing available and should be used if possible. While more expensive they have a life of 5 years or more. It is very important to angle the collector at the correct angle to the sun:

i. The angle should be greater than 15° to allow rain water to run off the collector should be angled at 90° to the mid-day sun

ii. The collector should face south in the Northern hemisphere and north in the Southern the collector should be sited away from shadows from trees or buildings

2.3 Classification of solar energy drying systems

In broad terms, Ekechukwu (1987) classified them into two major groups namely:

- Active solar energy drying systems
- Passive solar energy drying systems

Three distinct subclasses of either the active or passive solar drying systems can be identified which vary mainly in the design arrangement of system components and the mode of utilization of solar heat, namely:

- Integral type solar dryers
- Distribution type solar dryer and
- Mixed mode solar dryer
Main features of typical design of the various classes of solar energy dryer are illustrated in figure 2.1.

![Diagram of solar energy dryer design](Source: Ekechukwu (1987))

Furthermore, solar dryer can be classified according to

(i) The mode of air flow through the dryer

   (a) Natural convection and

   (b) Forced convection

The natural convection dryers do not require mechanical/electrical power to run the fan, whereas the forced convection dryers require a fan or blower.