Faculty of Mechanical Engineering

STUDY THE ABSORPTION AND REGENERATION OF DESICCANT MATERIAL

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STUDY THE ABSORPTION AND REGENERATION OF DESICCANT MATERIAL

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DECLARATION

I hereby declare that this project entitled “Study the absorption and regeneration of desiccant material” is the results of my own work except as cited in the references.

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Date : ……

SUPERVISOR DECLARATION

I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for award of the degree of Bachelor of Mechanical Engineering

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Date : …….

ABSTRACT

Desiccant drying has been widely used in many industries such as shoes, food, flower and many more in the whole world. It can absorb water molecule and maintain at very low humidity for the aim to preserve the item or product for storing a longer period. Mixed mode Solar and Desiccant Dyer is designed to have both drying ability by using solar energy during the day while desiccant material continues the drying process at the night to improve the efficiency and improve drying rate of the product. This system has been constantly developed in the last few years to acquire better effective results and drying performance. The efficiency of the performance of a solar and desiccant dryer is an essentially depends on the temperature and humidity inside the drying chamber. There is various type of desiccant dryer have been developed and are classified based on the type of desiccant such as liquid desiccant flowing system, solid wheel desiccant dryer and solid recycle drying chamber. Therefore, in this study mixed mode dryer integrated with desiccant material been developed have been used to study the performance of the desiccant material. Solid desiccant that been chosen which is the silica gel are very attractive to water molecule and can absorb up to 30% of its own weight depend on which types of silica gel used. On the other hand, silica gel also can be regenerated naturally under certain temperature produce by the hot sun. It can be reused, and it is a kind of renewable source for drying products. Moreover, silica gel acts as a drying agent in agriculture field nowadays, to optimize the performance of the silica gel. Experiments need to be carried on for the optimization the ability of silica gel in drying process. In addition, data collected form the results by using Anemometer had been calculated to plot the temperature and humidity profile and analysis the trend of the performance. In results of the finding, the higher the temperature in the closed system, the lower the ambient air humidity, then will affect the drying rate to be higher throughout the whole drying process. On the other hand, regeneration requires a high and constant heating temperature, low surrounding air humidity, and a constant air flow to obtain the optimum regeneration rate for the silica gel.

ABSTRAK

Bahan pengering telah banyak digunakan di banyak industri seperti kasut, makanan, bunga dan banyak lagi di seluruh dunia. Ia boleh menyerap molekul air dan mengekalkan kelembapan yang sangat rendah untuk tujuan mengekalkan item atau produk untuk menyimpan masa yang lebih lama. Mesin pengering mod bercampur direka untuk mempunyai keupayaan pengeringan dengan menggunakan tenaga solar pada siang hari manakala bahan pengering meneruskan proses pengeringan pada masa malam untuk meningkatkan kecekapan dan meningkatkan kadar pengeringan produk. Sistem ini telah sentiasa dibangunkan dalam beberapa tahun kebelakangan ini untuk memperoleh hasil yang lebih baik dan prestasi pengeringan. Kecekapan prestasi pengering suria dan pengering adalah pada dasarnya bergantung pada suhu dan kelembapan di dalam ruang pengeringan. Terdapat pelbagai jenis pengering desiccant yang telah dikembangkan dan dikelaskan berdasarkan jenis pengering seperti sistem aliran pengeringan cecair, pengering desiccant roda pepejal dan ruang pengeringan kitar pepejal. Oleh itu, dalam kajian ini, pengering mod bercampur yang disepadukan dengan bahan desiccant yang telah dibangunkan telah digunakan untuk mengkaji prestasi bahan desiccant. Bahan pengering padat yang dipilih ialah gel silika yang sangat menarik untuk molekul air dan dapat menyerap sehingga 30% dari beratnya sendiri bergantung pada jenis gel silika yang digunakan. Sebaliknya, gel silika juga boleh diregenerasi secara semula jadi di bawah suhu tertentu yang dihasilkan oleh matahari panas. Ia boleh digunakan semula dan ia adalah sejenis sumber yang boleh diperbaharui untuk pengeringan produk. Selain itu, gel silika bertindak sebagai agen pengeringan di bidang pertanian pada masa kini, untuk mengoptimumkan prestasi gel silika. Eksperimen perlu dijalankan untuk mengoptimumkan keupayaan gel silika dalam proses pengeringan. Di samping itu, data yang dikumpulkan membentuk keputusan dengan menggunakan Anemometer akan dikira untuk merancang profil suhu dan kelembapan dan menganalisis trend prestasi. Dalam hasil penemuan, semakin tinggi suhu dalam sistem tertutup, semakin rendah kelembapan udara ambien, maka akan mempengaruhi kadar pengeringan menjadi lebih tinggi sepanjang keseluruhan proses pengeringan. Sebaliknya, penjanaan semula memerlukan suhu pemanasan yang tinggi dan berterusan, kelembapan udara persekitaran yang rendah, dan aliran udara malar untuk mendapatkan kadar pertumbuhan semula optimum untuk gel silika.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drying is defined as a process which reduce the level of dampness of the grain and ensure it to be secure for storing purpose over a long period of time. Theoretically, drying involves heat and mass transfer among the particles of air and the product itself. Temperature plays an important role during the drying process. For the normal drying process, heat energy will be transferred to the product with the increasing in temperature. As the temperature increases, heat energy increase, water molecule reaches the boiling point, evaporation starts to occur until the product completely dry. In fact, the heat transfer rate will be proportional to the temperature. Other than temperature, the mass is also transferred and called mass-transfer coefficient (R.L.Earle, 2018). High temperature dry air is used to dry the product, and totally remove all the moisture content inside it. The result can be clearly seen by experiment and plotting moisture content versus function of time graph. In the industrial field over the world, drying process used up to 12% of total energy. Moreover, the increasing in fuel price will lead to reduce the income of industries who involved in drying (Misha S. M., 2012).

Based on the Figure 1.1 below, it is the post production system of food or agriculture field industry. Normally, it always before the storage process and called in-store drying and

usually is the last step and a simple step in production. If drying process does not carry up properly, industries will face high losses although storage is done perfectly. Why is drying so important? A good drying will increase the quality of the product. If the products are wet always, it does not preserve long and lead to bad quality issues. At last, the industry will have less profits.

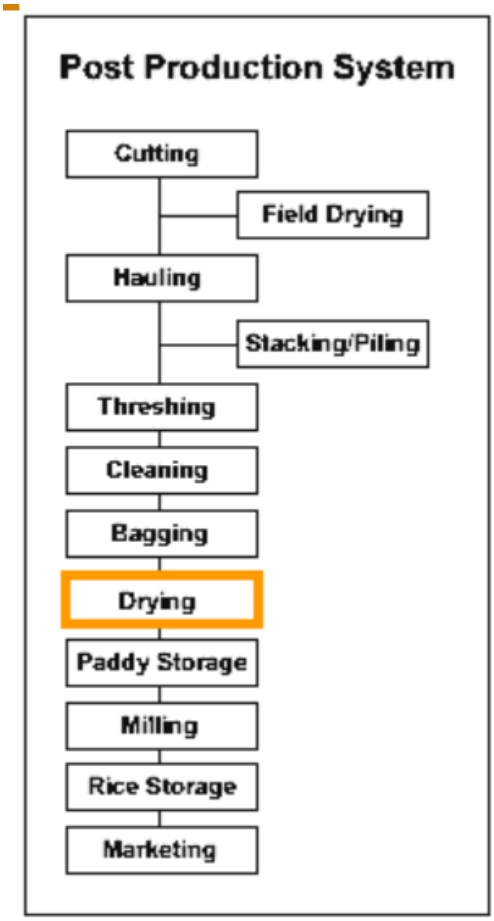

Figure 1.1 Post Production System (User.S, 2018)

The table 1.1 below shoes the perfect moisture content (MC) to store the paddy grain and seed. It also noted down all the possible problem that will be faced if the moisture content is not right (User.S, 2018).

Table 1.1 Moisture content and possible problem faced (User.S, 2018)

Storage period	Required MC for safe storage	Possible problems
2-3 weeks	14-18%	Molds, discoloration, respiration loss
8 to 12 months	13% or less	Insect damage
More than 1 year	9% or less	Loss of viability

For example, after harvesting wheat from the paddy field, rice will contain a total of 25% moisture. Without proper drying process before storage, many problems will be occurred such as changes in color, attract pests, and causes the rice to be decay. The rate of germination of the rice seed can also decrease. The perfect timing to dry the rice grain ideally is within 24 hours after harvesting. If not, there will be very bad quality and results in losses (Drying - IRRI Rice Knowledge Bank. , 2018).

Solar drying has been implemented worldwide since century ago. It is a traditional method and normally used for crops, fruits and vegetables. Solar drying happens anytime as long as the products is direct contact to the sun under the open sky. Solar energy is the main source for producing heat energy to the particular product. Either natural or forced convection occur and create an air flow. The heating process could be either preheated air flow cross over the product or the product direct expose to solar radiation or a mix of both (Ekechukwu, 1999). Solar energy is a renewable energy which can use only in daytime only. So many designs have been created with the aids of desiccant materials. It has a function of absorbing moisture from the surrounding no matter with or without solar energy.

Desiccant materials are often used in drying purposes. They are chemical who have good properties and special function. They are sensitive to moisture which mean that they can easily absorb or release the moisture. This is because vapour pressure between the surrounding air and the desiccant contact surface have changes. With the change of pressure until the desiccant surface is less than surrounding air, drying or dehumidification will happen. The process will continue till pressure equilibrium is achieved within desiccant material and surrounding air. Heat up the desiccant material is one of the methods to aid them for regeneration. When temperature increase, vapour pressure of desiccant surface will then larger than surrounding air and then regeneration started to occur (Jeong Jongsoo, 2011).

1.2 Problem Statement

The desiccant material chosen for the experiment is the silica gel. The experiment is carried up mainly focus on food or agriculture industry. During the process, air will be flow in through the fan and pass through the silica gel, all the water will be absorbed and produce dry air to the food. The problems faced on this experiment is the silica gel might not fully absorb the water molecule in the food and might give serious effect to health problem. In result, wet products cannot be kept for a longer time and faced quality issues. For this project, there are some question included:

1. What is the rate for the desiccant material to absorb the moisture content of the product?
2. What are the effects to the health when the dry air which water is been absorbed by the desiccant to the product?

3. What is the amount of desiccant required to run the drying process?

1.3 Objectives

The objectives of this project are as listed:

1. To conduct experiment on the performance of desiccant material
2. To analyze and discuss the performance of desiccant material with water
3. To study the absorption rate and regeneration rate of desiccant material

1.4 Scope of Project

The work scope of this study focused on two main components which are desiccant material (silica gel), and the circulation air flow of the chamber. Air flow temperature are uniformity inside the drying chamber along with the air velocity are the most important measured parameters. The relative humidity would be reduced during day time due to the high temperature. Some designs have been implemented to ensure that the air is dried and managed to absorb the water from the food sample until it reaches its moisture content level. Silica gel is chosen and aimed to be investigated in this study to achieve better and efficient drying of the food samples. The experiment work is carried up in UTEM lab at the faculty of mechanical engineering. After the drying process, final moisture content will be achieved based on different products. The regeneration rate and absorption rate of silica gel will be tested to ensure that it is efficient to be used for drying purpose. Agricultural product will be replaced by wet sponge that have been absorbed water to be dried. Drying rate will be tested throughout the experiment based on the wet sponge.

CHAPTER 2

LITRETURE REVIEW

2.1 Desiccant Materials

Desiccant defines as a drying agent which has a very high attraction towards the moisture content. It is a hygroscopic material that convince or assist the surrounding humidity or serves to keep up a condition of dryness; it's the inverse of a humectant, which serves to advance moisture retention. The purpose of desiccants used to wipe out humidity from the surrounding air. Desiccant materials mostly used in agriculture and food products. Choosing a desiccant material to use must be concerned. The reason behind this is the possibility of affecting the products quality or damaging them. The selection must base on different working parameters, including vapour pressure, boiling point elevation, energy storage density, thermo physical properties, regeneration temperature, availability, cost and many more (Shukla, 2017). A moisture removal process produces not just dried air but rise up thermal rate is obtained, because of the isothermal operation. When the thermal rate and moisture is very low, the drying process can be achieved by utilizing a material that can keep the color of the product fresh. The main function of desiccant in accordance to the concept of humidity transferring because of the vapor pressure with the air and the desiccant material (C.L. Hii, 2009). The invention of desiccants is counted as renewable energy, but it needed renewable or non-

renewable energy to regenerate. There are many types of desiccants and can be divided into many groups such as montmorillonite clay, silica gel, molecular sieve, calcium sulfate and calcium oxide.

Montmorillonite Clay is a natural occurring permeable adsorbent. It is a type of mined clay which is operated for utilize as a desiccant through careful drying. The clay can be used for many times at very low temperature without physical changes. Silica gel is a kind of polymeric colloidal silicic acid at incompletely dried out shape. On the surface of the silica gel contain lots of interconnected pores that will hold water, allowing it to absorbs up to 40% of its weight in water. Molecular sieves have a higher adsorption rate than silica gel or clay. Although molecular sieves are the best among all, but it is higher in cost and lack of support for further studies. Calcium oxide (CaO) also calls quick lime is efficient in keeping moisture content at very high temperature and have a moisture absorption level of not less than 28.5%. Calcium sulphate ($CaSO_4$) is invented to be broadly useful desiccant equipped. It is safe to use and chemical free although expose to high temperature. A comparison of the desiccants and graph of different desiccants showing their absorbing rate and capacity is shown in Fig 4. Selecting the suitable desiccant type can be done by comparing the features and capabilities of the desiccant in which the absorption rate and capacity are investigated in order to determine the suitability of the material for the specific application. From the studies of features, silica gel is the most suitable desiccant for application that requires high absorption rate. (Desiccant Chart Comparisons, 2018)

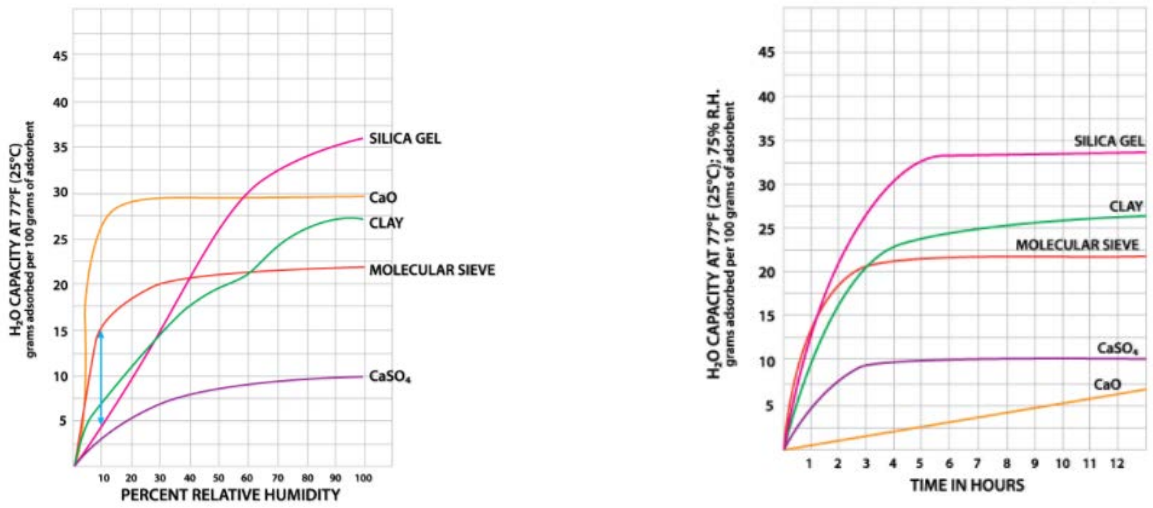

Figure 2.1 Absorbing rate and capacity of different desiccants (Desiccant Chart Comparisons, 2018)

2.2 Types of desiccant dryer

Desiccant materials consist of two types which are liquid or solid type. Both types have its own ability and properties. Every desiccant material has its own absorption rate and volume of moisture content. The best desiccant material has a high adsorption limit with respect to all scopes of relative moistness (humidification process) and can be recovered at low temperature. Different types of dryer need specific type of desiccant and will rely upon expected application. Normally, research stated that solid desiccant is more efficient than liquid desiccant. The reason of this statement might consider of the absorption rate, effective and easy to be found. Moreover, solid or liquid desiccant used in drying application is still new and normally used when sunlight is absence. If compared drying using solar or desiccant, solar energy still better than any desiccant material.

2.2.1 Solid Desiccant Based Dryer

There are many experiments on desiccant material have been carried up in air conditioning system. Hazeeb Halib et al. had conducted an experiment by testing the temperature of the process air inlet and outlet of the system. They have designed a desiccant wheel dehumidifier by themselves as the Figure 2.2 below. The system is designed to be two paths for the air stream to pass through. There is a desiccant process area which design to be round container to put the desiccant material inside. The first air flow which is called process air will pass through the desiccant to be dried. During the process, desiccant will absorb the moisture content, heat of absorption will then deliver to the air. Second air flow of the system named reactivation or regeneration air. Its function is to dry off the desiccant by heating it up. They also claimed that the rotational speed will affect the absorption rate also. The higher the speed of rotation, the lower the absorption rate.

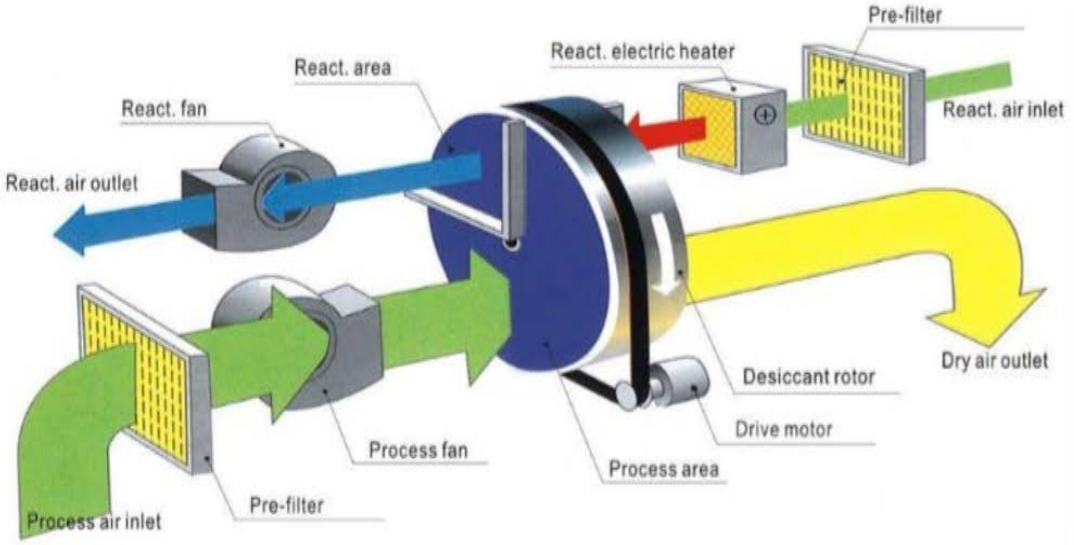

Figure 2.2 System flow of desiccant wheel dehumidifier (Hazeeb Halib, 2016)

Since the humidity is getting very low due to absorption by the desiccant, these will affect the temperature to increase too. This is because of the sensible heat created when the heat of sorption of moisture being reduce from the air. Other than that, during the regeneration process, desiccant is being heat up and remain hot. The heat energy will then transfer to the air when the dehumidifier process is carrying on. There will be around 80 to 90% of the increment of the temperature of the air flow from the heat of sorption. has analysis the temperature and recorded during experiment. The table 2.1 below show the temperature difference of inlet and outlet of the system. (Hazeeb Halib, 2016)

Table 2.1 Temperature difference with inlet and outlet (Hazeeb Halib, 2016)

Inlet Temperature(^{0}C)	Outlet temperature(^{0}C)
28.1	34.3
28.6	34.6
29.2	35.5
29.8	35.9
30.4	36.8
31.7	37.8
32.3	38.2
32.9	38.8