العنوان:	Study of the effect of different parameters on drying process
المؤلف الرئيسي:	Ali, Ahmed Abd Albadie Ibrahim
مؤلفين آخرين:	واصل، محمد جمال حسن، مصطفى، هشام محمد، سلطان، جمال إبراهيم(مشرف، مشرف مشارك)
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الملخص العربي

إن عمليات التجفيف للمواد الرطبة تعتبر من العمليات الهامة في الكثير من التطبيقات مثل صناعة الورق وصناعة الدواء والصناعات الكيميائية وصناعة المنسوجات وصناعة تجفيف الألبان وكذلك تجفيف المحاصيل الزراعية عند الحصاد.

وفي هذه الدراسة تم دراسة بعض العوامل المؤثرة على عملية التجفيف معمليا وما يصحب ذلك من إنتقال للحرارة وانتقال للكتلة مابين الوسط المسامي المبتل المراد تجفيفه والهواء الذي يمر خلال ذلك الوسط. لإتمام هذه الدراسة تم تصميم وتنفيذ دائرة اختبار معملية تتكون من مجرى أنبوبي دائري رأسي موجود بداخله الوسط المسامي المبتل وهو عبارة عن كرات من الطوب المسامي المشبع بالماء. تحدث عملية التجفيف نتيجة لدفع الهواء الساخن جبريا رأسيا لأعلى ليمر خلال الوسط المسامي المبتل فيحدث تبخير للرطوبة الموجودة في ذلك الوسط بفعل إنتقال الحرارة وإنتقال الكتلة الآنيين. ظروف التشغيل المختبرة هي معدل تدفق الهواء (١- ١,٨ -٣,٣٦ -٤,٠٨ كجم/م^{٢}.ث) ودرجة حرارته (٣٠ – ٤٠ – ٥٠ – ٦٠م°) وسمك طبقة الوسط المسامي (٠,١٥٧٥ - ٠,١٠٥ -٠,٠٥٢٥م) ومسامية كرات الطوب. وقد تمت دراسة تأثير تغيير ظروف التشغيل هذه علي عملية التجفيف عن طريق قياس كمية الماء المتبخرة من الوسط المسامى المبتل وقياس كل من درجات الحرارة والرطوبة النسبية وسرعة الهواء أثناء كل تجربة. ومن هذه القياسات المعملية أمكن حساب كمية الحرارة والكتلة المنتقلة. وبالتالى تم حساب معامل إنتقال الحرارة المتوسط ومعامل إنتقال الكتلة المتوسط لسريان الهواء المار خلال الوسط المسامى المبتل الموجود فى المجرى الأنبوبى الرأسى.

أظهرت النتائج أن عملية التجفيف تزيد مع زيادة معدل تدفق الهواء ودرجة حرارته ومسامية كرات الطوب وتقل مع زيادة سمك طبقة الوسط المسامي. وبالتالي فان عملية التجفيف تأخذ زمن أقل مع زيادة معدل تدفق الهواء ودرجة حرارته. أيضا تمت مقارنة النتائج الحالية مع نتائج الأبحاث السابقة حيث أعطت نفس المنحى.

والرسالة تتكون من ثلاثة أبواب وأربعة ملاحق .

الباب الأول: ويشتمل على مقدمة للموضوع وعرض للأبحاث السابقة والمرتبطة بالموضوع قيد البحث ويختتم بعرض نقطة البحث الحالى والهدف منه.

الباب الثانى:ويشتمل على شرح الجهاز المعملي المستخدم فى الدراسة و الأجهزة المستعملة فى قياس كل من درجات الحرة والرطوبة النسبية والسرعة والكتلة كما يشتمل أيضا على الخطوات المتبعة أثناء التجربة وخطوات تحليل النتائج التى تم الحصول عليها.

الباب الثالث: يحتوى على عرض النتائج المعملية التى تم الحصول عليها فى صورة منحنيات وتحليلها وكذلك تفسيرها وعمل مقارنة بين النتائج المعملية و نتائج الأبحاث السابقة فى مجال الدراسة.

وتختم الرسالة بالخلاصة المستنبطة من هذا البحث ومقترحات بأبحاث مستقبلية فى هذا المجال.

الملاحق:

الملحق الأول: ويشمل جدول للقراءات المعملية لتجربة واحدة من التجارب التي تم إجراؤها.

الملحق الثاني: ويشمل جدول النتائج للقيم المحسوبة لتجربة واحده.

الملحق الثالث: ويشمل برنامج بلغة الفورتران لحساب خصاص الهواء عند درجات الحرارة المختلفة.

الملحق الرابع: ويشمل حسابات نسبة الخطأ المحتملة فى قيم النتائج المعملية

Abstract

In the present experimental work, drying process has been carried out by forcing air to flow, in upward direction, through the wet porous bed which put in vertical circular duct. Wet porous bed was packed with a uniform 20 mm in diameter wet porous clay balls. Drying process occurs due to the simultaneous heat and mass transfer between wet porous bed and airflow. The affecting parameters on drying process are ,experimentally, investigated. The studied affecting parameters on the drying process are inlet air temperature (30 - 40 - 50 - 60 ^{o}C), inlet air mass flux (1 - 1.8 - 3.36 - 4.08 $kg/m^2.s$), porous bed depth (0.1575 - 0.105 - 0.0525 m) and porosity of balls ($\varepsilon = 0.6$, $\varepsilon = 0.7$). To perform this experimental study an experimental test-rig was designed and constructed. During each experiment the required measurements for air velocity, air temperature and relative humidity were obtained.

Experimental results show that, drying process can be achieved in ,lower, time as mass flux of air increases and or inlet air temperature increases. The evaporation rate increases as ball porosity increases, due to the increasing in the amount of initial water content. Also, heat transfer coefficient (or in turn Nusselt number) decreases with increasing inlet air temperature and increases with increasing air mass flux, and ball porosity. Mass transfer coefficient (or in turn Sherwood number) increases with increasing inlet air temperature, air mass flux, and ball porosity. But, as

bed depth increases the heat transfer coefficient and mass transfer coefficient are decreased .

Comparison between the present experimental results and that of previous works gives the same trend.

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Faculty of Engineering
Mechanical Power Eng. Dept.

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B. Sc. Mechanical Engineering
Higher Technological Institute
10th of Ramadan City

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Researcher Name : Ahmed Abd El-Badie Ibrahim Ali

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Abstract

In the present experimental work, drying process has been carried out by forcing air to flow, in upward direction, through the wet porous bed which put in vertical circular duct. Wet porous bed was packed with a uniform 20 mm in diameter wet porous clay balls. Drying process occurs due to the simultaneous heat and mass transfer between wet porous bed and airflow. The affecting parameters on drying process are ,experimentally, investigated. The studied affecting parameters on the drying process are inlet air temperature (30 - 40 - 50 - 60 $^{\circ}C$), inlet air mass flux (1 - 1.8 - 3.36 - 4.08 $kg/m^2.s$), porous bed depth (0.1575 - 0.105 - 0.0525 m) and porosity of balls ($\varepsilon = 0.6$, $\varepsilon = 0.7$). To perform this experimental study an experimental test-rig was designed and constructed. During each experiment the required measurements for air velocity, air temperature and relative humidity were obtained.

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Nomenclature

A	Area, m^2
C_P	Specific heat of air, J/(kg . °C)
C_v	Specific heat of water vapor, J/(kg . °C)
d	Bed diameter ,m
D	Diffusion coefficient, m^2/s
G	Mass flux, kg/m^2.s
h_{con}	Convective heat transfer coefficient, W/(m^2. K)
h_{evp}	Evaporative heat transfer coefficient, W/(m^2. K)
h_m	Mass transfer coefficient, m/s
h_{fg}	Latent heat of vaporization, J/kg
k	Thermal conductivity, W/(m. °C)
L	Bed depth, m
$m^{\cdot}_{air}$	Air mass flow rate, kg/s
$m^{\cdot}_{evp}$	Evaporation rate, kg/s
Nu	Nusselt number ($Nu=hL/k$), -
P	Pressure, Pa
Q	Rate of heat transfer, W
r	ball radius, m
R	Gas constant, Pa.m^3/(kg.K)
Sh	Sherwood number ($Sh=h_m L/D$), -
T	Temperature, °C
u	Air velocity, m/s
X_{in}	Initial moisture content, kg_{water} /$kg_{dir\ air}$
X	Free moisture content, kg_{water} /$kg_{dir\ air}$
X_c	Critical moisture content, kg_{water} /$kg_{dir\ air}$
V_{solid}	Volume of solid porous material, m^3
ΔT_{ch}	Characteristic temperature difference, °C
$\Delta \rho_{ch}$	Characteristic density difference of moist air, kg/m^3

Greek symbols

ε	Porosity, -
ρ	Density, kg/m^3
τ	Time, s
Ø	Relative humidity,-
ω	Humidity ratio, $kg_{water}/kg_{dry\ air}$

Subscripts

atm	atmospheric
av	average
b	ball
c	cross section
con	convection
ch	characteristic
d	dry
db	dry bulb
dp	dew point
eff	effective
evp	evaporation
in	inlet
m	mass
out	outlet
sat	saturation
v	water vapor
s	surface

Chapter (1)

Introduction and Literature Review

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Introduction and Literature Review

1.1 Introduction

Drying is the removal of a liquid from a moist material. The separation of liquid from a moist material may be carried out in a rough mechanical manner (without phase change) or by heat supply, i.e. thermal drying. Drying is often performed by allowing hot gas to come into contact with wet material. The drying process requires a lot of energy for evaporation of liquid. The traditionally drying medium is the hot air, so that convective drying can be carried out. Slow drying at low temperature (where range of air temperature from ambient to ambient plus 10 ^{o}C) is quite important because it is low cost process. Drying is widely used in a variety of thermal energy applications. Industrial applications for drying include the production of paper, textiles, food, chemical, pharmaceutical, ceramics, wood , building and construction materials and grains industries.

The drying of grains is of great interest in the agricultural sectors. The optimization of cost of this operation and the preservation of the quality require a study of heat and mass transfer during drying. Heat may be supplied to a wet material by conventional heating methods (convection, conduction, radiation) or high frequency heating.

The drying of solids is one of the oldest and most common unit operations found in diverse processes. Nevertheless, it is still one of the sciences that need basic research, partially because of the difficulties and deficiencies in mathematical process descriptions and partially because of the lack of detailed knowledge of the coupled momentum, heat and mass transfer phenomena.

1.1.1 Types of Dryers

A. Tray Dryer

In tray dryer, the material which my be a lumpy solid or a pasty solid, is spread uniformly on a metal tray to a depth of 10 to 100 mm. Such a typical tray dryer is shown in Fig.(1.1). It contains removable trays loaded in cabinet. After drying, the cabinet is opened and the trays are replaced with a new batch of trays. A modification of this type is the tray-truck type, where trays are loaded on trucks which are pushed into the dryer. In the case of granular material, the materiel can be loaded on screens, which are the bottom of each tray. Then through-circulation dryer, heated air passes through the permeable bed, giving shorter drying times because of the greater surface area exposed to the air.

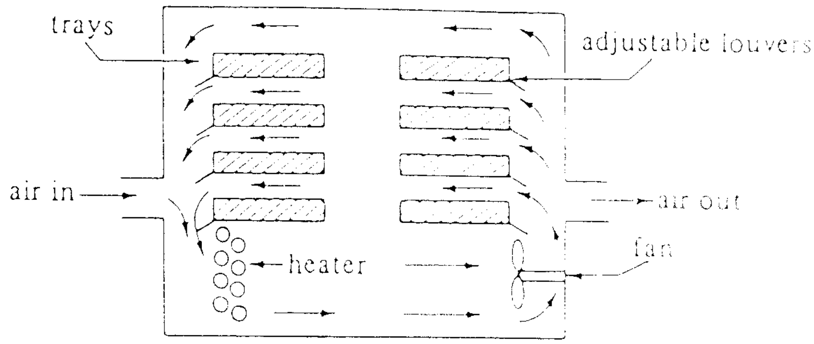

Fig. (1.1) Tray or shelf dryer.

B. Vacuum-Shelf Indirect Dryer

Vacuum-shelf dryers are indirectly heated batch dryers similar to tray dryers. Such a dryer consists of a cabinet made of cast-iron or steel plates fitted with tightly fitted doors so that it can be operated under vacuum. Hollow shelves of steel are fastened permanently inside the chamber and are connected in parallel to inlet and outlet steam headers. The trays containing the solids to be dried rest upon the hollow shelves. The heat is conducted through the metal walls and added by radiation from the shelf above. For low-temperature operation, circulating warm water is used instead of steam for furnishing the heat to vaporize the moisture, the vapors usually pass to a condenser. These dryers are used to dry expensive, or temperature-sensitive, or easily oxidizable materials. They are useful for handling materials with toxic or valuable solvents.

C. Continuous Tunnel Dryers

Continuous tunnel dryers are often batch truck or tray compartments operated in series, as shown in Fig.(1.2-a), the solids are placed on trays or on trucks which moves continuously through a tunnel with hot gasses passing over the surface of each tray. The hot air flow can be countercurrent, cocurrent, or a combination. Many foods are dried in this way.

When granular particles of solids are to be dried, perforated or screen-belt continuous conveyors are often used, as in Fig.(1.2-b). The wet granular solids are conveyed as a layer 25 to about 150 mm deep on a screen or perforated apron while heated air is blown upward through the bed, or downward the dryer.

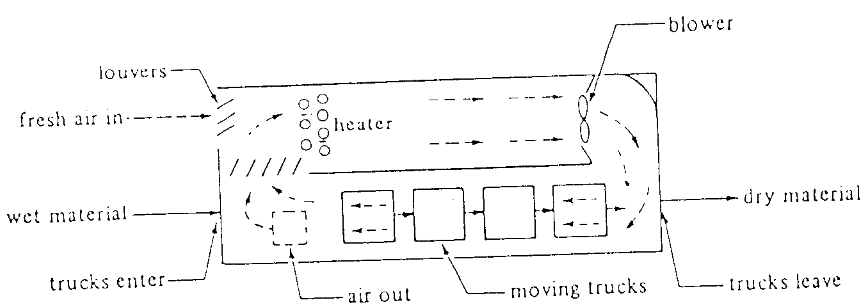

Fig.(1.2-a) Continuous tunnel dryers trucks with countercurrent air flow.

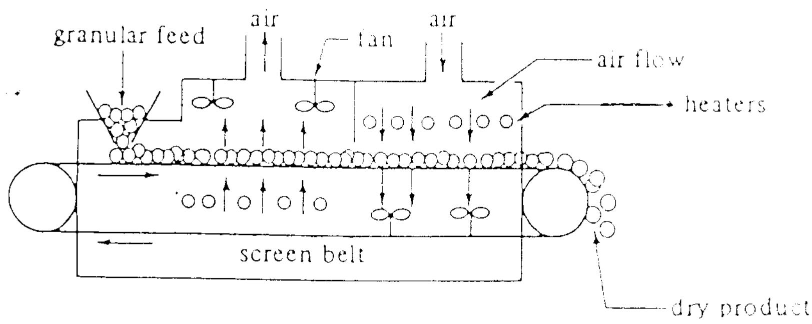

Fig. (1.2-b) Continuous tunnel dryers through-circulation screen Conveyor.

D. Rotary Dryers

A rotary dryer consists of a hollow cylinder, which is rotated and usually slightly inclined toward the outlet. The wet granular solids are fed at the high end as shown in Fig.(1.3), and move through the shell as it rotates. The heating of solids in this figure is by direct contact with hot gases in countercurrent flow. In some cases the heating is by indirect contact through the heated wall of the cylinder.

The granular particles move forward slowly a short distance before they are showered downward through the hot gasses as shown.

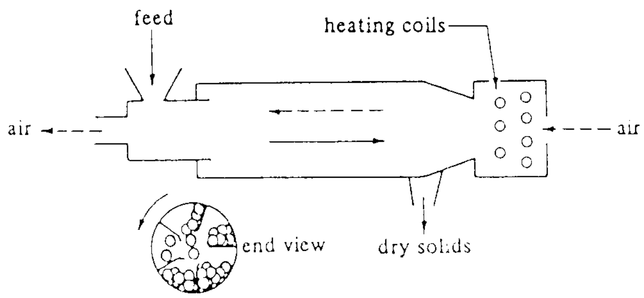

Fig. (1.3) Schematic drawing of a direct-heat rotary dryer.

E. Drum Dryers

A drum dryer consists of a heated metal roll shown in Fig.(1.4). The outside of which is a thin layer of liquid or slurry to be evaporated to dryness. The final dried solid is scraped off the roll, which is revolving slowly.

Drum dryers are suitable for handling slurries or pastes of solids in fine suspension and also for solutions. The drum functions partly as an evaporator and also as a dryer. Other variations of the single-drum type are twin rotating drums with dip feeding or with top feeding to the two drums. Potato slurry is dried using drum dryers, to give potato flakes.

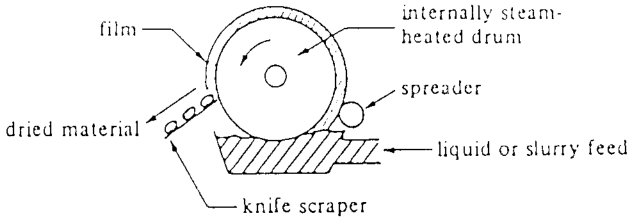

Fig. (1.4) Rotary-drum dryer.

F. Spray Dryers

In a spray dryer a liquid or slurry is sprayed into a hot gas stream in the form of a mist of fine droplets. The water is rapidly vaporized from the droplets, leaving particles of dry solid, which are separated from the gas stream. The flow of gas and liquid in the spray chamber may be countercurrent, cocurrent or combination.

The fine droplets are formed from the liquid feed by spray nozzles inside a cylindrical chamber, as shown in Fig.(1.5), it is necessary to ensure that the droplets or wet particles of solid do not strike and stick to solid surfaces before drying has taken place. Hence large chamber are used. Dried milk powder is made from spray-drying milk.

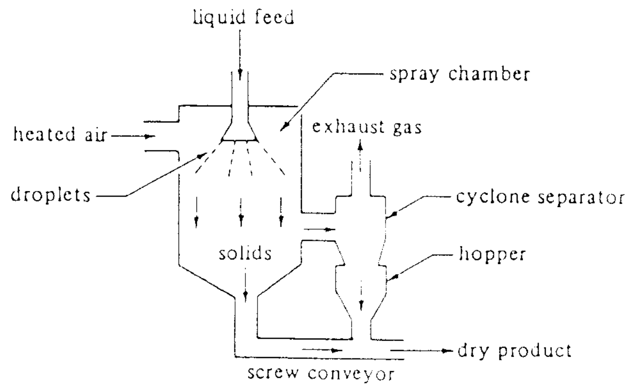

Fig.(1.5) Process flow diagram of spray-drying apparatus.

G. Drying of crops and grain

In the drying of grain from a harvest, the vertical continuous-flow grain dryer, as shown in Fig.(1.6), is used.

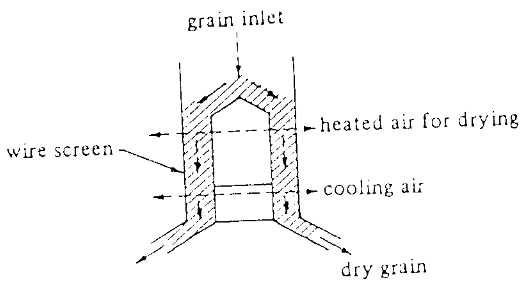

Fig.(1.6) Vertical continuous- low grain dryer.

1.1.2 Equilibrium moisture content

Suppose that a wet solid containing moisture is brought into contact with a stream of air having a constant humidity and temperature. A large excess air is used, so its conditions remain constant. Eventually, after exposure of the solid sufficient long for equilibrium to be reached, the solid will attain a definite moisture content. This is known as the equilibrium moisture content of the material.

The equilibrium moisture content of the material depends on the relative humidity as shown in Fig.(1.7).

جا معة المنصورة
كلية الهندسة
قسم هندسة القوى المكانيكية

دراسة تأثير العوامل المختلفة على عملية التجفيف

رسالة

مقدمة للحصول على درجة الماجستير
فى هندسة القوى الميكانيكية

مقدمة من

المهندس / أحمد عبد البديع إبراهيم على
بكالوريس الهندسة الميكانيكية
المعهد التكنولوجى العالى العاشر من رمضان

تحت إشراف

أ٠د محمد جمال حسن واصل
أستاذ بقسم هندسة القوى الميكانيكية
كلية الهندسة جامعة المنصورة

أ٠م٠د هشام محمد مصطفى
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