STUDY ON APPLICATION OF FUZZY CONTROL SYSTEM FOR THE GRAIN DRYING EQUIPMENT OF AGRO-PRODUCTS

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SUMMARY

Control system is used in drying equipment in the process of drying grain aiming at reducing the moisture of agro-products down to a desired level. Conventional methods applied in drying control process have shown limited results as seen in uneven dried products quality, high rate of energy consumption. Modern control method, in which fuzzy control system is applied, proves its advantages by eliminating the above limitations. However, in order to obtain drying control results as desired, thorough studies on drying process for an accurate prediction of control model are required. Results obtained from the study of dynamic model over drying process using fuzzy control system for grain moisture reduction have brought prospects to drying technology to increase dried products quality and its economic effectiveness in the area of storage and processing of agro-products.

Key words: *Application of Control system, Food grain Drying*

Symbols:

W_0 - Initial grain Moisture Content, %
W_{cb} - Grain Equilibrium Moisture Content, %
W - Final Moisture Content, %
MR - Moisture Content, %
Q_a - Airflow through grain mass, m^3/h
RH - Air Relative Humidity, %
t - Drying Time, min
v - Drying Air Velocity, m/s
T_s - Drying Air Temperature, ^oC
T_a - Ambient air Temperature, ^oC
T_f - Final Air Temperature, ^oC.
C_g - Grain Specific Thermal Capacity, J/kg ^oC

INTRODUCTION

In the process of food grain drying, many factors are involved in drying agent temperature, temperature for grain mass heating, rate of drying agent, grain moisture content as well as time for grain kept in drying bin affect greatly quality of dried products. If the temperature of drying agent exceeds the allowable drying one, grain cracking and embryo deterioration situation may easily occur. The proper drying agent temperature also depends on initial moisture of grain to be dried. The temperature for heating grain mass inside drying bin shall be inversely proportional to the initial grain moisture. Therefore, selection of drying system and time will depend on initial moisture status of each grain type.

The process of food grain drying is quite complicated and not so stable since, the processes of heat-moisture that are transfer inside and between the grain, and the ambient condition simultaneously occur. The heat-moisture transfer process is generally described by a system of complicated differential equations. Therefore, identifying the rule of variation as occurring in the above processes by the method of separating the components of the above equations system - which requires solving non-linear differential equations with some constraints- is a difficult task.

In order to solve the problem, the control system for food grain drying is to meet following requirements:

- Ensure maintaining quality of the products to be dried without considering unexpected disordered ambient and mechanical effects during operation of drying machine or, changes in the process of supplying material to be dried.

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- Increase drying machine capacity, maximize specific energy consumption during drying process and minimize drying costs.

- Drying operation process is kept stable and preventing effects from the unexpected disordered ambient factors.

- In considering (i) drying control process with its related variables like temperature, moisture content, airflow, pressure, etc, and also, (ii) the drying-type method like batch-type or continuous flow drying, the drying control systems could be classified into two types: batch-type drying control system and continuous flow type drying one [5,7].

By conventional control methods, the control sets include: manual control/handle, PID control, etc. These methodologies generally give uneven quality of dried grain products and high energy consumption.

By modern control method, the control sets include: adaptive control, fuzzy control, etc., [2,7]. Application of this methodology could help to eliminate the weak-points derived from the use of conventional methods. However, in order to find an adequate control system model as mentioned-above, further thorough studies over dynamic modeling of drying process are required.

RESEARCH METHODLOGY

Dynamic Model on Drying Process

Let us consider the relationship among the inputs, outputs and the disordered ambient factors in the drying process as presented in Fig. 1:

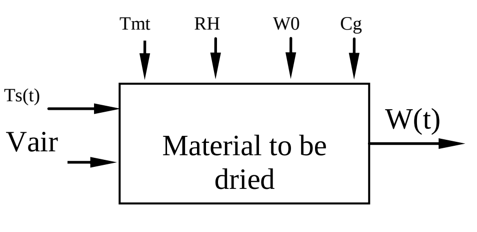

Fig.1: *Factors affecting drying process*

- *Input variables of the dryer include:* Temperature of drying agent T_s; velocity of the airflow of the drying agent V_{air} ; velocity of drying material supply T_s, etc..

- *Most typical output variables of a drying machine include:* Moisture content of the products after drying W(t); temperature of the products after drying T_c; exhausted air temperature, exhausted air moisture content; quality of dried products (color, smell, activate character, etc.).

- *In addition, other most popular disordered factors involved in a drying machine are:* Ambient temperature T_{mt} , ambient air humidity RH, moisture content of input material W_0 , grain temperature, etc.

In the drying process as mentioned above, there appears certain variables being difficult to define as: interior temperature of the grain, grain moisture content in drying process…

Kinetic model for drying process has been developed based upon theoretical equations by Li and Morey as following [1,5,6,and 7]:

$$W = W_{cb} + \left(W_0 - W_{cb}\right) e^{\left\{-K.t^N\right\}} \quad (1)$$

Where: K,N – empirical coefficients to be defined following drying agent temperature and initial grain moisture content for each type of drying equipment.

Model on drying process regulation

Food production is generally facing difficulty in grain drying, especially when a harvesting season is experienced in rainy season. Although lots of studies in drying techniques have been done [5,6], much more efforts need to be carried out so as an optimal model in drying, appropriate to the grain to be dried, could be developed. One among considerable drying techniques is of tower drying type.

Almost present studies on control system of drying machines are still modest that have not met the demand of proper drying technology. Regulation of drying process is still done manually so that the quality of dried grain shall be affected. In order to increase the quality of the dried grain, a control system for use in regulating drying process of the tower drying machine so as drying agents like temperature, humidity, etc, shall be designed.

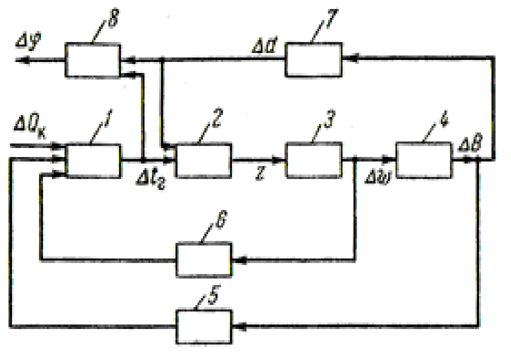

Fig.2. *Flow diagram showing regulation system in drying process of a tower drier*

Fig.2 represents a structural flow diagram [8] showing regulating system in drying process of a tower dryer through which, the tower drying machine dynamics could be defined.

where: Δφ - relative humidity of the air; ΔB- pressure in the drying chamber;

Δω- changing levels of grain moisture; Δd- moisture drying agent.

Δt – changing temperature of the grain; z - grain type

Transmission function 1 characterizes inertia of heat exchange process in the dryer which is defined from the heat equilibrium equation of drying machine [8].

$$Q_k=Q_1+Q_2+Q_3 \quad (2)$$

where: Q_k- heat flow total; Q_1 –heat used for moisture evaporation;

Q_2 - heat used for air heating ; Q_3 – heat being lost into the ambient media.

Transmission function 2 characterizes effect of ambient air moisture of the media on the temperature of the heat loading agent.

Transmission function 3 characterizes drying time interval.

Transmission function 4 characterizes intensity of separating moisture from grain corn by average moisture.

Transmission function 5 characterizes heat consumed depending on the intensity variation of moisture separation of corn.

Transmission function 6 characterizes heat consumed as caused by moisture function of the material.

Transmission function 7 characterizes the variation of air moisture function in accordance with the intensity variation in moisture separation.

Transmission function 8 characterizes air relative humidity in accordance with its temperature and moisture.

In order to determine relationships among the above operations, following studies shall be carried out:

- Study on heat transmission of corn grain.
- Study on heat transmission of the tower drying equipment.

The results as obtained will be analyzed through practical evaluation.

Results from experimental tests

Table 1. *Experimental data list*

Drying time (hr)	**Progress in moisture variation of corn grain**		
	u_0=27,1%; t=70 °C (First trial)	**u_0=19,2%; t= 90 °C (Second trial)**	**u_0=28%; t=100°C (Third trial)**
0	27.1	19.2	28
1	25.6	14.2	21
1.5	24.6	13.15	18.2
2.5	23.1	10.2	13.6
3.5	22	9.8 (2,67)	10.4
4.5	18.9		8.8 (4)
5.5	17.5		
6.5	16.3		
7.5	15.2		
8.5	14.9		
9.5	14.6		

(The above experiments were carried out at the Vietnam Institute of Agricultural Engineering and Post-Harvest Technology).

From calculation for determining coefficient of moisture conduction and heat calculation of the tower drier based upon moisture and heat equilibrium equations, the following chart illustrating regulations in the tower dryer could be introduced as follows:

Transmission function 1 – showing heat flow total in the process of drying [1]:

$$Q_k = \left[\frac{1{,}004t_1 + d_1\left(2500 + 1{,}842t_1\right) - 1{,}004t_0 - d_0\left(2500 + 1{,}842t_0\right)}{d_1 - d_0}\right]$$

Transmission function 2 –expresses temperature of drying agent t_1(°C) in accordance with the moisture amount of the ambient air d_0 (g /kg kk)

$t_1 = -0.01d_0^4 + 0.4725d_0^3 - 8.0301d_0^2 + 63.893d_0 - 142.96$

Transmission function 3 – expresses drying time in accordance with moisture content and coefficient of moisture conduction

MR = (W-We)/(Wi-We) = exp(-K.tN)

with their experimental coefficients as:

$K = -0{,}096914101 - 1{,}979960571.10^{-4}.T + 0{,}037766202.T.W$ (3)

$N = 1{,}426585003 - 2{,}279949923.\ W_i^2 + 6{,}606504798.10^{-5}.T^2$ (4)

and the coefficient of moisture reduction as

$a_m = 0.011 + 0.378u + 5.67u^3 + 0.015ut + 0.232u^3t - (1.512 + 0.062t)u^2$ (5)

Transmission function 4 – expresses the intensity in moisture separation W (kg /h) following the grain moisture content u (%)

$W = -6E\text{-}11u^2 + 122u - 2196$ (6)

Transmission function 5 – expresses the calorific energy Q (MJ/h) in accordance with the intensity in moisture separation W (kg /h)

$Q = -1E\text{-}06w^4 + 0{,}0027w^3 - 1{,}9926w^2 + 648{,}87w - 78350$ (7)

Transmission function 6 – expresses the calorific energy Q (MJ/h) in accordance with grain moisture content u (%)

$Q = 0{,}4167u^4 - 36{,}667u^3 + 1209{,}6u^2 - 17436u + 92463$ (8)

Transmission function 7– expresses the intensity in moisture separation W (kg /h) inaccordance with ambient air moisture amount d_0 (g /kg kk): W= 488

Transmission function 8 – expresses relative humidity according to the temperature and moisture amount contained in drying air [1]:

$$\varphi = \frac{0{,}98d}{\left(0{,}621 + d\right)e^{\left(12 - \frac{4026{,}42}{235{,}5t}\right)}}$$

CONCLUSION

- The article gave the kinetic model and parameter transmission function of the tower dryer, object is dried corn kernels, these results are useful for the process design calculations tower dryer as well as calculate the all drivers grain corn drying in the tower dryer.
- Transmission functions have been established which are considered aspremises for the application of control process in drying agro-products.
- A dynamic model on the process of drying grain corn for a tower drier (equations 3; 4 and 5) has been established.

REFERENCES

1. Trần Văn Phú, *Calculations for the Design of Drying system,* Education Publishing House, Hanoi, 2001.
2. Phạm Công Dũng. *Study in the process and its related equipment of fluidized-bed Drying Applying in the drying and storage of corn grain* – PhD Dissertation, Hanoi, 1999
3. MSc. Trần Hồng Thao, Assc.Prof. Dr. Nguyễn Văn Liễn, Assc.Prof. Dr. Trương Ngọc Tuấn. *Establishment of a mathematical model for agro-*

products drying of tower type. Journal of Heat Energy, a Journal of the Vietnam Association for Heat Technology Sciences, No. 95 - 9/2010.

4. Assc.Prof, Dr. Trương Ngọc Tuấn, Lê Tiến Mười, MSc. Trần Hồng Thao. *Determination of Moisture Transmission in Corn Grain.* Journal of Scientific & Technology Study in Military, Hanoi, No. 16 – Dec. 2011.

5. Trần Hồng Thao, *Study on Effective Energy System in the Process of Drying Corn Grain;* Ph.D Thesis, University of Ruse, 2014.

6. MSc.Tran Hong Thao, Vietnam Institute of Agricultural Engineering and Post-Harvest Technology; Prof. Hristo Ivanob Beloev, Ph.D, Dr.Sc, DHC, "Angel Kanchev" University of Ruse; Assc. Prof. Krasimir Velikov Martev, Ph.D, "Angel Kanchev" University of Ruse. *Dynamic Modeling of Tower-Type Corn Grain Dryer in Vietnam.* PROCEEDINGS, Volume 51, Book 1.1 - Agricultural Machinery and Technologies; Agrarian Sciences and Veterinary Medicine; Repair and Reliability. Ruse 2012.

7. И. П. Баумштейн, Ю. А. Майзель. *Автоматизация процессов сушки в химической промышленности*. Издательство "Химия", 1970, 19-25.

8. Phạm Văn Lang, Nguyễn Huy Mỹ (1992). Methodology on Technical Control and Applications in Agriculture. Agricultural Publishing House, Hanoi, 1992.

TÓM TẮT
NGHIÊN CỨU ỨNG DỤNG BỘ ĐIỀU KHIỂN TRONG THIẾT BỊ SẤY HẠT NÔNG SẢN

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Các loại thiết bị sấy được sử dụng bộ điều khiển để thực hiện quá trình làm khô nông sản đến một độ ẩm nhất định theo yêu cầu. Các phương pháp điều khiển quá trình sấy truyền thống còn thể hiện nhiều hạn chế như chất lượng sản phẩm không đều, tiêu tốn nhiều năng lượng; các phương pháp điều khiển hiện đại, mà trong đó có điều khiển mờ tỏ ra có nhiều lợi thế khi khắc phục được những nhược điểm trên. Tuy nhiên, để đạt được kết quả điều khiển tốt cần có các nghiên cứu kỹ về quá trình sấy để quá trình nhận dạng mô hình điều khiển được chính xác. Kết quả nghiên cứu mô hình động học quá trình sấy, sử dụng bộ điều khiển mờ làm giảm ẩm hạt nông sản mở ra nhiều triển vọng cho công nghệ sấy để nâng cao chất lượng sản phẩm và hiệu quả kinh tế trong lĩnh vực bảo quản chế biến nông sản.

Từ khóa: *Ứng dụng bộ điều khiển, sấy hạt lương thực*

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