Simplified Approach for Paper Drying Modeling Using Matlab

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Index Terms—Introduction, Factors affection drying process, what is Matlab, Model Equation, Matlab Models,results

Abstract

In this proposed work model for the paper drying process has been designed in Matlab Simulation toolbox developed, for   modeling ,the drying section divides into component such as PAPER,CANVAS,AND CYLINDERS. The dynamic model of these component are represented as lumped parameter system and connected to each other to model the entire paper drying process. Matlab simulation helps in developing model for paper dryer. simulation studies are carried out to study the effect of grade change and other process variables on the final moisture of the paper. the novel approach of modeling the paper dryer as lumped parameter system reduced he numerical complexity of the model

Introduction

Paper is used for printing and writing, for wrapping and packaging and for a variety of other application ranging from kitchen towel to the manufacture of building material , it simply comes in an enormous variety of quantities. Some common types of paper qualities include the following:

- ➢ Copy paper for printer
- ➢ Newsprint
- ➢ Cardboard
- ➢ Light-weight coated paper for magazines
- ➢ Wrapping and packaging paper
- ➢ Currency paper

The function of a paper machine is to form the paper

sheet and remove the water from the sheet. A paper machine is divided into three main parts, the wire section, the press section and the drying section shown in fig 1.1, when a stock enters the head box in the wire section it contains roughly 1% of fiber or less. The viscous mix is dispensed through a long slice onto the wire. As it travels on the wire, mu of the water drains way by gravitational forces or is pulled away by suction from underneath. As a water disappears, the cellulose fiber starts to adhere to one another by hydrogen bonds and form a paper web. when the paper web leaves the wire section and enters the press section ,the dry solids content around 20%. In the press section, the newly formed

sheet is pressed between rotating steel rolls and water is displaced into a press felt. After a few press nips the web enters the drying section with a solid content of approximately about 50%. It now encounters the dryer cylinders. These are large hollow metal cylinders, heated internally with steam, which dry the paper as it passes them, Finally the paper wound up on a big roll and removed from the paper machine .the moisture content is now roughly 5-10%.
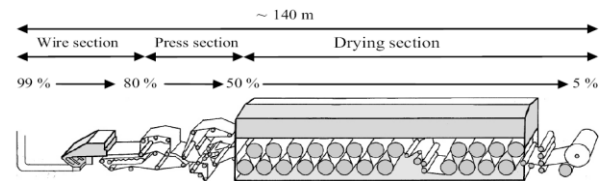

Figure :-basic principle of paper machine

Introduction of Drying section:-

Paper dryer is an important equipment in paper making process. The dryer section is the last part of the paper machine which consist of series of steam drums. The most common way to evaporate water from the paper web is to use the latent heat of vaporization in steam. A steam-filled dryer is a cost effective method to transfer heat into the sheet. The moist paper web is rolled on these steam fed drums. Where the steam is used to evaporate the moisture from the web. The heat to the paper web is controlled by the steam pressure in the drum. The drying section consumes 70% of the total steam used in the paper mill. During grade transition, the drying section consumes energy without producing desired quality of paper.

1.4)- FACTORS AFFECTING ON THE MOISTURE IN THE PAPER :-

There are large number of variables that determine the moisture in the paper sheet,shown in fig1.4. To indicate the complexity of the problem some of them are listed below.

- ➢ **Production speed-** Affects the amount of steam needed, since high production also involves higher vaporization.
- ➢ **Dry weight-** A thick sheet is more difficult to dry than a thin sheet at the same production speed.
- ➢ **Inlet moisture-** The moisture content of the sheet after the press section is a

disturbance variable that normally is unknown.

> **Degree of Refining-** The parameter naturally affects both the freeness and the ability to dry the sheet

> **Air dew point-** A high dew point inhibits effective evaporation.

> **Dryer Fabric Condition-** An old fabric can be clogged and give a higher evaporation resistance.

> **Bulk-** High bulk means that the water inside the web has a longer transport distance to the surface and ambient air.

> **Web Tension-** High web tension increases the heat transfer coefficient and the drying rate.

> **Leakage air-** The air from the machine room is cooler that the preheated supply air and therefore impair the drying condition

> **Ply loading-** In paperboard, different layers consist of different pulps, hence different physical properties. This influences the drying
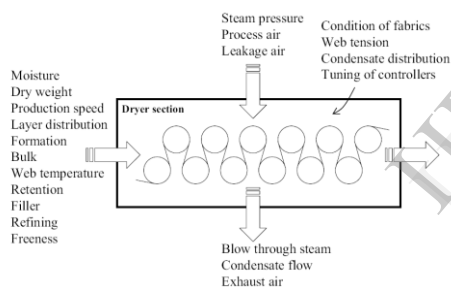

FIGURE 1.4 factors affecting on the moisture in the paper during drying process

The name MATLAB stands for Matrix Laboratory. MATLAB was written originally to provide easy access to matrix software developed by the LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is a high-performance language for technical computing. It integrates *computation*, *visualization*, and *programming* environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated *data structures*, contains built-in editing and *debugging tools*, and supports *object-oriented programming*. These factors make MATLAB an excellent tool for teaching and research.MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving

technical problems. MATLAB is an interactive system whose basic data element is an *array* that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. It has powerful *built-in* routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as *toolbox*. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering.

Introduction of Matlab-

Introduction to MATLAB for Engineering Students" is a document for an introductory course in MATLAB R°1 and technical computing. It is used for freshmen classes at North-western University. This document is not a comprehensive introduction or a reference manual. Instead, it focuses on the specific features of MATLAB that are useful for engineering classes. The lab sessions are used with one main goal: to allow students to become familiar with computer software (e.g., MATLAB) to solve application problems. We assume that the students have no prior experience with MATLAB.The availability of technical computing environment such as MATLAB is now reshaping the role and applications of computer laboratory projects to involve students in more intense problem-solving experience. This availability also provides an opportunity to easily conduct numerical experiments and to tackle realistic and more complicated problems.

Modelling Of Steam dryer-

Inlet paper web is to be dried to a desired moisture content using steam heated drums. To support and transport the paper web, it is covered with canvas or paper fabric. The canvas is also used to provide good thermal contact between the web and the cylinder. the drying section is enclosed within a drying hood to provide controlled ambient condition. The exhaust air from the hood removes

the evaporated water and preheated air is fed to the hood to maintain controlled environment for paper drying process. This results in better heat utilization and less variation in the paper quality. The basic configuration of a dryer shown in fig.
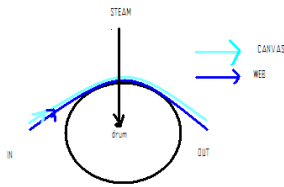

FIGURE:-input output stream of dryer

MODEL EQUATION –
The mathematical modeling of a dryer is based on mass/energy balance equation. In this case the assumptions are outer surface area and inner surface area of the dryer.

Outer surface area of cylinder is-

$$D_A = r\theta L \qquad (1)$$

Corresponding outer surface area of web and canvas over cylinder

$$w_A = (r + w_{th})\theta L \qquad (2)$$

$$c_A = (r + w_{th} + c_{th})\theta L \qquad (3)$$

Inner surface area of cylinder

$$S_a = (r - D_{th})\theta L \qquad (4)$$

The density of the web depends on its moisture content

$$\rho_i^w = 265(1 - MT_i^w) + 1000\, MT_i^w \qquad (5)$$

MASS balance on the web is-

$$\frac{dM}{dt} = m_{in} - m_{out} - \lambda W_A \qquad (6)$$

where –

$$m_{in} = R_S L D_{th}\rho_i^w \quad , \quad M = D_{th}\frac{DA+WA}{2}\rho_o^w,$$

$$m_{out} = R_S L\, D_{th}\rho_o^w$$

Substituting these values in mass balance equation-

$$W_{th}\frac{DA+WA}{2}\frac{d\rho ow}{dt} = R_S L W_{th}(\rho_i^w - \rho_o^w) - \lambda W_A \qquad (7)$$

similarly mass balance for moisture-

$$W_{th}\frac{DA+WA}{2}\frac{d\rho ow\ MT\ (wat)}{dt} =$$

$$R_S L W_{th}(\rho_i^w MT_{in}^{wat} - \rho_o^w MT_o^{wat}) - \lambda W_A \qquad (8)$$

Heat energy balance on web -

$$SH_o^w\frac{DA+WA}{2}W_{th}\frac{d\rho ow\ TO(w)}{dt} =$$

$$W_{HD}D_A(D_T - T_O^W) - WC_H W_A(T_O^W - T_O^C) + R_S L W_{th}(SH_i^w\rho_i^w T_i^w - \rho_o^w T_o^w SH_o^w) - \lambda W_A\Delta ev_H \qquad (9)$$

heat balance on the cylinder-

$$\frac{DA+Sa}{2}\frac{2\pi}{\theta}\frac{dDT}{dt}Dth\rho_D SH_D =$$

$$S_a SD_h(D_T - T_o^W) - r(2\pi - \theta)LDA_h(D_T - d_T) \qquad (10)$$

heat balance on canvas-

$$\frac{CA+wA}{2}\frac{dTo(c)}{dt}C_{th}SH_C\rho_C = W_A WC_h(T_O^W - T_O^C) - C_A CA_h(T_O^C - D_T) + \rho_W R_S C_{th}LSH_C(T_i^C - T_O^C) \qquad (11)$$

Amount of steam required is given by total heat demand divided by the latent heat of condensation of steam-

$$"ms = ((DA+WA))/2\ DWh(DT - TO(W))/Lat\ h$$

Relation between steam pressure and steam temperature

$$S_T = 100((P + S_P)/10^5)^{0.25} \qquad (12)$$

Specific heat capacity of the web=

$$SH_O^W = (0.32 - 1.366 as_r + MT_o^{w})/1 + MT_o^w \qquad (13)$$

The evaporation rate,

$$\lambda = [WA_h(S_{hu} - hu)]/SH_A + S_{hu}SH_v \qquad (14)$$

where air humidity is-

$$S_{hu} = 0.62197 Ps/(P - Ps)$$

$$Whu = 0.62197 ap/(p - ap)$$

the exhaust air moisture given by soinien and karlosson –

hu
$$= (1.0048(wT - dT) + whu(2501 - 2.3237wT))/(2501 + 1.86dT - 4.19wT)$$
(15)

From antoine equation the vapour partial pressures Pa AND Ps are-

$$a_p = 10^5(10^{5.11564 - \frac{1687.537}{wT+230.17}})$$

$$S_P = 10^5(10^{5.11564 - \frac{1687.537}{WT+230.17}})$$

The heat of evaporation, ΔH_{ev} is the sum of the latent heat of vaporization and heat of sorption

$$\Delta ev_{H=} \Delta Vap_h + \Delta S_h$$
(16)

where

$$\Delta Vap_h = 505.3747(1-R_T)^{0.354} + 269.658(1-R_T)^{0.456}$$

reduced temprature

$$R_T = T_o^W/373.95$$

$$\Delta S_h = -0.10085R(\frac{1-\phi}{\phi})MT_W^{1.0585}WE_T^2$$

Relative humidity of air
$$\phi = 1 - \exp(-47.58MTwat^{1.877}) - 0.100085WETMTwat^{1.0585}$$
(17)

Heat transfer coefficient between air and web-

$$wa_{h=}k_1B_WR_S^n\exp(k_2B_WN^nMT_O^W) + k_3B_WR_S^n\exp(k_4B_WR_S^nMT_O^W)$$
(18)

Heat transfer coefficient between drum and web-

$$DW_h = c_1\exp(c_2MT_o^w) + c_3\exp(c_4M_o^w)$$
(19)

Fig :-represent the simulation model and simulated graph for a steam required m_s depends upon heat demand latent heat of condensation of steam
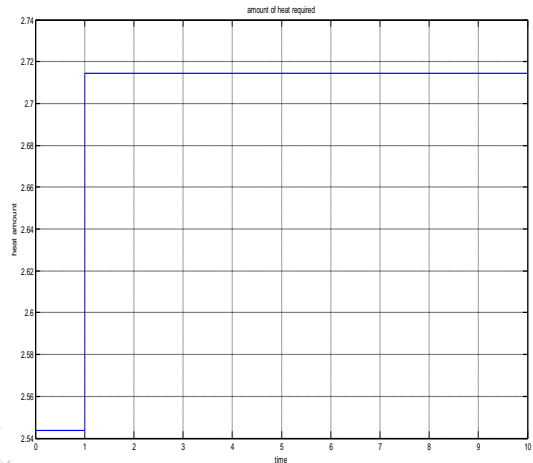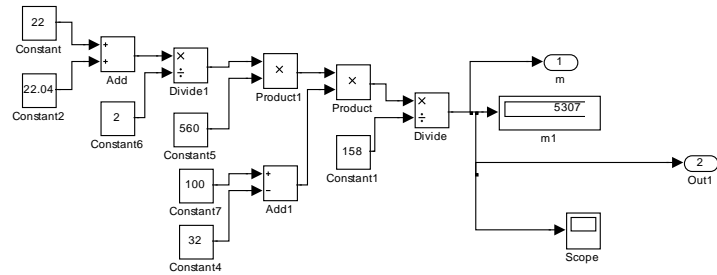

FIGURE-AMOUNT OF STEAM REQUIRED(ms)

Fig; represents the simulation model and simulated result for relation between steam pressure and steam temperature
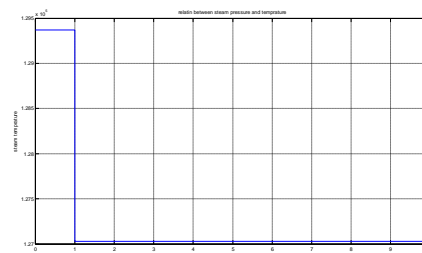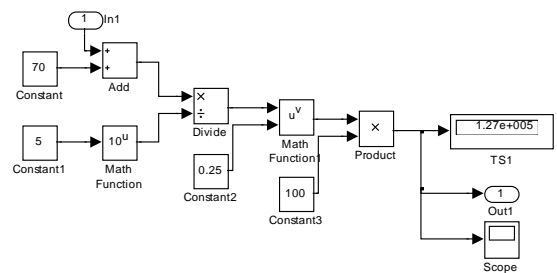
FIG-RELATION BETWEEN STEAM PRESSURE AND TEMP. T_S

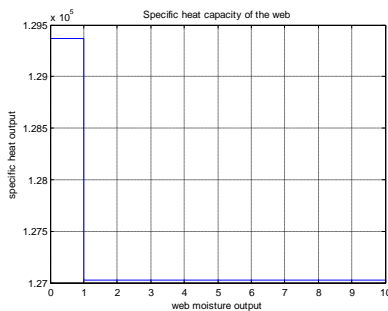Fig:represents the simulation model and simulated result for the specific heat capacity

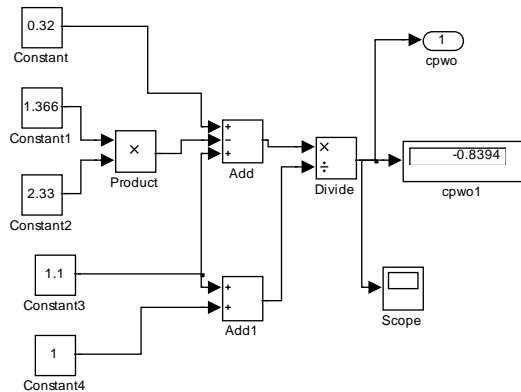
FIG:- EVAPORATION RATE(λ)

FIGURE -SPECIFIC HEAT CAPACITY SH_O^W

fig represents the simulated model and simulation result for evaporation rate which depends air humidity with respect to time
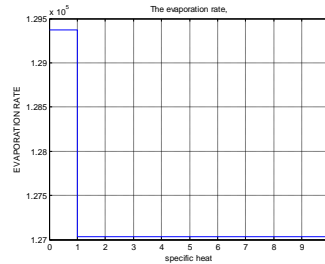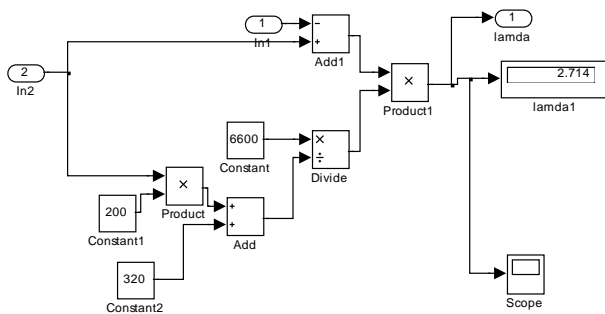

Conclusion

This paper presents modeling and simulation of a paper drying machine. A SIMULINK model of the drying machine is developed considering the effects of moisture,pressure and temperature. Modification of paper machine SIMULINK model is done to obtain the model of a drying process. The theoretically obtained characteristics of the paper drying experimentally verified for different ambient conditions.

Different drying system parameters were studied and it was concluded as a Matlab model. SIMULINK model was developed for a paper drying process. The performance of the system for different temperatures is analyzed. It was observed that a good matching can be achieved

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