A Software for Calculation of Optimum Conditions for Viscose Based Bobbin Drying in a Hot-Air Bobbin Dryer

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Abstract: - In this study, a software has been developed to predict the optimum drying conditions of viscose based yarn bobbins for drying in a pressurised hot air dryer. For this purpose, firstly, a suitable drying model has been found in defining the drying behaviour of bobbins using the experimental drying behaviour. After that, additional regression analyses have been made to take into account the effect of drying parameters on drying. Then, a software has been developed using Visual Basic programming language. With the aid of this software, optimum drying conditions for drying time and energy consumption can be obtained.

Key-Words: - Drying, moisture ratio, bobbin, viscose, Visual Basic, optimum parameters

1 Introduction

Yarn bobbins are passed through several processes such as dyeing and drying before they become market-ready-products. Drying is a time consuming, energy intensive and expensive process and constitutes one of the major cost elements among the finishing operations. The purpose of drying is to remove the water inside the bobbins. Part of the water in the bobbins is removed mechanically. But this mechanical process is not sufficient to remove water entirely. Therefore, a pressurised convective air dryer is generally used after this process.

In this study a software has been developed to obtain optimum drying conditions for viscose based yarn bobbins. For this purpose, firstly, a suitable drying model has been found in defining the drying behaviour of bobbins using the experimental drying behaviour. After that, further regression analyses have been performed to obtain drying time and energy consumption equations depending on the drying parameters. The developed software specifies the optimum drying conditions using these equations.

2 Material and Method

A PLC controlled pressurized hot-air bobbin dryer was used to obtain the drying behaviour of viscose based yarn bobbins. The schematic view of the experimental setup is shown in Fig. 1. Ambient air is directed to an electrical heater by a centrifugal fan. Pressurization is realized by a compressor. After the heater, air enters to a bobbin carrier system where the bobbins are dried. The carrier consists of four parts and four bobbins can be placed at each part. In the carrier, hot air is passed repeatedly 10 minutes from inside to the outside of bobbins and 10 minutes from outside to the inside of the bobbins in radial direction. After the carrier, drying air enters to a cooling exchanger and relative humidity of drying air is reduced. Next, drying air enters to a separator. In the separator, water droplets hanging on the air are separated from the air. Drying air finally returns to the fan. The carrier has been placed on a load cell. The conditions of air at different locations in the carrier and weights of the bobbins can be monitored by a software program, and the process can be controlled by an automatic control system.

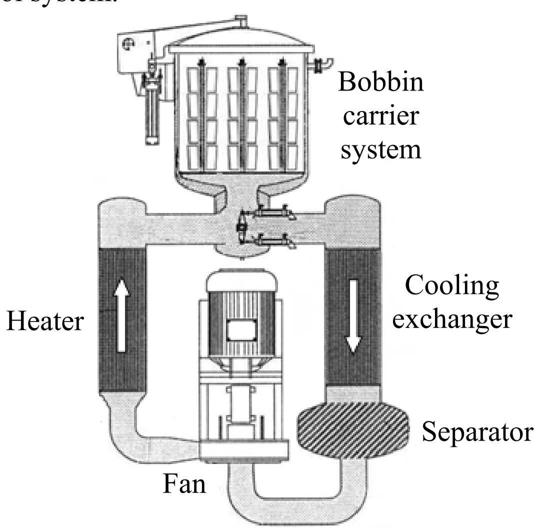

Fig. 1 Schematic view of the experimental bobbin dryer.

Drying air is heated in a heating exchanger (Fig. 2) consisting of 10 electrical resistances of 2.5 kW power. The control of heating power is realized by a solid state relay adjusting the phase difference of sinusoidal wave. Haters are PID (Proportion Integral Derivate) controlled and temperature adjustment is carried out according to this algorithm. Feedback control is provided using a Cu-Ni thermocouple. Four double-acting pneumatic pistons (Fig. 3) with magnetic sensors are used to open, to close, and to secure the lid of bobbin carrier and to control the air redirecting valve. The pistons are driven by pressurised air of 4 bar with the control of valves by outputs of PLC relays.

Fig. 2 Heating exchanger.

Fig. 3. Pneumatic pistons.

Relative humidity of the drying air at various location is conveyed to the PLC after measuring it by a sensor of 4-20mA output and 0.1 g/m3 accuracy. Hot air leaving the bobbin carrier is cooled by a cooling exchanger of 3.89m^2 surface area and 35kW cooling power (Fig. 4). After the cooling exchanger, drying air enters to a separator (Fig. 5) and excess moisture is separated from the drying air.
An analogue loadcell (Fig. 6) with a 500kg capacity has been used to measure the the weight of the bobbins during the drying period. The loadcells are under the bobbin carrier and have 3 load cells.

Fig. 4 Cooling exchanger.

Fig. 5 Seperator.

Fig. 6 Loadcells.

Analogue thermocouples of 3-4mm diameter, 10mm length and 4-20A (10 - 350 Ω) output (Fig. 7) are used to measure the temperature of the drying air at various location of the experimental setup.

The temperature at output of separator has been measured with a PT 100 temperature sensor (Fig. 7). An analogue pressure sensor of 0.5% accuracy and 0-5bar capacity (Fig. 8) is used to measure the pressure of drying air. Measured value is conveyed to the PLC using the analogue input of the PLC. A casting-bodied, electromagnetic type, analogue volumetric flow meter of 4-20mA output (Fig. 9) is used to measure the volumetric flow rate of the drying air.

Fig. 7 Thermocouples and PT100 sensor.

Fig. 8. Pressure sensor.

Fig. 9 Flowmeter.

Control of the drying system is provided by a Siemens S7-200 PLC (Fig. 10). By the Ladder diagram of controlling software, drying conditions are observed and controlled on a touch-operated screen.

Fig. 10 Control panel.

The experimental study are carried out for various values of four different drying parameters: temperature, pressure, volumetric flow rate, and bobbin outer diameter. The moisture ratio of the bobbins and energy consumption during drying are monitored during drying.

3 Problem Formulation

Four different empirical or semi empirical drying models given in Table 1 are taken into account to determine the most appropriate model for drying simulation of viscose based yarn bobbins.

Table 1. Drying models

Name	Model equation	Ref.
Page	$mr = \exp(-kt^n)$	[1]
Henderson and Pabis	$mr = a\exp(-kt)$	[2]
Geometric	$mr = at^{-n}$	[3]
Wang and Singh	$mr = 1 + at + bt^2$	[4]

mr in the drying models is the moisture ratio defined as:

$$mr = \frac{m - m_e}{m_o - m_e} \qquad (1)$$

Here m, m_o m_e are the instantaneous, initial and equilibrium moisture contents, respectively.

3 Problem Solution

The dimensions of the bobbins used in the experiments are shown in Table 2. The experimental results were obtained for drying temperature of 70°C, 80°C, and 90°C, for effective drying pressure of 1bar and 2bar, for volumetric flow rate of $42.5m^3/h$, $55.0m^3/h$, and $67.5m^3/h$ per bobbin. Curve fitting computations were carried on the four drying models given in Table 1 relating the drying time and moisture ratio. The results show that the most appropriate model in describing the drying curves of viscose based yarn bobbins is the Page model. After obtaining the coefficients of the Page model, additional regression analyses have been carried out to obtain equations for drying time and energy consumption depending on the drying parameters. The results are shown in Table 3.

Table 2. Dimensions of the bobbins.

H (cm)	d (cm)	D (cm)
15.5	5.4	10
		14
		18

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Table 3. Drying time and energy consumption equations.

$mr = \exp(-kt^n)$, $t = [-\ln(mr)/k]^{1/n}$, $k = a_1D + a_2Q + a_3P + a_4T + a_5DQ + a_6DP + a_7DT + a_8QP + a_9QT + a_{10}PT + a_{11}$

a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	RMSE
-0.082970	-0.003521	0.015623	-0.005693	0.000022	0.000889	0.000008	0.000231	0.000165	0.000772	1.686960	0.035

$n = b_1D + b_2Q + b_3P + b_4T + b_5DQ + b_6DP + b_7DT + b_8QP + b_9QT + b_{10}PT + b_{11}$

b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}	b_{11}	RMSE
0.046697	-0.005618	0.035802	-0.002806	-0.000120	-0.003958	0.000104	0.001649	0.000098	-0.000694	0.298765	0.049

$E = f_1D + f_2Q + f_3P + f_4T + f_5DQ + f_6DP + f_7DT + f_8QP + f_9QT + f_{10}PT + f_{11}$

f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	RMSE
-0.366154	0.529711	9.516899	0.659287	-0.012119	0.287709	0.011125	0.019661	-0.006218	-0.156664	-35.59452	1.403

4 Conclusion

Using the equations for drying time and energy consumption, a software was developed using the Visual Basic programming language. With the aid of this software, optimum drying conditions for drying time and energy consumption can be obtained. The main window of the developed software is shown in Fig. 11.

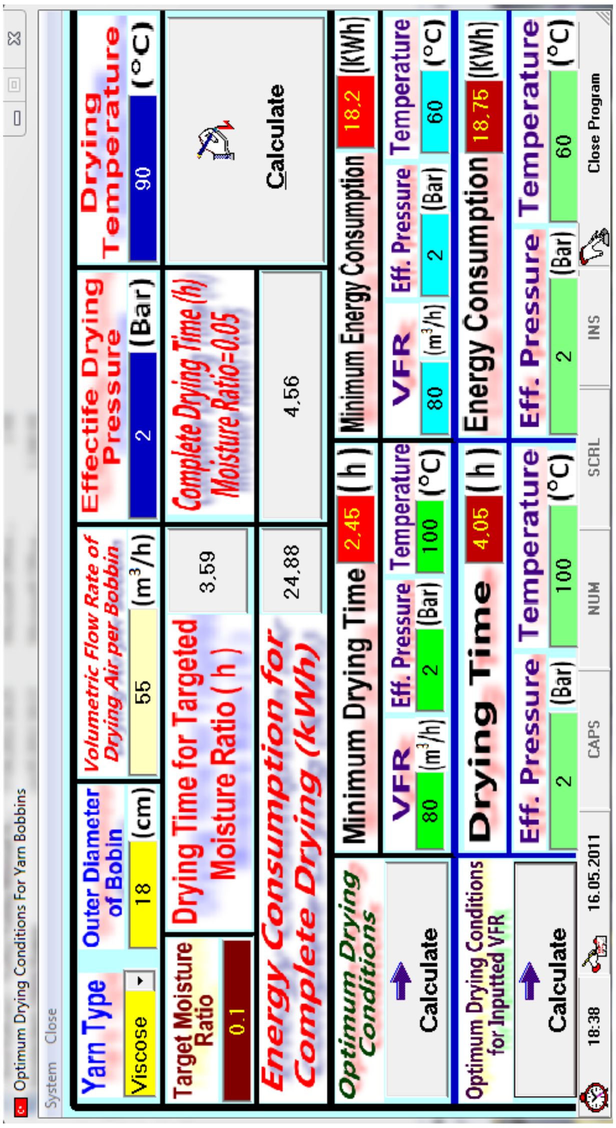

Fig. 11 The main window of the developed software.

As shown in Fig. 11, software has three sections. In the uppermost first section, there are boxes to input the values of parameters: outer diameter of bobbins, volumetric flow rate of the drying air per bobbin, effective drying pressure and drying temperature. If the calculate button is pressed, drying time and energy consumption are calculated by the software for the inputted values of the parameters. In the middle second section, optimum conditions for drying time and energy consumption is shown on the screen for the inputted outer diameter of bobbin after the calculate button is pressed. In the undermost third section, optimum conditions for drying time and energy consumption is shown on the screen for the inputted outer diameter of bobbin and volumetric flow rate of drying air per bobbin after the calculate button is pressed. In the code developed, the coefficients

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including in the equations for drying time and energy consumption are assigned to the elements of a matrix as shown in Fig. 12. The calculation procedure of optimum drying conditions is shown in Fig. 13.

```
Private Sub cmbTip_Change()
If cmbTip.Text = "Viscose" Then
    a(1) = -0.08297: b(1) = 0.046697: c(1) = -0.366154
    a(2) = -0.003521: b(2) = -0.005618: c(2) = 0.529711
    a(3) = 0.015623: b(3) = 0.035802: c(3) = 9.516899
    a(4) = -0.005693: b(4) = -0.002806: c(4) = 0.659287
    a(5) = 0.000022: b(5) = -0.00012: c(5) = -0.012119
    a(6) = 0.000889: b(6) = -0.003958: c(6) = 0.287709
    a(7) = 0.000008: b(7) = 0.000104: c(7) = 0.011125
    a(8) = 0.000231: b(8) = 0.001649: c(8) = 0.019661
    a(9) = 0.000165: b(9) = 0.000098: c(9) = -0.006218
    a(10) = 0.000772: b(10) = -0.000694: c(10) = -0.156664
    a(11) = 1.68696: b(11) = 0.298765: c(11) = -35.594517
End If
If cmb
```

Fig. 12 Coefficients of the equations.

```
Private Sub Command1_Click()
On Error GoTo hata
Dim k, n, j, ee, tt As Double
Dim kucukZaman, kucukEnerji, kucukBasinc, kucukDebi, kucukSicaklik As Double
Dim r, i, z As Integer
Dim t(700), e(700), Sicaklik(700), Basinc(700), Debi(700) As Double
r = 0
'-----------------------------
For i = 30 To 80 Step 5
    For j = 0.5 To 2 Step 0.25
        For z = 60 To 100 Step 5
            k = a(1) * Val(txtCap.Text) + a(2) * i + a(3) * j + a(4) * z + a(5) * Val(tx
            a(6) * Val(txtCap.Text) * j + a(7) * Val(txtCap.Text) * z + a(8) * i * j + a
            n = b(1) * Val(txtCap.Text) + b(2) * i + b(3) * j + b(4) * z + b(5) * Val(tx
            b(6) * Val(txtCap.Text) * j + b(7) * Val(txtCap.Text) * z + b(8) * i * j + b
            ee = c(1) * Val(txtCap.Text) + c(2) * i + c(3) * j + c(4) * z + c(5) * Val(t
            c(6) * Val(txtCap.Text) * j + c(7) * Val(txtCap.Text) * z + c(8) * i * j + c
            ee = Int(ee * 100) / 100
            tt = Abs((-Log(0.05) / k)) ^ (1 / n)
            tt = Int(tt * 100) / 100
            t(r) = tt: e(r) = ee
            Sicaklik(r) = z: Basinc(r) = j: Debi(r) = i
            r = r + 1
        Next z
    Next j
Next i
r = r - 1
kucukZaman = t(0): kucukBasinc = Basinc(0): kucukDebi = Debi(0): kucukSicaklik = Sicakl
For i = 0 To r - 1
        If t(i + 1) < t(i) Then
            kucukZaman = t(i + 1)
            kucukBasinc = Basinc(i + 1)
            kucukDebi = Debi(i + 1)
            kucukSicaklik = Sicaklik(i + 1)
        End If
Next i
```

Fig. 13 Calculation procedure for optimum drying conditions.

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