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Development of Human Machine Interfacing (HMI) Software for Force Circulated Wood Pulp Digester

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Abstract

In this study an automated computer control small size force circulated pulp digester is designed and fabricated in BCSIR. Pressure and temperature sensors are used to read monitor and control the digestive system. A single parameter, H-Factor is used to control the pulp digestive process by measuring temperature and time. Depending on the properties of raw materials, H-Factor is set in the software. The analog values of temperature and pressure are being read by an analog programmable logic controller. These readings are then transferred to a computer using Visual Basic software. The temperature readings are then stored after every fifteen minutes and it is further proceed to calculate the H-Factor in the software itself. When the calculated H-Factor is less than that of set value, the heater and pump remains running condition. The heater, digester, pressure and temperature meters have been drawn and shown graphically on the monitor using this developed human machine interfacing (HMI) software.

Keywords: *H-factor, micrologix 1000 PLC, temperature and pressure transmitter, VB6 software*

Background

Forced circulated pulp digester is available in Canada, USA, EEC, Japan, Korea, Taiwan, China[6]. The digester vessel is designed and fabricated according to the codes of American Standard and Manufacturing Engineering (ASME) [1]. Nowadays this pulp digester is incorporated with full automatic computer controlled human machine interfacing software. As a result the price of pulp digester becomes very high. The cost of a ten liter capacity pulp digester including HMI software is about twenty lakh taka. Where as we designed and fabricated the same capacity pulp digester as per ASME code and developed HMI software for this digester at the cost of ten lakh taka. The international manufacturing companies design and develop the HMI software for their business purpose and sale only front edge software not the the back end software. As a result we are bound to buy their digester at higher cost. If we are capable to develop the back end program of HMI software, various types of digester, equipment and machine can be manufactured in Bangladesh in near future. With a view to this target, the HMI software is developed.

Introduction

This digester is a self-contained circulation type pulping pressure vessel system. The vessels are available in the standard ten liter size or sizes (ranging from one to twenty liters, with practically any size available). The vessels are designed, manufactured as per ASME Pressure Vessel Code Section VIII, Div 1. The vessels are easy to operate and maintenance. A reciprocating pump circulates the liquor through a 3 kW electric heater. The heated liquor returns to the top of the vessel where it is distributed over the pulp. The liquor return is directly over the center of the chip basket to assure even distribution of the liquor. The circulation flow is variable by means of a variable speed motor controller on each pump. An optional flow meter is available for indication of the actual circulation calibrated in liters per minute. The flow enters the vessel on top of a removable stainless steel basket in which the wood chips are placed. A perforated weight is supplied for placement on top of the wood chips to ensure chip packing and uniform distribution of the liquor. A valve in the top cover provides a means for application of steam or for the evacuation of air. The dual vessel system enables the user to generate steam or to preheat liquor in one vessel for use in cooking in the other vessel. One K type thermocouple sensor is used to measure the temperature of the liquor in the vessel. A temperature transmitter (4 -20 mA) is also used to connect with an analog based PLC to control and interface data transfer to a computer. Visual Basic 6 is used to show temperature meter, pressure meter, electric heater and a pump. Cook programming and control is run by means of Windows compatible software. The software features graphical temperature and pressure indicators, Temperature vs. time graphing, Proportional, Integral and Derivative (PID) type control with and auto-tune feature, and H-factor cook control (the cook may be automatically terminated when a user defined H-factor is achieved[2].

H-factor- Time and Temperature

The delignification process is strongly depended on temperature. At low temperature, below140^{0}C, the delignification reactions are slow but increases fast in rate as the temperature rises. An increase in temperature with 10^{0}C results in a twofold increase in delignification rate. For this reason, it is difficult to judge how far the delignification has been preceded by the cooking time if the temperature has fluctuated. The time and temperature have therefore been combined in a single expression, the H-factor. This has been accomplished with the equation (1) $H = \int_0^t k_r \, dt$

$$\text{or } H = \int_0^t e^{(43.2 - \frac{16113}{T})} dt \qquad (1)$$

k_r is called the relative rate constant or comparison rate constant at a temperature to that at 100^{0}C[3]. Here temperature T must be at absolute temperature. H factor is different for different wood pulp. It varies from 500 to 2000 to be completed for the digestion of various wood pulps.

Determination of H-Factor

In order to determine H- factor, temperature readings are taken every 15 minutes of the cook and relative rate constants k_r determined. The k_r is plotted versus time. The area under the curve is equivalent to the H factor (Figure1). Sample calculations for the determination of the H factor can be found in figure2. The calculation method is given in table-1 for the determination of endpoint at 3 different temperatures. It needs to be stressed that this equation only estimates the effects of time and temperature and assumes constant effective alkali, sulfidity, liquor/wood, wood species, etc. The temperature is recorded every fifteen minutes and at same time relative reaction rate constant is also calculated for each temperature using equation (1). The area under the curve is determined by trapezium rule. The total area is segmented after each fifteen minutes (0.25 hr.). The relative constant rate k_r is determined at the temperature attained after each fifteen minutes. Then it is made average taking consecutive two respective values of k_r. The area of each segment is determined by multiplying this average k_r with time interval. Successively it is added and goes up to fixed value of H- factor that is previously set or given. In the following table and curves it is shown the relative constant rate (K_r) and H- factor. Considering the temperature 80^{0}C and its absolute temperature T = (80+273) K = 353 Kelvin. Putting this value in equation (1) , relative constant rate,

$$k_r = e^{43.2 - \frac{16113}{T}} = e^{43.2 - \frac{16113}{353}} = e^{43.2 - 45.65} = e^{-2.45} = 0.086 = 0.$$

Similarly, the relative constant rate is calculated for different temperature and shown in table 1.

Table 1: Calculation of H-factor when temperature rose to 170^0C within 3 hours

Start h	Temp ^{0}C	Relative Constant	Av. relative Constant	Multiply X	Time interval	=	H-factor
0.00	80	0	0	x	0.25	=	0
0.25	95	0	2	x	0.25	=	1
0.50	110	3	9	x	0.25	=	2
0.75	125	15	41	x	0.25	=	10
1.00	140	66	163	x	0.25	=	41
1.25	155	258	590	x	0.25	=	148
1.50	170	921	921	x	0.25	=	230
1.75	170	921	921	x	0.25	=	230
2.00	170	921	921	x	0.25	=	230
2.25	170	921	921	x	0.25	=	230
2.50	170	921	921	x	0.25	=	230
2.75	170	921	921	x	0.25	=	230
3.00	170	921	921	x	0.25	=	
Total							1582

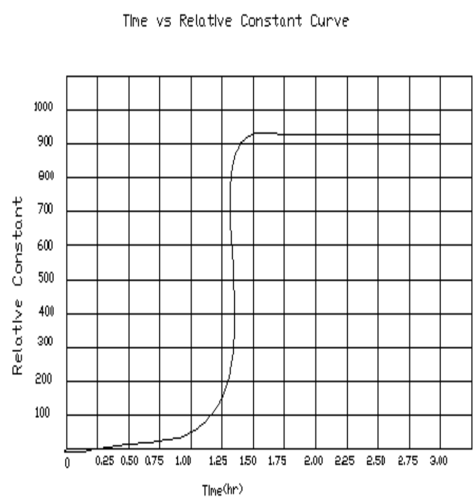

Fig.1

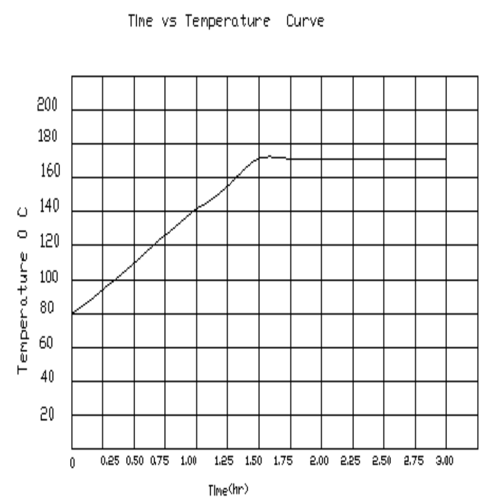

Fig.2

The area (A) under the time (t) vs relative constant rate (k_r) is defined as A = f(t, k_r) = k_r x t . From figure-1 and figure-2, it is seen that temperature gradually raises and after certain period temperature is kept constant by using a thermocouple controller. The average (Av.) relative constant is determined by adding successive two k_r values and diving by two i.e. (Av. k_r)i = $\{(k_r)_i + (k_r)_{i+1}\}/2$. It is noticed that $k_r \geq 0.5$ is treated as 1. For example, at 95^0C, $(\text{Av. } k_r)_2 = (0+3)/2 = 1.5 \approx 2$.

Software Design and Analysis

To fabricate a forced circulated wood pulp digester, a strong pressure vessel is designed as per ASME pressure vessel code. To operate and control the digester an electric heater, a reciprocating pump, safety valve, K type thermocouple (0-650^0C), temperature and pressure transmitter (4-20 mA) and an analog based programmable logic controller (PLC) are used. At first electric heater and pump motor is being started and temperature rises gradually. The analog value of corresponding temperature is transmitted to the PLC by the transmitter and afterwards this value is interfacing to a computer through a serial port. The micrologix 1000 analog model of allenbradly PLC is operated on RSLogix500, Visual Basic ActiveX control and Visual Basic 6 (VB6) software[4]. These three software are used to develop to control and monitoring this forced circulated wood pulp digester. Grade-Industrial software built in VB6 is also used to develop the human machine interfacing (HMI) of this digester. One temperature meter, one pressure gauge, one heater and a pump is chosen from the Grade Industrial software and placed on the VB6 display form. Ten text boxes are taken to show actual value of temperature, time, H-factor, set H-factor etc. The design of software display is shown below.

Graphical HMI Software

HMI Program in VB6, Active X control and Grade Industrial

```
Option Explicit
Dim i As Byte
Dim x As Byte
Dim y As Byte
Dim h As Integer
Dim m As Byte
Dim n As Integer
Dim p(10) As Long
Private Sub cmdRUN_Click()
GXLight1.LampOn = True
Gadget1.Discrete01 = True
```

```
Gadget2.Discrete01 = True
Gadget2.Discrete02 = True
End Sub
Private Sub cmdSTOP_Click()
Unload Me
End Sub
Private Sub Timer1_Timer()
Text11 = Val(Text11.Text)
Text9 = Val(Text9.Text)
Text9 = Val(p(0)) + Val(p(1)) + Val(p(2)) + Val(p(3)) + Val(p(4))+ Val(p(5))
If Text9 < Text11 Then GXLight1.LampOn = True
If Text9 < Text11 Then Gadget1.Discrete01 = True
If Text9 < Text11 Then Gadget2.Discrete01 = True
If Text9 < Text11 Then Gadget2.Discrete02 = True
n = n + 1
GXDisplay2.Text2 = Val(n)
Text12 = Val(n)
If n >= 15 Then
m = m + 1
n = 0
GXDisplay3.Text2 = Val(m)
Text13 = Val(m) '
End If
Text9 = Val(p(0)) + Val(p(1)) + Val(p(2)) + Val(p(3)) + Val(p(4))+ Val(p(5))
If Text9 < Text11 Then GXLight1.LampOn = True
If Text9 < Text11 Then Gadget1.Discrete01 = True
If Text9 < Text11 Then Gadget2.Discrete01 = True
If Text9 < Text11 Then Gadget2.Discrete02 = True
If m >= 5 Then
m = 0
Text6 = Val(Text16.Text)
GXDisplay1.Text2 = Val(Text16.Text)
GXDisplay10.Text2 = Val(Text16.Text) / 2 + Val(GXDisplay9.Text2) / 2
Text8 = Val(Text16.Text) / 2 + Val(Text7) / 2
Text7 = Text6
GXDisplay9.Text2 = Val(GXDisplay1.Text2)
p(i) = Val(Text8.Text)
GXDisplay6.Text2 = Val(p(0)) + Val(p(1)) + Val(p(2)) + Val(p(3)) + Val(p(4))
Text9 = Val(p(0)) + Val(p(1)) + Val(p(2)) + Val(p(3)) + Val(p(4))
i = i + 1
If i >= 5 Then i = 0
GXDisplay7.Text2 = Val(Text11.Text)
Text11 = Val(Text11.Text)
If Text9 < Text11 Then
GXLight1.LampOn = True
Gadget1.Discrete01 = True
Gadget2.Discrete01 = True
Gadget2.Discrete02 = True
Else
GXLight1.LampOn = False
Gadget1.Discrete01 = False
Gadget2.Discrete01 = False
Gadget2.Discrete02 = False
End If
End If
End Sub
Private Sub Timer2_Timer()
GXMeter1.Value = Val(Text16.Text)
GXLEDDisplay1.Value = Val(Text16.Text)
```

```
GXMeter2.Value = Val(Text17.Text)
GXLEDDisplay2.Value = Val(Text17.Text)
End Sub
```

Comparison between existing and developed one

HMI software can be developed by Java, Visual C++, Visual Basic language. It can also be developed by Labview or any other automation software. Siemens, Honeywell, Mitsubishi, Sony, Philips company use their own developed software. For example Siemens company use SIMATIC WINCC software which is very customized for only Siemens' product. Visual Basic software is used to create this HMI applications for several reasons[5]. Visual Basic language has some limitations to develop industrial HMI applications due to lack of tools for industrial applications such as control system hardware connectivity and data visualization. New technologies based on COM and grade industrial software have removed these barriers by extending the suite of tools and objects available to the Visual Basic developer. Engineers can utilize Visual Basic and quickly create simple HMI applications. From a budgetary standpoint, the potential savings are large. Developers creating applications in Visual Basic can distribute their compiled EXE applications at minimal cost. Per machine no licenses are required by the provider for the actual Visual Basic code. The developer creates or may use the built-in objects (text boxes, command buttons, etc). The Programmble logic controller or microcontroller can be used in this HMI software.

Discussion and Recommendations

The amount of lignin in different wood pulp depends on properties of wood. Therefore H-factor is not similar to all wood pulp. In table 1 it is shown that the general calculation method for finding H-factor. But in the software we can set the H-factor according to the required H-factor. Continuously the temperature and pressure is recorded in the software and calculated the relative constant rate, k_r every fifteen minutes and saves in another text. Timer1 is used to calculate every fifteen minutes and timer2 is used to read the temperature and pressure from the respective sensors through PLC to VB6 software that is developed for HMI monitoring and controlling the forced circulated wood pulp digester. There are many software available for developing human machine interfacing software. But the cost is too high. We have developed the HMI software using simple VB6 , active X control and RXlogix500 software. In this experiment we have used analog based alenbradly micrologix 1000. It is also possible to develop the HMI using microcontroller chip and hence cost will be lower.

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