Research Article

Design And Development Of A Fuzzy Controlled Cooling Uint Integrated With The Industrial Wax Moulding Unit Using Lab View

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Abstract:
The wax moulding plant requires a cooling unit to cool various types of molten paraffin wax into specific sizes to a temperature 5^0 C above the wax melting point . The presently used systems use a moulding plant which comprises of Wax Precooler section, Wax moulding Unit and a cooling fan Unit. The inefficiency of the existing system employed at CPCL is due to the non uniform cooling of the wax due to the combined effect of the atmospheric temperature and the unchanging speed of the cooling fan resulting in production and energy loss. The proposed technique exploits the use of a conveyor with variable speed drives and varying cooling fan speed which is implemented with fuzzy logic algorithms using LabVIEW which provides high accuracy and precision. The moulded wax has a variety of applications in lubrication, electrical insulation, food processing industry and in pharmaceutical industry.

Keywords: LabVIEW, wax moulding, cooling fan speed, fuzzy logic algorithm

1. INTRODUCTION:

Usually, beeswax was processed in various ways by sculptors to make waxes of varying hardness. The use of beeswax has reduced due to the increased production of synthetics such as microcrystalline and paraffin wax. Microcrystalline has the advantage of using it in different colours especially for sculptures. The properties of wax such as protection against atmospheric ozone and its easy availability from animal and plant fats widen its applications using slack waxes. The slack wax is refined by various processes to produce Paraffin Wax especially by reducing the oil content in the de-oiling unit after which the colour and the odour is purified. The processes involved in the de-oiling technique are

1. MEK Process by Texaco (MEK + Toluene)
2. Dilchill Process by Exxon (MEK + Toluene)
3. MIBK Process by Union Oil Company

The proposed technique uses the deoiling technique adopted by Union Oil Company, USA.

The following techniques are also being implemented in the proposed system for cooling Paraffin wax.

a. ***Extraction of Paraffin Wax from Slack Wax:***
Three grades of wax were obtained with reference to its melting point such as low melt, mid melt and high melt. Low melt blend of slack wax comprises of HVI and LVI IN LVI and HVGO, the mid melt blend of slack wax is the blend of IN HVI/LVI and HVGO. High melt is the combination of INHVI,HN HVI and HVGO.

b. ***Wax level detection in the Balance Tank:***
After the de-oiling operation the product liquid wax is is circulate in the APV moulding plant using a pump 14G13AB followed by the moulding process. The level of the tank is sensed using a pressure pad at the base of the tank and sends a pneumatic signal to a controller in the control panel and controls the air signal through a modulating valve.

c. ***Control of Cooler temperature:***
The temperature is reduced to 5^0C above the melting point of the wax in the shell and the heat exchanger where the wax and the cooling water flow in the counterclockwise direction. The cooler

temperature is monitored and any increase in temperature alerts an alarm and cuts of the outlet if the threshold limits are exceeded.VSD is used for cooling fan and drive motor.

d. Non contact temperature sensor for inlet and outlet wax temperature

The non contact temperature sensor is used to measure the temperature at the inlet and the outlet molten wax.

Section II comprises of the literature survey on the existing systems for extraction of Paraffin wax from slack wax, cooling techniques and temperature control systems in Wax moulding plants. Section III describes the details of the proposed methodology where the schematic is elaborately explained. Section IV gives an overview of the prototype used as hardware and the associated software. Section V discusses the results and the merits over the previous and existing techniques.

II. Literature Survey:

Huang Mingji, Wu Geng and Shan Yan[1] have used the casting wax due to the properties such as low shrinkage, small deformation and environment friendly characteristics. The dimensional accuracy of the wax is improved by optimizing the protyping process. Mattia Didone et.al [2] have researched on the materials of the products and the applications of such materials and observed that molded pulp products are widely and predominantly used in various applications such as packaging, food containers and serving trays due its composition being cellulose which are totally renewable and biodegradable. Omkar Bemblage et.al [3] have reviewed the casting processes and have preferred Investment casting since it possesses the ability to produce an excellent surface finish and accuracy in dimension even for complex shapes. Tsotorvor et. al [4] have explored the significance of natural latex for mould making in sculpture making and found its effectiveness in art and agriculture due to its eco-friendly nature.

III. Proposed Methodology:

The existing systems face challenges in the inconsistency of wax molding, less conservation of energy due to the digital operation of the cooling fan and absence of electronic monitoring and control systems. Hence the need for a proper cooling system arose and it was proposed to assure the proper cooling of wax using non contact temperature sensors at the inlet to measure the initial temperature and another at the middle of the tray to measure the desired temperature.

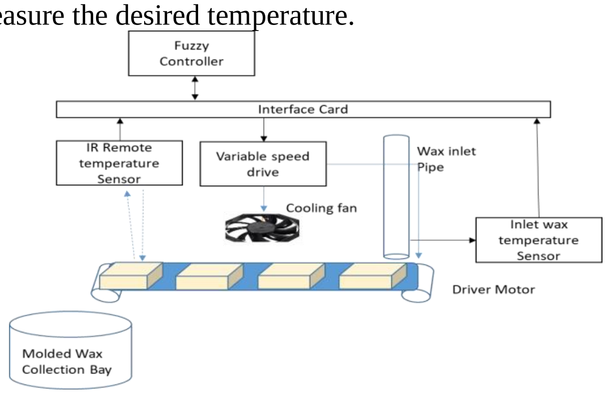

Fig.1. Proposed system schematic diagram

The schematic diagram consists of sensors to measure the Plant parameters and transducers to convert the physical parameters into electrical signals which are transmitted to the EDAQ card that digitizes the analog signal compatible to be processed using LabVIEW software. The Fuzzy Controller designed using the tool executes the instructions as required to measure, monitor and control the temperature of the molten wax at specified environmental conditions.

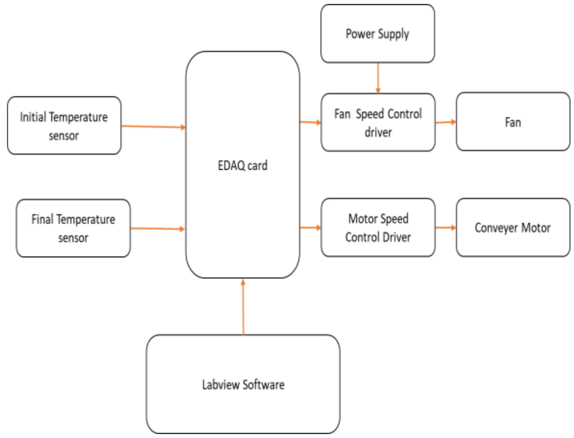

Fig. 2. Data acquisition using LabVIEW

Fig. 2 depicts the data acquisition system using LabVIEW and the control of speed of cooling fan and the motor driving the conveyor using the same tool. The EDAQ card is capable of converting the input analog signal into digital signal and also to convert the output signal to a PWM (Pulse Width Modulated) signal which drives the motor controlling the conveyor, the speed of which is controlled based on the temperature of the molten wax at the moment. The flow diagram for the control mechanism is shown in Fig.3.a. and 3.b..

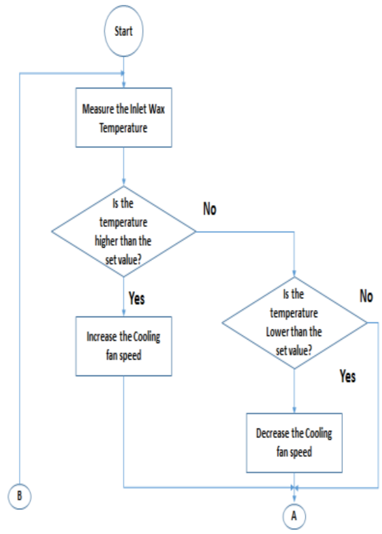

Fig. 3. a. Control mechanism used for conveyor belt speed in LabVIEW

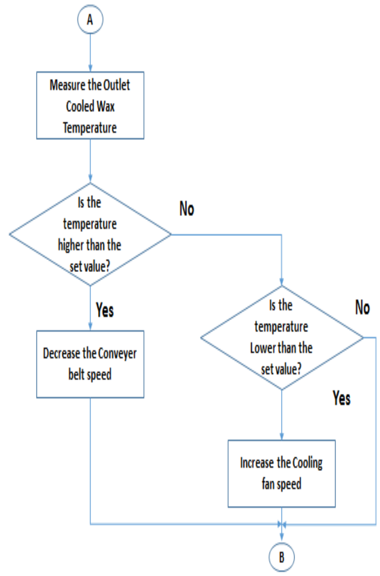

Fig. 3. b. Control mechanism used for cooling fan in LabVIEW

Hence the parameters acquired using the DAQ are tested with the threshold levels of the cooling temperature and uniformity of temperature throughout the mould and controlled according to the requirements.

IV. Hardware prototype and components:

The hardware system consists of a non-contact temperature sensor which is an Infrared sensor which measures the temperature of the molten wax and configures the output into a 10 bit PWM signal proportional to the temperature ranging between -20 to 120^{0}C with an output resolution of 0.14^{0}C. L293 and L293D devices are used to provide bidirectional drive currents upto 1A at operating voltages between 4.5 V and 36 V each of them enabled with a pair of signals connected to the enable pins. The outputs of these pins are connected to the inductive loads such as relays and solenoids, DC motors and Bipolar Stepper motors. The speed of the cooling fan is varied to maintain a constant temperature throughout the mould. The cooling fan is controlled using a BLDC motor.The physical parameters such as temperature of the room and the mould are sensed using the EDAQ and being a transducer converts the sensed signal into equivalent electrical signals. Fig.4 shows the working of a DAQ system.

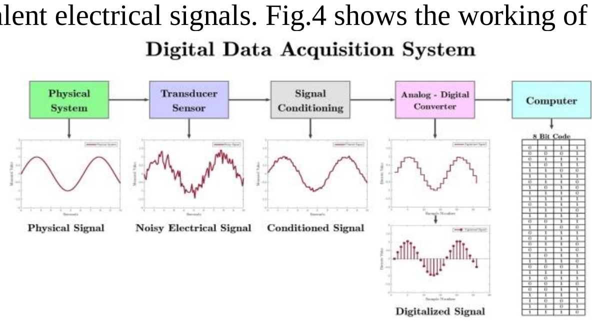

Fig. 4. Working of a DAQ system

The signal conditioning section of the DAQ system converts the analog signal into its equivalent digital signal using the internal ADC (Analog to Digital Converter**)**

LabVIEW is used as the software tool to control the speed of the conveyor and the cooling fan. The LabVIEW PID and Fuzzy Logic Toolkit performs the Fuzzy Logic Control mechanism.

a. FUZZY SYSTEMS

A fuzzy controller uses a set of defined rules to control a fuzzy system based on the current values fed as input variables. Fuzzy systems consist of three main components : linguistic variables, membership functions, and rules.

►Linguistic Variables

Linguistic variables represent, the input variables and output variables of the system to be controlled. For the maintenance of temperature of the molten slab, the input and the desired temperature of the slab are the linguistic variables.

► Creating Membership Functions

Membership functions are numerical functions corresponding to linguistic terms. A membership function represents the degree of membership of linguistic variables within their linguistic terms.

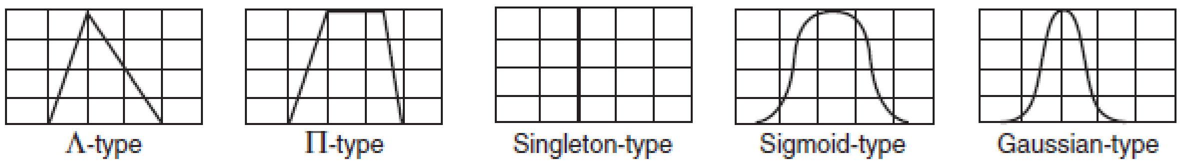

Fig.5.a. Types of Membership Functions

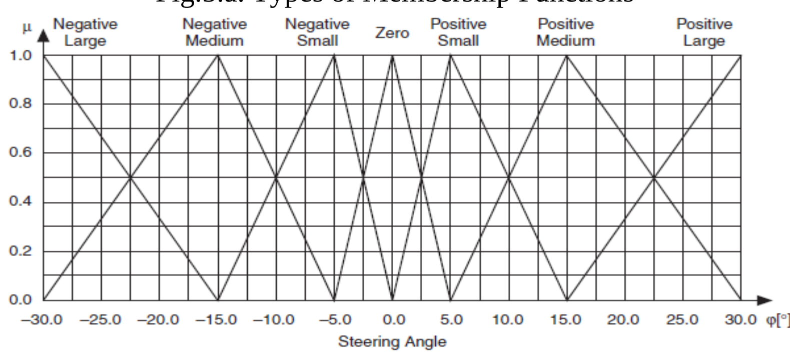

Fig. 5.b. Membership Function

The linguistic variable is created according to the temperature at a specified point on the slab. Using LabVIEW, the Control Design and Simulation - Fuzzy System Designer is used to launch the Fuzzy System Designer. The Fuzzy System Designer displays the Variables page by default.

The input and the desired variables are added along with its membership function as shown in Fig.5.a. and b and is simulated as shown in Fig 5.c. Each of the variables are associated with the membership functions..

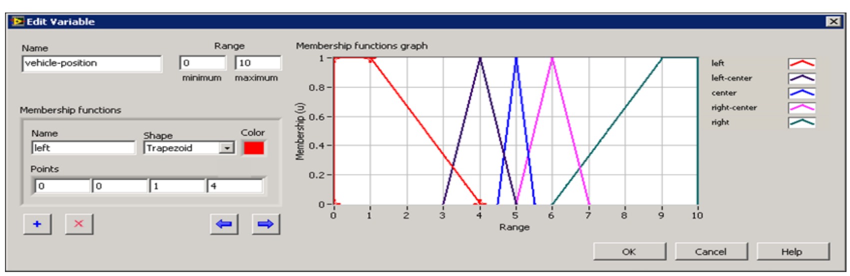

Figure 5.c. Membership Function Graph

►Rules

Rules need to be formulated to define the function mapping the input variable to the desired variable using the Pre Generate Rules function of the Fuzzy system. These rules are associated with a weighting factor. The minimum consequent implication permits the truncation of the output membership function proportional to the weights before the defuzzification process.

b. FUZZY CONTROLLERS

Fuzzy controllers are ruled by the fuzzy rules designed for the systems and is a combination of the membership function associated with the input variables and governed by a set of predefined rules to produce output variables as shown in Fig. 6 based on whidh the temperature value may correspond to one of the linguistic variables.

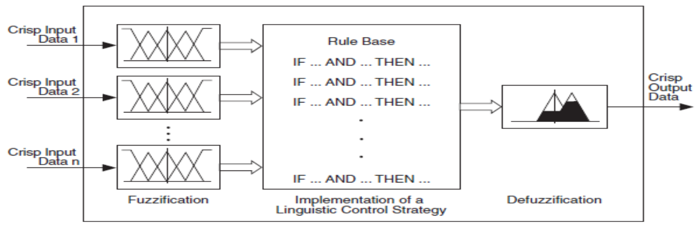

Fig. 6. Fuzzy Controller

The temperature of the room is associated with a comparatively lower membership function and the desired temperature is mapped with a higher membership function.

The control mechanism depends upon the temperature of the room and the desired temperature and sets the heater setting to low if the temperature of the room is low and the desired temperature is moderate.

The truth value of each antecedent is equal to the degree of membership of the

linguistic variable within the corresponding linguistic term. The fuzzy logic controller uses an antecedent connective to determine how to cculate the truth value of the aggregated rule antecedent. Suppose the invoked rule in this example uses the AND (Minimum) antecedent connective, which specifies to use the smallest degree of membership of the antecedents as the truth value of the aggregated rule antecedent. Therefore, the truth value of the aggregated rule antecedent is 0.4

A degree of support can be specified for each rule of a fuzzy system. The weight of a rule is equal to the degree of support multiplied by the truth value of the aggregated rule antecedent. The fuzzy controller uses an implication method to scale the membership functions of an output linguistic variable based on the rule weight before performing defuzzification.

V. Results and Discussion:

The input and output variables are set as control variables and indicators respectively. The front panel Fig.6.a., 6.b., 6.c. and 6.d. show the temperature sensed by the sensors with a Self Development Kit and based on the interpreted values of the measured temperatures, the motor speed is controlled accordingly for which the respective control signals are sent based on the Fuzzy Rule incorporating membership functions.

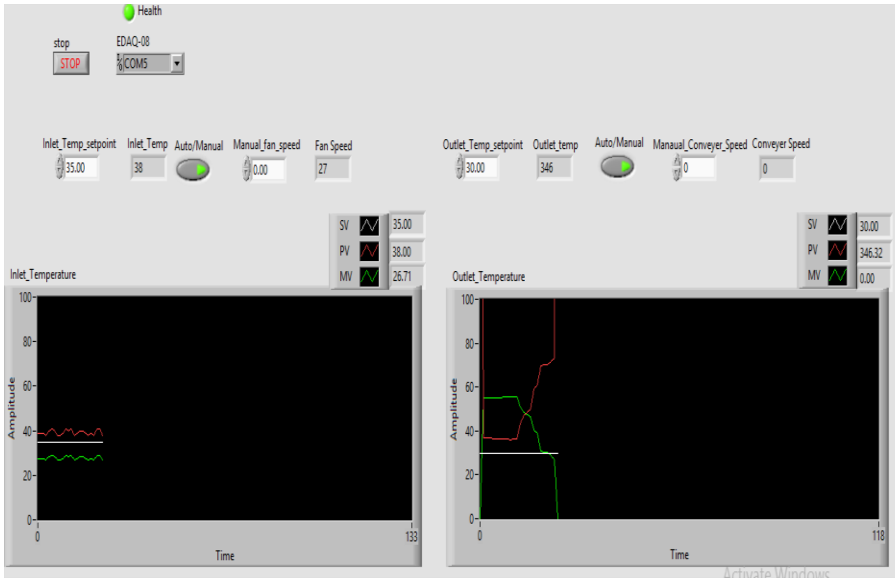

Figure 6. Case 1

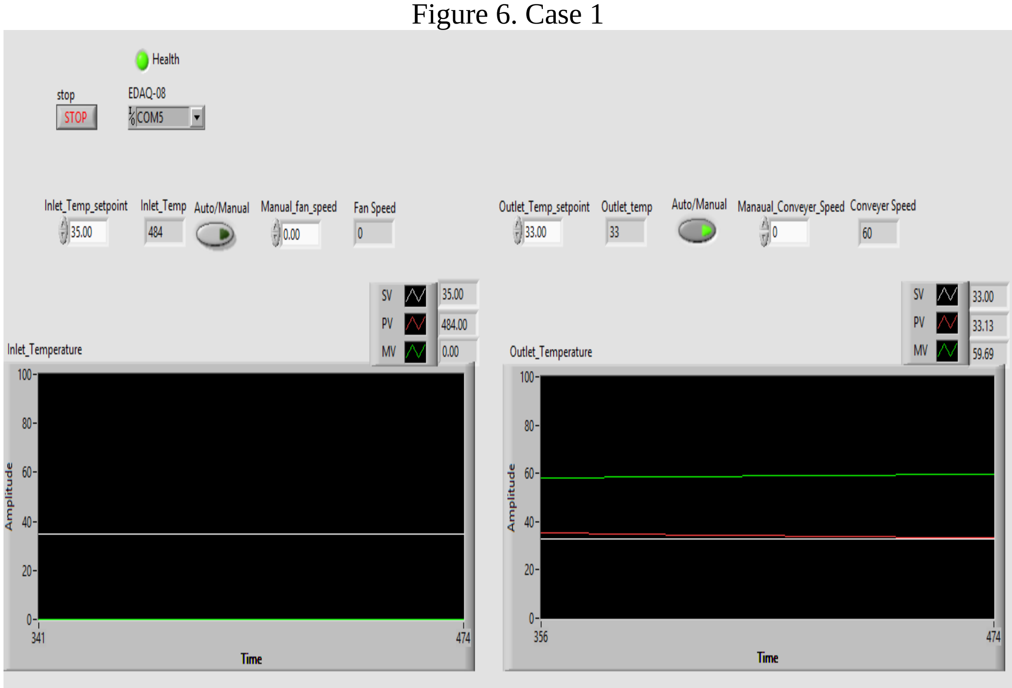

Fig. 6.b. Case 2

Fig. 6.c. Case 3

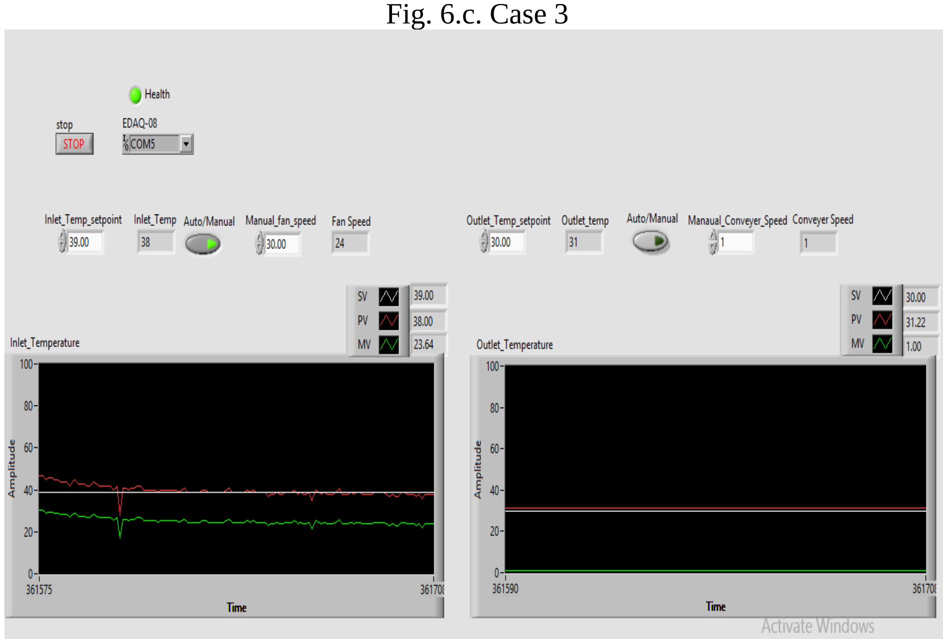

Fig. 6.d. Case 4

The system outputs are measured under running conditions under four circumstances,

(1) **Case 1:**conveyor speed becomes 0 when outlet temperature is very high
(2) **Case 2:**conveyor speed becomes high when outlet temperature reaches setpoint/ lower temperatue
(3) **Case3:** fan speed increases when inlet temperature is high
(4) **Case 4:** fan speed decreases when inlet temperature is low.

These cases are shown in figures above under the various temperatures as input variables and the speed as the output variable

All these graphs show easy monitoring of the temperature and automated control of the conveyor speed and the cooling fan speed and hence these systems bulit with LabVIEW and integrated with non contact temperature sensors provides an accurate cooling system using fuzzy logic.

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