Process Monitoring Device for Polymer Moulding Machine

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Abstract

The principal objective of this project is real time monitoring of three parameters i.e. pressure, temperatures of the upper and lower members of a polymer moulding machine. These values are instantaneously logged into a memory chip for future analysis and quality control. The main components of this system will be the sensors, the signal conditioning circuit, the CPU, an external memory chip and the graphical display which serves as a GUI. The device is compact, multi-faceted, user friendly durable and flexible.

Keywords - real time monitoring, future analysis, quality control, GUI, user-friendly device.

1. Introduction

The polymer rubber has an excellent property of **elasticity** which describes its physical nature to return to its original shape after the stress that caused their deformation is no longer applied. But this becomes an inherent property of rubber only when it undergoes a process of **vulcanization.** Vulcanization is a chemical process by which the physical properties of natural or synthetic rubber are improved; finished rubber has higher tensile strength and resistance to swelling and abrasion, and is elastic over a greater range of temperatures. In its simplest form, vulcanization is brought about by heating rubber with sulphur. . Vulcanization brings about a change in the rubbers physical properties such as tensile and compressive strength which are very desirable in the applications in which rubber parts are used. **Moulding** is the process of manufacturing by shaping pliable raw material in our case rubber using a rigid frame or model called a **pattern.** Various rubber parts are required in various automobiles, industrial machinery, household products etc. Compression and Injected moulding are two methods currently in use.

The final rubber product produced should be completely cured i.e. it must be sturdy, without any air bubbles. The cross links in the product should be fully developed. If all these parameters are not met then the final product needs to be discarded as it does not meet the necessary properties for its particular application. Since moulding is an irreversible process, rubber cannot be reused. Waste of time, raw material, efforts and expenses is never a good sign. So as to produce a rubber part without any limitations the following parameters should be kept under constant vigilance for a particular period of time to ensure proper vulcanization:

- **Vacuum**
- **Pressure**
- **Temperature**

If any one of these parameters deviates from the desired level, the end product will not have the intended properties such as tensile strength, perfect dimensions, resistance to abrasion, chemical reactions and weather changes etc. Since regular testing of each product manufactured is practically impossible, there is a need for a quick and easy technique of monitoring process parameters for the purpose of quality control.

The objective of this project is monitoring of three critical parameters i.e. temperature of lower member of the mould, temperature of upper member of the mould and the applied pressure, real time data acquisition from the rubber moulding machine and finally logging the values in memory by sampling them at a particular time interval. The values will be saved for all the cycles separately. In case any deviation in the parameter values from the set values is detected, only then that particular rubber product of that cycle will be checked for errors. Hence, the cumbersome task of checking each end product individually is avoided, thereby conserving time, money and material.

An RS232 port is provided enabling the user to transfer the data onto an external memory device; here a PC; for further analysis is required. The parameter values will be saved in a systematic format and not just raw data. A single reading will be consisting of the cycle number, start time of cycle, and actual value in engineering units (ºC/psi). The data will be visually presentable. Any dip in the parameter values from set ones will be easily noticeable on the graph and an immediate alarm will be sounded, so that further steps can be carried out.

Most of the currently available devices similar to the above described have certain limitations, mostly concerned with power management, maintenance, inconvenient use, cost, absence of a user interface etc. The major producers include DATAQ Instruments, Onset Corporation, Pico Technologies etc.

2. System description

The major components of this device are the pressure and temperature sensors, signal conditioning stage, the microprocessor, the graphical LCD, the keypad and the memory chip.

The following are the different stages:

A. Sensor stage

The first stage of this whole device is the sensors. They are responsible for converting the physical pressure and temperature parameters to electrical form i.e. voltage or current. To implement an analogous input pressure sensor for demo purposes we have selected the SPD030G manufactured by SMARTEC. It has a range of 2 bars. It is a commercial grade sensor based on the resistive bridge technology. It is cheap, durable and light in weight. For sensing temperature variations a standard K type thermocouple would suffice. Both sensors demand a typical excitation voltage of 5 V.

B. Amplification

The output voltages/ currents from the sensors need to be boosted to a higher level. An instrumentation amplifier is most suitable in this situation. A basic 2-opamp IA is used for the temperature section, while a 3-opamp IA is required for the pressure section. The gain is so adjusted that it reaches the level which can be detected by the on-chip ADC of the microprocessor; here a maximum of 3.3 V is required for LPC2138. Any voltage over that threshold may cause damage to the IC.

C. Microprocessor stage

LPC2138 is the most appropriate processor for this device. It satisfies all of the major requirements i.e. an inbuilt ADC, small size, large number of general purpose I/O pins (here; 47), multiple timers/ counters and above all low power consumption. It is of the ARMv7 family; hence availability of an IDE is not an issue. Numerous editors are available in the market. We have chosen Keil µVision4 for coding purposes in Embedded C language.

D. Interfaced Components

The microprocessor is interfaced with the following components:

1) Graphical LCD

The LCD used is LG128643 belongs to series of Laurel LCD manufactured by XSIS. It is 128 X 64 dots LCD (graphic module) which is further divided into two parts (64 X 64 each). These 2 partitions can be accessed depending on chip select (CS1 or CS2). Its data pins D0-D7 have been interfaced to the port 0 of the microprocessor. The Microprocessor accepts analog inputs from the signal conditioning circuit; the image used in each figure is clear, digitizes it using the inbuilt ADC & displays it on the LCD. LCD along with keypad is also used to improve user interface.

2) Keypad

A 4*4 matrix keypad is sufficient for our purposes. It accepts various inputs from user like modes of operation, set point values, and time of operation, user name and password.

3) Memory chip

The memory IC used is AT24C04A manufactured by ATMEL. The memory capacity is 4 Kbytes (512 X 8). The AT24C02A/04A/08A provides 2048/4096/8192 bits of serial electrically erasable and programmable read only memory (EEPROM) organized as 256/512/1024 words of 8 bits each. The device is optimized for use in many industrial and commercial applications where low power and low voltage operation are essential.

3. Performance evaluation and results

A. Pressure monitoring

The process monitoring system uses a tyre inflation mechanism to test the values of the pressure and display it on the graphical display. The ideal values and the values obtained displayed on the screen with intermediate values of the sensor output and also the output of the signal conditioning circuit have been listed in the following table in various stepwise stages.

TABLE I
READINGS FOR THE PRESSURE SENSOR OUTPUT AT VARIOUS FURTHER STAGES

Ideal Values (psi)	Sensor Output (mV)	Signal Conditioning Output (mV)	Displayed Value (psi)
1	3	60	1
2	5.9	130	2
3	8.4	190	3
4	10.7	250	4
5	13.7	330	5
10	28.2	705	10
15	41.5	996	15

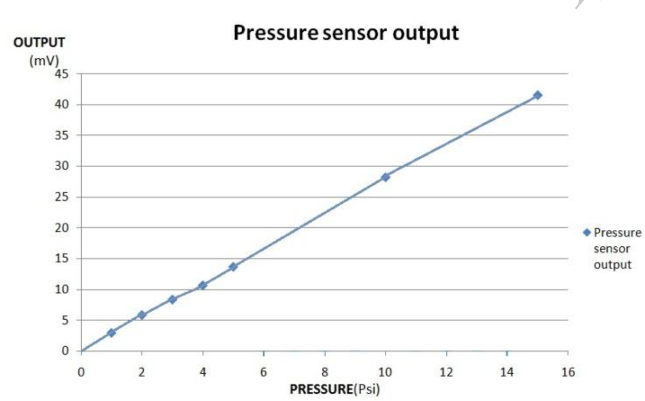

Figure1. Pressure sensor output

B. Temperature monitoring

The result table for various readings of temperature have been written in the following table:

TABLE II
READINGS AT THERMOCOUPLE OUTPUT AT FURTHER STAGES

Ideal Values (^{o}C)	Signal Conditioning Output (mV)	Display (^{o}C)
5	25	5
10	51	10
15	76	16
20	105	22
30	155	30
38	197	37
41	199	42
43	206	44
50	250	51

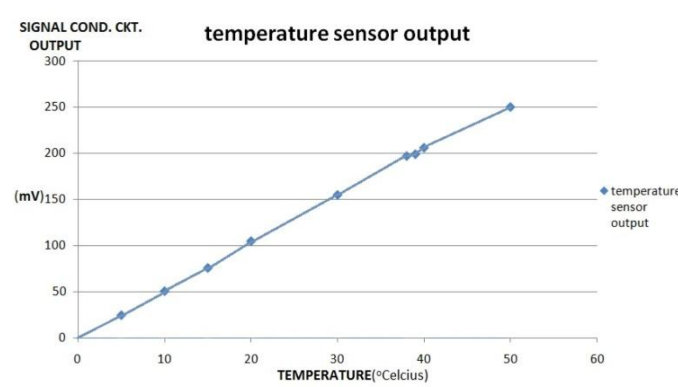

Fig. 2 Linearity graph for thermocouple outputs.

C. Modes of Operation

The process monitoring system consists of two modes: In both modes, the system asks for threshold values of the parameters of temperature and pressure. After inputting these values and the timer value of the cycle, the monitoring begins.

1) The Manual Mode

In this mode, the values get transferred to memory only when the values pass the minimum threshold value of the parameters and stops getting written in the memory after the timer stops or the value comes below the minimum set point value whichever occurs first. If the value goes above the maximum threshold values of the parameters then the system sounds an alarm to grab the attention of the supervisor working on the machine.

2) The Continuous Mode

In this mode, the system asks for the set point values as in the manual mode. But these set point values have nothing to do with the data logging in the memory. In continuous mode, the data gets written into the memory as soon as the cycle of the machine starts and writes till the end of one cycle (till the timer goes off).

D. Graphical User Interface

1) On the PC

The data transferred to the PC was arranged in a proper manner. A primitive GUI was constructed using Visual Basic 6.0. A snapshot of that GUI is given in Fig. 3

The figure shows a graphical representation of values of temperature parameter for one cycle.

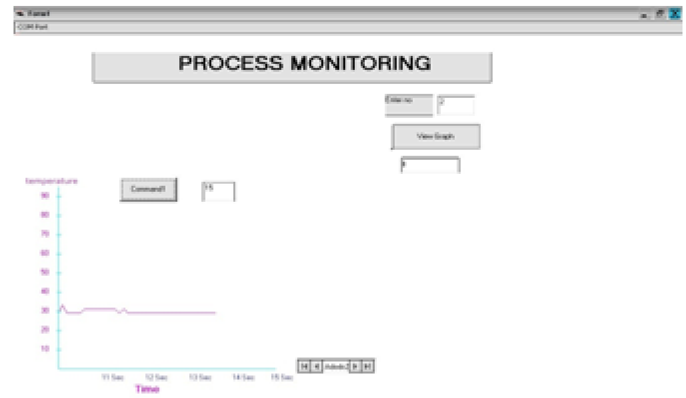

Fig. 3 GUI snapshot

2) On the Graphical LCD

The picture shows the interface on the LCD which displays the instantaneous values of pressure and temperature, cycle status, timer value, current time, threshold values and selected mode.

Fig. 4 Graphical LCD user interface

E. Features of the Final Device

The final device had features which satisfied the primary objective of quality control and forming a primitive database of the parameters for future analysis. Those features include:

- User friendly, very easy to use.
- Data storage format which includes cycle number start time of cycle, actual value.
- Instantaneous data logging

- Graphical LCD and simple keypad serve as a comprehensive control panel.
- Ability to be modified to include extra inputs.
- The value will be displayed in graphical and tabular form.
- Password protected data transfer via the RS232 port.
- Continuous mode/ Manual mode.

F. APPLICATIONS

The process monitoring system can be used as a management information system (MIS). It provides a database of the parameter values and a graph that gives a direct view of the values. A linear constant value graph shows the consistency and the accuracy of the industrial machine. Thus it helps to market the purity and the precision of the job being made over a period of time by comparing the values of various cycles.

This device can be used as a monitoring system for any other parameter with only minor changes in its hardware and software.

G. CONCLUSION

The aim of this project was the constant monitoring and logging of critical parameters i.e. pressure and temperature of both compression members. Quality control, which was the main requirement, was fulfilled successfully.

The pressure sensor and the K-thermocouple were calibrated and tested to verify if a linear output was obtained on excitation. Suitable tests were conducted to make sure that the true values of pressure and temperature were being obtained on the display. A suitable signal conditioning circuit was designed for both sensors to amplify the voltage to a level which can be read by the next stage i.e. the microprocessor. The other peripherals interfaced are the keypad, LCD, memory IC, RS232 ports. Instantaneous values were displayed on the graphical LCD. Password, set points for pressure and temperature and cycle period can be entered through the keypad.

The parameter values were logged in the memory and shown in a tabular and graphical format on the PC. This facility helps the user to view and save those values for future use. This would help in predicting the stability of the machine, the quality of the end product of that particular cycle, thereby simplifying the screening process.

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