Intelligent Manufacturing System for OTR Tyres using Proactive Control

Pradip Kumar Sadhu

Abstract—**Microprocessor based control of the vulcanizing process is not new and it has become almost traditional. However, the microprocessor-based process control has its limitations. A personal computer, on the other hand with its stronger computational ability, better programming flexibility makes it eminently suitable for application in the closed loop control scheme of cure monitoring process of Off The Road (OTR) tyres. Advanced graphics capabilities of a PC are another attractive feature of its use for the above. The measurement of curing environment has to be done with great care and suitable sensors are required to be installed for this. The parameters to be sensed continuously include layer pressure, temperature of layers, flow rates of cold water, hot circulating water and steam. While the continuous monitoring of layer pressure is done through piezo-electric sensors, the layer temperature is sensed by means of embedded thermistors. Other parameters are monitored by conventional methods. These parameters are continuously measured and down loaded to the personal computer. A multi-channel data acquisition system (DAS) has been used for this. A high speed DAS with high sampling rate can take care of fast changing signals without any problem. A software programme has been developed for reliable data acquisition and process control scheme. The PC based control actuates various solenoid valves according to the instantaneous requirements and thus provides an intelligent and proactive control of the vulcanizing procedures of OTR tyres.**

Index Terms—**Cure Monitoring, OTR, DAS, ADC, MUX**

I. Introduction

In the real life case study, the complicated moulds of the bag-o-matic curing (vulcanizing) presses are considered to be manufactured through intelligent rapid prototyping method with built-in-diagnostic based flexibly printed micro- circuit layer network of distributed piezo-electric actuators [1]. These actuators will establish sensitive micro-cure monitoring and intelligent on-line knowledge based corrective vulcanization procedures of raw rubber products. The aim of this paper is to suggest built-in-diagnostic features for implementation of intelligent cure monitoring process of rubber products in the micro manufacturing environment [3]. Proposed experimental set-up will be useful for improving the quality of curing of rubber related products in the vulcanizing presses. In order to build smart and intelligent systems materials must posses some extraordinary properties in comparison to the traditional materials [2] & [4]. In actual condition, mechanical and thermal stresses have to be sensed. In case of the smart materials the degree of intensity of the environment parameters has to be sensed. On-line corrective measures also have to be taken through actuators.

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1) A case study has been taken for premier Indian rubber manufacturing unit that has two major divisions. One is tyre and the other is the industrial product division. The tyre division is emphasized for the work as this division provides the bulk of the turn over and the profit for the companies. After analyzing a set of questionnaire is prepared for determining the agility of that organization. The following demerits of the company have been identified on the basis of previous analysis. Comparatively high rejection cost.
2) Inconsistency in product quality.
3) Comparatively non-proactive machineries.
4) Comparatively longer inspection time.
5) Pressure cure monitoring is minimum.
6) Temperature cure monitoring is not adequate.
7) Actuators are guided manually.
8) The defects like bag mark, over curing zone, under curing zone, shape deformation are very common.

II. Features of OTR Tyres

OTR tyres are used to meet with the most stringent demands imposed by heavy equipment operating under most difficult terrain and conditions. Fig. 1 and Fig. 2 depict Off The Road tyres and OTR tyres fitted dumper respectively. The salient features of OTR tyre are :

1) The cross bars ensure high tractive force with skid resistance. It is highly applicable for military application as the pattern is well proved design for the performance of any terrain i.e. Highway soft earth, mud & snow etc.
2) This type of tyre has strong scuff ribs specially built into both sides to prolong sidewall life. Particularly well-suited for machinery engaged in contour banking, deep drainage or continuous batter work where side wall protection is a vital factor. An OTR tyre will be rugged when minimum damage to the surface will be occurred with maximum traction under massive concentrated load. Nylon cord casing ensure dependable service and maximum relug–retread performance well on units operating in sand, loam, mud and soft greed.

Fig. 1. Off The Road (OTR) Tyres

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Fig. 2. OTR Tyre fitted dumper

3) This is very much suitable for front drive wheels on equipment operating in off the road condition.An all round multipurpose tyre which will give maximum service life when operating in the rough terrain, where long wear and toughness are important.
4) 50 percent more skid depth is required than normal road tyres. More tread base rubber gives extra body protection can be mounted in any wheel direction.
5) Not recommended for high speed – long haul operation.
6) So, OTR tyres are costlier than the normal road tyres due to the above mentioned reasons. Precautions must be taken against rejection of over cure cases, bag-mark cases, under cure cases, low pressure defects, diaphragm bag injury etc. At the time of manufacturing of OTR tyres. If rejection of final produced tyres will be less then production cost will be optimized.

III. PROPOSED SCHEME

To avoid the rejection of OTR tyres due to manufacturing defects, ON-line cure monitoring system is suggested in this paper. Such automation comprises with the following steps.

1) Smart layer based sensing.
2) Solenoid valve based actuation.
3) Piezo-electric sensor based pressure measurement in the mould.
4) Reliable on-line data acquisition.
5) PC interfacing.
6) Software development for PC based control.
7) Control room based monitoring.

Fig. 3 shows the intelligent manufacturing system for OTR tyres using proactive control. Pressure, temperature and flow sensors / transducers convert physical quantity into electrical signals, which are acceptable by the data acquisition system [5] & [6]. Signal conditioners are used for processing the transduced low amplitude signals into a usable format for the measurement. Sequential channel selection is done by means of a 16–channels analogue multiplexer. The multiplexer can handle sixteen single ended analogue signals. The switching-time of the multiplexer is software controllable and can be set / adjusted for optimum performance. The output of the multiplexer which represents one transducer signal at a time is suitably amplified by an instrumentation amplifier.

The gain of the amplifier is also software adjustable in steps. A 12-bit analogue to digital converter (ADC) is used to convert the analogue signals into the 12-bit digital format with good resolution. The digital output of the ADC is down loaded to the PC. A dedicated data acquisition (DAS) card [7], which is a combination of analogue multiplexer, sample-hold, amplifier and analogue to digital converter resides inside the PC and uses the internal power supply of the PC for its operation. It is well known that the signal fed to an analogue to digital converter (ADC) should be maintained constant during the conversion period.

The sample and hold circuit takes care of this and provides a constant input to the ADC during conversion period. For 16 inputs to the 16-channel analogue multiplexer, any one of the inputs can be obtained at the output of the multiplexer (MUX) at a time by applying appropriate logic channel address to the MUX [7] & [8].

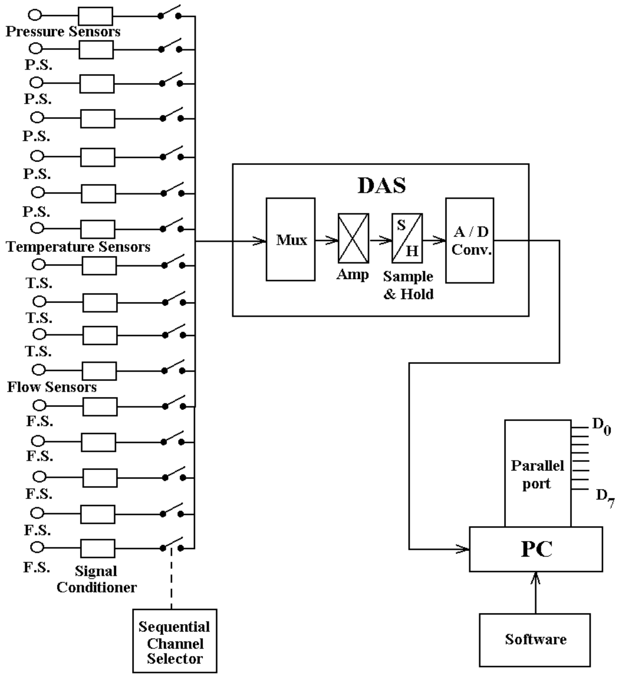

Fig. 3. Intelligent manufacturing system for OTR tyres using proactive control

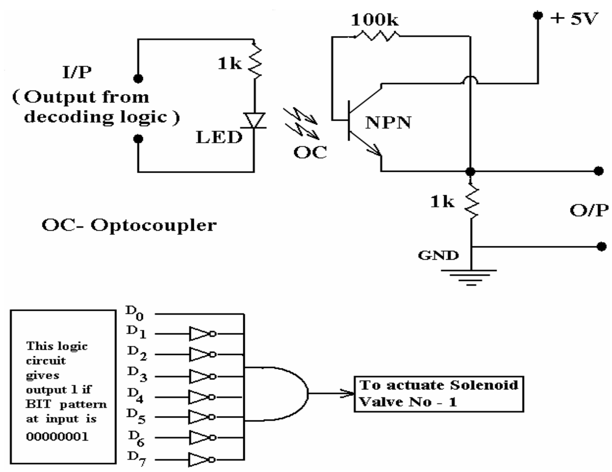

Fig. 4. Isolation and Decoding logic circuit

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Fig. 4 shows the isolation and decoding logic circuit. It isolates and protects the PC control circuit from voltage transients of the actuator circuit through optical isolation. Fig. 5 shows hardware circuit for plunger interface with PC. This circuit is driven by a low voltage / current signal which after adequate current amplification drives the high current plunger to actuate different valves. Fig. 6 shows solenoid-plunger actuation through parallel port of the PC using decoding logic. Fig. 7 depicts algorithm for solenoid-plunger actuation.

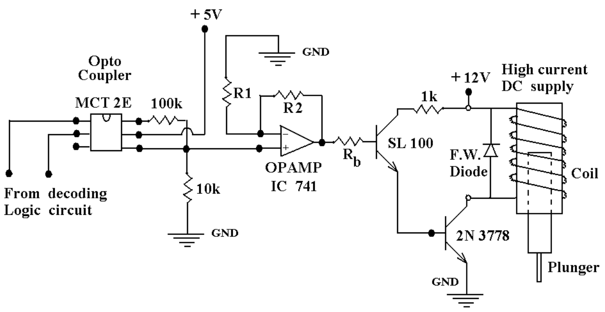

Fig. 5. Hardware circuit for plunger interface

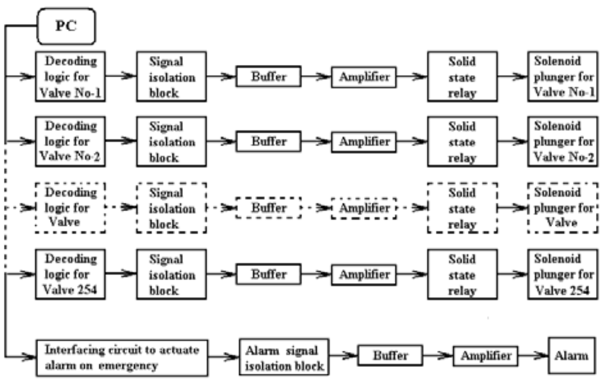

Fig. 6. Solenoid-plunger actuation through parallel port using decoding logic

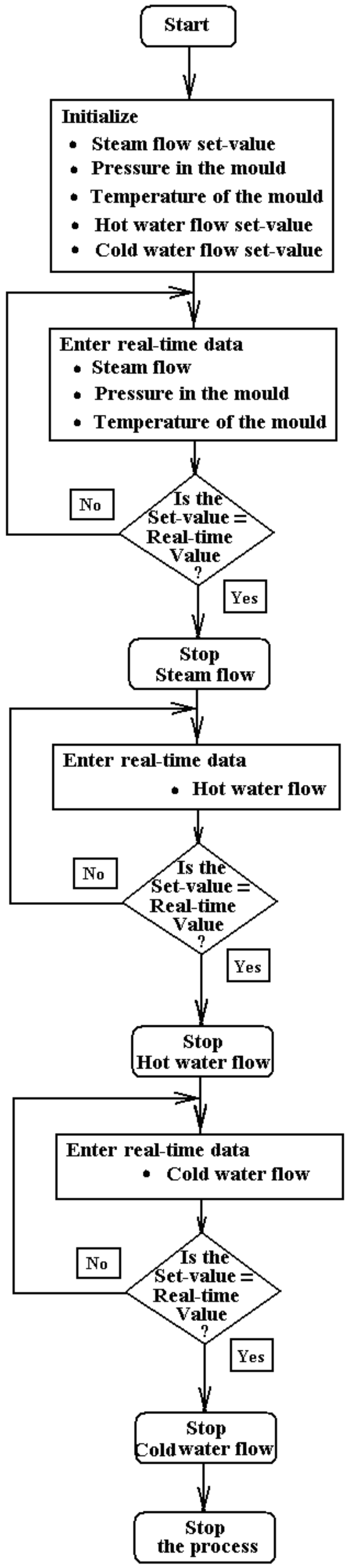

Fig. 7. Algorithm for solenoid-plunger actuation

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IV. RESULTS

TABLE I
CONVENTIONAL CONTROL VS PC-BASED CONTROL

Issues	By Conventional Control	By PC-Based Control
Over Cure Cases	15 out of 100	05 out of 100
Bag-Mark Cases	10 out of 100	03 out of 100
Under Cure Cases	13 out of 100	04 out of 100
Low Pressure Defects	09 out of 100	03 out of 100
Diaphragm Bag Injury	03 out of 100	01 out of 100

V. CONCLUSIONS

OTR tyres are expensive than the normal road tyres. Precautionary measures must be taken against rejection of Over Cure Cases, Bag-Mark Cases, Under Cure Cases, Low Pressure Defects, Diaphragm Bag Injury etc. at the time of manufacturing. The rejection of final produced tyres can be controlled by the proposed on-line PC based control scheme. It provides extensive cure monitoring. It also intricates sensing and subsequent actuation result in significant improvement of over and under cure cases. The on-line control scheme also ensures increased life of diaphragm bag and possible reduction of cure time. The proposed system is also expected to reduce downtime and minimize maintenance problem. Better data and documentation record is possible because of PC based control. The powerful software option of the system provides excellent flexibility of control.

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