Computerised Process Control for Paper Machine

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SUMMARY

Paper making is a complex process involving diverse types of equipment. The operational procedures required are extremely difficult to coordinate manually since the performance of a single piece of equipment affects the performance of a number of associated equipments. Better coordination of the operating procedures and equipment-unit-controls will improve both production and quality. Such coordination is best provided by a computer. A computer control system designed to meet paper making problems provides tighter limits on important variables, responds rapidly to equipment or process irregularities, changes control strategies as process conditions and operating demands dictate generates operating alarms and messages which clearly define process conditions and provides management reports in clear concise form. This paper outlines the objectives, types of control in brief and the computerised process control of paper machine in detail giving the economic benefits, controls desired, sensors and control techniques in use.

INTRODUCTION

Though there has been a significant growth in paper industry in India, we are not yet self-sufficient to meet our demand for various varieties of paper. Under the constraints imposed by the raw material shortage, higher cost of chemicals, growing market demand for paper with product uniformity and quality and an almost stagnated process technology, the only way to achieve our production target is by optimisation of raw material usage and better process control. The most powerful tool for such an optimisation and process control is a modern, high speed digital, process computer for online, real time, time shared, process, product and manufacturing control. This paper deals with the objective and type of computer control in brief and computerised process control of paper machine operations in detail illustrating the advantages, controls desired and the measuring and controlling techniques associated with various operating variables.

OBJECTIVE

The objective of any process control system is to produce a uniform product with certain given quality specifications and manufacturing it in the most economical manner. The process control digital computer can aid in identifying instability, memorising and achieving process standards, checking measured product characteristics against stored information and finally in selecting the optimum process economics.

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TYPES OF COMPUTER CONTROL

The development of computerised control of process was in stages. In order to understand the trends in the technology, four distinctly different types of computer control systems are briefed here.

ANALOG COMPUTER SYSTEM

A conventional analog control loop is given in Fig. 1. This can be an electric or pneumatic control loop. Because of the limited accuracy, difficulties in applying adaptive control, problems in generating time functions lasting several hours and the tediousness of the complex control strategies, their use in the industries are limited.

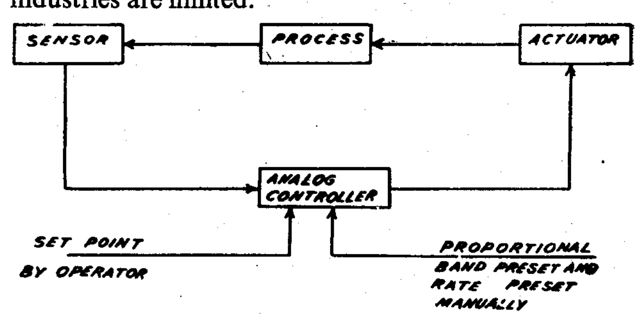

Fig. 1. Analog Computer System

SUPERVISORY CONTROL SYSTEM

In this a digital computer scans analog sensor inputs and performs the necessary control calculations to determine the most desirable operating position. It then electronically positions the set points of the analog controllers or valves through the necessary transducers. Fig. 2 represents the block diagram of a simple supervisory control system.

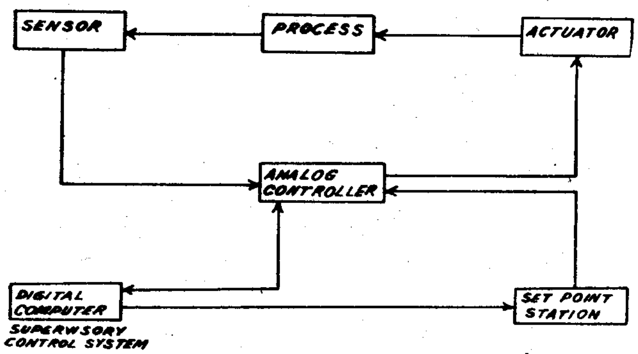

Fig. 2. Supervisory Control System

DIRECT DIGITAL CONTROL SYSTEM

This replaces the function of the analog controllers by software within the computer. The counterparts to the gain, reset and rate controls are now defined within the computer programme and the control point is entered into the computer by the operator or generated internally by a programmed strategy. The simplest form of Direct Digital Control is shown in Fig. 3.

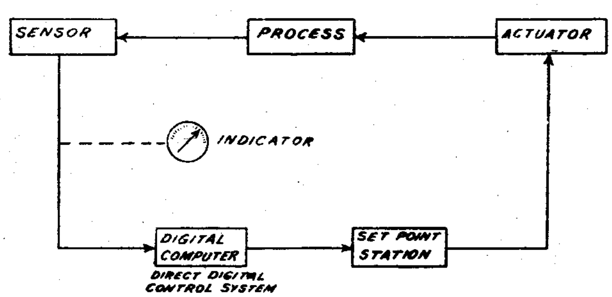

Fig. 3. Direct Digital Control System

HIERARCHICAL COMPUTER CONTROL SYSTEM

This consists of a central supervisory controller served by one or more dedicated mini computers located close to the process each one of which will provide direct digital control for a given subsection of the system. All computational operations associated with the supervisory function, models, standards, strategies, etc. will be performed in the central computer and its output will adjust the control parameters and control points in the direct digital control units. The block diagram of this system is given in Fig. 4.

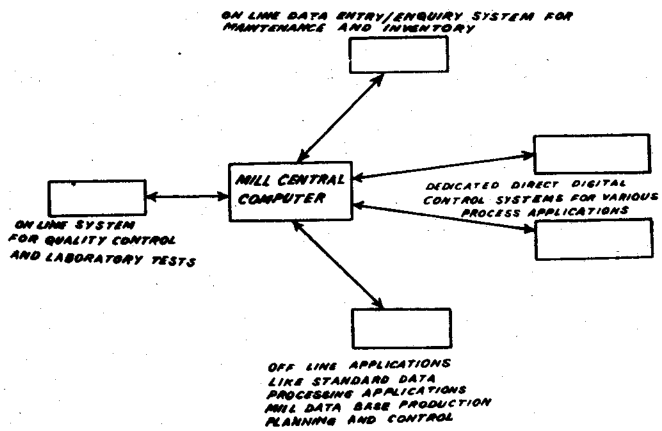

Fig. 4. Hierarchical Computer Control System

COMPUTERISED PROCESS CONTROL OF PAPER MACHINE

The ultimate aim of any process control is cost reduction and better quality. Though in paper making process many areas such as digester, bleaching, stock preparation, paper machine, recovery and power boilers are amenable for process control, the impact is more on paper machine as the benefits derived from such controls are higher and immediate. Further the economic benefits are achieved by controlling few variables in the paper machine. The substantial economic advantages of paper machine controls are:

Savings of fibre by accurate measurement and close control of basis weight and ash.

Working with moisture content at the optimum levels.

Better runnability of the paper machine due to improved control of process variable affecting the strength properties of the sheet.

Reduction in finishing losses due to consistent basis weight, moisture content and caliper.

Running the machine to the limit of drying capacity made possible by continuous moisture measurement and control.

Start-up and grade change time reduced by instantaneous display of important variables.

Better quality by the reduction of wet end variations, profile control, basis weight and moisture control.

AREAS OF CONTROL IN PAPER MACHINE

Some of the control applications in Paper Machine have been tabulated and given below along with their objectives and variables associated with them.

Application	Objective	Variables to be controlled
a) Stock Preparation	Consistent freeness	Refiner control
	Minimum shade variation	Flow control of pulp, colour, additives and chemicals

	pH Control	Pulp consistency, and flow, Alum addition
	Consistent furnish quality	Stock flow of different grades of pulp, broke
b) Wet end applications	Good sheet formation	Head box level, slice setting, Flat box vacuum
c) Basis weight control	Optimum basis weight within trade tolerance	Stock flow consistency of stock Head box level speed of the machine
d) Moisture control	Optimum moisture level avoiding calender blackening	Steam and condensate system Machine ventilation and Hood system Basis weight Speed of machine
e) Ash control	Optimum ash for given strength of paper	Flow control of additives and broke
f) Caliper control	Control within a given tolerance across the deckle	Control of Air shower to the calender rolls and paper web. Nip pressure control for presses and calender
g) Reel hardness	Uniform hardness across the deckle of the roll	Nip pressure control and cooling air system for calender
h) Colour, opacity and brightness control	Minimum shade variation and optimum opacity	Addition of colours, fillers and optical brighteners.
i) Automatic Grade change	Minimum settling time, loss of production from off specification product	Modified product specification
j) Coating control	Control of the weight and thickness of coating	Coat addition, knife pressure etc.
k) Operator lagging Dry end data collection and providing Management Information System	Record of process conditions; Summary reports on production, downtime etc.	

HEAD BOX AND WET END CONTROL

The computer control of the head box and wet end minimises machine direction variations, eliminates upsets caused by cutting out or adding cleaners, allows higher production speeds, provides faster speed and weight changes, enables fast grade changes with minimum breaks. The block diagram of the head box and wet end control is given in Fig. 5.

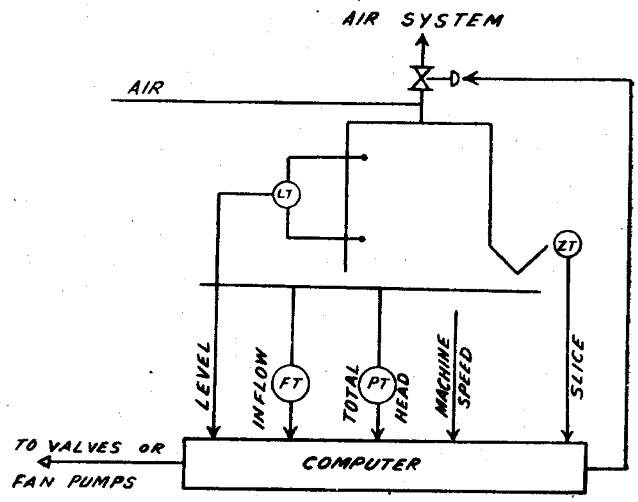

Fig. 5. Head Box and Wet End Control

BASIS WEIGHT CONTROL

Basis weight is controlled by remotely adjusting the thick stock flow valve based on the error signal given after the comparison of the set basis weight and the measured one with the Betameter, the most popular basis weight measuring gauge. The Betameter is a two sided transmission sensor based on the principle that variations in basis weight of a paper web produce variations in the beta particle absorption. The Betameter consists of a beta particle source (usually Krypton 85 or Strontium) a detector and a digital processor. In operation beta particles emitted by the source are attenuated by the moving web in proportion to the basis weight. The remaining particles enter the ionisation chamber and create a current which is converted into basis weight measurement. The simple diagram given in Fig. 6 represents the basis weight control.

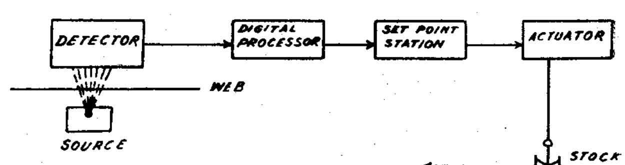

Fig. 6. Basis Weight Control

MOISTURE CONTROL

The control of moisture though influenced by steam, condensate, and air system, basis weight and speed of the machine, is mainly achieved by adjusting the steam flow controller, whenever a deviation is traced between the measured moisture content and the target value. The moisture in the paper web is measured using conductivity, dielectric and spectroscopic methods. But the spectroscopic method is predominantly used since the spectroscopic sensors used for moisture measurement are highly selective for the detection of water molecules and for all practical purposes, insensitive to all other materials normally found in paper. By observing electromagnetic energy absorption at specific frequencies (infrared and k-band microwaves) or wave length, characteristic molecular vibrations and rotations of water molecules are deduced. The absorbed energy is a measure of the number of water molecules present in the web. The infrared wave sensors are widely used for the measurement of low moisture content especially at dry end, whereas the k-band microwave sensors are capable of penetrating greater thickness of water and can be used to measure moisture in sheet with high moisture levels. Moisture content is measured using 22.2 GHz frequency, k-band microwave energy by means of two different techniques, transmission and surface contact.

In the transmission type sensor (Fig. 7) microwave energy leaves the source horn A, passes through the sheet and is received by horn B. It then passes

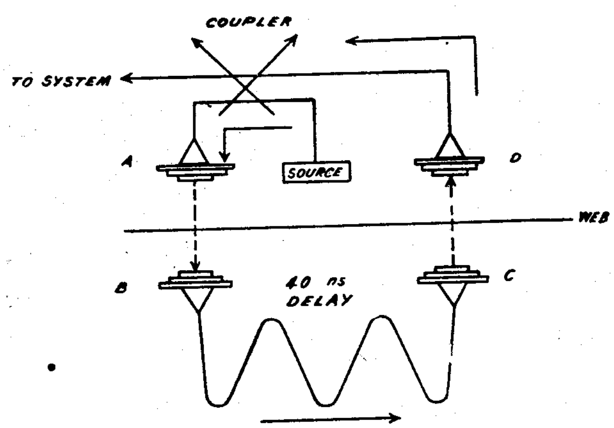

Fig. 7. Transmission-Type Moisture Gauge

through a 40 ns time delay to emerge from horn C and pass through the sheet to horn D. This return energy is coupled with currently-generated energy. The source frequency is modulated in time and there is a frequency shift due to the 40ns time delay. A beat frequency of 15 kHz is generated and is used in the detection circuits to sense the energy that has passed through the sheet twice. This provides a direct measure of moisture content.

The surface contact type sensor (Fig. 8) is single sided and in direct contact with the sheet, whose thickness together with the sensor's dielectric element forms the total microwave path from transmitter to receiver. Microwaves fill the sheet from one surface to the other and there is no significant energy loss other than that absorbed by the water molecules in the energy path. The resultant measurement gives total moisture content of the sheet irrespective of water layering and sheet composition.

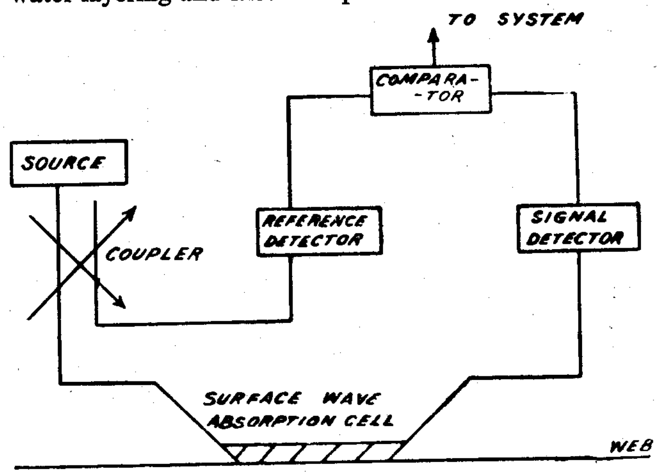

Fig. 8. Surface Contact Type Moisture Gauge

ASH CONTROL

The ash measurement and control results in the saving of pulp cost, costly fillers like TiO_2 improved retention and other quality benefits in surface finish, formation, printability, dye affinity, brightness, opacity and sizing.

The gauge to measure the ash content uses X ray fluorescene to selectively determine TiO_2 and calcium carbonate composition and preferential X ray absorption to determine filler composition. This gauge is designed with a Fe^{55} radioisotope X ray source with dual geometrics for fluorescence and absorption. Each analytical spectrometer employs a stable X ray proportional counter as the detector.

CALIPER CONTROL

Control of caliper improves the quality, reduces the rejects and increases the operating efficiency.

The principle applied in controlling the caliper is by cooling (by directing cool air) heating (using strip heating) a narrow width of the calender roll which causes the diameter to decrease/increase resulting in reduced/increased calendering at that point and an

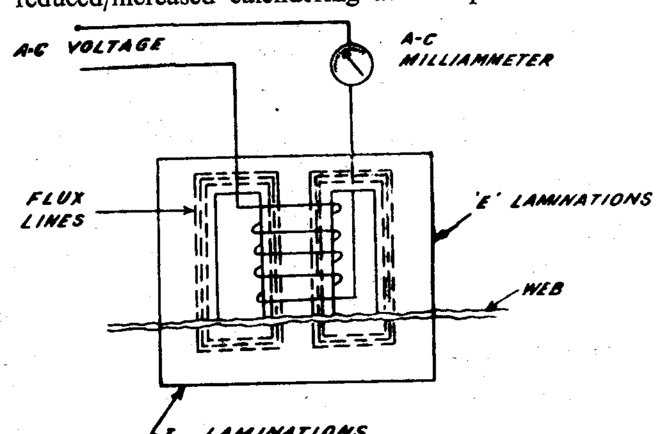

Fig. 9. Variable Reluctance Thickness Measuring Principle

increase/decrease in the sheet caliper. The speed of response is generally slow with this system. The modern control system consists of two cold air supply header one positioned above and the other below the moving web of paper just prior to its entering the calender stack. It is found that the air cooling applied to the web entering the calender is more effective and gives a more rapid response than when it is applied to the calender rolls themselves. The effect is apparently caused by the greater heat transfer efficiency from air to paper and then to the calender rolls. It may also be caused by the ability of the web to change the temperature of more than one calender roll.

The measuring principle is based upon varying the inductance of a magnetic circuit. This is also known as variable reluctance method. Fig. 9 shows the inductor core positioned with a web of paper separating the two parts. The center leg of the E laminator is surrounded by a coil of wire whose leads are terminated at a source of a-c voltage. An a-c milli ammeter is shown in one lead to read the current of this circuit. The impedence of this circuit is determined by the thickness of the non-magnetic material that separates the E and I laminators. The thicker the material (paper) the greater the milli ammeter reading. The gauge (Fig. 10) has a bottom shoe that supports the underside of the web and a top detector containing the inductance coil. Thickness detection essentially involves detecting the change of inductance of the circuit.

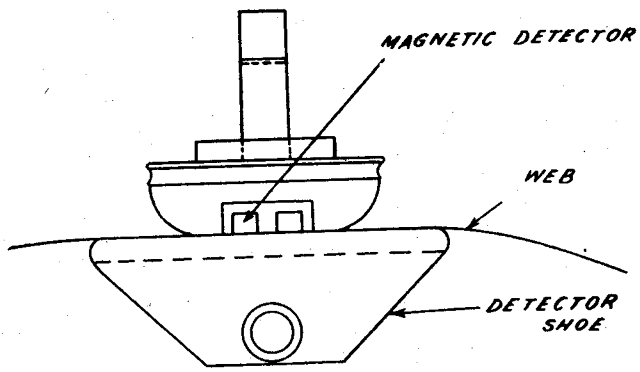

Fig. 10. Caliper Measuring Gauge

REEL HARDNESS CONTROL

The control of reel hardness results in reduced culls, higher moisture contents and improved rewinder runnability.

The hardness measuring sensor consists of a disc with piezo electric crystal rotating with the reel and gives a direct indication of reel hardness. The control strategy (Fig. 11) encompasses adjusting the air showers on the calender stack to provide cross machine control of reel hardness.

COLOUR, OPACITY AND BRIGHTNESS CONTROL

These sensors basically follow the principle of optics and the control of the variables results in reduced production loss due to off specification paper, reduction in colour grade change time, more efficient use of costly fillers, dyes and optical brightening agents and better colour uniformity resulting in more efficient finishing room operations.

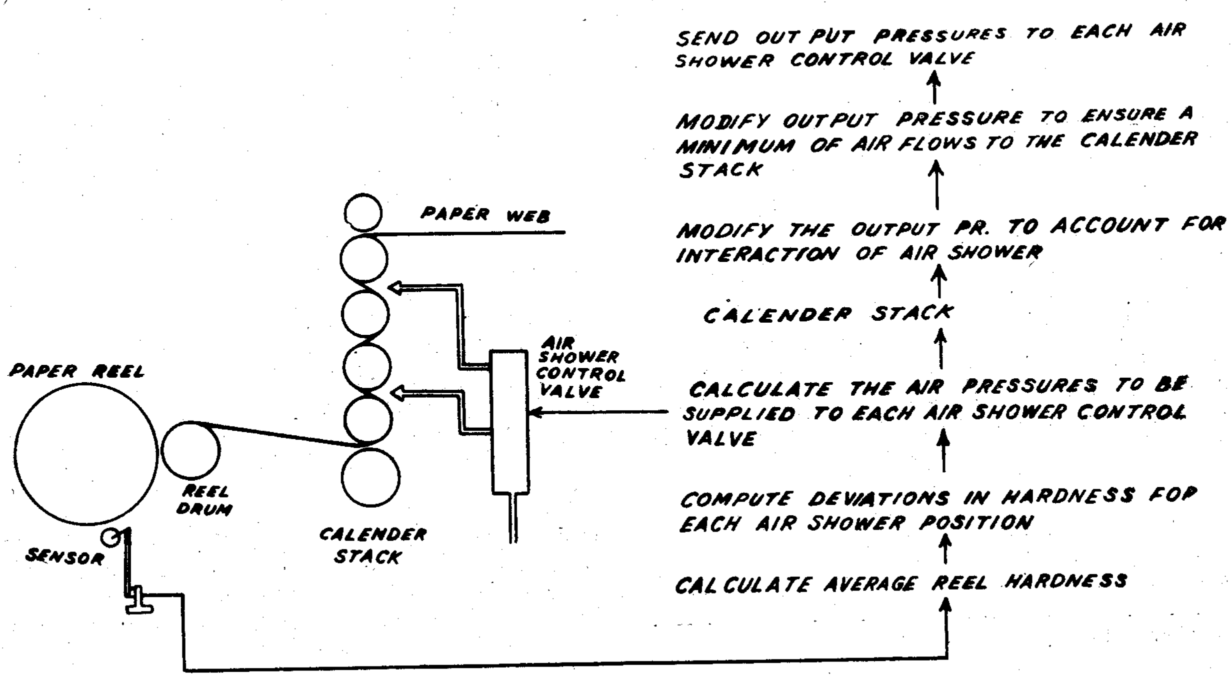

Fig. 11. Reel Hardness Control Strategy

CONTROL SYSTEM MANUFACTURERS

The complete control systems for paper machine are being manufactured and supplied by a lot of engineering firms and some of them are listed below:

Accuray International, S.A.	Belgium
Baile (Controle)	France
Sentrol	Canada
Measurex International Corporation	U K
Foxboro	U K, United States
Lippke	West Germany
Digimatics	U K
Muller Barlieri AG	Switzerland
Taylor Instrument Companies (U K) Ltd	U K
Boyle Industrial Gauging Systems Limited	U K

CONCLUSION

Computer control in paper industry is well established in advanced countries like USA, Canada, UK, and Scandinavia. The controls described in this paper are of proven design and of practical interest to Paper Makers. The delay in the introduction of computer control in India has been probably due to the non-availability of dependable control equipments and shortage of trained manpower. At the present higher level of labour and input costs, installation of computer control systems, particularly in paper machines, is definitely advantageous to Indian Paper Mills. It may be pointed out here that even old machines can be easily modified to have computer control systems. It is hence suggested that speedy action may be taken by Paper Mills in India to derive economic benefits of computer control.

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