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Advancements in Sensors and Controllers in Mechatronics

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Abstract- Mechatronics is the synergistic combination of mechanical engineering, electronics, controls engineering, and computers, all integrated through the design process. The cost-effective incorporation of electronics, computers, and control elements in mechanical systems requires a new approach to design. Technical systems, be they small consumer or medical devices or large production processes, increasingly employ electronics and computers to give the final product or system the desired properties. Driving factors are e.g. functional and quality demands, energy utilization, environmental demands, or cost reductions. A striking example of this development can be found in the automotive area – the modern passenger car depends on the integration of the car's mechanical subsystems with a substantial amount of embedded computers, sensors, actuators, and communication devices. In mechatronics, generally the objectives are to automate a process or to control parameters of system.

Keywords: - Mechatronics, Sensors, Controller, Feedback.

INTRODUCTION

Mechatronics is a multidisciplinary field combining Mechanical, Electronic, Computer, and other Engineering fields to develop intelligent processes and products. In mechatronics, measurement is an important subsystem of a mechatronics system. Its main function is to collect the information on system status and to feed it to the micro-processor(s) for controlling the whole system.

Measurement system comprises of sensors, transducers and signal processing devices. Today a wide variety of these elements and devices are available in the market. For a mechatronics system designer it is quite difficult to choose suitable sensors/transducers for the desired application(s) [1]. It is therefore essential to learn the principle of working of commonly used sensors/transducers. Sensors in manufacturing are basically employed to automatically carry out the production operations as well as process monitoring activities. Sensor technology has the following important advantages in transforming a conventional manufacturing unit into a modern one.Sensors alarm the system operators about the failure of any of the sub units of manufacturing system. It helps operators to reduce the downtime of complete manufacturing system by carrying out the preventative measures [2]. Reduces requirement of skilled and experienced labors. Ultra-precision in product quality can be achieved.

A mechatronic system consists by definition of a mechanical part that has to perform certain motions and an electronic part (in many cases an embedded computer system) that adds intelligence to the system. In the mechanical part of the system power plays a major role. In the electronic part of the system information processing is the main issue. Sensors convert the mechanical motions into electrical signals where only the information content is important or even into pure information in the form of numbers (if necessary, through an AD-converter). Power amplifiers convert signals into modulated power. In most cases the power supply is electrical, but other sources such as hydraulic and pneumatic power supplies are possible as well. A controlled mechanical motion system thus typically consists of a mechanical construction, one or more actuators to generate the desired motions and a controller that steers the actuators based on feed-forward and sensor-based feedback control.

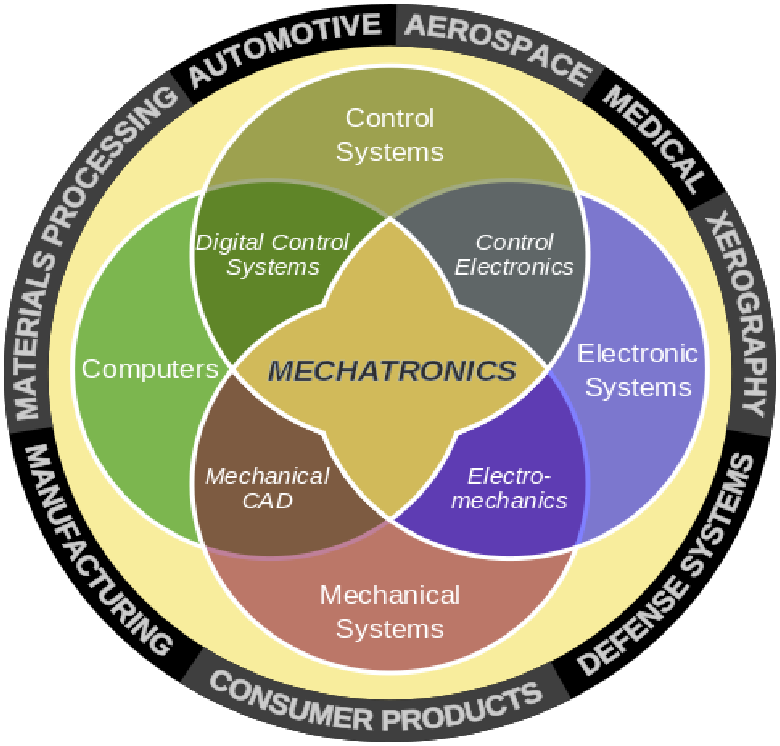

Fig 1: Mechatronics

SENSORS

In the broadest definition, a sensor is an electronic component, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics, whether as simple as a light or as complex as a computer.It is defined as an element which produces signal relating to the quantity being measured [3]. According to the Instrument Society of America, sensor can be defined as "A device which provides a usable output in response to a specified measured." Here, the output is usually an 'electrical quantity' and measurand is a 'physical quantity, property or condition which is to be measured'. Thus in the case of, say, a variable inductance displacement element, the quantity being measured is displacement and the sensor transforms an input of displacement into a change in inductance [4].

Table 1.Various types of sensor used in Mechatronics and their applications

Motion Sensors	
Parking Sensors	In road vehicles designed to alert the driver to obstacles while parking.
Speed Sensors	In transport vehicle to detect the speed of an object.
Torque Sensors	for measuring and recording the torque on a rotating system
Blind Spot Monitor	Detects other vehicles located to the driver's side and rear.
Radar Gun	Used to measure the speed of moving objects.
Speedometer	Measures and displays the instantaneous speed of a vehicle.
Wheel Speed Sensor	It is a sender device used for reading the speed of a vehicle's wheel rotation
Temperature Sensors	
Engine Coolant Temperature Sensor	Used to measure the temperature of the engine coolant of an internal combustion engine.
Air Flow Meter	In some automobiles to measure the quantity of air going into the internal combustion engine.
Air–Fuel Ratio Meter	Monitors the air–fuel ratio of an internal combustion engine
Light Sensors	
Photo Resistor	Resistance varies with change in light intensity
Sound Sensor	

Geophone	Converts ground movement (velocity) into voltage.
Hydrophone	Used underwater for recording or listening to underwater sound.
Contact Sensor	
Limit Switch	Used for obstacle avoidance robots.
Proximity Sensor	
Infrared (Ir) Transceivers	Detect the presence of a nearby object within a given distance, without any physical contact.
Ultrasonic Sensor	Generates high frequency sound waves; the received echo suggests an object interruption.
Pressure Sensors	
Tactile Sensor	Sensitive to touch, force and pressure.
Other Sensors	
Electro-optical sensors	Convert light, or a change in light, into an electronic signal.
Thermocouple	Two dissimilar electrical conductors forming electrical junctions at differing temperatures.
Thermistor	Resistance is dependent on temperature
Electromechanical Film	Convert electrical energy to vibration, functioning as an actuator
Ultrasonic transducers	Transmitters convert electrical signals into ultrasound, receivers convert ultrasound into electrical signals, and transceivers can both transmit and receive ultrasound.

There are hundreds of sensors made today to sense virtually anything we can think of, and it is almost impossible to list all available sensors. Apart from those mentioned above, there are many other sensors used for specific applications [5]. For example: Humidity Sensors measures Humidity; Gas sensors are designed to detect particular gases (helpful for robots which detects gas leaks); Potentiometers are so versatile that they can be used in numerous different applications; Magnetic Field Sensors detect the strength of magnetic field around it[6].

CONTROLLERS

Generally the objectives of mechatronics, are to automate a process or to control parameters of system. Control systems for manufacturing systems can be categorized into two types. Firstone is the sequential control where all the operations are carried out in a sequence to automate the mechanical system(s)[7]. The best example of such control system is automated vehicle assembly line. These types of operations are controlled by Programmable Logic Controller (PLCs).

The second type of the control system, precise control over output of system is to be obtained. Therefore a continuous monitoring of such system is essential. For example in Boiler based power plant there is a necessity to continuously monitor and control the fuel tank. This type of control is also called modulating control. Feedback systems and Proportional-integral-derivative (PID) controllers are employed in these systems. In general a closed loop system has several input variables and several output variables. However one or two dominant input variables are considered in designing the control system. Output variables are measured by using suitable transducer system and the feedback is sent to the controller for comparison.

THE STRUCTURE AND NATURE OF CLOSED-LOOP CONTROLS

The basic elements of a general closed-loop control system are shown in Fig. 2. A suitable transducer is used to measure the output variable and convertit into a proportional electrical signal, and fed back for comparison with the input command signal that represents the desiredvalue of the output variable. The error signal is the difference between the input command signal and the measured value of the output variable. It is fed to an amplifier where an adjustable gain is applied and the resulting gained-up signal drives the actuator that modifies the output variable. If disturbances upset the output variable, the feedback transducer senses the altered output variable, and the system makes the appropriate and necessary corrections.

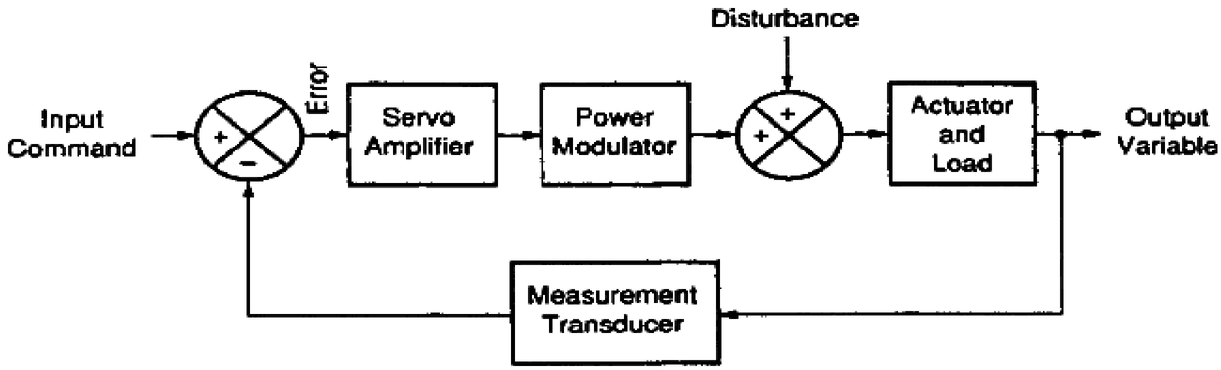

Fig 2: Feedback control system block diagram structure with disturbance input.

Thus, the output variable follows the input command in spite of disturbances that are always present in real systems. But, because of the loop structure, excessively high gain applied to the error signal may cause oscillatory unstable behavior.

Most closed-loop control systems have provisions for maintaining a tradeoff between a sufficiently high gain to maintaining good follow-up accuracy between the input command and the output variable without the undesirable oscillatory unstable behavior, Oscillatory unstable behavior is sometimes it called “drift.” A three-term controller is inserted between the error signal and the control actuator, as shown in Fig. 3. This type of controller or control algorithm is also called PID for proportional, integral, and derivative control action.

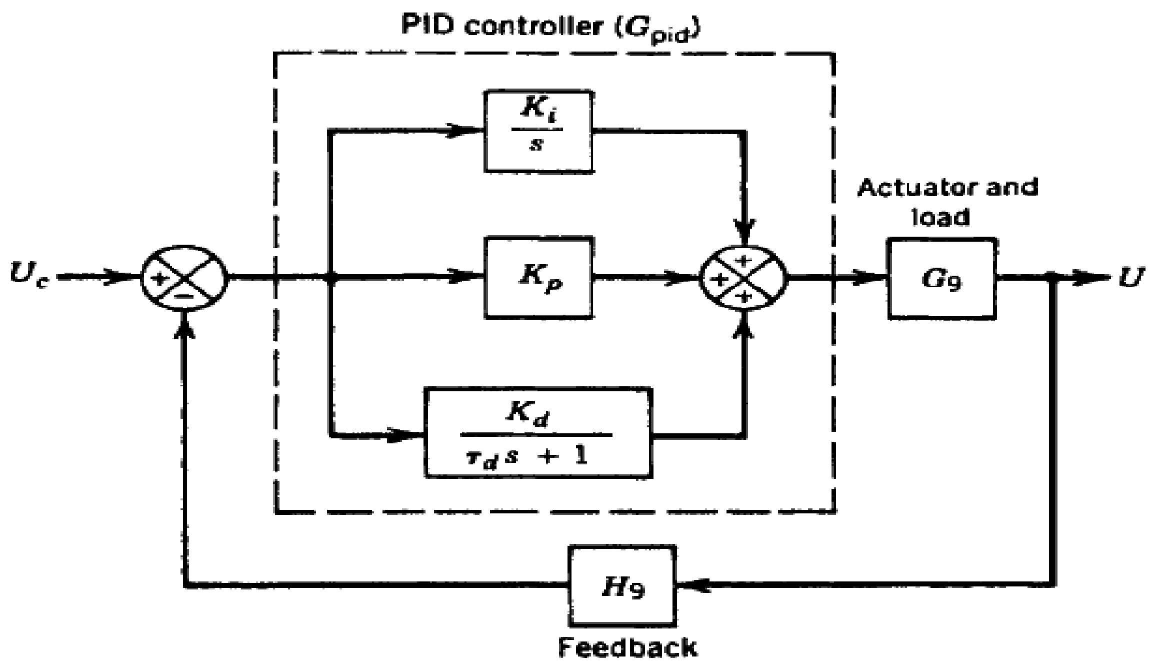

Fig 3: Generalized PID controller.

Operation on the error signal is exactly as suggested by the names of the three terms proportional gain, integration of the error signal over time, and differentiation of the error signal with respect to time. Each of these three processes has its own gain so that the relative amount of each type of control action can be operator-selected. The next two sections show how the closed-loop control structure and its associated three-term controller merge with a loss-in-weight or a weigh belt feeder to yield flow rate control.

WEIGH BELT FEEDERS AND THEIR FLOW RATE CONTROL LOOPS:

The components of a weigh belt feeder and its flow rate control loop is shown in Fig. 4. The weigh bridge is essentially a pair of load cells that carry one or more rollers or a slider pan to support a short section of belt as R transports material from the hopper to the discharge point. The weight signal generated by the load cells is fed to the totalizer for calculation of the live load per unit length of belt. It is called a totalizer because it also computes a running total of the weight of material that has passed over the weigh bridge since some starting time. Flow rate requires another measured variable the motion of the belt itself. This is typically accomplished by a shaft encoder coupled to one of the roller shafts; a non-driving shaft if possible. The internal clock of the microprocessor totalizer and a gating circuit adds yet another measurement to the determination of flow rate: the time between pulses of the shaft encoder. From these three separate measurements, the flow rate of the material conveyed by the belt is calculated by the totalizer.

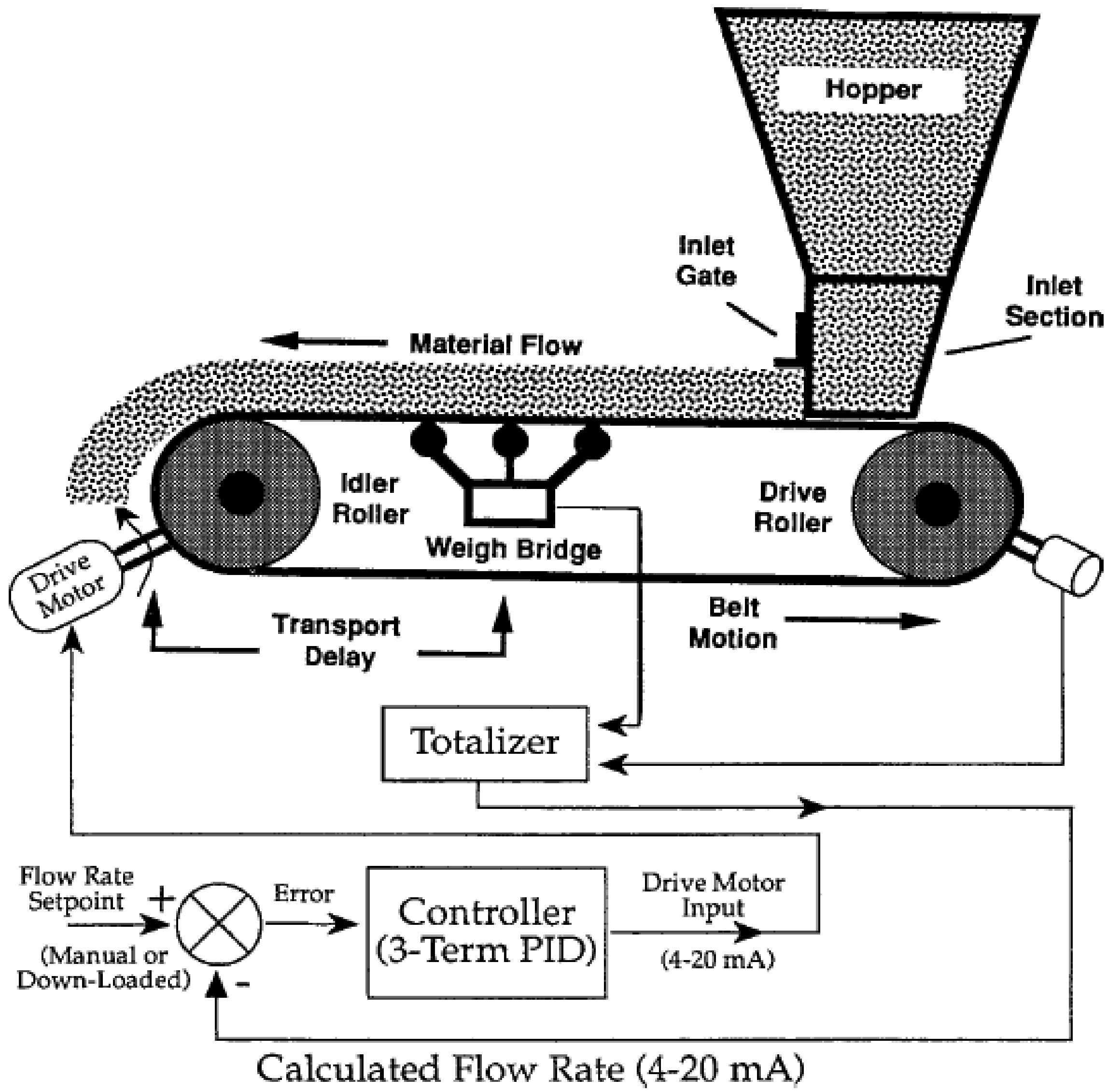

Fig 4:Closed-loop weigh belt feeder control.

Control of the flow rate in a weigh belt feeder is accomplished by comparing the calculated flow rate with the flow rate set point and generating an error signal that is processed by the controller, typically a three-term controller, as shown in Fig. 5. The flow rate set point may be a constant value, a preprogrammed function of time, or a signal downloaded from another manufacturing or processing portion of the plant. For example, if the flowing material in Fig. 5 is one of several ingredients in a proportioning system, this flow rate may need to be metered in proportion to the other ingredient flow rates. In this case, the flow rate set point would be downloaded from another machine in the proportioning network.

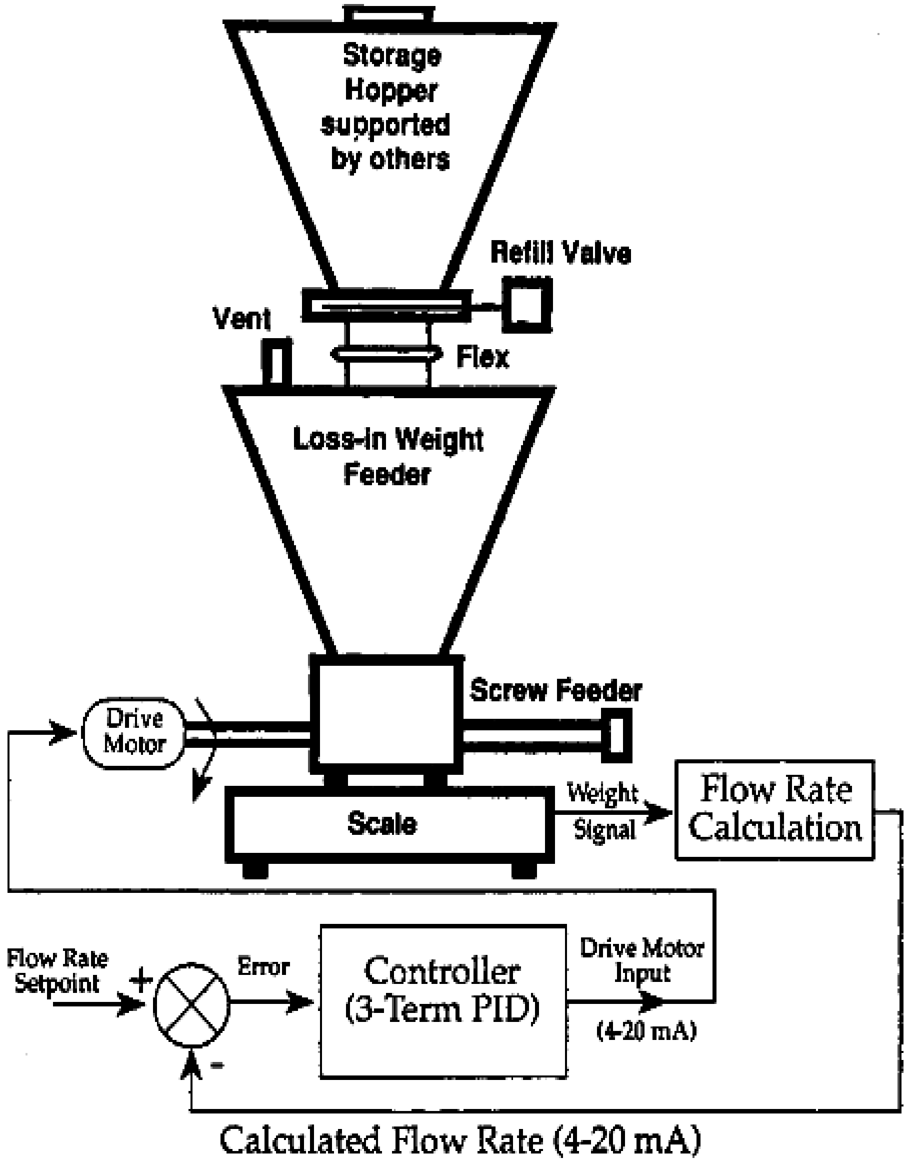

Fig 5: Closed-loop loss-in-weight feeder control.

Modulation of the flow rate is accomplished by speeding up or slowing down the belt drive motor while keeping the belt material loading as uniform as possible. Note that there is a transport delay time between the belt load sensed at the weigh bridge and the discharge point. Therefore, a well-designed controller would build in a similar time delay between the time it makes a decision to change the belt speed and the time it actually carries out the speed change.

LOSS-IN-WEIGHT FEEDER AND ITS FLOW RATE CONTROL LOOP

The components of a loss-in-weight feeder and its flow rate control loop are shown in Fig. 5. A loss-in-weight feeder decreases as the feeder discharges. Measurement of the live material is implemented by mounting the entire machine on load cells just as in weigh belt feeders; flow rate is also a derived or calculated variable. But in this machine, the flow rate calculation is considerably less complicated because flow rate is simply the change in weight of the hopper divided by the increment of time over which the loss in weight is measured. Increases or decreases in flow rate are achieved by increasing or decreasing the rotational speed of the feeder screw that delivers material. Except for the method of calculating flow rate, the structure of the control loop is substantially the same as for a weigh belt feeder. A three-term controller operates on the error signal and delivers a 4–20-mA signal to the drive motor. One important difference in the control strategy of the two machines is that the loss-in-weight feeder must switch to a constant screw feed speed when the hopper runs empty and during refilling of the hopper. During the fill time, the scale obviously cannot generate a signal indicative of the outflow from the feed screw.

CONCLUSION

Mechatronics is more a way of thinking than a completely new discipline. It still needs advanced knowledge of specialists from different disciplines who meeteach other in a mechatronic design team. Mechatronicsis a design philosophy. It has been mentioned in theintroduction that it is important to make a design from asystems approach in order to get the best possible performance. But it is not realistic, nor needed to invent thewheel again and again, because time to market is animportant issue. Mechatronic designs of production machines can help to react faster to market demands. Aflexible production line that can be reconfigured bymeans of software is much easier to adapt than conventional lines that require that mechanical devices be reconfigured[7]. But also in the design stage of products andproduction means, time to market is an important issue. The application of closed-loop control to weigh belt feeders and to loss in weight feeders is both simple and complicated. Both machines must rely on a computed variable as the feedback signal. On the other hand, the control requirements for either machine are generally not particularly difficult to meet.

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