Utility of Mechatronics in Industry

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ABSTRACT

As the human civilization makes great strides in technological advancements, the manufacturing industry has experienced a big boost with the introduction of a new automation concept. Mechatronics is fast becoming a popular way for companies to produce goods with the quality and speed modern consumers have come to expect. Originally referred to electro-mechanical systems and hatched in automotive manufacturing plants, the field of mechatronics has leaped into many other industries. As engineering and information technology have evolved, so has the mechatronics speciality. It now represents the combination of mechanics, electronics, control systems and software computing. Advanced hybrid control automation technology systems optimize space and productivity for heavy manufacturing facilities, performing tasks that otherwise requires extensive manual labor, such as equipment assembly, loading and unloading, picking and palletizing.

Keyword : - *Sensors, Temperature Sensors, Pressure Sensors, Displacement Sensors, Liquid Flow Sensors, Ultrasonic/Laser Nondestructive Evaluation Sensor, Image Transmission Sensor*

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1. SENSORS IN MANUFACTURING

Many types of sensors have been developed during the past several years, especially those for industrial process control, military uses, medicine, automotive applications, and avionics. Several types of sensors are already being manufactured by commercial companies.

Process control sensors in manufacturing will play a significant role in improving productivity, qualitatively and quantitatively, throughout the coming decades. The main parameters to be measured and controlled in industrial plants are temperature, displacement, force, pressure, fluid level, and flow. In addition, detectors for leakage of explosives or combustible gases and oils are important for accident prevention.

2. TEMPERATURE SENSORS IN PROCESS CONTROL

Temperature is one of the most important parameters to be controlled in almost all industrial plants since it directly affects material properties and thus product quality. During the past few years, several temperature sensors have been developed for use in electrically or chemically hostile environments. Among these, the practical temperature sensors, which are now commercially available, are classified into two groups: (1) low-temperature sensors with a range of -100 to +400°C, using specific sensing materials such as phosphors, semiconductors, and liquid crystals; and (2) high-temperature sensors with a range of 500 to 2000°C based on blackbody radiation.

2.1 Semiconductor Absorption Sensors

Many of these sensors can be located up to 1500m away from the optoelectronic instruments. The operation of semiconductor temperature sensors is based on the temperature dependent absorption of semiconductor materials.

Because the energy and gap of most semiconductors decrease almost linearly with increasing temperature T, the band-edge wavelength λg (T) corresponding to the fundamental optical absorption shifts toward longer wavelengths at a rate of about 3 A/°C [for gallium arsenide (GaAs)] with T. As illustrated in Fig. 2.1, when a light-emitting diode with a radiation spectrum covering the wavelength λg (T is used as a light source, the light intensity transmitted through a semiconductor decreases with T.

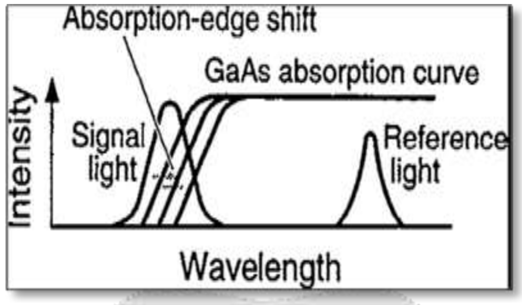

Fig. 2.1 Operating principle of optical-fiber thermometer based on temperature-dependent GaAs light absorption.

Fig.2.2 shows the reflection-type sensing element. A polished thin GaAs chip is attached to the fiber end and mounted in a stainless-steel capillary tube of 2-mm diameter. The front face of the GaAs is antireflection-coated, while the back face is gold-coated to return the light into the fiber.

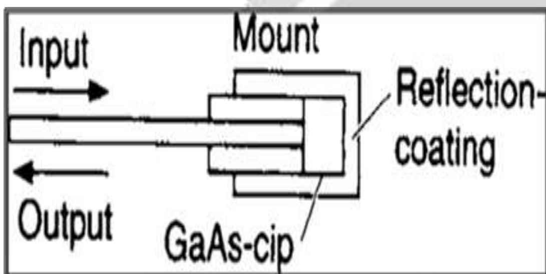

Fig. 2.2 Sensing element of the optical-fiber thermometer with GaAs light absorber

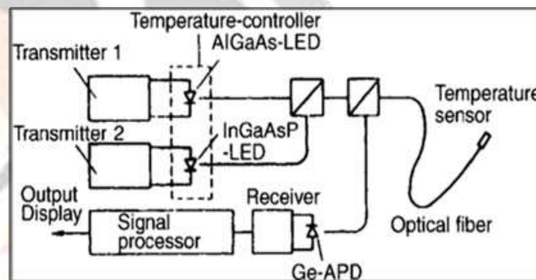

Fig. 2.3 System configuration of the optical-fiber thermometer with GaAs light absorber.

The system configuration of the thermometer is illustrated in Fig. 2.3. In order to reduce the measuring errors caused by variations in parasitic losses, such as optical fiber loss and connector loss, this thermo sensor employs two LED sources [one aluminum gallium arsenide (AlGaAs), the other indium gallium arsenide (InGaAs)] with different wavelengths. A pair of optical pulses with different wavelengths λs = 0.88 µm and λr = 1.3 µm are guided from the AlGaAs LED and the InGaAs LED to the sensing element along the fiber. The light of λs is intensity-modulated by temperature. On the other hand, GaAs is transparent for the light of λr, which is then utilized as a reference light. After detection by a germanium avalanche photodiode (GeAPD), the temperature-dependent signal λs is normalized by the reference signal λr in a microprocessor.

2.2 Semiconductor Temperature Detector Using Photoluminescence

The sensing element of this semiconductor photoluminescence sensor is a double-heterostructure GaAs epitaxial layer surrounded by two AlxGa1-x As layers. When the GaAs absorbs the incoming exciting light, the electron-hole pairs are generated in the GaAs layer. The electron-hole pairs combine and reemit the photons with a wavelength determined by temperature. As illustrated in Fig. 2.4, the luminescent wavelength shifts monotonically toward longer wavelengths as the temperature T increases. This is a result of the decrease in the energy gap Eg with T. Therefore, analysis of the luminescent spectrum yields the required temperature information. The double heterostructure of the sensing element provides excellent quantum efficiency for the luminescence because the generated electronhole pairs are confined between the two potential barriers (Fig. 2.5).

The system is configured as shown in Fig. 2.6. The sensing element is attached to the end of the silica fiber (100-µm core diameter). The excitation light from an LED, with a peak wavelength of about 750 nm, is coupled into the fiber and guided to a special GRIN lens mounted to a block of glass. A first optical inference filter IF1, located between the

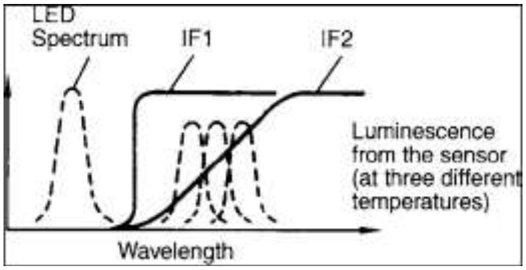

Fig. 2.4 Operating principle of optical-fiber thermometer based on temperature-dependent photoluminescence from a GaAs epitaxial film.

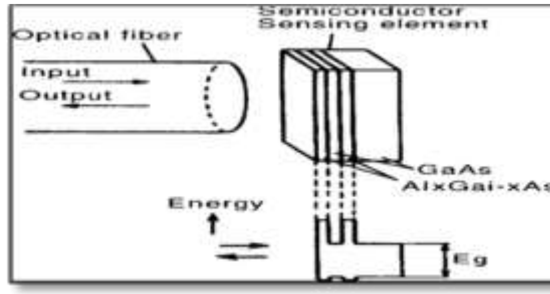

Fig. 2.5 Sensing element of optical-fiber thermometer based on temperature-dependent photoluminescence.

GRIN lens and the glass block, reflects the excitation light, which is guided to the sensing element along the fiber. However, this optical filter is transparent to the returned photo luminescent light. The reflectivity of the second interference filters IF2 changes at about 900 nm. Because the peak wavelength of the luminescence shifts toward longer wavelength with temperature, the ratio between the transmitted and the reflected light intensifies if IF2 changes. However, the ratio is independent of any variation in the excitation light intensity and parasitic losses. The two lights separated by IF2 are detected by photodiodes 1 and 2. The detector module is kept at a constant temperature in order to eliminate any influence of the thermal drift of IF2.

The measuring temperature range is 0 to 200°C, and the accuracy is ±1°C. According to the manufacturer's report, good long-term stability, with a temperature drift of less than 1°C over a period of nine months, has been obtained.

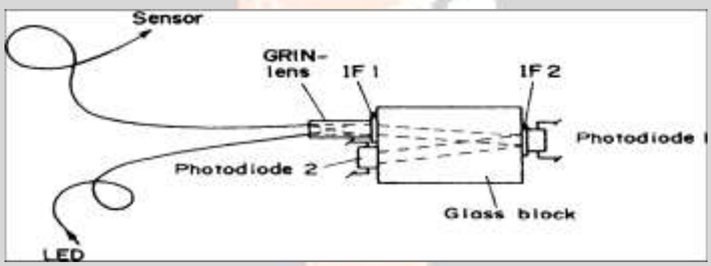

Fig. 2.6 Optical system of optical-fiber thermometer based on temperature-dependent photoluminescence.

2.3 Temperature Detector Using Point-Contact Sensors in Process Manufacturing Plant

Electrical sensors are sensitive to microwave radiation and corrosion. The needs for contact type temperature sensors have lead to the development of point-contact sensors that are immune to microwave radiation, for use in: (1) electric power plants using transformers, generators, surge arresters, cables, and bus bars; (2) industrial plants utilizing microwave processes; and (3) chemical plants utilizing electrolytic processes.

The uses of microwaves include drying powder and wood; curing glues, resins, and plastics; heating processes for food, rubber, and oil; device fabrication in semiconductor manufacturing; and joint welding of plastic packages.

2.4 Noncontact Sensors—Pyrometers

The noncontact sensors, pyrometers do not affect the temperature of the object they are measuring. The operation of the pyrometer is based on the spectral distribution of blackbody radiation, which is illustrated in Fig.2.6 for several different temperatures. According to the Stefan-Boltzmann law, the rate of the total radiated energy from a blackbody is proportional to the fourth power of absolute temperature and is expressed as:

$Wt = \sigma T^4 Wt = \sigma T^4$ - - - - - - - - - - - - (1.2)

Where σ is the Stefan-Boltzmann constant and has the value of $5.6697 \times 10^{-3}\ W/m^2 .\ K^4$

The wavelength at which the radiated energy has its highest value is given by Wien's displacement law,

$\lambda mT = 2.8978 \times 10^{-3}\ m\ .\ K^4$ - - - - - - - - - (1.3)

Thus, the absolute temperature can be measured by analyzing the intensity of the spectrum of the radiated energy from a blackbody. A source of measurement error is the emissivity of the object, which depends on the material and its surface condition. Other causes of error are deviation from the required measurement distance and the presence of any absorbing medium between the object and the detector.

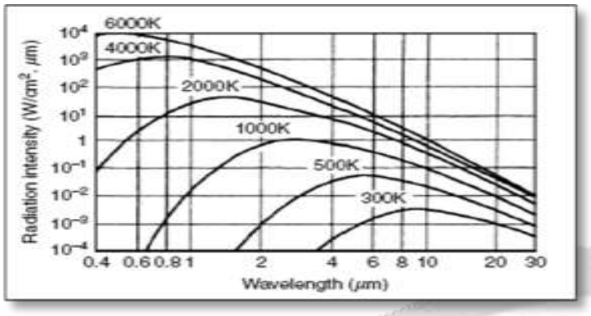

Fig. 2.7 Spectral distribution of blackbody radiation.

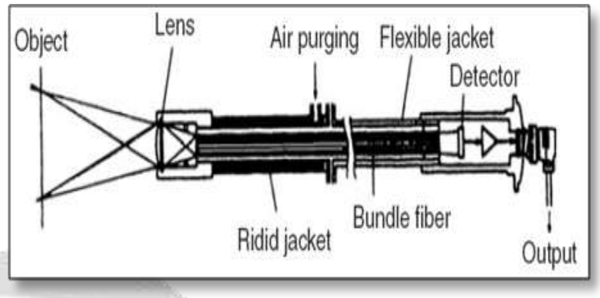

Fig. 2.8 Schematic diagram of an optical-fiber pyrometer.

Use of optical fibers as signal transmission lines in pyrometers allows remote sensing over long distances, easy installation, and accurate determination of the position to be measured by observation of a focused beam of visible light from the fiber end to the object. The sensing head consists of a flexible bundle with a large number of single fibers and lens optics to pick up the radiated energy (Fig. 2.8).

The use of a single silica fiber instead of a bundle is advantageous for measuring small objects and longer distances transmission of the picked-up radiated light. The lowest measurable temperature is 500°C, because of the unavoidable optical loss in silica fibers at wavelengths longer than 2 μm. Air cooling of the sensing head is usually necessary when the temperature exceeds 1000°C.

Optical-fiber pyrometers are one of the most successful optical-fiber sensors in the field of process control in manufacturing. Typical applications include:

- Casting and rolling lines in steel and other metal plants
- Electric welding and annealing
- Furnaces in chemical and metal plants
- Fusion, epitaxial growth, and sputtering processes in the semiconductor industry
- Food processing, paper manufacturing, and plastic processing

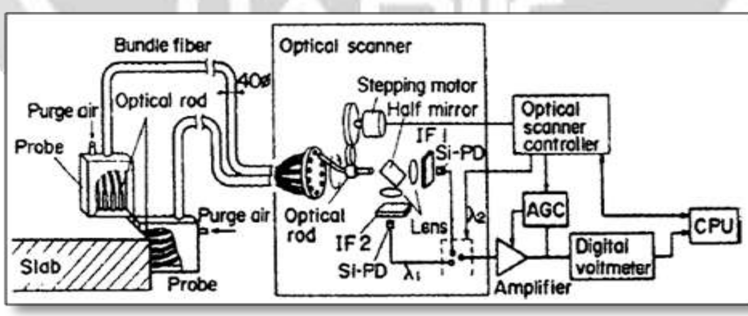

Fig. 2.9 Temperature distribution measurement of steel slabs by an optical-fiber pyrometer using two-wavelength method.

Figure 2.9 is a block diagram of the typical application of optical-fiber pyrometers for casting lines in a steel plant, where the temperature distribution of the steel slab is measured. The sensing element consists of a linear array of fused-silica optical rods, thermally protected by air-purge cooling. Light radiated from the heated slabs is collected by the optical rods and coupled into a 15-m-long bundle of fibers, which transmits light to the optical processing unit. In this system, each fiber in the bundle carries the signal from a separate lens, which provides the temperature information at the designated spot of the slabs. Anoptical scanner in the processing unit scans the bundle and the selected light signal is analyzed in two wavelength bands by using two optical interference filters.

3. PRESSURE SENSORS

If a pressure, P, acting on a diaphragm compresses a spring until equilibrium is produced, the pressure can be represented as:

F (kg) = A (m^2) x P (kg/m^2) - - - - - - - - (2.1)

In this equation, F represents the force of the spring and A represents a surface area of the diaphragm. The movement of the spring is transferred via a system of levers to a pointer whose deflection is a direct indication of the pressure (Fig. 3.1).

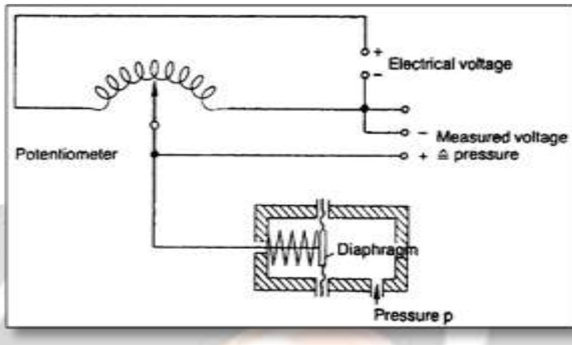

Fig. 3.1 Deflection as a direct indication of pressure.

If the measured value of the pressure must be transmitted across a long distance, the mechanical movement of the pointer can be connected to a variable electrical resistance (potentiometer). A change in the resistance results in a change in the measured voltage, which can then easily be evaluated by an electronic circuit or further processed. This example illustrates the fact that a physical quantity is often subject to many transformations before it is finally evaluated.

3.1 Piezoelectric Crystals

Piezoelectric crystals may be utilized to measure pressure. Electrical charges are produced on the opposite surfaces of some crystals when they are mechanically loaded by deflection, pressure, or tension. The electrical charge produced in the process is proportional to the effective force. This change in the charge is very small. Therefore, electrical amplifiers are used to make it possible to process the signals (Fig. 3.2).

Pressure in this situation is measured by transforming it into a force. If the force produced by pressure on a diaphragm acts on a piezoelectric crystal, a signal that is proportional to the pressure measured can be produced by using suitable amplifiers.

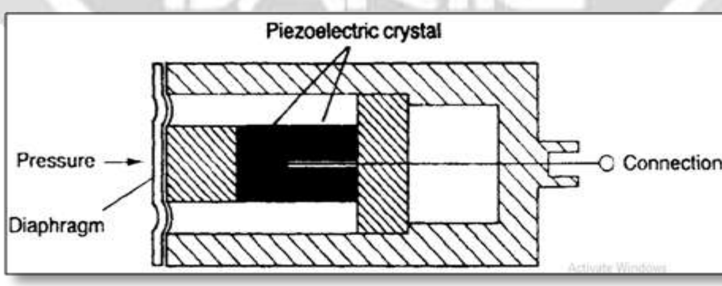

Fig. 3.2 Electrical amplifiers are connected to a piezoelectric crystal.

3.2 Strain Gauges

Strain gauges can also measure pressure. The electrical resistance of a wire-type conductor is dependent, to a certain extent, on its cross-sectional area. The smaller the cross section (i.e., the thinner the wire), the greater the resistance of the wire. A strain gauge is a wire that conducts electricity and stretches as a result of the mechanical influence (tension, pressure, or torsion) and thus changes its resistance in a manner that is detectable. The wire is attached to a carrier, which in turn is attached to the object to be measured. Conversely, for linear compression, which enlarges the cross-sectional area of a strain gauge, resistance is reduced.

If a strain gauge is attached to a diaphragm (Fig. 3.3), it will follow the movement of the diaphragm. It is either pulled or compressed, depending on the flexure of the diaphragm.

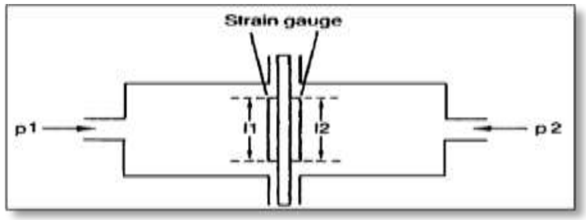

Fig. 3.3 Strain gauge for measurement of pressure.

4. FIBER-OPTIC PRESSURE SENSORS

A Y-guide probe can be used as a pressure sensor in process control if a reflective diaphragm, moving in response to pressure, is attached to the end of the fiber (Fig. 4.1). This type of pressure sensor has a significant advantage over piezoelectric transducers since it works as a noncontact sensor and has a high frequency response. The pressure signal is transferred from the sealed diaphragm to the sensing diaphragm, which is attached to the end of the fiber. With a stainless-steel diaphragm about 100 µm thick, hysteresis of less than 0.5 percent and linearity within ±0.5 percent are obtained up to the pressure level of 3 × 105 kg/m2 (2.94 MPa) in the temperature range of −10 to +60°C.

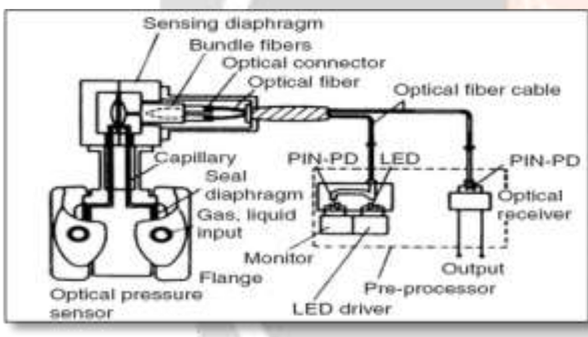

Fig. 4.1 Schematic diagram of a fiber-optic pressure sensor using Y-guide probe with a diaphragm attached.

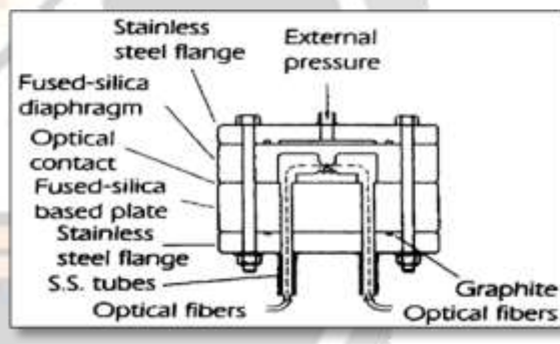

Fig. 4.2 Fiber-optic microbend sensor.

The material selection and structural design of the diaphragm are important to minimize drift. Optical-fiber pressure sensors are expected to be used under severe environments in process control. For example, process slurries are frequently highly corrosive, and the temperature may be as high as 500°C in coal plants. The conventional metal diaphragm exhibits creep at these high temperatures. In order to eliminate such problems, an all fused-silica pressure sensor based on the microbending effect in optical fiber has been developed (Fig. 4.2). This sensor converts the pressure applied to the fused silica diaphragm into an optical intensity modulation in the fiber.

5. DISPLACEMENT SENSORS FOR ROBOTIC APPLICATIONS

The operating principle of a displacement sensor using Y-guide probes is illustrated in Fig. 5.1. The most common Y-guide probe is a bifurcated fiber bundle. The light emitted from one bundle is back-reflected by the object to be measured and collected by another bundle (receiving fibers). As a result, the returned light at the detector is intensity-modulated to a degree dependent on the distance between the end of the fiber bundle and the object.

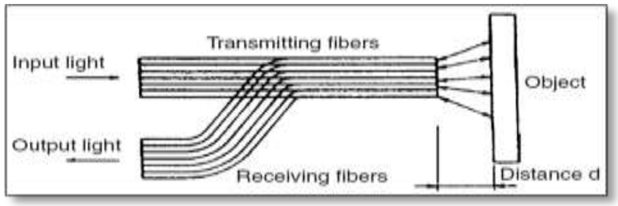

Fig. 5.1 Principle of operation of fiber-optic mechanical sensor using a Y-guide probe.

The sensitivity and the dynamic range are determined by the geometrical arrangement of the array of fiber bundles and by both the number and type of the fibers. Figure 5.2 shows the relative intensity of the returned light as a function of distance for three typical arrangements: random, hemispherical, and concentric circle arrays. The intensities increase with distance and reach a peak at a certain discrete distance. After that, the intensities fall off very slowly. Most sensors use the high-sensitivity regions in these curves. Among the three arrangements, the random array has the highest sensitivity but the narrowest dynamic range. The displacement sensor using the Y-guide probe provides a resolution of 0.1 µm, linearity within 5 percent, and a dynamic range of 100 µm displacements. Y-guide probe displacement sensors are well-suited for robotics applications as position sensors and for gauging and surface assessment since they have high sensitivity to small distances.

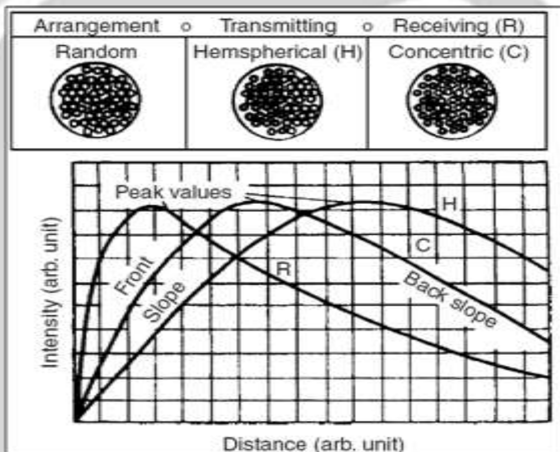

Fig. 5.2 Relative intensity of returned light for three fiber optic arrangements.

6. PROCESS CONTROL SENSORS MEASURING AND MONITORING LIQUID FLOW

According to the laws of fluid mechanics, an obstruction inserted in a flow stream creates a periodic turbulence behind it. The frequency of shedding the turbulent vortices is directly proportional to the flow velocity. The flow sensor in Fig. 6.1 has a sensing element consisting of a thin metallic obstruction and a downstream metallic bar attached to a multimode fibermicrobend sensor.

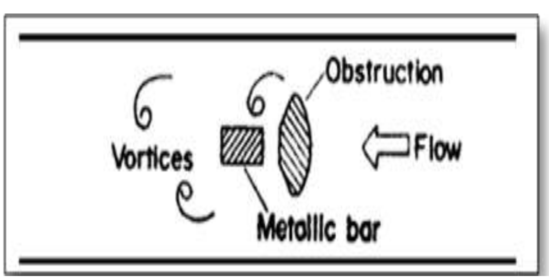

Fig. 6.1 Principle of operation of a vortex-shedding flow sensor.

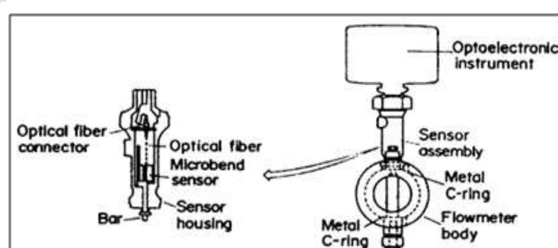

Fig. 6.2 Schematic diagram of a vortex-shedding flow sensor

As illustrated in Fig. 6.2, the vortex pressure produced at the metallic bar is transferred, through a diaphragm at the pipe wall that serves as both a seal and a pivot for the bar, to the microbend sensor located outside the process line pipe. The microbend sensor converts the time-varying mechanical force caused by the vortex shedding into a corresponding intensity modulation of the light. Therefore, the frequency of the signal converted into the electric voltage at the detector provides the flow-velocity information. This flow sensor has the advantage that the measuring accuracy is essentially independent of any changes in the fluid temperature, viscosity, or density, and in the light source intensity. According to the specifications for typical optical vortex-shedding flow sensors, flow rate can be measured over a Reynolds number range from 5×10^3 to 6000×10^3 at temperatures from -100 to +600°C. This range is high compared to that of conventional flow meters. In addition, an accuracy of ±0.4 and ±0.7 percent, respectively, is obtained for liquids and gases with Reynolds numbers above 10,000.

6.1 Flow Sensor Detecting Small Air Bubbles for Process Control in Manufacturing

The optical-fiber flow sensor employed in manufacturing process control monitors a two fluid mixture (Fig. 6.3). The sensor can distinguish between moving bubbles and liquid in the flow stream and display the void fraction, namely, the ratio of gas volume to the total volume.

The principle of operation is quite simple. The light from the LED is guided by the optical fiber to the sensing element, in which the end portion of the fiber is mounted in a stainless steel needle of 2.8-mm outer diameter. When liquid is in contact with the end of the fiber, light enters the fluid efficiently and very little light is returned. However, when a gas bubble is present, a significant fraction of light is reflected back. With this technique, bubbles as small as 50 µm may be detected with an accuracy of better than 5 percent and a response time of only 10 µs.

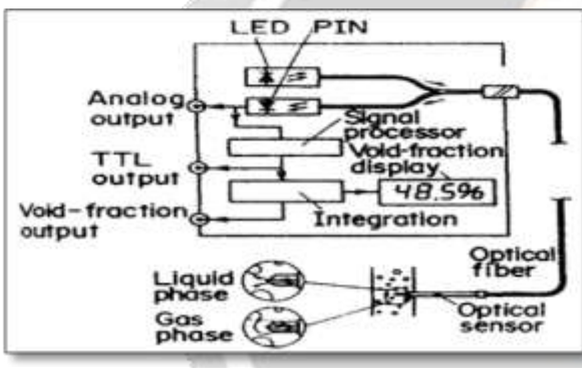

Fig. 6.3 Flow sensor for two-phase mixtures.

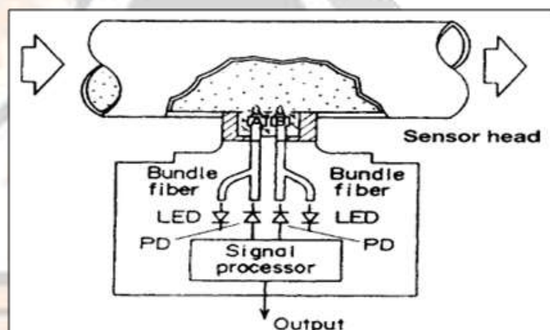

Fig. 6.4 Flow sensor using two Y-guided probes based on a correlation technique.

An optical-fiber flow sensor for a two-phase mixture based on Y-guide probes is shown in Fig. 6.4. Two Y-guide probes are placed at different points along the flow stream to emit the input light and to pick up the retroreflected light from moving solid particles in the flow. The delay time between the signals of the two probes is determined by the average velocity of the moving particles. Therefore, measurement of the delay time by a conventional correlation technique provides the flow velocity. An accuracy of better than ±1 percent and a dynamic range of 20:1 are obtained for flow velocities up to 10 m/s. A potential problem of such flow sensors for two-phase mixtures is poor long-term stability, because the optical fibers are inserted into the process fluid pipes.

6.2 Liquid Level Sensors in Manufacturing Process Control for Petroleum and Chemical Plants

Several optical-fiber liquid level sensors developed in recent years have been based on direct interaction between the light and liquid. The most common method in commercial products employs a prism attached to the ends of two single optical fibers (Fig. 6.5). The input light from an LED is totally internally reflected and returns to the output fiber when the prism is in air. However, when the prism is immersed in liquid, the light refracts into the fluid with low reflection, resulting in negligible returned light. Thus, this device works as a liquid level switch. The sensitivity of the sensor is determined by the contrast ratio, which depends on the refractive index of the liquid.

The output loss stays at a constant value of 33 dB for refractive indices higher than 1.40. The signal output of a well-designed sensor can be switched for a change in liquid level of only 0.1 mm.

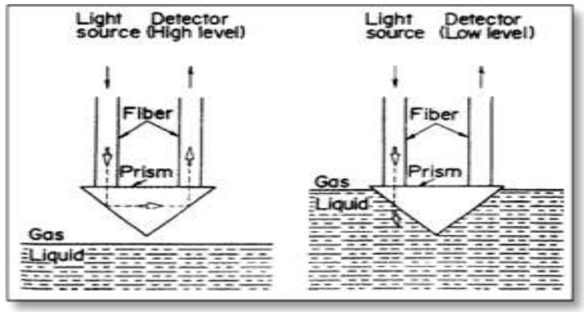

Fig. 6.5 Principle of operation of a liquid level sensor with a prism attached to two optical fibers.

Another optical-fiber liquid level sensor, developed for the measurement of boiler-drum water level, employs a triangularly shaped gauge through which red and green light beams pass. The beams are deflected as it fills with water, so that the green light passes through an aperture. In the absence of water, only red light passes through. Optical fibers transmit red or green light from individual gauges to a plant control room located up to 150 m from the boiler drum (Fig. 6.6). The water level in the drum is displayed digitally.

This liquid level sensor operates at temperatures up to 170°C and pressures up to 3200 lb/in2 gauge. Many sensor units are installed in the boiler drum, and most have been operating for seven years. This sensor is maintenance-free, fail-safe, and highly reliable.

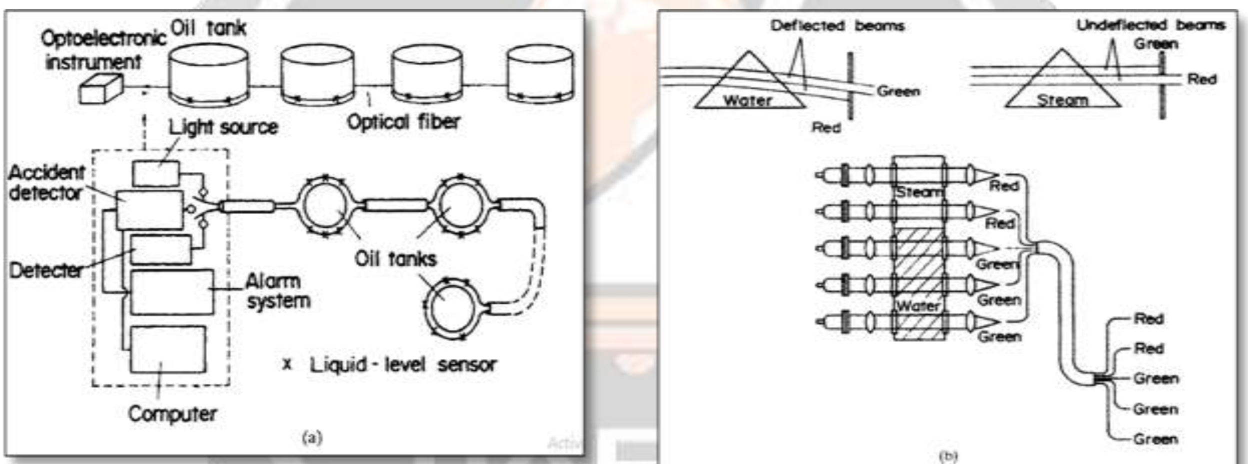

Fig. 6.6 (a) Principle of operation of liquid level sensor for the measurement of boiler-drum water. (b) Liquid level sensor for the measurement of boiler-drum water with five-port sensors.

7. CONTROL OF INPUT/OUTPUT SPEED OF CONTINUOUS WEB FABRICATION USING LASER DOPPLER VELOCITY SENSOR

A laser Doppler velocimeter (LDV) can be configured to measure any desired component velocity, perpendicular or parallel to the direction of the optical axis. An LDV system has been constructed with a semiconductor laser and optical fibers and couplers to conduct the optical power. Frequency modulation of the semiconductor laser (or, alternatively, an external fiber-optic frequency modulator) is used to introduce an offset frequency. Some commercial laser Doppler velocimeters are available with optical-fiber leads and small sensing heads. However, these commercial systems still use bulk optical components such as acousto-optic modulators or rotating gratings to introduce the offset frequency.

With an LDV system, the velocity can be measured with high precision in a short period of time. This means that the method can be applied for real-time measurements to monitor and control the velocity of objects as well as measure their vibration. Because the laser light can be focused to a very small spot, the velocity of very small objects can be measured, or if scanning techniques are applied, high spatial resolution can be achieved. This method is used for various applications in manufacturing, medicine, and research. The demands on system performance with respect to sensitivity, measuring range, and temporal resolution are different for each of these applications.

In manufacturing processes, for example, LDV systems are used to control continuous roll milling of metal (Fig. 7.1), to control the rolling speed of paper and films, and to monitor fluid velocity and turbulence in mixing processes. Another industrial application is vibration analysis. With a noncontact vibrometer, vibration of machines, machine tools, and other structures can be analyzed without disturbing the vibrational behavior of the structure.

Interestingly, the LDV system proved useful in the measurement of arterial blood velocity (Fig. 7.2), thereby providing valuable medical information. Another application in medical research is the study of motion of the tympanic membrane in the ear.

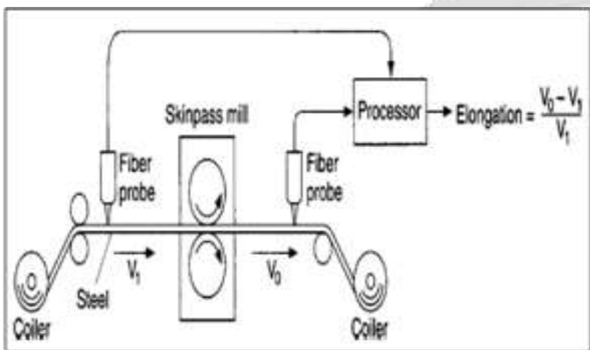

Fig. 7.1 Fiber-optic laser Doppler velocimeter at a rolling mill controls pressure by measuring input speeds.

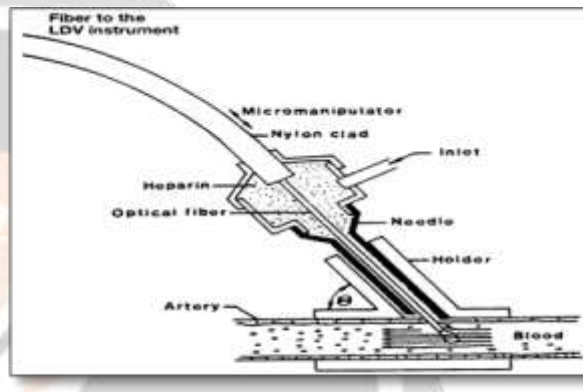

Fig. 7.2 special probes for measurement of blood velocity.

8. ULTRASONIC/LASER NONDESTRUCTIVE EVALUATION SENSOR

Ultrasonic/laser optical inspection is a relatively new noncontact technique. A laser system for generating ultrasound pulses without distortion of the object surface is shown in Fig. 8.1. A laser pulse incident on a surface will be partly absorbed by the material and will thus generate a sudden rise in temperature in the surface layer of the material. This thermal shock causes expansion of a small volume at the surface, which generates thermoplastic strains. Bulk optical systems have been used previously to generate the laser pulse energy. However, the omnidirectionality of bulk sources is completely different from other well-known sources, and is regarded as a serious handicap to laser generation. To control the beam width and beam direction of the optically generated ultrasonic waves, a fiber phased array has been developed. In this way the generated ultrasonic beam (Fig. 8.1). This system has been optimized for the detection of fatigue cracks at rivet holes in aircraft structures.

The combination of laser-generated ultrasound and an optical-fiber interferometer for the detection of the resultant surface displacement has led to a technique that is useful for a wide variety of inspection tasks in manufacturing, including areas difficult to access and objects at high temperature, as well as more routine inspection and quality control in various industrial environments. Such a system can be applied to the measurement of thickness, velocity, flaws, defects, and grain size in a production process.

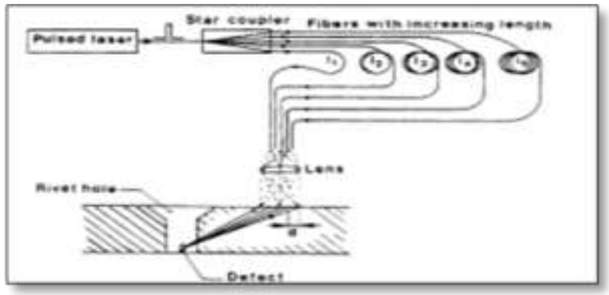

Fig. 8.1 Setup for beam steering of laser-generated ultrasound by fiber-optic phased array.

9. PROCESS CONTROL SENSOR FOR ACCELERATION

The principle of operation of the process control acceleration sensor is illustrated in Fig. 9.1. The sensor element, consisting of a small cantilever and a photo luminescent material, is attached to the end of a single multimode fiber. The input light of wavelength **λ***s* is transmitted along the fiber from a near-infrared LED source to the ensor element. The sensor element returns light at two different wavelengths—one of which serves as a signal light and the other as a reference light—into the same fiber. The signal light at wavelength **λ***s* is generated by reflection from a small cantilever. Since the relative angle of the reflected light is changed by the acceleration, the returned light is intensity-modulated. The reference light of wavelength **λ***r* is generated by photoluminescence of a neodymium-doped glass element placed close to the sensor end of the fiber.

The optoelectronic detector module has two optical filters to separate the signals λ*s* and λ*r*, and also two photodiodes to convert the signal and the reference light into separate analog voltages. The signal processing for compensation is then merely a matter of electrical division. A measuring range of 0.1 to 700 m/s^2 and a resolution of 0.1 m/s^2 is obtained over the frequency range of 5 to 800 Hz.

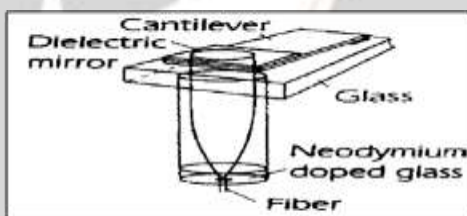

Fig. 9.1 Cantilever-type acceleration sensors.

10. AN ENDOSCOPE AS IMAGE TRANSMISSION SENSOR

An imaging cable consists of numerous optical fibers, typically 3000 to 100,000, each of which has a diameter of 10 µm and constitutes a picture element (pixel). The principle of image transmission through the fibers is shown in Fig. 10.1.

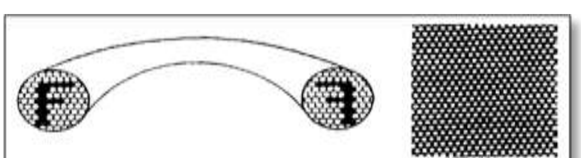

Fig. 10.1 Image transmission through an image fiber.

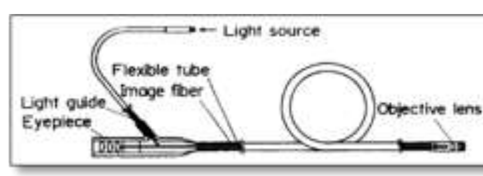

Fig. 10.2 Basic structure of fiber scope.

The optical fibers are aligned regularly and identically at both ends of the fibers. When an image is projected on one end of the image fiber, it is split into multiple picture elements. The image is then transmitted as a group of light dots with different intensities and colors, and the original picture is reduced at the far end. The image fibers developed for industrial use are made of silica glass with low transmission loss over a wide wavelength band from visible to near infrared, and can therefore transmit images over distances in excess of 100 m without significant color changes. The basic structure of the practical optical-fiber image sensing system (endoscope) is illustrated in Fig. 10.2. It consists of the image fiber, an objective lens to project the image on one end, an eyepiece to magnify the received image on the other end, a fiber protection tube, and additional fibers for illumination of the object.

11. REFERENCES

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