Assessment of technical condition of underwater transitions of main pipelines in real

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Abstract. The paper presents a computer-aided system with the help of which it is possible to watch the technical condition of the underwater passage of the main pipeline in Ethernet. Strain gauge have to be installed as fix of the deformation of the pipeline will happen, the sensors will signal a change in the stress-strain state. The information would then be sent to the dispatch center via fiber optic cable. The dispatcher will have the opportunity to react and prevent an accident.

1. Introduction

The pipeline system in the oil and gas industry is an important component in the transfer of the product from the producer to the consumer. The main goal of the producer is uninterrupted supply of oil and gas in time. It is necessary to reduce the risk of accidents, but now there are no technologies used and approved by the technical documentation.

The essence of this work is to develop automated monitoring of the technical condition of the underwater passage of the main pipeline in Ethernet. It is nessesary to install the sensors to monitor the stress-strain state of the pipeline and select a cable to transfer information from the sensors to the measuring point, which will flag in real time possible changes in the pipeline.

The parameters by which it is possible to determine the leakage of gas and oil from the pipeline using sensors are a drop in pressure in the pipeline, an increase in the percentage of air pollution in the environment, a change in soil temperature near the point of leakage and so on.

2. Materials and methods

The lead-tin-base bronze of the BrO10S10 grade (Russian grade abbreviation) was used as a material for investigation. This bronze contains 10 % wt. of lead, 10 % wt. of tin and 80 % wt. of copper. The multicomponent bronzes under study were melted in the induction high-frequency furnace in crucibles. The crucibles' material is silicicated graphite. Melting was conducted using the components of technical grade. Cathode copper of the Mlk grade (GOST 859-78), sheet lead of the C-2 grade (GOST 3778-77); rod tin of the O1 grade (GOST 860-75) were used as a charge mixture. The phosphorous-copper alloy of the MF1B grade (GOST 4515-93) was used as a deoxidizer. The preliminarily placed in the copper foil powder-modifier was introduced into the melt. For this project, it is possible to use ultrasonic sensor sensors, the principle of which is that an audio signal is sent and, after reflection from the obstacle, returns.

Knowing the speed of sound propagation in the environment and the time measured by the timer, you can find out the distance to the measured point, and if the position of the pipeline changes in space, the sensors will signal a violation. But despite that, this method has a number of shortcomings, because of which we can not use it to implement the project. Disadvantages of the ultrasonic method are the fact that faults can occur with different types of vibration, and it is also not possible to use it in directional drilling, due to the absence of a distance between the pipeline and the ground. The viewing angle is 15 ° of the ultrasonic sensor, hence, at close distances, a small area of control, in consequence of which it will be necessary to install a large number of sensors along the entire length of the pipeline, which is inexpedient and economically unprofitable.

The most profitable and rational use of strain gage sensors is namely semiconductor from germanium or silicon. Strain gauging is used to control the stress-strain state of structures and materials through deformation or change in voltage. The change in the stress-strain state can be due to deterioration in the quality of materials, subsidence of the soil, the appearance of corrosion, etc. The load cell is a resistor whose resistance varies with the deformed body. With a reliable label on the monitored surface, the strain gage gets the same strain with it. When stretching or compressing the part, elongation or shortening of the wire will occur, as well as a change in the cross-sectional area, which will lead to a change in the resistance of the strain gage.

$$R = rL/S$$

where, R - resistance of the strain gage; r - specific resistance; + L – stretching strand; - L – contraction strand; S - section area of the strain gauge.

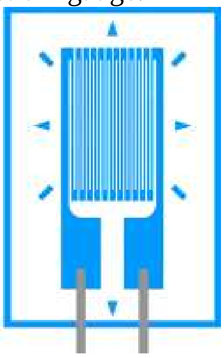

Figure 1. Semiconductor strain gage.

Semiconductor strain gauges made of germanium or silicon were chosen not accidentally, since the materials from which they are made have a high coefficient of strain-sensitivity and have a high level of the output signal, ensure the stability of the parameters of the sensors. The specific conductivity of a semiconductor at a given temperature due to the ionization of impurities is determined by the concentration of charge carriers and their mobility. The strain effect in these sensors is manifested in the fact that the pressure applied along one of the axes of the crystal causes a change in the electrical conductivity. It is established that the strain effect depends on the crystallographic directions and the type of conductivity.

These sensors are produced by the sawing method, which consists in the following. The ingots of germanium or silicon monocrystals are subjected to a control test, after which a section with the necessary resistivity is cut out. Then determine the main crystalline axes and cut the bar into washers whose height is equal to the length of the strain gage. Washers sawed into thin plates and polished until the removal of microcracks, later produced chemical or electrochemical etching and polishing. Wash the plates and cut into strain gauges, re-thoroughly cleaned and dried. The most important and responsible creation is the one of a contact between the semiconductor and the metallic lead-out. Advantages of using strain gauges are cheapness, low weight, small dimensions and the possibility of fastening to any point of the pipeline.

Of all the existing cables for transmitting information, a fiber-optic cable of the type TPS2 for directional drilling and trenching, a standard type of DPO for micro-tunnelling, was chosen.

Figure 2. Cable type TPN2. 1 - optical fiber; 2- hydrophobic gel; 3- optical module; 4 - hydrophobic gel; 5 - iron wire armor; 6 - water-blocking tape; 7 - aluminopolymer tape; 8 - polyethylene sheath; 9 - hydrophobic gel; 10 - iron wire armor; 11 - polyethylene sheath.

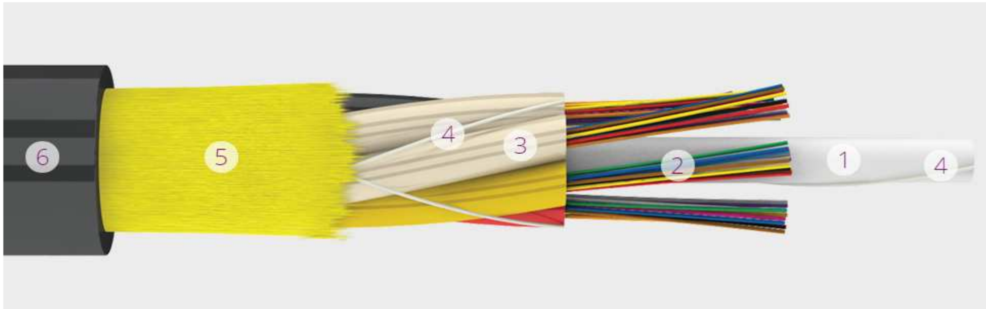

Figure 3. Cable DPO. 1- The central force element is a fiberglass rod; 2 - optical fiber; 3 - optical module from PBT, filled with hydrophobic gel; 4 - water-blocking threads; 5 - aramid threads; 6 - sheath of polymeric material.

The TPS2 cable is designed for high-speed information transfer, the depth of the embankment is 2500 meters, the bending radius is 214.5 mm, thepermissible tensile loading is 20-70 kN, the permissible crushing load is from 1.5 kN / cm. Two layers of polyethylene sheath and double armor made of steel wire allow to lay and operate this cable under particularly difficult conditions, and a triple layer of hydrophobic gel allows working with this cable even when in contact with water. The cable type DPO the permissible crushing load is from 0.3 kN / cm and thepermissible tensile loading is of 1.5 kN. Dielectric - is not sensitive to electric fields. The service life of these cables is 25 years.A typical circuit for measuring analog signals in a system with resistive sensors can be represented as shown in figure 4.

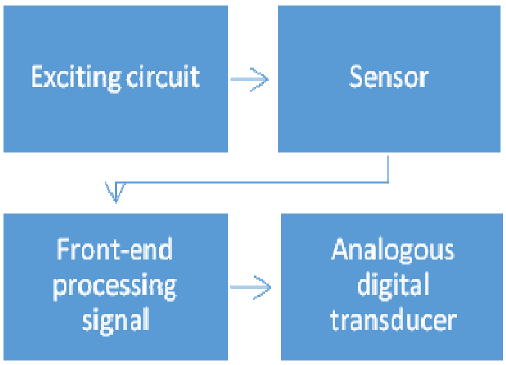

Figure 4. Basic chain dimension analog signal.

3. Measurements of signals from strain gauges.

Reasoning from theoretical premises, the main consequence of nanopowder introduction into the melt should be refinement of the macro- and microstructure, as the powder particles must serve as nuclei of new grains. Typical load cell is four resistors, included in the scheme of the Wheatstone bridge.

Temperature changes significantly affect the load cell due to the thermal expansion of the material, which changes the resistance, so the change in resistance can be erroneously detected as part of the voltage measurement. With the inclusion of strain gauges in the configuration of the Wheatstone bridge, the temperature change can easily be compensated. In such a configuration, the temperature will affect equally all the bridge's shoulders, which reduces the resistance change to zero, providing an auto-compensation of the temperature effect.

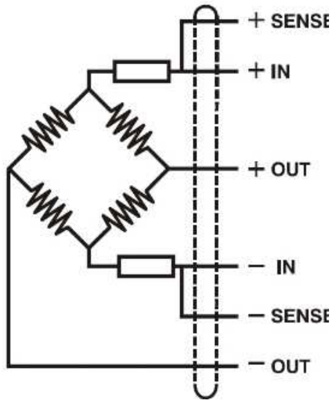

Figure 5. A scheme dimension signal with a strain gauge.

However, the configuration of strain gauges in the form of a Wheatstone bridge has a major drawback - a zero offset. This occurs when one of the sensors is not properly installed or deformed. This defect is overcome by a shunt resistor for balancing the bridge. However, balancing of the bridge in the field is impractical, because The sensors are also deformed when they wear out during operation.

When using a gain stage to expand the measurement range, interference is also amplified, which can affect the measurement results. The interference affects the number of bits used by the analog-to-digital converter at a given gain. Therefore, you need to choose an analog-to-digital converter that provides optimal resolution at the required gain.

Typically, a sigma-delta analog-to-digital converter and low-pass filters are used to measure the output from strain gauges. In some sigma-delta analog-to-digital converters, it is possible to amplify the signal in the sigma-delta modulator itself. There is one additional advantage to this. As we increase the gain of the analog-to-digital converter modulator, the bandwidth of the analog-to-digital converter decreases. This is not a problem when measuring signals from sensors. Their operating frequency is much less. However, reducing the bandwidth can be an advantage, because it acts as a low-pass filter and does not allow interference to affect the system.

Another important problem related to the strain gauge interface is the probability of gain deviation, since the range of the output signal depends on the excitation voltage. Small deviations in the excitation voltage can cause a proportional gain error in the measurements. This can be avoided if measurements are made with respect to the magnitude of the excitation voltage. There are two ways to achieve this.

We can measure the signal and excitation voltage separately, and then calculate their ratio, thus eliminating the error in the gain. However, this method requires multiplexing an analog-to-digital converter for two signals. Another problem is that the measured signal is in the 10-mV range, and the excitation voltage is in the volt range. This would mean a dynamic change in the setting of the gain and parameters of the analog-to-digital converter, which is not practical in most analog systems.

Another way is to use a reference voltage source for an analog-to-digital converter. Typically, the analog-to-digital converter has a terminal for connecting an external reference voltage source. Each measurement in the analog-to-digital converter is made with respect to this reference voltage. Thus, if we use excitation voltage as a reference voltage for an analog-to-digital converter, we provide relative signal measurements.

The efficiency of the system, which is used to determine the small values of the signal from the load cell, becomes critical in order to ensure an acceptable measurement accuracy. The usual methodology for measuring signals from strain gauges

However, as it was said above, in the strain gauges included on the bridge circuit, there is a problem of displacement of zero, and this displacement varies with time.

The problem can be solved with a simple microcontroller and bias correction in firmware. When the load cell is not loaded, the signal from its output can be considered as an offset, and subtracted or added for each following data read from the analog-to-digital converter. By auto-correction, you can also compensate for the aging effect of the sensor during operation.

It is worth noting other problems of the usual measurement method.

The voltage source used to drive the bridge circuit is usually located some distance from the device. Therefore, the resistance of the wires connecting the inputs of the bridge circuit with the voltage source also introduces an error in the system.

Since the output signal from the load cell is very weak, either an analog-to-digital converter with high resolution or signal amplification before processing into an analog-to-digital converter is required. The use of a constant-signal amplifier introduces an additional error in the gain and offset.

Using a high-resolution analog-to-digital converter or low-offset amplifiers, a gain error also increases the cost of a complete system.

The method of double correlated sampling. This method is used to accurately measure signals of a very small level. It automatically compensates for the bias caused by the amplifier with programmable gain, and the thermal noise generated by the system. With this approach, the controller uses an analog multiplexer to switch the analog-to-digital converter input between a DC voltage source, bridge circuit outputs and a reference voltage.

One of the drawbacks of conventional methods, as was shown above, is the error introduced by the resistance of the source and wires.

In the double-correlated sampling method, the control voltage is measured directly on the bridge control leads. This measured voltage can be used to calculate the change in resistance. Since this value will not be affected by the resistance of the source, the calculated value will be much more accurate.

Another significant advantage of this method is the automatic compensation of bias. In this configuration, the multiplexer switches the input of the amplifier with a programmable gain between the bridge output and the reference voltage source. The signal received when connecting the programmable gain to the reference voltage source will be the offset of the system.

Thus, before each reading of the indicators, the system calculates the offset by means of the firmware based on the data received from the analog-to-digital converter when the programmable gain is connected to the output voltage of the bridge. In addition to the offset, the thermal noise generated in the system is also cleared.

Another limitation in measuring signals with high accuracy is the gain error of the programmable gain. However, this error can be calibrated.

4. Measurements of signals from strain gauges.

Before insulation and packing work, it is necessary to install semiconductor strain gauges from germanium or silicon directly onto the pipeline itself along the entire length every 40 cm and varnish. The fiber-optic cable is cut to the required length, mark the section with this marker, open the outer shell with a stripper, cut the shell through the entire thickness of the cross section, then make a longitudinal cut from the transverse opening to the end of the cable and, on the other hand, remove the outer shell . The next step is to remove the winding threads and armor with the help of rope (in the case of the DPO cable instead of the armor aramid threads), then it is necessary to remove the hydrophobic gel with the help of D-gel liquid. After you need to insert the optical cable into the coupling and using a special tool, pull the steel module off and, in parallel, get rid of the hydrophobic gel, it is convenient to perform the opening step by step at 70 cm, and at the end it is necessary to rub the fibers with isopropyl alcohol. The connection of the fiber optic cable with the strain gauges is made with the help of a patch cord. Upon completion of these works, insulation-laying operations are carried out. The incoming and outgoing cables are output to the outside with connection to the control point and output of information to the computer.

5. Conclusion

If oil and gas companies can prevent accidents, the risk of environmental pollution will be minimized. Thanks to these design, operators will be aware of the stress-strain state of the pipe in real time. The authors need to know what will also affect the economic indicators, because now the losses of enterprises associated with the loss of the product and the elimination of accidents will decrease several-fold.

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