Underwater Pipeline Monitoring and Crack Detection

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Abstract- *The world is booming in the present era. The infrastructure, facilities and all other needs are developing technologically as well as efficiently. The basic need of all this development is the energy. The main source of energy is petroleum products even though new sources are emerging. Not only for energy generation but also used as asphalt, road oil, feed stocks for making chemicals, plastics and synthetic materials. And the main petroleum plants are in offshore. Hence these petroleum products reach the sea shore through underwater pipelines. These pipelines are made of high-yield strength steel for withstanding the pressure through it. Small damage or holes in it result of leakage of crude oil, other gaseous and non-gaseous product into the ocean which will result in the destruction of life in water. Hence there should be a proper monitoring in the pipe to avoid the leakages and other damages. The underwater vehicle is a method of monitoring these pipelines. But they use visual inspection, acoustic waves, sonar waves etc. most of the methods are time consuming and some other will affect the underwater life. This paper combines sensor network and AUV (Autonomous Underwater Vehicle) for monitoring the pipe more efficiently. By sensor network the exact range of place of the crack can be detected and hence the detection of crack or damage using AUV will be more easy process. The AUV utilizes magnetic flux leakage detection so as to locate the exact position of the crack. By the combination of sensor based network and the AUV the monitoring and detection of crack and damage in underwater pipeline is much efficient.*

Keywords- Pipe monitoring, Sensor network, AUV, magnetic flux leakage detection.

I. INTRODUCTION

The petroleum products are being the major source of energy in the world. Even though they are the most used energy source they are non-renewable, hence they must be preserved. These petroleum products are extracted from the earth, they are in onshore as well as off shore. In offshore petroleum plants the products are brought to the land through underwater pipelines, since most of them are liquid and gaseous in nature. Hence these pipelines should be monitored and protected carefully to avoid the leakage of these products to the water, since it is vulnerable to the water lives. There are many methods for monitoring these underwater pipelines that utilize ROV, AUV, wireless networks etc. and they use visual inspection, acoustic waves, sonar waves etc. for the monitoring. But these systems are time consuming and complicated. For example in the visual inspection technique takes a long duration even for few meters hence it is difficult to detect the defects for kilometers of length of pipeline. Europe -1 subsea pipeline in Norwegian North Sea is the longest underwater pipeline of about 620 kilometers, hence it will difficult to monitor this much length. This paper is to introduce another efficient method that can reduce the distance to be monitored. This method is by placing pressure sensors at a regular interval to monitor the pipeline by comparing the pressure values between two adjacent pressure sensors. Hence only the defected areas have to be monitored or analyzed. And that region that is detected by the sensor network can be monitored by using a AUV or ROV so as to locate the crack in the pipeline by using magnetic flux leakage detection.

The main problem was:

- The long distance to be monitored
- Time consumption
- Cost of monitoring long distance

Objectives of this work:

The objective of the work is to build a system that will help to monitor the whole length of underwater pipeline in a short span of time. By this design we have to only monitor a small distance with the help of a ROV or an AUV. Hence the monitoring efficiency can be increased and even a small damage in the pipeline can be detected by using this method, since it might cause a huge change in the pressure inside the pipeline, we could easily detect the region of damages as well as the leakages. And the exact location of the crack can be detected in no time.

II. METHODOLGY

This paper proposes a design which divides the long distance pipeline into certain number of segments and places the pressure sensors for monitoring the pipeline and also an underwater vehicle that uses magnetic flux leakage detection for the detection of crack. In normal condition the pressure sensors will detect approximately same values of pressure and any deformations or even the leakage will result in difference in the pressure value between the two adjacent pressure sensors. With the help of a decoder the defected region can easily be detected. Hence the distance in which the AUV or ROV system must monitor will be reduced to a segment and the time consumption for detecting the defect or leakage will be easy. The AUV will use magnetic property of the underwater pipeline so as to locate crack in a short span of time.

III. PROPOSED MODEL

The whole system is divided into two segments so as to detect the crack in an underwater pipeline with less time, cost and power consumption.

(a)Sensor based network

(b) AUV utilizing the magnetic flux leakage detection

SENSOR BASED NETWORK

The whole underwater pipeline length is divided into certain segments so that the pressure sensors can be placed. The pressure sensors are placed at a distance so as measure pressure at that point.

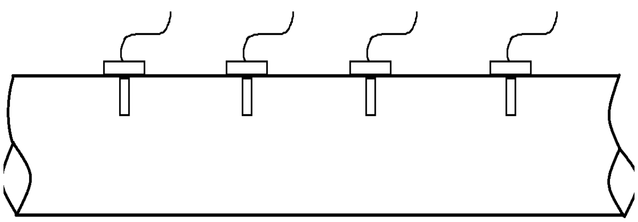

Figure 1: The segmentation of the pipeline and placing the pressure sensors.

These pressure sensors will measure the pressure at the points then adjacent pressure sensors are paired and given to a comparator so as to compare the value between the pressure sensors.

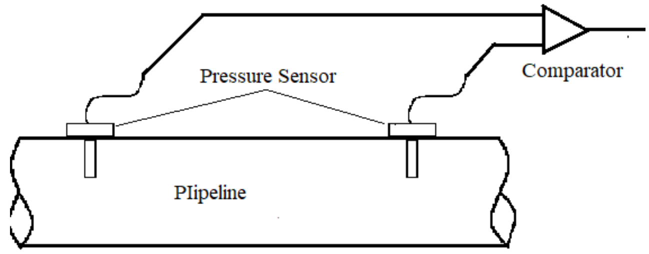

Figure 2: The segmentation of the pipeline and placing the pressure sensors.

The pressure inside the pipeline will be around 350-500 MPa. The pressure inside the pipeline can be controlled at the inlet of the pipeline and hence an approximated value of pressure will be inside the pipeline. The sensors will show similar values of pressure and the comparator won’t have an error signal as output. When there is any major difference in the pressure values between the adjacent pressure sensors, the comparator will generate an error signal as output. This error signal will be due to the pressure difference taken place by the crack or deformations.

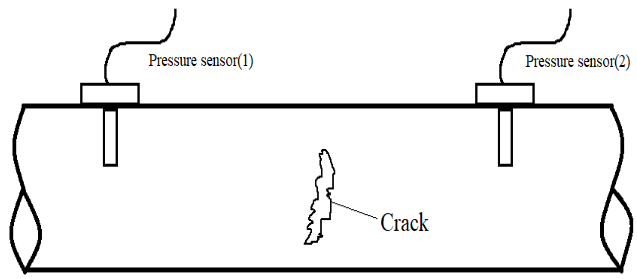

Figure 3: The pipeline with crack.

When a crack appears in the pipeline, the gas or liquid material will start to leak through it. Hence the pressure inside the pipe will get dropped at that point.

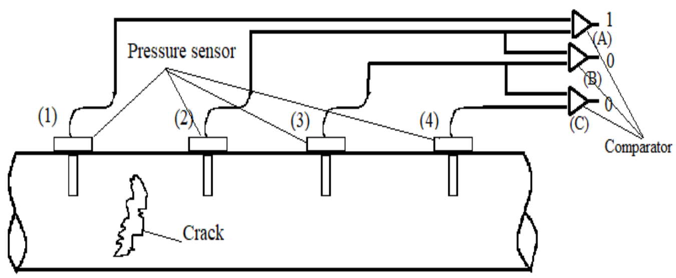

Figure 4: Figure illustrating how the pressure sensor and comparator works

When the pressure inside the pipeline is 350 MPa and the pressure sensor 1 as shown in figure 4 will show a pressure of about 350±5 MPa. The approximation is due to small deformation in the pipeline, due to fatigue or any other issues like blocks. When a crack occurs as shown in figure 4, the pressure inside it will drop since the fluid in it will leak through the crack. The pressure sensor 1 won't experience that much deference in the value, but the value of pressure measured by the pressure sensor 2 will effect adversely and the pressure in the point of pressure sensor will be less. Hence the comparator A will show a value of 1 since there is a major difference of pressure between the adjacent pressure sensor 1 and 2 respectively. But the pressure measured by the pressure sensors 3 and 4 will be same since it is after the crack. From the above figure we will get same value of pressure in pressure sensors 2, 3 and 4. Then the comparator B and C will show an output value of 0 since the pressure sensors 2, 3 and 4 have same value of pressure.

From the figure 4 we have to monitor only the length of pipeline between the pressure sensors 1 and 2. We get the exact spot of pipeline to be monitored by the output value of the comparators.

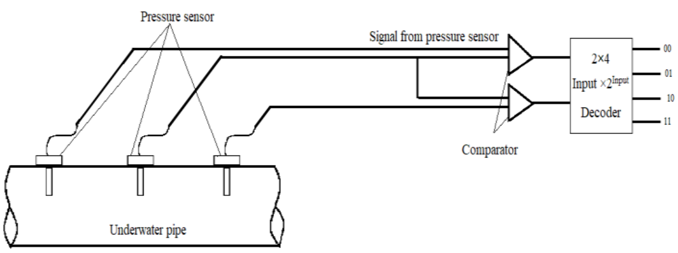

Figure 5: The model of the system for monitoring ht underwater pipeline.

Figure 5 depicts the model which is proposed by this paper. The decoder that helps to find out the region exactly other than checking each of the comparator output. The comparators are connected to the decoder input and the decoder is selected based on the inputs i.e., the number of comparators.

Inputs		Output			
A	B	D_0	D_1	D_2	D_3
0	0	1	0	0	0
0	1	0	1	0	0
0	1	0	0	1	0
1	1	0	0	0	1

Table 1: Truth table of a decoder.

In table 1 shows the input and the output of the decoder which is the overall output of the system. Based on the output D the length to be monitored can be identified easily.

If the length is too long, the decoder will be bulky. Hence we can provide separate decoder to a certain length so as to make the system circuit simple and easily decode the output. By using this method the pipeline can be monitored. And if a damage in any part of the pipeline occurs, the length of pipeline that is to be monitored by using AUV can be reduced.

AUV UTILIZING THE MAGNETIC FLUX LEAKAGE DETECTION

The AUV or ROV is particularly designed to detect the exact location of the crack. The vehicle is characterized by magnetic sensitive sensor so as to detect the location of the crack. The sensor network is used to detect the region of the damage and that gives the data to the central control room, that signal is given to the underwater vehicle to detect the exact location of the crack. The region is detected; hence the AUV need not monitor the whole length of the underwater pipeline. The vehicle can be directed towards the region of damage from the control room or from the ship.

The AUV designed in this paper consist of a magnetic sensitive sensor to detect the crack in the underwater pipeline from the region detected by the sensor based network.

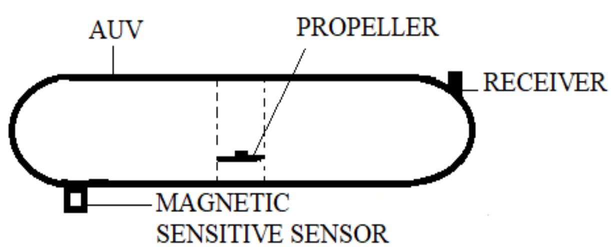

Figure 6: AUV with magnetic flux leakage detection.

Since the AUV is utilizing the magnetic flux leakage detection for crack detection, the basic principle behind it is to magnetize the ferromagnetic material of the pipeline close to its saturation under the applied magnetic field. And the magnetic sensitive sensor is used to detect the leakage flux.

When pipeline has no crack or damage the magnetic flux applied will move through it easily and the path of the magnetic flux won't have any deformations. Hence the amount of magnetic flux leakage will be very negligible. The magnetic flux leakage detected by the magnetic sensitive sensor will be negligible and can be calibrated to avoid these values, and the magnetic flux line path through the part of underwater pipeline will be as shown in figure 7.

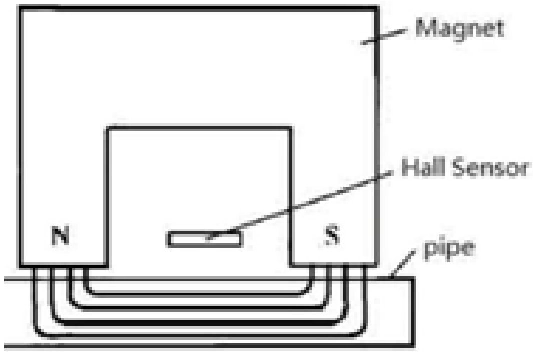

Figure 7: Scanning of pipeline with no defects or cracks.

When the pipeline has the crack there will be a space without the ferromagnetic material and that crack will increase the resistance to the magnetic flux. There will be more leakage of magnetic flux in it and the path of the magnetic flux will change due to the presence of the crack, since the crack imposes high resistance to the magnetic flux lines. Hence the path of the magnetic flux will change its shape as shown in figure 8.

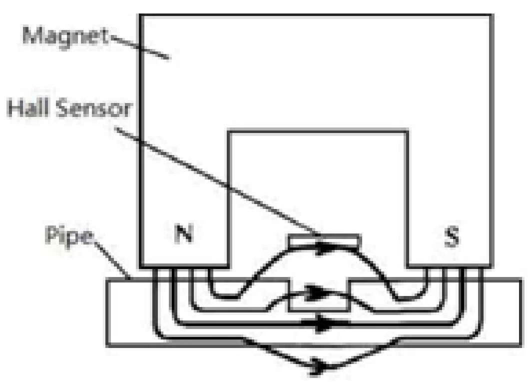

Figure 8: The change of path of magnetic flux line.

As the path of the magnetic flux line changes due to the increase in resistance to magnetic flux lines will result in the magnetic flux leakage and this magnetic flux leakage is detected by the magnetic sensitive sensor say hall sensor. Since the sensor is calibrated we can calculate the length and depth of the crack easily. This process takes place when the AUV comes above the crack as shown in figure 9.

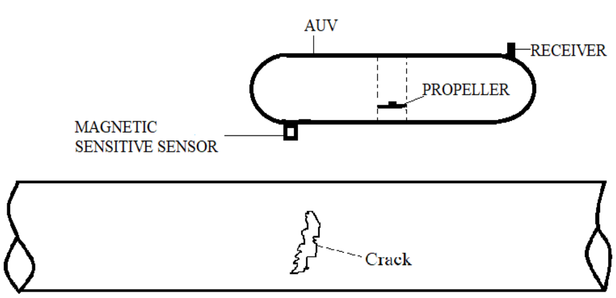

Figure 9: .Detection of crack by using AUV

As the length of the underwater pipeline to be monitored so as to detect the crack is reduced by using sensor based network and hence the region in which the AUV should be employed is reduced. By this magnetic flux leakage detection method the part of the pipeline that is detected can be scanned easily and detection of the exact location is possible. The monitoring and detection of crack in underwater pipeline can be done easily, efficiently, cost effectively and also by reducing the time consumption by this designed method.

IV. FUTURE WORK

As the world is developing, the energy source is a vital part in it. The world is in search of another energy resources as well as searching for new petroleum mines hence the underwater pipe monitoring is an important thing. Our majority of earth surface is covered with water there will be more energy source in underwater too. And the underwater pipeline will be a mode of transport; hence the monitoring of pipeline is to be done more efficiently and easily. This system utilizes pressure and the system is irrelevant of the fluid that flows through the pipeline. Hence that makes it more applicable to man applications. A very long underwater pipeline can monitor and detect any crack by combining the sensor based network and AUV. The sensor based network can be made into wireless network and can automatically send signal to the AUV when a pressure difference takes places. The AUV can be automated and it can detect the crack without the aid of human command.

V. CONCLUSION

This paper proposes a system model that uses sensors for monitoring the underwater pipeline that is to give a more accurate detection of leakage or damage in the pipeline. This model uses pressure as a medium for monitoring. The pressure sensors that is used for detection is the basic unit and the comparator and decoder completes the system for detection. After the system detect the part of the pipeline that is under damage or leakage, the AUV can be used for exact detection of position of the leakage by using magnetic flux leakage detection. Since the underwater pipeline is made of ferromagnetic material this method will be more efficient. Hence the pipeline to be monitored using the AUV can be minimized along with the cost of monitoring and time of monitoring.

VI. ACKNOWLEDGMENT

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