Vol. 6(22), Oct. 2016, PP. 3160-3165

Contents list available at IJMEC

International Journal of Mechatronics, Electrical and Computer Technology (IJMEC)

Journal Homepage: www.aeuso.org

PISSN: 2411-6173 - EISSN: 2305-0543

Oil Pipelines Leakage Detection and Location by Sensing the Temperature Distribution of Optical Fiber

Afshin Bahrami* and Ali Mir

Faculty of Engineering, Lorestan University, Khoram-Abad, Iran

Phone Number: *+98-166670873*

****Corresponding Author's E-mail:*** *afshin.bahramia@gmail.com*

Abstract

In this essay, we present design and simulation of a Leakage detection and alocation of oil pipelines system using sensing the temperature distribution of optical fiber by COMSOL Multiphysics software. In this system, telecommunication single-mode optical fiber, 200 m typical length is used, in 1.55 µm electromagnetic wave. The proposed system, uses of Brillouin frequency shift occurred on fiber optics caused by temperature varyation because of oil spillition. High-sensitivity in detection and location of oil lekages, low cost and constant monitoring of oil pipelines are the main advantages of the proposed system.

Keywords: *Brillouin scattering, Brillouin frequency shift, transmission lines, Optical fiber*

1. Introduction

Today, various fluid and gas transmission pipelines have important role in everyday life. Perhaps the most application of pipelines is transportation of oil and gas. In terms of environmental, any damage to these lines is very dangerous and economically costly. Given that these lines have been scattered in different areas of environmental risk. With various natural factors such as earthquakes, landslides and humanly intentionally or accidentally exposed that can disrupt the operation of the lines. Since the length of these lines to several hundred kilometers monitor these lines is very hard horse costs. Because the lines need to monitor the installation and commissioning of the thousands of sensors that supply these sensors will be more complex. So this method is relatively limited to some areas along the pipelines term and cannot be used .Current monitoring is a method used to current flow measurement in the beginning and end of the pipeline, that in method The occurrence of leaks can be discovered along the pipeline, but we do not give information on the location of the leak and find out the location of leakage according to the length of pipelines will be difficult and time consuming as well as costly. Another technique that is highly efficient and more interesting is the optical fiber temperature distribution based on Raman and Brillouin scattering [1]. So using continuous fiber optical sensors along the pipeline supervising the behavior of structural and functional lines with accurate measurement of physical and chemical parameters and high spatial resolution in thousands of places all along the lines might be a reasonable cost. As noted, the expansion of fiber optical distributed sensor technology is based on Raman and Brillouin scattering [1]. Both systems using a non-linear

Article History:
Received Date: Jun. 16, 2016
Accepted Date: Sep. 19, 2016
Available Online: Oct. 05, 2016

interaction between light and matter silica that is the same fiber made, so they are completely different spectral characteristics. Figure 1 shows the scattered light in the optical fiber [3]. As we see, it can be noticed that the position of the peak frequency to conditions temperature and strain fiber which Brillouin scattering occurs is dependent, While the intensity of the Raman peak is only dependent on the temperature And it can be concluded measuring systems based on Brillouin rival are for based on Raman systems, But to measure strain based on Brillouin systems are unrivaled

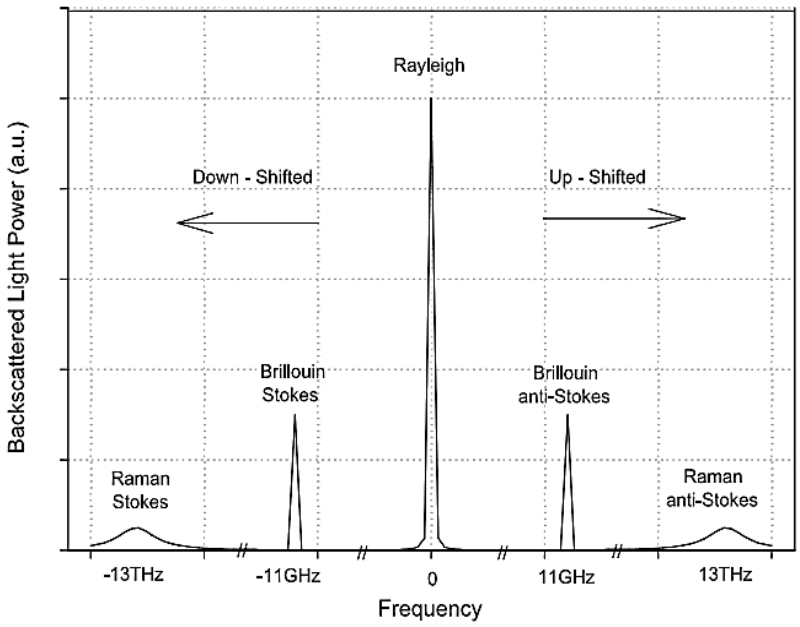

Figure 1. Schematic of a wavelength spectrum of scattered light, propagated in the optical fiber

Raman scattering light caused by thermal molecular vibrations consequently light backward contain local heating information that where occurred the dispersion. Actually the frequency shift of the backward scattering of light has two components. They are Stokes and anti-Stokes component [2]. Amplitude of the anti-Stokes component is strongly dependent on temperature while the Stokes component is independent on temperature.

So the Raman measurement method requires filtering to isolate the corresponding frequency components and also requires to record the ratio of anti-Stokes and Stokes in a range of temperature variation. Since the Raman backward scattering of light is very low, in order to maximize the intensity of the scattered light, guided multi-mode fiber with high numerical aperture is used [2]. Despite the relatively high fiber features Raman-based systems are limited to distance of 8 km [2].

Brillouin scattering is because of the interaction between the propagated light signal and heat acoustic waves, in the range GHz in the silica fibers and also increasing of frequency shift components. Brillouin scattering can be seen in a grating generated by acoustic waves (Ordinary acoustic wave is a pressure wave, in which the refractive index modulation is introduced through the elasto-optic effect) [2]. Phonons excited acoustic waves, generate periodic modulation of the refractive index [4]. The most interesting aspect of Brillouin scattering are measuring the temperature and pressure dependent on frequency shift [4]. In general, multimode fibers based on Raman systems are doing well. But as previously mentioned, they are limited to 8 Km, while single-mode fiber based on Brillouin systems are used and the ability of long distance are over 50 Km.

2. Simulation of Leak detection and location using COMSOL software

This system, using Brillouin frequency shift, detects the changes in temperature. The temperature of optical fiber under the pipeline and below the surface of the earth, approximately 1 to 1.5 m, is nearly constant and equal to about 13 °C. On the other hand, the temperature of oil inside the pipelines under normal conditions is about 26 °C. Temperature of an optical fiber at the location of the leakage, is different from the temperature of the other parts of the fiber. Hence, due to temperature dependence of the Brillouin frequency shift, the location of the leakage is determined exactly.

The value of Brillouin frequency shift, in an optical fiber is obtained according to equation (1) [5]:

$$V_B = \frac{2nV_A}{\lambda} \tag{1}$$

where V_B is the Brillouin frequency shift, n is the refractive index of the core of fiber, V_A is the acoustic velocity waves and λ is the wavelength of the propagation wave into the optical fiber. The acoustic velocity in the optical fiber is calculated according to equation (2) [6]:

$$V_A = \sqrt{\frac{K}{\rho}} \tag{2}$$

where K is the Slenderness ratio (bulk modulus) of fiber material and ρ is the density of the material. In our simulation, conventional telecom single-mode fibers SMF- 28 is used, that its velocity is equal to 5900 m/s. Figure 3. Shows the Brillouin frequency shift in the optical fiber.

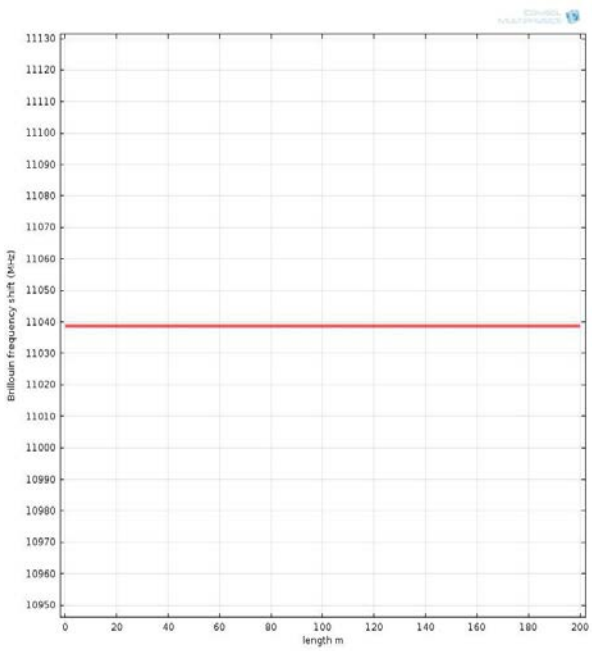

Figure 2. The value of Brillouin frequency shift in the Optical Fiber

As we can see in Figure 2, the Brillouin frequency shift, in the optical fiber is equal to 11.039 GHz. This value of shift, is constant in the whole fiber length. Brillouin frequency shift caused by changing the refractive index of the optical fiber, is temperature dependent that is stated in equation (3) [7].

$$n_{eff} = \frac{(V_{B0} + C_T \Delta T)\lambda}{2V_A} \tag{5}$$

where V_{B0} is the Brillouin frequency shift at a reference temperature T_0 which is almost equal to 13 °C and C_T is the frequency-temperature coefficient. The value of C_T is determined by the fiber composition, laser wavelength, and additional fiber coatings and jacket. This parameter in our simulation, is 1.22 MHz/°C.

Also equation (4) confirms the temperature dependence of the Brillouin frequency shift due to the Brillouin scattering mechanism [5].

$$V_B(T) = V_{B0} + C_T(T - T_0) \tag{5}$$

It can be used for temperature measurement. Considering that our reference temperature in the optical fiber lengths is 13 °C, we can calculate the amount of Brillouin frequency shift in any other temperature. The desired temperature is clearly shown in Figure 4. Its amount is equal to 11.2 GHz.

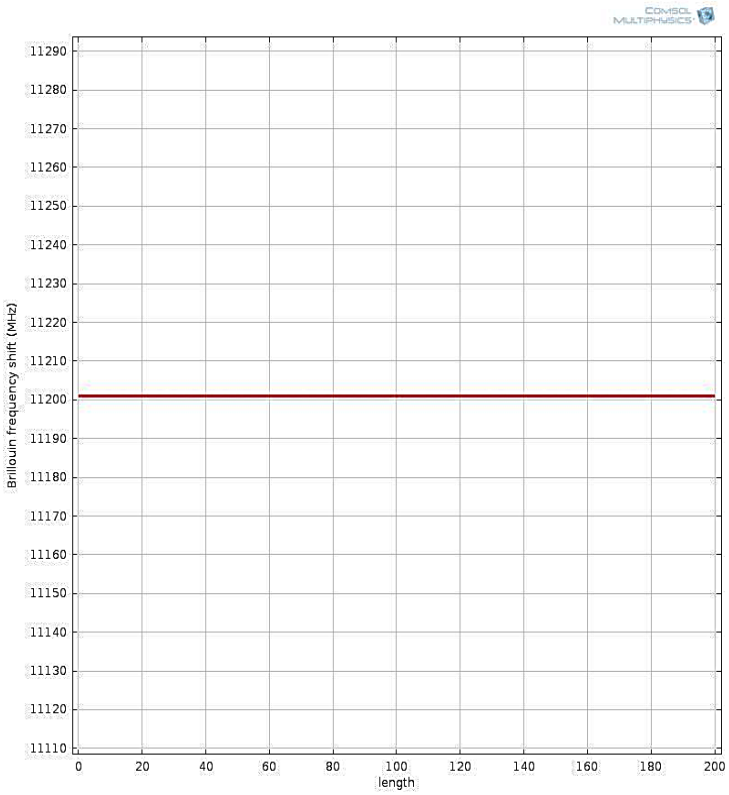

Figure 3. Brillouin frequency shift at a temperature of 13 ° C

In this stage, we have examined three leakages along the fiber in different places and temperatures. The first of leakage is placed at a distance of 20 meters with a temperature equal to 26 °C. The second is located at position 80 meters with 18 °C temperature and finally the third at position 190 meters with 43 °C temperature. The results are shown in Figure 5 and 6. Figure 5, shows different temperatures in the different position of the pipeline distance. Temperature dependence of the Brillouin frequency shift investigate in the Figure 6. As you can see in the first area due to the difference between the reference temperature and the temperature of 13 °C leak, Brillouin frequency shift is

about 16 MHz. For the leakages at points 2 and 3, the Brillouin frequency shift is 6 MHz and 36 MHZ respectively.

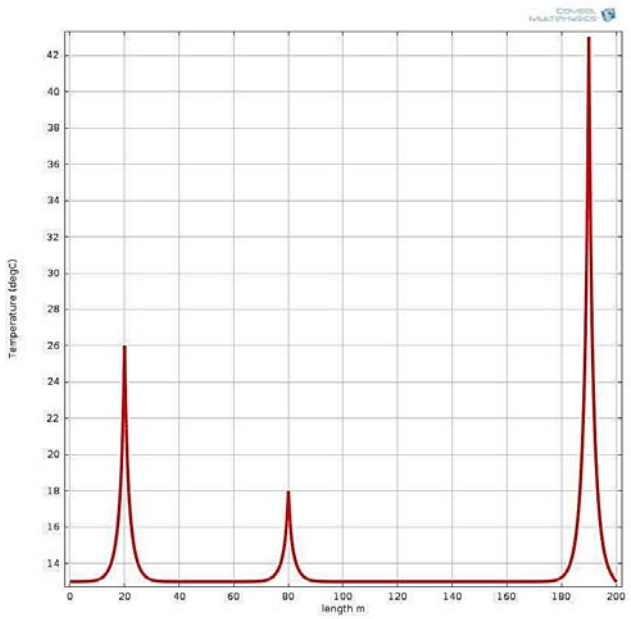

Figure 4. Applying different temperatures along the optical fiber

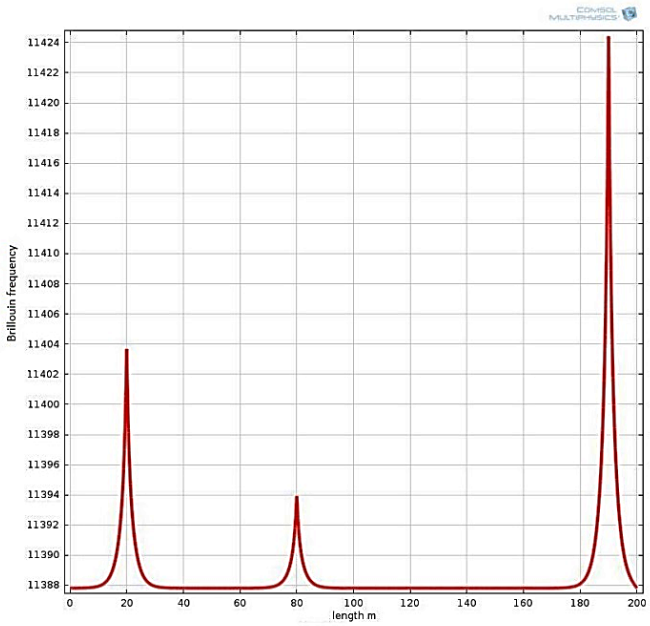

Figure 5. Brillouin frequency shift at different temperatures along the optical fiber

CONCLUSION

In this paper, we offered a system for detecting leaks in oil pipelines by using the COMSOL software. In this system, we observed that the Brillouin frequency of the optical fiber is linearly dependent on the temperature and any amount temperature increasing, the Brillouin frequency shift will be more shifted. As a result, using this property we can detect the oil pipelines leakage continuously with very reasonable cost and very high spatial resolution for detection and location.

References

[1] A. X, Bao and L, Chen "Recent Progress in Brillouin Scattering Based Fiber Sensors" Physics Department, University of Ottawa, Ottawa, ON K1N6N5, Canada. 7 April 2011.

[2] B. D, Inaudi and B, Glisic" Distributed Fiber optic Strain and Temperature Sensing Structural Health Monitoring" SMARTEC SA, Manno, Switzerland. IABMAS'06 The Third Int'l Conference on Bridge Maintenance, Safety and Management, 16 - 19 July 2006, Porto, Portugal

[3] C. M n, Alahbabi" distributed optical fiber sensors Based on the coherent detection of spontaneous brillouin scattering" BS California university. June 2005.

[4] D. M Nikles, F Briffod, R Burke and G Lyons" GREATLYEXTENDED DISTANCE PIPELINE MONITORING USING FIBRE OPTICS" 24th International Conference on Offshore Mechanics and Arctic Engineering, OMAE2005-67369.

[5] E. Z. Liu, G. Ferrier, X. Bao, X. Zeng, Q. Yu and A. Kim" Brillouin Scattering Based Distributed Fiber Optic a Temperature Sensing for Fire Detection" Department of Physics, University of Ottawa, Ottawa, Ontario, Canada, pp.221-232

[6] F. L, THÉVENAZ, "Brillouin distributed time-domain sensing in optical fibers: state of the art and perspectives" . Higher Education Press and Springer-Verlag Berlin Heidelberg 2010.

[7] G. E, Kirui, D, Waswa and K. M. Muguro" Modeling of Optical Fiber Temperature Sensor Based on Stimulated Brillouin Scattering" Proceedings of 2014 International Conference on Sustainable Research and. Innovation, Volume 5, 7th-9th May 2014.

[8] H. M. Frede, R. Wilhelm, D. Kracht, "250 W end-pumped Nd: YAG laser with direct. Pumping into the upper laser level",.. Opt. Lett., Vol. 31, No. 6, pp. 3618-3619, 2006.Meacham, B. J., "International Developments in Fire Sensor Technology," . J. of Fire Protection Engineering, 6 (2), 89-98, 1994.

[9] I. Ericsson Network Engineering AB, Sundbyberg, Sweden, "Distributed Temperature Measurement Using Optical. Fibres," – System Document, 1994.

[10] J. Dr. Stuart L. Scott, Dr. Maria A. Barrufet, - Worldwide Assessment of Industry Leak Detection Capabilities for Single &. Multiphase Pipelines, 2003

[11] K. X, Bao "Combined distributed temperature and strain sensor based on Brillouin loss in an optical fiber", Opt. Lett., vol. 19, 141, 1994.

[12] SMR. Hashemi, M. Kalantari, and M. Zangian, "Giving a New Method for Face Recognition Using Neural Networks.", International Journal of Mechatronics, Electrical and Computer Technology Vol. 4(11), A pr, 2014, pp. 744-761, ISSN: 2305-0543

[13] SMR. Hashemi, A. Broumandnia, "A New Method for Image Resizing Algorithm via Object Detection." International Journal of Mechatronics, Electrical and Computer Technology, Vol 5, Issue 16 2015.

[14] SMR. Hashemi, S. Mohammadalipour and A. Broumandnia, " Evaluation and classification new algorithms in Image Resizing.", International Journal of Mechatronics, Electrical and Computer Technology Vol. 5(18) Special Issue, Dec. 2015, PP. 2649-2654, ISSN: 2305-0543

[15] SMR. Hashemi, M. Faridpoor "Evaluation of the Algorithms of Face Identification" IEEE-2015, 2nd International Conference on Knowledge-Based Engineering and Innovation (KBEI).

[16] SMR.Hashemi, M. Hajighorbani, Mohammad Mahdi Deramgozin and B. Minaei-Bidgoli, " Evaluation of the Algorithms of Face Identification ", International Journal of Mechatronics, Electrical and Computer Technology, Vol. 6(19), Jan. 2016

[17] SMR. Hashemi, Mohammad Mahdi Deramgozin, M.Hajighorbani and Ali Broumandnia, " Methods of Image Re-targeting Algorithm Using Markov Random Field ", International Journal of Mechatronics, Electrical and Computer Technology Vol. 6(20), Apr. to Jul., 2016

Authors

Afshin Bahrami-Nejad was born in Khoramabad, Lorestan, Iran on 22th September, 1984. He received BE (Electrical Engineering) degree from Lorestan University in 2015 from College of Engineering.