Doppler Effect method of Underground oil leakage prediction by Optical Fiber Communication (OFC)

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***Abstract*—** A leakage from oil-pipeline is fatal to the people. It contaminates soil and ground-water. It also causes high economic losses. The aim of this paper is to establish a theoretical analysis to predict the place of oil leakage by using pulse propagation, fiber geometry and optical-time-domain analysis. The governing equations convert into probability-density-function by using requisite transformation and then solve numerically. Numerical results of probability-density-functions are obtained from the effect of various parameters involved such as the radius of the fiber, surface tension, angle of reception, electric vectors and discussed them theoretically in the suitable manner. Interesting aspect of the fiber reliability can be adopted. Comparison of results of the two-dimensional Bernoulli equation and the brittle factor of the fiber is considered.

Keywords - fiber geometry, leakage, optical fiber, probability-density-function.

Leakages of oil and gas from the pipeline are dangerous for people and the environment. Oil contaminates soil and ground water, whereas gas leaks can cause explosions and are harmful to vegetation and atmosphere. Furthermore, oil and gas leakages may introduce high economic losses. However, detection of leakage along pipelines which is obviously an important part of the maintenance activity has always been a difficult task.

INTRODUCTION

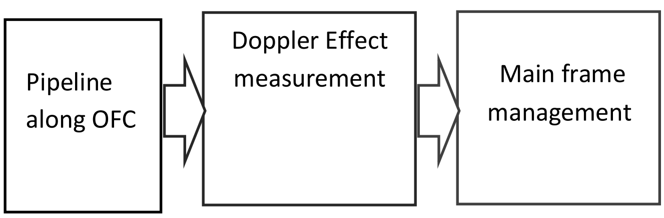
Most of the time a visual inspection of the pipeline is required to attest of the absence of leakage. In the case of buried pipeline, where an inspection is impossible, the presence of a leak is identified by a drop of the pressure the aim of the project is to detect the place of oil spills where the problem is exactly occurred by the method leakage detection by using optical fiber communication.

Over more than 30 years the wide range of fiber optic cable has been developed for telecommunication applications featuring high resistance to mechanical and chemical damage.

The cables can integrate multiple optical fibers, can be placed directly in the soil or embedded in concrete. Moreover, they are designed to operate over a wide temperature range (-50°C to 80°C) and can sustain pressure in excess of 75 MPa, which makes them very suitable for temperature monitoring. In addition to a long-term stability (the cables are constructed to last more than 30 years), the cables are designed to be insensitive to humidity, corrosion while the optical fibers are totally immune to electromagnetic perturbations. Finally, the preparation and the installation of the sensing cable is extremely convenient and low-cost, since only one cable is unwound and placed along the pipeline compared to the installation of thousands of multiplexed pin-point sensors.

Most liquids in general have refractive indices in the range of between 1.45 and 1.55 with the number of liquids outside this range becoming increasingly scarcer as you move further away from the range. Between 1.45 and 1.55, there are liquids that have properties opportune for most applications. Outside this range are rare especially for refractive indices below 1.40 and above 1.64.

Density may be important in a system such as one requiring the suspension of particles in the optic liquid or one requiring the formation of layers of Optic Liquids. Density and refractive index are directly related to each other in so far that both are dependent on the concentration of molecules of a liquid in a given volume. When a liquid is heated and expands, both the refractive index and density decrease. Most liquids have densities between 0.8 and 1.3 g/cc. Liquids with densities below 0.8 g/cc tend to have low refractive indices (1.33 to 1.46) but higher densities do not necessarily mean higher refractive indices.



According to the Snell law, when the light travels from a different medium, if it is in perfect condition, the light is total internal reflection. The reflected light is observed by photo sensing device. The observed reflected light is used to notice the leakage by using Doppler measurement.

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The velocity is a function of time and distance, so we can easily find the distance by using this formula

C=X/2T

C=velocity of light, X=distance travelled by the light, T=time taken to travel 2t reflected wave time period h

The optical fiber enclosed with the pipeline will get broken due to pressure through leakage. Then it causes the problem to light which propagated on the optical fiber. The light propagating in the hollow area is filled with oil, it changes the refractive index. It behaves like the denser medium because the optical-fiber is rarer medium and the angle of incident is predefined as the angle of incident is greater than the critical angle. So, the light is reflected from the oil is observed then it is an easy task to calculate the place the leakage occurs.

PIPELINE DESIGN

Let us consider the pipeline length L, the circular circumference area K, the optical fiber circumference of the circle is D and the number of cables enclosed in the pipeline N, the s is tangent compound around the circle with respect to the larger circle

N=K/S (1)

S=n-polygonal shape circumscribed inner circle, the number of n is increasing the value is equal to 2π, the n is smaller the amount of area not surrounded by pipeline is

G=n d/π^2-nd^2/4π (1.1)

Here the G value is larger the two consecutive circles overlapping area will be less, so the leakage of oil detection purely depending on the brittle factor of optical-fiber and pressure of the oil

If the oil leaked the pressure of oil changes the electric field vector of the electromagnetic wave this measured by mainframe unit the pressure of the oil is p >>j where j is a brittle factor of optical-fiber, the radius of optical-fiber is very small, due to the thickness of optical-fiber and surface tension of the oil it produce layer on the optical-fiber this layer does not break due to the inner pressure of the pipeline the light hit this layer change its wavelength, the layer behaves rarer medium, so it's a chance to refracted, observed and TIR, consider the pressure on the boundary of pipeline is X, the pressure in the boundary line X= {X1, X2, X3---X∞} the boundary of the layer maximum value is 2π of radius of the pipeline. The leakage detection is depending upon light received and transmitted in the same side is Y. so the leakage is occurring due to the pressure gradient vector changes in the boundary. It breaks the optical-fiber due to the brittle factor of optical-fiber the light hit on the optical-fiber circle tangent compound function is continuous probability distribution function

$$P(Y) = [e^{-1/2\left\{\frac{Y-u}{\sigma}\right\}^2}]/\sigma\sqrt{2\pi}] \qquad (2)$$

The mean u is the average pressure gradient vector changes in the pipeline

$$u = n \longrightarrow \infty \sum_0^n tanx/n \qquad (2.1)$$

$$u = n \longrightarrow \infty \left(1/n \int_0^n tanxdx\right) \qquad (2.2)$$

The above series is convergent so the value approximately equal to π/4 *R, R is radius of the pipe lines. The standard deviation σ is

$$\sigma^2 = n \longrightarrow \infty 1/n \{\sum (tanu-tanu1)\} ^2 \qquad (2.3)$$

$$\sigma^2 = n \longrightarrow \infty 1/n \{\sum (Z /1-Z)\} ^2 \qquad (2.4)$$

While Z=tan a *tan b

$$\sigma^2 = n \longrightarrow \infty 1/n \{\sum Z^{-n}\} ^2 \qquad (2.5)$$

It's about continuing function so we can integrate

$$\sigma^2 = n \longrightarrow \infty \frac{1}{n}\left\{\iint_0^N (Z^{-n}\right\}^2 \qquad (2.6)$$

$$\sigma^2 = \ln(\tfrac{\pi}{4}) \qquad (2.7)$$

P(Y) = 0.4976e^-1/2(tan Y– R π /4) (2.8)

P(X) is the PDF occur on the circle circumference remaining will occur the remaining will occur in G space. The wave length is dispersed, it's been negligible the observer unit contain lots of delay unit it used to predict the exact value, and this equation says where the oil leak exactly occurs.

C=X/2T+d1 (3)

D1 is delay of the circuit, T=t1+t2 t1 is time travel to incident ray + wave length dispersion in reflected wave, C is known , T, d is known so we can exactly find out the X .

The advantage of the system is we can use the fiber refractive index greater than oil. Two types of cable one of source another from receiving it so accurate method to detect the leakage

PIPELINE AND OPTICAL PRESSURE FACTOR

The pipe length L, area A, the force acting on the pipe line P is measured

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P=F/A (4)

Maximum gradient of near the cylinder is δv/δr= WX/δ neglecting the friction on the bottom of the cylinder the total viscous force acting on the cylinder is

F=ή A δv /δr=ή (2πRρ/ρ1h) [(1+i)/δ] iWX (4.1)

That for small oscillation, the motion of the fluid near the oscillating cylinder extends distance ∂ approximately equal to $\sqrt{ή/\boldsymbol{\rho w}}$ from the edge of the cylinder the

|F|=2πRhρ (ήw^3/ρ1) ^1/2|x| (4.2)

The pressure acting on it, the velocity will be taken to the pipeline not rotational at the time, for which have v=ΔΦ

Δ .V=K δ ((x-a) (x-b)) due to the presence of the walls the flow must be such that v(x) (0, y) =0 and v(y) (x, 0) =0, for a source of strength k the solution to

Δ^2 Φ=k δ ((x-a), (y-b)) is

K/2πlog($\sqrt{((\mathbf{x}-\mathbf{a})^2+(\mathbf{y}-\mathbf{b})\text{^}\mathbf{2})}$) (4.3)

The velocity potential flows with boundaries are

Φ= k/2π (log$\sqrt{((\mathbf{x}-\mathbf{a})^2+(\mathbf{y}-\mathbf{b})\text{ ^}\mathbf{2})}$)
+log($\sqrt{((\mathbf{x}-\mathbf{a})^2+(\mathbf{y}+\mathbf{b})\text{^}\mathbf{2})}$) +
log($\sqrt{((\mathbf{x}+\mathbf{a})^2+(\mathbf{y}-\mathbf{b})\text{^}\mathbf{2})}$) +
log($\sqrt{((\mathbf{x}+\mathbf{a})^2+(\mathbf{y}+\mathbf{b})\text{^}\mathbf{2})}$) (4.5)

Use Bernoulli's equation to relate the velocity to pressure is

P/2 (ΔΦ) ^2+P=P1 (4.6)

Where P1 is the pressure as v⟶0 thus the pressure is given by

P=P1-1 / 2ρ (k/π) ^2 [(x-a) /b^2 + (x - a) ^2+ (x + a) /b^2+ (x + a) ^2] ^2 (4.7)

P=P1-1/2ρ (k/π) ^2[(y-b)/a^2+(y-b) ^2+(y + b)/a^2+(y + a) ^2] ^2 (4.8)

Equation 1 tell that pressure along on OB of brittle factor of optical fiber is B

The leakage occur in pipeline is the probability density function copulas with the optical fiber probability density function .this copulas used to find out the error function γ(x, y), x is the probability of break occur in optical fiber ,this equation calculated Holland and Wang local dependence index measure

γ (x, y)=

$$\lim_{dx,dy\to 0}\frac{\theta(x,y;x+dx,y+dy)}{dx\ dy}=\delta^2/\delta x\,\delta y\log h(x,y)$$

(5)

Let us assume the partial derivative of the second order exists. The expression γ (x, y) is the local index that can be used to measure a local defect property

$$\gamma\ (x,y)=\lim_{dx,dy\to 0}\ [\log\frac{\left(\frac{h(x,y)h(x+dx,y+dy)}{h(x+dx,y)h(x,y+dy)}\right)}{dxdy}\ ]$$

(5.1)

CONCLUSION

This paper conclude the theoretical approach to find the oil leakage occurring place and optimum design of pipeline and probability measurement to oil leakage place by using copula theory

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