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Dynamic Model of Hydrocarbon Pipeline Leak Location Pinpoint

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ABSTRACT

Pipeline is the means of transporting natural gas product from distribution terminal to the end users. It comprises several millions of networks and still in expansion. The global challenge of the natural gas pipeline is leaks, which leads to environmental degradation, economical treats due to product loss and above all treat to human existence. This work infuses analytical dynamic mathematical model of isothermal of steady state methodology. To pinpoint accurate leak location, a horizontal cylindrical pipe of inlet and outlet sections, were used to carry out the leak location incidents. Two equations were generated, describing the pipeline sections under affected and unaffected leak areas of the pipeline, with trivial modified Weymouth's equation fluid flow of a straight cylindrical pipeline. The field data of nine (9) cases were used in the model simulation with their respective leak location pinpoints (L_p), gas leak constant of proportionality (k), the gas flowrate in the pipeline (r) and the gas pressure at leak point (P_f) were ascertained. The comparison of the field experimental result of leak location pinpoint and the gas flowrate in the pipeline with their MATLAB simulated results has mean square error of 0.735% and 0.356% respectively, showing high accuracy level below signal to leak percentage minimum acceptable limit. The model made a significant impact for accurate leak location pinpoint in natural gas pipeline with distributed strain/pressure sensory as the key parameter.

1. INTRODUCTION

Pipeline is a means of transportation which involves the movement of liquid, gases, and solid product over a long distance. The transportation of crude oil, petroleum products, and natural gases from the transmissions line, distribution line, and to the end user without traffic multiplies its important. These Oil and gas transportation through pipelines involves a network of numerous millions of kilometers globally which is continuous in expansion. The configurations of the pipeline networks can be above or below ground made of different sizes and lengths. The safety and security of

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all pipelines, regardless of their sizes and locations is of great importance to stakeholders and the public. The protection of hydrocarbon pipelines against sabotage, leakages and in-line equipment failure are of high priority in all countries although it has been extremely difficult to achieve. Recently, there have been increasing cases of pipeline attacks by militants and terrorists in various countries. A lot of studies have been undertaken while many are still ongoing in a bid to find an enduring solution, not a remedial one, to the increasing pipeline incidences.

In recent times, oil pipelines have been faced with many leaked problems such as vandalism, sabotage, ageing effect, corrosion, ground movement, crack, manufacturing error, terrorism etc. These problems have huge environmental, economic, health and safety as well as security implications on the Government, pipeline operators and host communities alike. In contrary, hydrocarbon pipeline leak detection method is divided into two clutches, externally and internally based method. The externally based category is the type of hydrocarbon pipeline leak detection that detect the leaking product using contact detection method of non-procedural principle and internally based methods are the techniques that operate by utilizing field sensor outputs to monitor internal pipeline parameters such as: pressure, temperature, viscosity, density, flow rate, product sonic velocity, etc. These inputs are then used for deducing a commodity release by mathematical model computation in solving general energy equation of mass conservation and momentum that of quick evaluation at a very lower cost continually. This method has a higher accuracy in leak detection with no distortion in operation, perhaps very uncertain and requires flow parameters in computation that is not always available when compared with the physical inspection technique.

The figure summarized leak detection techniques (Externally and internally based leak detection systems).

This work is hosted by dynamic mathematical model to pinpoint leak location and the gas flowrate in a hydrocarbon pipeline with the approach based on mass balanced and strain at leak point analysis in the pipeline, perhaps some scholarly works have done several reviews on the leak locations using several techniques.

Mostafapour and Davoodi (2013) used acoustic emission model to locate leakage in underground high pressure gas pipeline. The major noise of the acoustic emission signal is removed by wavelet transform and filtering techniques. After removing the noise, the time difference between the signals recorded at two sensors is precisely computed by cross correlation function. To achieve model, the experiment is carried out in a continuous leakage sources and linear array of two sensor positioned in two side of the leakage sources, the accuracy of the model was obtained at less than 5% error by changing the source sensor distance of several test conducted. Liu *et al* (2015) presented the new leak detection and location method for oil and natural gas pipeline based on acoustic wave using propagation model theory is used by analyzing the impact damping factor that causes the attenuations, thereafter the

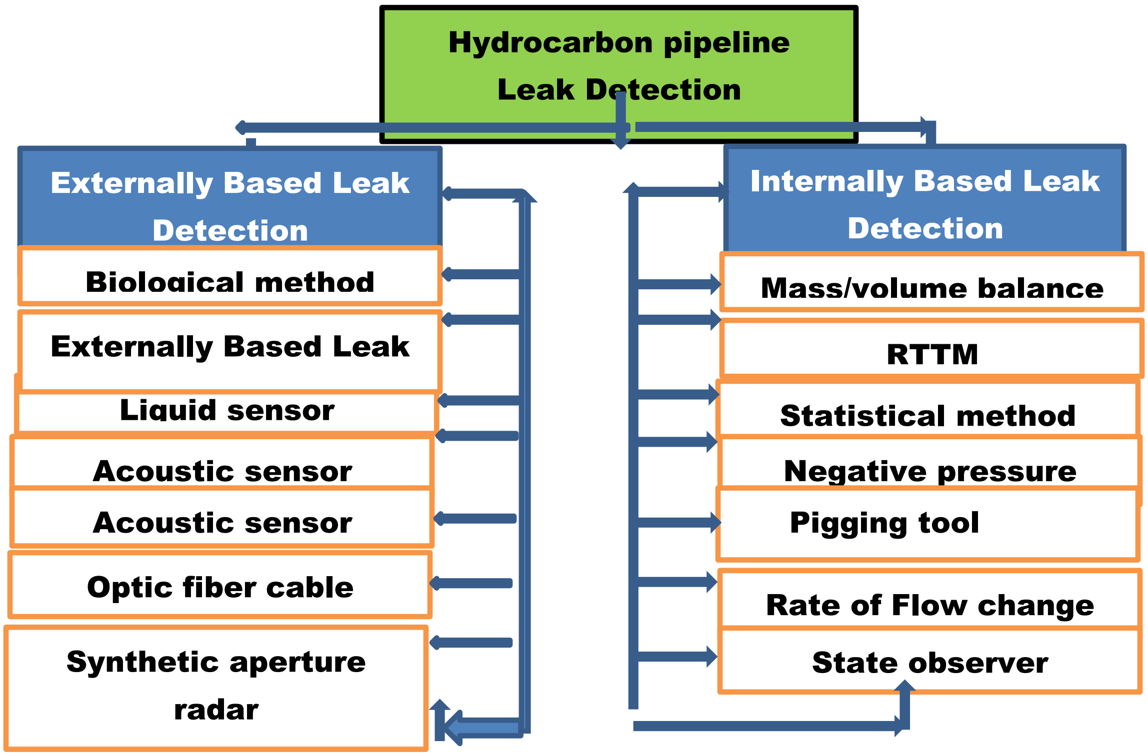

Figure 1: Categorization of Pipeline Monitoring Techniques

dominate energy frequency bands of leakage acoustic waves are obtained through experiment by wavelet transform analysis. This model is efficient as it can be applied in both oil and gas pipelines as compared to the traditional location model based on the velocity and the time difference. Ahmadi *et al* (2016) uses a regression model to optimized residual complexity in the presence of correlated and non-correlated noise; this model is highly robust since it takes into account of both the simple level and complexity of noise using a recorded sound of leaking from pipe confirm its robustness against multiple reflection. Obibuike *et al* (2019) Uses analytical model for leak location in natural gas pipeline. The model employs an isothermal steady state approach to generate state equations. Analyses of leak incidences were carried out in the two pipeline sections giving rise to two equations being developed to address the leak localization using leak at pressure points. The Weymouth's equation was modified for gas flow in horizontal pipeline, the mathematical models developed gave the leak locations for each of the field cases. Comparison of the simulated results with actual results of leak locations determined experimentally revealed high level of accuracy with an average error of only 0.377% which is below the minimum acceptable limit was obtained with the MATLAB simulation. Islam and Aslan (2021) present a sensor network design model that uses pressure sensor to measure water pressure inside a pipe in different location. Zigbee was used to collect the pressure data and the data were analyzed using exponential curve fitting techniques to determine leak and pinpoint the location. Jia *et al* (2021) uses the time frequency signal of pipeline leakage acoustic wave, these waves were studied using the method of ‘’acoustic pipeline and acoustic pressure’’ multi physical field coupling, thereafter the acoustic leakage monitoring method was applied to the field pipeline, the result shows that natural gas pipeline leakage is a kind of broadband noise, with the increase of frequency, the energy tends to oscillates and decay, as the acoustic wave propagate from the leak hole, the amplitude decreases rapidly the leakage acoustic energy is mainly concentrated below 20 Hz, while, the mean sound pressure increases with the increase of internal pressure and leakage diameter and ultra-low frequency sound pressure level is of great significance to the detection of natural gas pipeline leakage by the acoustic method. Jiajian *et al* (2022) Used a model based on compressed sensing (CS) theory as a novel pipeline leak detection and localization method to replace the solutions of the arrival time difference of negative pressure wave knee points. To validate the localization accuracy and stability of the presented method, a pipeline leak simulation test under flow conditions is conducted on a steel pipe leak test platform.

2. METHODOLOGY

Dynamic model of hydrocarbon pipeline for leak location pinpoint is the representation of the gas natural flow behavior at different category using the mathematical models, such enable to narrow down the possible leak location interval of the physical inspection of any monitoring techniques in practices. The pipeline leak detection frame theory on real time transient model (RTTM) and steady state model (SSM) were used as the method of analysis for the hydrocarbon pipeline since it is suitable for fluid pipeline leak detection and location.

The figure shows the framework of acoustic wave sensor, the length of pipeline, the position of sensors, the unaffected and affected hydrocarbon moving after leaks, and the leaking hydrocarbon interlocked together for hydrocarbon leak monitoring to pinpoint the leak location, time of occurrence, size of the leak, and the flow rate.

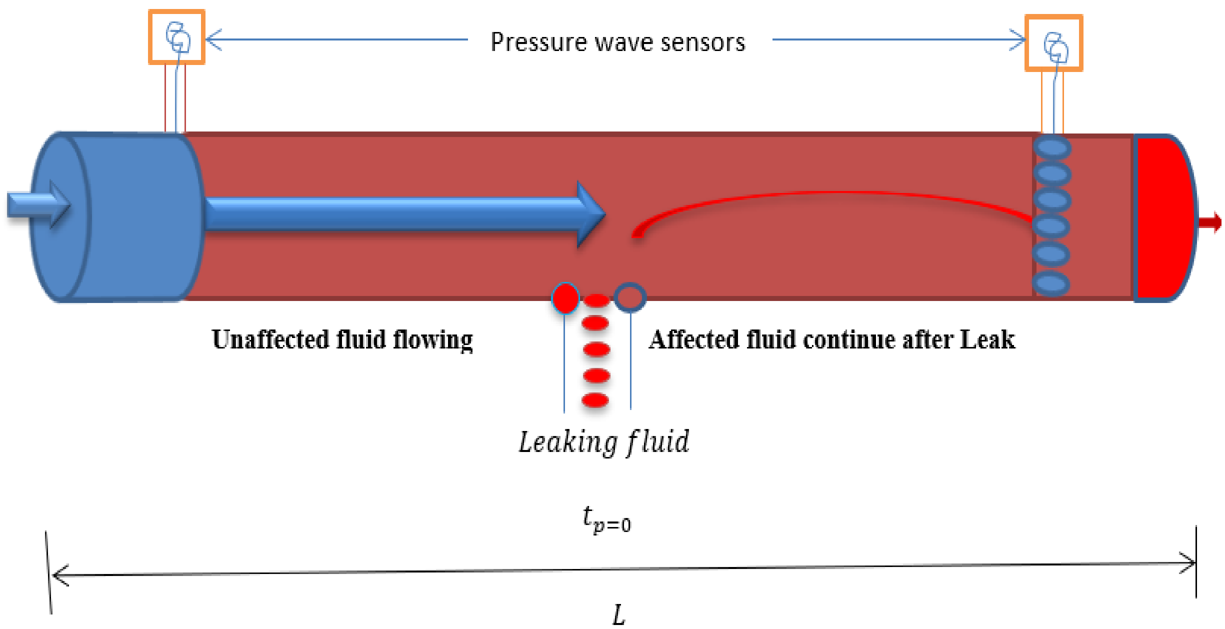

Figure 2: The hydrocarbon Pipeline diagram for Determination of Leak location

2.1 The hydrocarbon pipeline model on a steady state operation

According to Ekikere and Amadi (2023), derivative of continuity equation is one of the most important derivations in fluid dynamics. The continuity equation stated that the product of cross-sectional area of the pipe and the fluid velocity at any point along the pipe is always constant. This product is equal to the volume flow per second or simply the flow rate.

$A \propto u$ i.e., the flow area of the pipeline is directly proportional to the flow velocity. This can be mathematically representing as.

$$R = Au = constant \tag{1}$$

Where, R, is the volume flow rate, A, is the flow area and u, is the flow velocity.

In this paper we maintain a model of interest (pinpoint location at which the leak occurs mathematically).

***2**.2 Hydrocarbon pipeline Leak Location pinpoint*

We realize the leak location of the hydrocarbon pipeline experiencing a leak using the existing models we got from the continuity equation by dividing it into three parts as follows.

1. inlet of the leak
2. outlet of the leak
3. The exact location of the leak, let us consider the figure 3 diagram

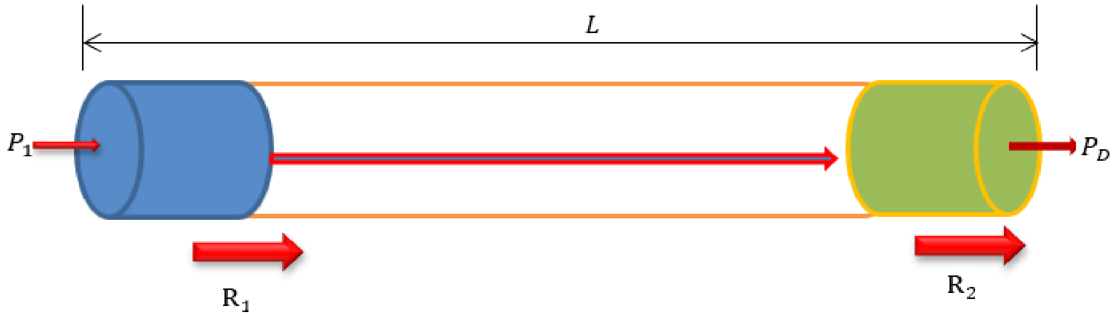

Figure 3: Hydrocarbon pipeline condition for no leak

The figure shows a pipeline profile in the event of no leak, the red arrow represents total product delivery from the pipeline, where.

$R_1 = r = R_2$
(2)

By parameter definition

R_1 , is the inlet gas flow rate without leak $(m^3\ /hr)$

R_2 , is the output gas flow rate without leak $(m^3\ /hr)$

R_D , is the documented flow rate at the output section of the pipeline in $(m^3\ /hr)$

P_D , is the documented output pressure from the monitoring team at the workstations in (bar)

L , is the length of the pipeline (km)

P_1 , P_2, is the hydrocarbon inlet and outlet pressure in (bar)

r , is the resultant flow rate without leak in $(m^3\ /hr)$

From figure 3, the flowrate is equal throughout the whole section of the pipeline since flow is in steady state without leakage.

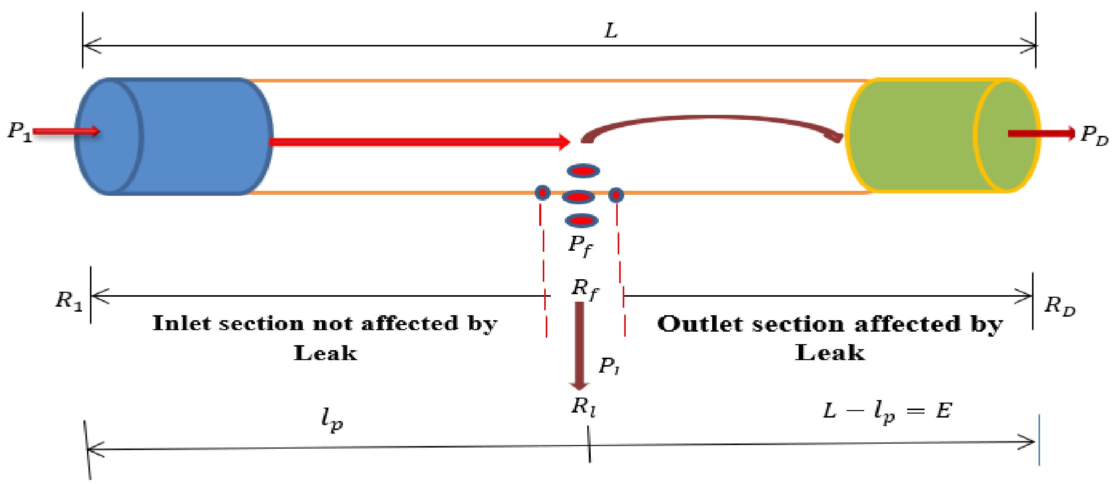

Figure 4: Hydrocarbon pipeline with leak (Ekikere and Amadi (2023)

Figure 4 shows a pipeline profile in the event of leak, the 3 dots red accents represent product loss from the pipeline.

Thus,

$R_D = R_f$
(3)

The work adopted Weymouth's equation as the hydrocarbon flow in horizontal pipeline model is written as;

$$r = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\sqrt{\frac{(P^2{}_1 - P^2{}_2)}{SL\,TZ}} \quad (4)$$

Definitions of parameter are as follows.

r , is hydrocarbon flow rate in (m/s),T_b, is Hydrocarbon pipeline base temperature (12.78℃), P_b , is Hydrocarbon pipeline base pressure (1.034 bar), f *is* Fanning friction factor (1E-5 to 5E-2), P_1 , is inlet pressure, (bar), P_2, is outlet pressure, (bar), S, is specific gravity of hydrocarbon in the pipeline, T, is Absolute temperature of gas (33℃ - 55℃) , Z, is the hydrocarbon gas deviation factor (0.9960), L, is Length of the pipeline (km), l_p, is the pipe Leak point (km), D, is pipeline inside diameter (inches), n and y is the Weymouth constant of panhandle A at 2.5 and 0.5 respectively.

Perhaps, looking at our parameter definition, we can adjust equation (4) of Weymouth's to be.

$$r = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^n}{SL\,T\bar{Z}}\right)^y [(P^2{}_1 - P^2{}_2)^y] \quad (5)$$

The simplified equation (5) gives a leak location equation development direction. The general equation for gas flow in pipeline is given in compact form as.

$$r = K(P^2{}_1 - P^2{}_2)^{0.5}$$

This equation (4) is similar to the Weymouth's equation as K is the constant of proportionality that represent the non-pressure term at the right-hand side of the equation.

$$K = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^5}{SL\,TZ}\right)^{0.5}$$

Using figure 4, when leak occurs in the pipeline, the pipeline can be modeled in sections, the inlet section not affected by the leak and the outlet section affected by the leak. The mid-let is not actually a section but a unique point from which references to the two sections of the pipeline are being made which measures flow rate leak (R_l).

Considering the unaffected inlet section of the pipeline, the flow equation for the hydrocarbon becomes.

$$R_f = K_f(P^2{}_1 - P^2{}_2)^{0.5} \quad (6)$$

Therefore,

R_f , is the flowrate at the point where leak has occurred

P_f , is the pressure of the pipeline at leak point

K_f, is the constant of proportionality in the leak situation like K above with L replaced by leak point (l_p). (7)

Equation (6) describes the fluid flow equation in the pipeline in the absence of leak while equation (8) describes the fluid flow in the upstream section of the pipeline when leak has occurred.

Perhaps, in combining equation (6) and (8) taking ratios it will become.

$$\frac{R_f}{r} = \frac{K_f(P^2{}_1 - P^2{}_2)^{0.5}}{K(P^2{}_1 - P^2{}_f)^{0.5}} \quad (9)$$

Hence, making K_f the subject formula, as the constant of proportionality the equation becomes.

$$K_f = K\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (10)$$

But in rewriting equation (7) to represent location of the leak, l_p takes the place of L as describe that K_f is the constant of proportionality in the leak situation like k above with L replaced by leak point (l_p)

$$K_f = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTSl_p}\right)^{0.5}$$

Having seen l_p as the location of the leak, we can substitute the values of k and K_f into the equation (11) to becomes.

$$3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTSl_p}\right)^{0.5} = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTSL}\right)^{0.5}\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (12)$$

Hence factoring the leak location l_p and length L in equation (12), we have.

$$3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTS}\right)^{0.5}\left(\frac{1}{l_p}\right)^{0.5} = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTS}\right)^{0.5}\left(\frac{1}{L}\right)^{0.5}\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (13)$$

Hence, in eliminating out the factors in equation (13)

$$3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTS}\right)^{0.5}\left(\frac{1}{l_p}\right)^{0.5} = 3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\left(\frac{D^{2.6}}{ZTS}\right)^{0.5}\left(\frac{1}{L}\right)^{0.5}\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (14)$$

Equation (14) returns to

$$\left(\frac{1}{l_p}\right)^{0.5} = \left(\frac{1}{L}\right)^{0.5}\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (15)$$

Subsequently, removing the brackets on leak location l_p and the length L the equation becomes.

$$\frac{1}{l_p{}^{0.5}} = \frac{1}{L^{0.5}}\left(\frac{R_f}{r}\right)\left(\frac{P^2{}_1 - P^2{}_2}{P^2{}_1 - P^2{}_f}\right)^{0.5} \quad (16)$$

Hence, taken the reciprocal at both sides of the equation (39) it becomes.

$$l_p{}^{0.5} = \left(\frac{r}{R_f}\right)\frac{(P^2{}_1 - P^2{}_f)^{0.5}L^{0.5}}{(P^2{}_1 - P^2{}_2)^{0.5}} \quad (17)$$

The model of equation (16) and (17) showcase presence of negative pressure wave that travels forward and backwards respectively from the leak point along the inlet and outlet sections of the pipeline. If we consider the unaffected section of the pipeline, the negative pressure wave travels counterclockwise in a opposite direction.

Hence the flow rate in forward direction becomes equation (16) and the flowrate in opposite or reverse direction becomes equation (17)

$$l_p^{0.5} = \left(\frac{R_f}{r}\right)\frac{(P^2{}_1-P^2{}_f)^{0.5}L^{0.5}}{(P^2{}_1-P^2{}_2)^{0.5}} \quad (18)$$

Hence, squaring both side of the equation becomes.

$$l_p = L\left[(\frac{R_f}{r})^2\left(\frac{P^2{}_1-P^2{}_f}{P^2{}_1-P^2{}_2}\right)\right] \quad (19)$$

However, since point l_p is the leak location at upstream and it is determined from the pipeline inlet section we shall denote inlet leak location to be. l_{p_1}

$$l_{p_1} = L\left[(\frac{R_f}{r})^2\left(\frac{P^2{}_1-P^2{}_f}{P^2{}_1-P^2{}_2}\right)\right] \quad (20)$$

2.3 The Leak Location Model Outlet Section of the Pipeline

Considering the outlet section of the pipeline, equation (21) satisfied that flowrate in inlet section of the pipeline is uniform while the flowrate in outlet section is also uniform and equal to the documented output flow rate as $R_D = R_f$

Therefore, the outlet section of the pipeline becomes.

$$R_D = K_f(P^2{}_f - P^2{}_D)^{0.5} \quad (21)$$

R_D is the documented flowrate at the output section of the pipeline in m/s

P_D is the documented output pressure in psi

K_f is the Constant which comprise all the other terms in the Weymouth's equation

Hence, comparing equation 6 and 8 it becomes.

$$\frac{R_D}{r} = \frac{K_f(P^2{}_f - P^2{}_D)^{0.5}}{K(P^2{}_1 - P^2{}_2)^{0.5}} \quad (22)$$

But putting back K_f *and* K value the equation becomes.

$$\frac{R_D}{r} = \frac{3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\ (\frac{D^{2.6}}{ZTS(L - l_p)})^{0.5}\ ({P^2}_f - {P^2}_D)^{0.5}}{3.23\frac{T_b}{P_b}\sqrt{\frac{1}{f}}\ (\frac{D^{2.6}}{ZTSL})^{0.5}\ ({P^2}_1 - {P^2}_2)^{0.5}} \tag{23}$$

Solving the equation (23) by separating the variables gives.

$$\frac{R_D}{r} = \frac{({P^2}_f - {P^2}_D)^{0.5} L^{0.5}}{({P^2}_1 - {P^2}_2)^{0.5}(L - l_p)^{0.5}} = [\frac{L({P^2}_f - {P^2}_D)}{(L - l_p)({P^2}_1 - {P^2}_2)}]^{0.5} \tag{24}$$

Squaring both sides of the equation (24) above it becomes.

$$(\frac{R_D}{r})^2 = \frac{L({P^2}_f - {P^2}_D)}{(L - l_p)({P^2}_1 - {P^2}_2)} \tag{25}$$

Hence, the location at which the leak occurred is within $(L - l_p)$ so as.

$$(L - l_p) = (\frac{r}{R_D})^2 \frac{L({P^2}_f - {P^2}_D)}{({P^2}_1 - {P^2}_2)} \tag{26}$$

Making the location of the leak l_p the subject formula, then the equation becomes.

$$-l_p = -L\left[(\frac{r}{R_D})^2 \frac{L({P^2}_f - {P^2}_D)}{({P^2}_1 - {P^2}_2)}\right] \tag{27}$$

Multiplying both sides by -1 the equation becomes.

$$l_p = L - \left[(\frac{r}{R_D})^2 \frac{L({P^2}_f - {P^2}_D)}{({P^2}_1 - {P^2}_2)}\right] \tag{28}$$

Therefore, since the leak location l_p is determined from the outlet section of the pipeline we assign l_{p_2} to the equation as.

$$l_{p_2} = L - \left[(\frac{r}{R_D})^2 \frac{L({P^2}_f - {P^2}_D)}{({P^2}_1 - {P^2}_2)}\right] \tag{29}$$

Hence, the equation (29) is used to determine the leak distance by considering the flow from the outlet end of the pipeline; the model is reversal in nature which means it can handle the inlet section of the pipeline by using l_{p_1} but with high level of intrinsic interpolations.

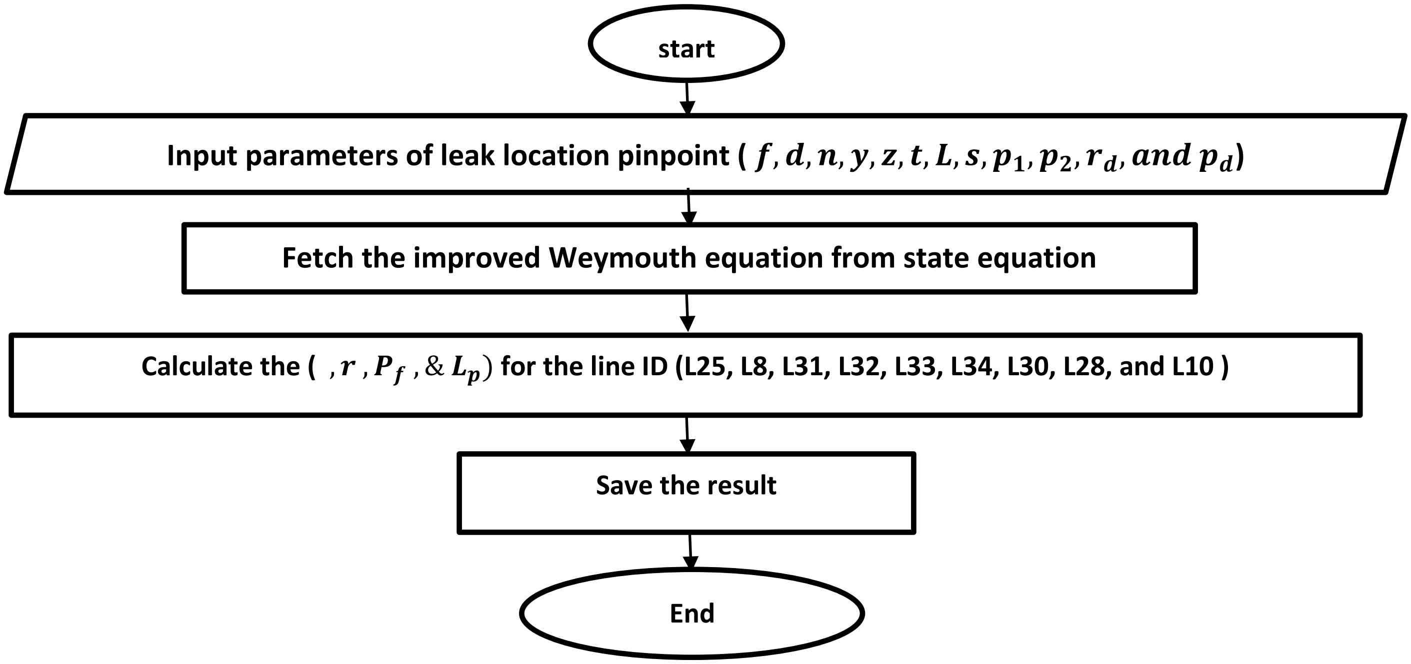

Figure 5: Hydrocarbon pipeline leak location pinpoint on algorithm

2.5: Mathematical model simulation

The simulations for leak location involve the data collection, validation, to ascertain the accuracy of the data, actual simulation, and confirmation of simulated results with experimental figures. Table 1 is input data collected from Nigerian gas company (NGC) a subsidiary of NNPC monitored with a mass balance technique.

Table 1: Model Simulation for Leak Location

Line ID	**L25**	**L8**	**L31**	**L32**	**L33**	**L34**	**L30**	**L28**	**L10**
Pipeline length (km)	50	44	90	99	91	105	196	196	128
Diameter (inch)	36	16	18	36	36	36	36	24	18
Pressure inlet (bar)	89.63	72.39	65.50	82.74	70.33	74.48	86.18	75.84	68.95
Pressure outlet (psi)	51.04	55.16	51.71	49.64	46.88	33.09	34.47	37.47	41.37
Temp. flow (℃)	40.56	26.67	37.78	40.56	40.56	40.56	40.56	43.33	37.78
Base temp (℃)	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78	12.78
Gas flow-rate at inlet (MM**S**m^3/hr)	15.99	26.90	09.06	19.21	15.94	19.60	28.30	16.36	11.00
Output Flow-rate recoded at leak (MM**S**m^3/hr)	0.170	0.094	0.110	0.051	0.030	0.040	0.060	0.140	0.098
Base pressure (bar)	1.034	1.034	1.034	1.034	1.034	1.034	1.034	1.034	1.034
Standard temperature condition (℃)	35	35	35	15	15	15	15	15	15
Output pressure recorded at leak (Bar)	51.43	66.65	52.11	46.77	42.54	40.20	41.60	46.31	51.83
Gas deviation factor	0.90	0.92	0.90	0.85	0.95	0.90	0.93	0.95	0.90
Gas specific gravity	0.60	0.67	0.65	0.66	0.60	0.65	0.67	0.60	0.65

3. RESULTS AND DISCUSSION

Table 2: Model simulation results from NNPC hydrocarbon pipeline of various lines ID.

Line ID	Leak location pinpoint (km) L_p	Hydrocarbon pipeline length (km)	Pressure at leak point (P_f) bar	Gas flow rate (model) (MMSm^3/ hr) (r)	Gas leak constant of proportionally (k)	Gas drop flow rate (MMS$m^3 h$) (r_f)
L25	11.09	50	8.19	16.00	17.53	0.05
L8	15.71	44	19.26	26.91	08.67	0.026
L31	17.60	90	27.15	09.09	11.67	0.014
L32	21.22	99	13.84	19.22	23.97	0.509
L33	12.85	91	15.97	15.96	23.00	0.23
L34	11.62	105	15.21	19.62	24.41	0.009
L30	1.38	196	16.56	28.36	06.81	0.016
L28	6.18	196	9.23	16.43	19.82	0.06
L10	19.95	128	7.92	11.05	13.15	0.072

The table shows the k, r, P_f, L_p & r_f calculated from the various input variables of line ID of table 1. The table result shows the pipeline lengths cases under monitor, the model ability to locate the point of the leak within the pipeline length, the pressure at the point of leak, the calculated flowrate and Gas leak constant of proportionally (k). The table shows their respective corresponding value at each of the pipeline length.

3.1 Comparison of Field Instrument Measured and Model Results

Table 3: The table of gas Leak location

Line ID	Leak pinpoint (km) L_p	Field Result (km) L_p	Observed error
L25	11.09	11.05	0.04
L8	15.71	15.70	0.01
L31	17.60	17.55	0.05
L32	21.22	21.18	0.02
L33	12.85	12.82	0.03
L34	11.62	11.61	0.01
L30	1.38	1.37	0.01
L28	6.18	6.16	0.02
L10	19.95	19.93	0.02
Average observed Error.			0.21
MSE			0.00735
MSE%			0.735%

The table result shows the mean square error obtained from comparing the model result of the gas leak location in the pipeline and the field operation result as 0.735%.

Table 4: The Table of gas flow rate

Line ID	**Gas flow rate (model) (MMSm^3/hr) (r)**	**Field Result (MMSm^3/hr) (r)**	**Observed error**
L25	16.00	15.98	0.01
L8	26.91	26.90	0.01
L31	09.09	09.07	0.02
L32	19.22	19.20	0.02
L33	15.96	15.95	0.01
L34	19.62	19.60	0.02
L30	28.36	28.35	0.01
L28	16.43	16.40	0.03
L10	11.05	11.00	0.05
Average Error.			0.18
MSE			0.0036
MSE%			0.36%

The table result shows the mean square error of 0.36% as obtained from comparing the model result of the gas flowrate (r) as given by improved Weymouth equation and the field operation result.

3.2 Discussions of Results

a) It is seen that the model in table 2 made a reasonable prediction between the P_f, L_p using the leak at L25 as example, the leak was located at 11.09 [km], with the pressure at the leak point 8.19 bar or 118.79 [psi]. Perhaps considering the input pressure 1300psi or 89.63[bar] and the output pressure 51.04 [psi] or 3.52 [bar] and the distance of location, it expected that the input pressure will be higher than the pressure at leak point and the output pressure will be lower than the pressure at leak point as it the midpoint pressure.

b) It is confirmed in the gas flow rate using line ID {L25} for example, at the location distance of the leak, the gas flow rate maintains the same flow rate with 0.01 error difference. This concurs with the expectation that the input flow rate will match the model flow rate with a very minimal error value, which confirms the model operation at the steady state.

c) The table 3 and 4 result shows the mean square error obtained from comparing the model result of the gas leak location and model gas flow rate in the pipeline and the field operation result at 0.735% and 0.36 % respectively as it very low compare with the Obibuike etal (2019) that has average error at 0.377% which is acceptable in leak location in natural gas pipeline. Perhaps the model gives a more accurate result for hydrocarbon pipeline leak location and flowrate identification.

4. CONCLUSION

The dynamic model was realize using a general state equation with an improve Weymouth equation divided into two parts of the inlet and outlet of the pipeline for an accurate leak location pinpoint, out of the two parts only one of the models is used at a point to locate distance and pressure at the leak point in the natural gas pipeline as shown in this work where the mean square error of the leak location was obtained at 0.735%. This analytical model has shown a reasonable accuracy with a very low cost comparing with inspection method and it can be used to validate the correctness of any techniques in leak location as its capable of calculating the $k, r, P_f, L_p \,\&\, r_f$ within the line ID.

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