International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 96-101
Published Online March 2021 in IJEAST (http://www.ijeast.com)

NUMERICAL SIMULATION OF LEAKAGE FLOW FIELD OF RAILWAY FREIGHT BRAKING PIPELINE

Q. Huang
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

L. Ge
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China,

Y. M. Mo
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

Y. D. Duan
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China,

Z. Y. Li
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

W. Q. Chen
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China,

J. R. Song
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

X. W. Yi
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China,

S. F. Liao
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

C. Wang
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China,

L. Xie
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, Sichuan, China

H. Cao
College of Electrical and Mechanical Engineering
Southwest Petroleum University, Chengdu, China

***Abstract*— pipeline leakage causes great harm in industrial production, and the detection of pipeline leakage has important application value in industrial production. Ultrasonic testing technology has a wide range of applications in the field of industry, is one of the main means of non-destructive testing. It is very difficult to distinguish between human eyes and ears. Therefore, by using the propagation characteristics and unidirectionality of ultrasonic, non-destructive testing can be realized, and the detection distance is wide, and the safety of personnel can be guaranteed. In this paper, ANSYS software is used to simulate different cases of pipeline leakage, mainly including the relationship between leakage velocity and ultrasonic frequency with different leakage aperture, different pressure in the pipe, different spacing between two holes. The simulation is of great significance for the field theory research of pipeline leakage and the detection of pipeline leakage.**

Keywords— **Fluent, pipeline leakage, finite element simulation, numerical simulation**

I. INTRODUCTION

Ultrasonic testing technology has a wide range of applications in the industrial field, is one of the main means of nondestructive testing[1]. It is very difficult to distinguish between human eyes and ears. Therefore, by using the propagation characteristics and unidirectionality of ultrasonic, non-destructive testing can be realized, and the detection distance is wide, and the safety of personnel can be guaranteed. Ultrasonic testing started in the 1930s, and was widely used in the 1940s. Firestone of the United States introduced the pulse echo ultrasonic testing instrument for the first time, which can accurately determine the location and size of defects by using the reflection property of ultrasonic[2]. In the 1960s, ultrasonic detector improved the resolution, sensitivity and linear function of amplifier, making ultrasonic testing a reliable non-destructive testing method. However, due

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 96-101
Published Online March 2021 in IJEAST (http://www.ijeast.com)

to its fixed frequency response and wide frequency range, it has low signal-to-noise ratio and poor adaptability to the environment[3]. The traditional analog ultrasonic detection system is very inconvenient to use because it is inconvenient to record data and has no image, which restricts the development of ultrasonic detection. The digital ultrasonic detector can integrate image and intelligent processing, which simplifies the detection steps more humanized[4]. Foreign countries began to study pipeline leakage systematically in the 1970s, and produced different types of products in the 1980s. In recent years, foreign research achievements on high-pressure pipeline leakage mainly include infrared imaging, distributed optical fiber sensor, olfactory sensor detection, statistical detection, neural network and other technologies. At present, the more advanced detection products based on different principles are designed by the company, Ateq company of France, Uson and InterTech company of the United States, Florish company of Germany, Microctrol company of Italy, etc., and their respective gas leakage detection technologies have become mature[5]. Since the 1980s, with the rapid development of modern microelectronics and computer technology, ultrasonic nondestructive testing instrument has been developing in the direction of intelligence, miniaturization and digitization. At present, the representative ultrasonic detectors include SDT series of SDT company in Belgium, Ultraprobe series of UE company in the United States, LKS series of Leakshooter company in France. The effective distance can reach 20m, the minimum detection aperture can reach 0. 1mm (depending on the pressure), the maximum sensitivity can be adjusted to 110dB, and the frequency response range can be improved20-100khz adjustable. Leakshooter 1000 can realize visual detection and directly display the location of leakage source on the display screen[6].

II. THE ESTABLISHEMENT OF THE MODEL WITH SINGLE HOLE

The gas in the pipeline may leak in the process of transportation or transportation, which may form jet injection. We can simulate it. Using ANSYS Workbench simulation software, we can more vividly express and analyze the structure of jet injection, and deepen the understanding of the relevant data of gas jet at the hole leakage.

\The rectangular coordinate system is adopted, and the coupling algorithm of flow velocity and pressure is used to solve the problem. The grid is divided as follows: the calculation model diagram of single hole pipeline leakage, and the size is shown in the figure. The simulated areas are as follows.

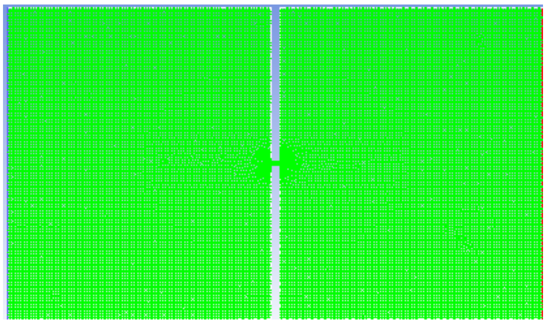


Fig. 1 leakage single hole model

In the mesh generation of the model, the square partition unit is used. Because of its regular structure, convenient calculation, and fine mesh of the jet area, the jet area at the leakage of the pipe aperture can be more accurately simulated. It is assumed that the gas in the pipeline is ejected from the left side to the right space at high speed through the small hole, that is to simulate the actual situation when the gas in the pipeline leaks into the outside air. Therefore, the boundary type set in the left space is inlet, and the boundary type set in the right is outlet
(outlet), the diameter of the leakage hole is 4mm × 1mm.
When the pressure inside the pipeline is 0. 18mpa and the pressure outside the pipeline is 0. 1MPa, the velocity vector distribution of the leakage flow field in the pipeline is as follows: the left is the axial velocity distribution, and the right is the radial velocity distribution
It can be seen from the figure that in the jet flow field, the maximum axial velocity can reach 300m / s, which is far greater than the radial velocity. Therefore, the axial velocity plays a dominant role in the jet flow field and plays a major role in the propagation disturbance of sound wave, which is also the main research object.

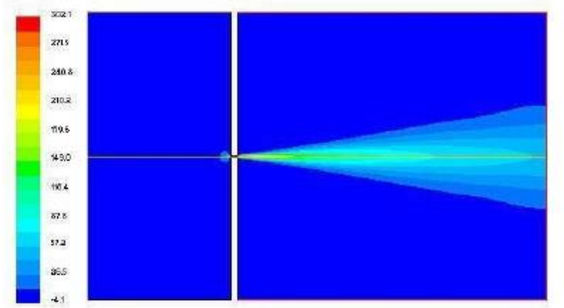


Fig. 2 Schematic diagram of gas leakage[7]

In the figure, the exit velocity of the nozzle is the largest, and momentum exchange occurs between the jet and the surrounding static medium, which makes the static medium in the surrounding space continuously flow into the jet boundary layer, which is also the place where the jet sound source is most concentrated. When a large amount of medium enters the jet, the jet velocity decreases gradually and the jet area increases gradually. The uniform jet shear layer decays and diffuses along the axial direction downstream.

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 96-101
Published Online March 2021 in IJEAST (http://www.ijeast.com)

III. THE INFLUENCE OF LEAKAGE PORE DIAMETER ON THE FLOW FIELD

The inlet pressure is 0. 2MPa, the temperature is 300K, and the outlet pressure is 0. 1MPa. The models of leakage aperture d = 1, 2, 3, 4, 5mm are established to simulate the distribution of flow field under different leakage diameters[8]

It can be seen from the flow field diagram that the leakage velocity varies with the diameter of the leakage hole. The following figure shows the relation curve between leakage aperture D and maximum leakage velocity $V_{max.}$

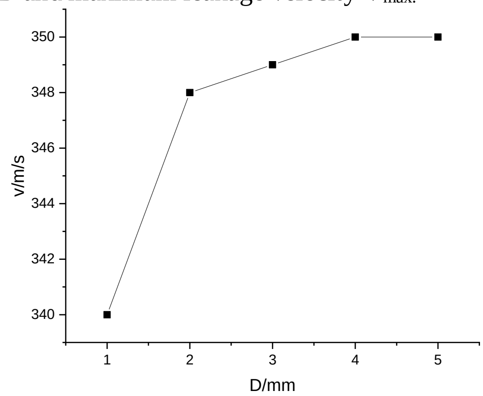


Fig. 3 Relationship between leakage aperture and leakage velocity

It can be concluded from the results that with the increase of the leakage hole diameter, the maximum leakage velocity changes little, but in a small speed range, the velocity shows a regular increasing trend, that is, the larger the leakage hole diameter is, the larger the maximum leakage velocity is; on the contrary, the smaller the hole diameter is, the smaller the maximum leakage velocity is [9].

The leakage calculation model of double hole pipeline is shown in the figure. The simulated areas are as follows

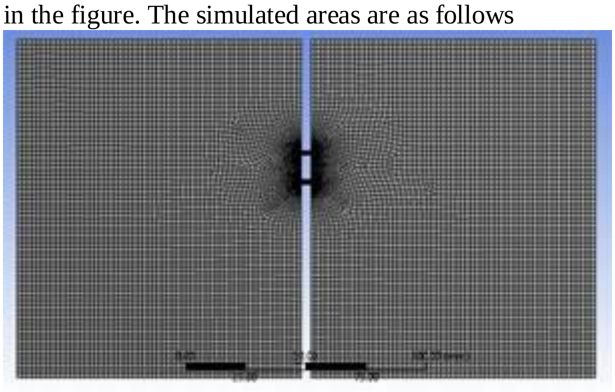
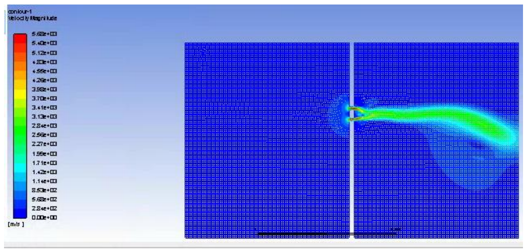


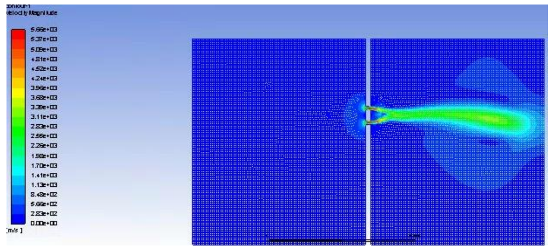
Fig.4 double hole gas leakage model

The influence of different leakage pore spacing on the flow field of pipeline is analyzed [10].

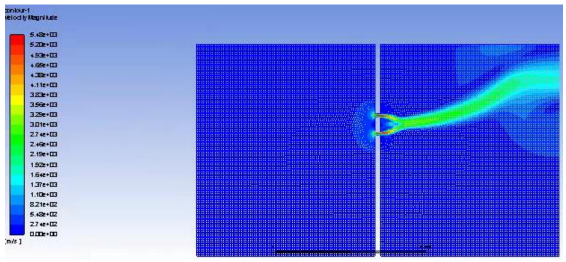
When the inlet pressure is 0. 15pa, the temperature is 300K, and the outlet pressure is 0. 1MPa, the models with the spacing of leakage holes L = 6, 8, 10, 12mm are established to simulate the distribution of flow field under different spacing of leakage holes



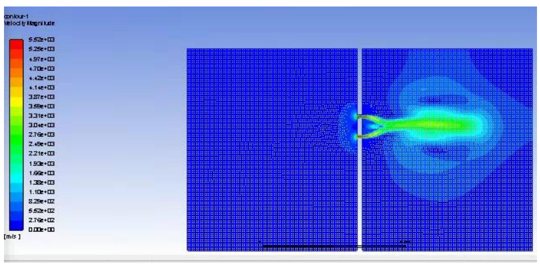
L = 6mm



L = 8mm



L=10cm



L = 12mm

Fig.5 gas leakage velocity at different aperture distances

It can be seen from the comparison of the above figures that the leakage flow field velocity of the pipeline basically does not change with the leakage hole spacing L under the same working conditions[11].

The following figure shows the relation curve between leakage hole spacing L and maximum leakage velocity $V_{max.}$

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 96-101
Published Online March 2021 in IJEAST (http://www.ijeast.com)

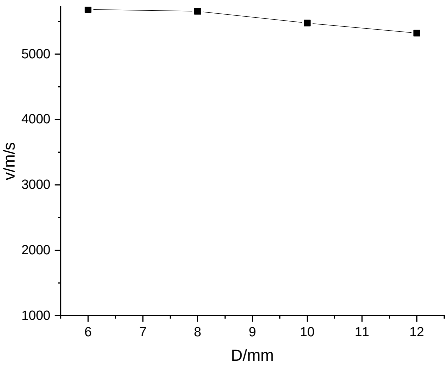


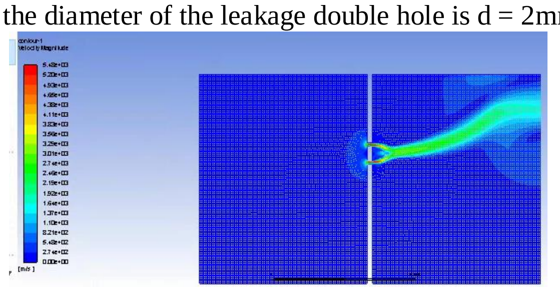
Fig. 6 relationship between two hole spacing and leakage velocity

It can be seen from the figure that the maximum leakage velocity changes little with the increase of the leakage hole spacing, but in a small speed range, the velocity shows a regular decreasing trend, that is, the larger the leakage hole spacing is, the smaller the maximum leakage velocity is; on the contrary, the smaller the two holes spacing is, the greater the maximum leakage velocity is[12].

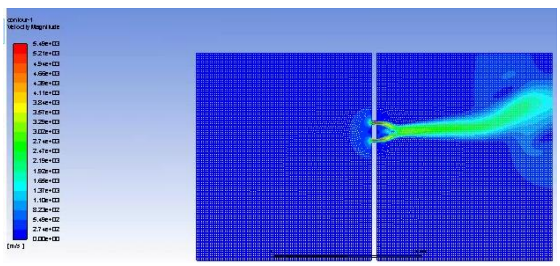
IV. THE INFLUENCE OF INTERNAL PRESSURE ON FLOW FIELD OF PIPELINE

The model of D = 2mm is selected for simulation. The constant downstream outlet pressure is 0. 1MPa, the outlet temperature is 300K, the medium is ideal gas, and the upstream inlet pressure PA is set as 0. 15Mpa, 0. 20mpa, 0. 25MPa, 0.30MPa, and 0.35MPa to study the influence of the left inner pressure on the flow field.

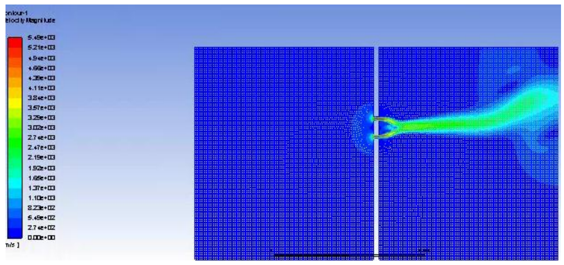
The following figure shows the comparison of the leakage flow field of the pipeline under different internal pressure when the diameter of the leakage double hole is d = 2mm



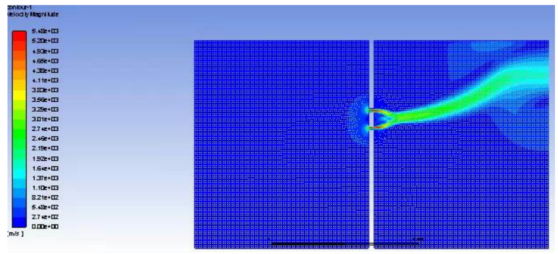
Pa=0.15Mpa



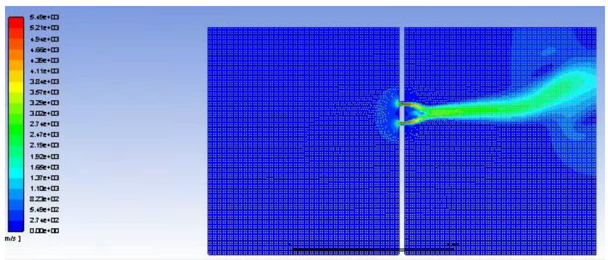
Pa=0.20Mpa



Pa=0.25Mpa



Pa=0.30Mpa



Pa=0.35Mpa

Fig. 7 gas leakage velocity under different internal pressure

It can be seen from the above figure that the change of internal pressure in the left pipe has little effect on the leakage jet velocity. With the increase of upstream pressure, the pressure difference between inside and outside the pipe increases gradually, and the velocity at the leakage pore fluctuates slightly.

The following figure shows the relationship curve between the internal pressure and the maximum leakage velocity under the condition that the diameter of double leakage holes is d = 2mm and the spacing is L = 10mm.

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 96-101
Published Online March 2021 in IJEAST (http://www.ijeast.com)

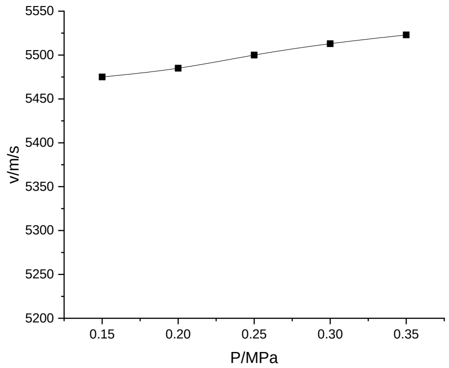
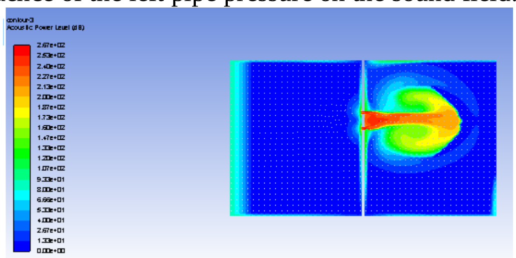


Fig. 8 relationship between internal pressure and gas leakage rate

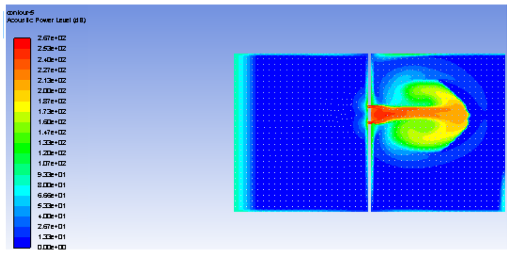
It can be seen from the figure that the maximum leakage velocity fluctuates little with the increase of pressure. It can be seen that the pressure inside the pipeline has little effect on the maximum leakage velocity at the leakage hole. Acoustic field and ultrasonic frequency under different internal pressure

Choosing d = 2mm, the field and power spectral density are simulated under different pipe pressure, and the downstream outlet pressure is constant at 0.

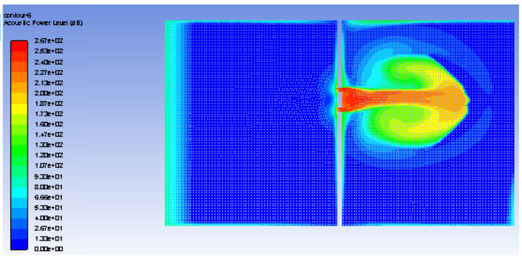
The medium is ideal gas, the upstream pressure is 0.15Mpa, 0.20MPa, 0.25MPa, 0.30mpa, 0. 35Mpa respectively, to study the influence of the left pipe pressure on the sound field.



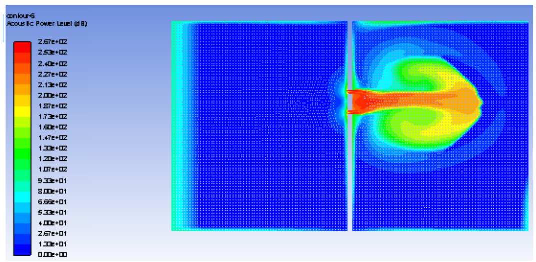
P=0.15MPa



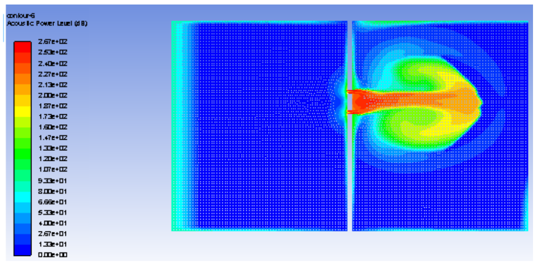
P=0.016MPa



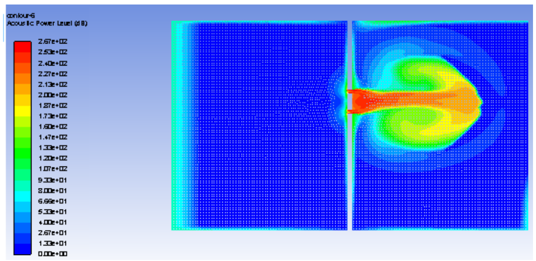
P=0.017MPa



P=0.018MPa



P=0.019MPa



P=0.020MPa

Fig. 12 The influence of internal pressure on flow field of pipeline

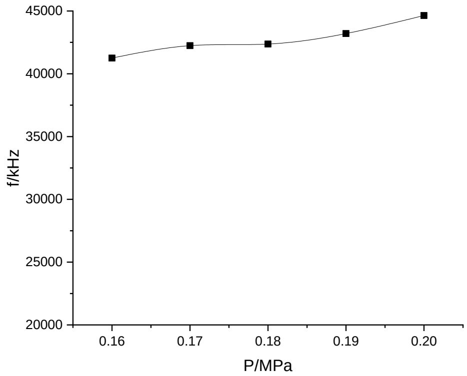


Fig. 13 relationship between internal pressure and center frequency

V. CONCLUSION

In this paper, ANSYS fluent is used to simulate the pipeline leakage, and the effects of internal pressure, leakage aperture and hole spacing on the leakage sound field, flow field and leakage velocity are simulated. The main achievements are as follows:

(1) The two-dimensional model of the pipeline is built by using ANSYS Workbench. The boundary type set on the left side is inlet, and the boundary type set on the right side is outlet. The diameter of the leakage hole is 4mm × 1mm.

(2) In the case of single hole, the change of gas leakage velocity at different pore sizes of 1 mm, 2 mm, 3 mm, 4 mm and 5 mm, and the gas leakage velocity at different pipeline pressures (0.15MPa, 0.20MPa, 0.25MPa, 0.30MPa, 0.35MPa and 0.40MPa).

(3) In the case of two holes, the leakage gas velocity and the center frequency of the ultrasonic signal generated by different gap spacing and different internal pressure.

VI. ACKNOWLEDGMENT

This work is supported by National College Students' innovation and Entrepreneurship Project (No. 201910615010).

VII. REFERENCES

[1] B. Zhou, V. Lau, and X. Wang, “Machine-Learning-Based Leakage-Event Identification for Smart Water Supply Systems,” *IEEE Internet Things J.*, vol. 7, no. 3, pp. 2277–2292, 2020, doi: 10.1109/JIOT.2019.2958920.

[2] Y. Li and C. Liu, “Advances in leak detection and location based on acoustic wave for gas pipelines,” *Chinese Sci. Bull.*, vol. 62, no. 7, pp. 650–658, 2017, doi: 10.1360/N972015-01452.

[3] M. A. Adegboye, W. K. Fung, and A. Karnik, “Recent advances in pipeline monitoring and oil leakage detection technologies: Principles and approaches,” *Sensors*, vol. 19, no. 11, 2019, doi: 10.3390/s19112548.

[4] P. Lopes, T. Azevedo-perdicoúlis, G. Jank, J. A. Ramos, and J. L. M. De Carvalho, “Leakage detection and location in gas pipelines through an LPV identification approach,” *Commun. Nonlinear Sci. Numer. Simul.*, vol. 16, no. 12, pp. 4657–4665, 2011, doi: 10.1016/j.cnsns.2011.03.029.

[5] W.-W. Lin, “The Feasibility Study of a Leak Detection System for an Underwater Pipeline.pdf,” in *Celebrating the Past ... Teaming Toward the Future (IEEE Cat. No.03CH37492)*, 2003, pp. 2100–2104.

[6] S. Li, Y. Wen, P. Li, J. Yang, and L. Yang, “Leak detection and location for gas pipelines using acoustic emission sensors,” in *IEEE International Ultrasonics Symposium, IUS*, 2012, pp. 957–960, doi: 10.1109/ULTSYM.2012.0239.

[7] Q. Xu, L. Zhang, and W. Liang, “Acoustic detection technology for gas pipeline leakage,” *Process Saf. Environ. Prot.*, vol. 91, no. 4, pp. 253–261, 2013, doi: 10.1016/j.psep.2012.05.012.

[8] Y. Zhong, Y. Xu, X. Wang, T. Jia, G. Xia, and A. Ma, “Pipeline leakage detection for district heating systems using multisource data in mid- and high-latitude regions,” *ISPRS J. Photogramm. Remote Sens.*, vol. 151, no. February, pp. 207–222, 2019, doi: 10.1016/j.isprsjprs.2019.02.021.

[9] A. Benkherouf and A. Y. Allidina, “Leak detection and location in gas pipelines,” *Control Theory Appl. IEE Proc.*, vol. 135, no. 2, pp. 142–148, 1988.

[10] A. Keramat, X. Wang, M. Louati, and E. Al, “Objective functions for transient based pipeline leakage detection in a noisy environment least square and matched filter,” *J. Water Resour. Plan. Manag.*, vol. 145, no. 10, pp. 1–13, 2019.

[11] D. Zaman, M. K. Tiwari, A. K. Gupta, and D. Sen, “A review of leakage detection strategies for pressurised pipeline in steady-state,” *Eng. Fail. Anal.*, vol. 109, no. October 2019, p. 104264, 2020, doi: 10.1016/j.engfailanal.2019.104264.

[12] H. Jin, L. Zhang, W. Liang, and Q. Ding, “Integrated leakage detection and localization model for gas pipelines based on the acoustic wave method,” *J. Loss Prev. Process Ind.*, vol. 27, pp. 74–88, 2014, doi: 10.1016/j.jlp.2013.11.006.