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Inspection Robots Future Directions

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Abstract
Future inspection robots are trending toward fully autonomous, AI-driven systems that combine multi-modal sensors (visual, thermal, acoustic) with swarm intelligence for efficient infrastructure monitoring. Key directions include enhanced 5G connectivity for real-time analysis, digital twinning for predictive maintenance, and increased miniaturization to access constrained industrial spaces.

Keywords: *Future Directions, Pipeline, Inspection Robot, Leakages, Problems, Solutions.*

I. INTRODUCTION

Pipelines are now the most widely used method of transport for gases and liquids [1–3]. Therefore, ongoing pipeline monitoring is necessary to assure its safety and health [4] Non-Destructive Testing (NDT) inspection techniques that are widely used includes optical testing, radiographic testing, ultrasonic testing, hydrostatic testing, among others [5]. However, because of the recent advancements in robotic technology [6, 7], which is being brought about by industry 4.0 they are now the preferable choice. Robots are a superior choice because it is challenging for people to access a small pipeline [8]. Recent years have witnessed significant advancements in In-pipe Inspection Robots (IPIR), with innovations categorised into distinct locomotion patterns. In the references listed below are examples of the Pipeline Inspection Gauge (PIG) [9, 10], screw [11, 12], inchworm [13–19], wall press [20–24], walking [25–29], caterpillar [30–34], and wheel type [35–50]. These popular forms of movement have drawbacks in addition to their benefits [40].

1.1.In-pipe Inspection Robot Types (IPIR)

The Pipeline Inspection Gauge (PIG) type can be utilised for large distances [51–55] and moves inside pipelines using water pressure. The inside surface of the pipelines is not harmed by the screw-helical type's motion when it moves [56–60]. The inchworm may pass through pipelines because of its strong grasp despite its poor traction [13–17]. Using contact force, the wall press type steadily passes through the pipelines [20–24]. The walking kind employs legs to move and has a complex mechanism, which causes reduced surface wear and slippage [25–29]. Caterpillars move inside pipelines using tracked wheels, and its system enables them to adjust to the circumstances there [30–34]. The wheel type is more mobile than the other varieties and can travel inside pipelines by simply rotating its wheels [35, 36, 43–45]. Due to the pipeline's curved and branching pipes, these robots must overcome numerous obstacles. It encounters motion singularity and erratic motion while doing this [46–50, 37].

1.2.Motion Singularity

The "Motion Singularity" is the loss of contact or traction between a robot and pipeline intersections such curved pipes, L-branch pipes, and T-branch pipes [41, 42]. Due to its powerful traction force and substantial contact area, the caterpillar robot offers more stability and is the most widely used IPIR. The pipeline is kept in contact with the inner surface no matter how the pipeline is turning by using tracked wheels [30, 34, 41]. If one of the wheels loses contact with the inner surface of the pipe, it is unable to pass through it, leading to motion singularity [41]. A caterpillar robot that is travelling through

T-branch pipes uses two modules in place of one to prevent motion singularity. Three caterpillar wheels are mounted on the first module at a 120° angle to one another, and the second module is infix at a 60° angle to the front module [41]. The "Famper" pipeline exploration robot loses contact with the inner surface of the pipeline when turning at Y and T-branch pipes, which results in motion singularity. The caterpillar wheels were positioned at a 5-degree inclination with regard to the robot body rather than set straight to compensate for the loss of contact. "Motion singularity" is thereby avoided [42]. A two-wheel chain robot that avoids the motion singularity is shown in [61].

1.3.Irregular Motion

According to published research, conventional wheeled robots frequently employ wheels that are symmetrically positioned at a 120° angle to ensure even loading and improved stability while moving through pipelines. The wheeled robots achieve this stability through the wall press feature [30, 41], [62–64]. According to Li et al. [36, 43], the addition of six wheels corrects the uneven motion that happens along the circumferential axis of the pipeline in forward motion produced by the three-wheel arrangement in wheeled IPIR. The wheeled robot has a three-wheel layout and moves inside the pipelines using two different types of wheels. When moving forward, the robot's single three-wheel design tries to rotate in the pipeline's circumferential direction [65]. Only straight pipelines have been the subject of investigations about their motion. The orientation of the robot at the completing end is different from the starting end in circumstances [66] where it tries to roll over in order to maneuver through the curved pipeline. Additionally, steering inside branching pipes is challenging due to how the wheels are positioned. This study focuses on the development of a wheeled IPIR with a single three-wheel arrangement to prevent the motion singularity and the irregular motion while maintaining same orientation before and after entering the curved pipeline [67]. Contribution In this research article, a wheeled type of IPIR was proposed and developed to address the issue of irregular movement and motion singularity in pipelines. The wheels on this robot are different from those on conventional robots in that they are not fixed at a 120- degree angle from one another. The placement of the wheels ensures that they remain in constant touch with the pipe surface and prevents the robot from rolling over while travelling down a curved pipeline. It also aids the robot's navigation through branched pipes [67].

II. PIPELINE INSPECTION ROBOT-RELATED PROBLEMS EXPERIENCED BY CLIENTS

1. Are Pipeline Inspection Robot Maintenance Procedures Users-Friendly?

The ease of maintenance procedures worries the pipe inspection robot. The maintenance times will climb in tandem with a linear increase in the frequency of robot operation. Consumers are worried about how simple these steps will be to execute; after all, they don't have unlimited time or energy to devote to the complete upkeep of inspection robots.

2. Key Factors that Affect the Service Life of Pipeline Inspection Robots

A number of variables affecting the service life of pipeline inspection robots are included in the problem that has customers upset. Customers place a high value on a robot's ability to maintain a stable running status and consider longer service life to be essential. Customers do not investigate short-running time inspection robots, which can easily lower their cost-effectiveness and raise the price they pay.

3. Essential Factors to Consider during Pipeline Inspection Robots Operations

Customers may lead a dependable pipe crawler robot to penetrate pipelines deeply and quickly finish the work of detecting various pipes, streamlining the operation processes in the process. The several issues that need to be taken into consideration throughout the operating stage are the subject of the customer's question. The corresponding links need to be made clear sense they are concerned that incorrect operation will interfere with the robot's ability to function [70].

III. CRITICAL FACTORS FOR EFFECTIVE PIPELINE INSPECTION ROBOTS IN OPERATIONS AND MAINTENANCE

1. Extreme security: Enter the pipeline using the pipeline robot to quickly assess its interior conditions and/or remove any potential hazards. Because of the high labor intensity and greater safety risks associated with manual labor; these jobs are not good for employees' health. The Easy Sight pipeline robot's intelligent operation may significantly enhance the operation's performance in terms of safety.
2. Labor-saving: Small and lightweight, the pipe inspection robot can be controlled by one person. The controller can be put on the vehicle, which will save time and room.
3. Improved effectiveness and caliber: In addition to accurate positioning, the Easy Sight smart pipeline robot can display real-time data such as date and time, crawler inclination (pipeline slope), air pressure, crawling distance (meters of line), laser measurement results, and azimuth (optional). The function keys allow you to control the lens angle of view clock display as well as the display status of this information (positioning of pipeline defects).
4. Great level of protection: There is no need to be concerned about the quality of the pipe camera because it has a high level of protection, airtight protection, and the material is waterproof, anti-rust, and corrosion resistant.
5. Receiving and releasing cables won't interfere with one another with a high-precision cable reel, and the length is configurable. The pipe inspection robot can inspect pipelines with diameters ranging from 100 mm to 2000 mm. It can raise productivity and save labor in addition to enhancing task precision. Additionally, it can maintain the pipeline in some locations where manual labor is not appropriate and quickly identify the internal sources of pipeline degradation [68].

III. KEY FUTURE DIRECTIONS AND TECHNOLOGIES

i) **AI-Driven Autonomy:** Integration of artificial intelligence and machine learning allows robots to navigate complex environments, perform real-time data analysis, and make autonomous decisions, reducing reliance on manual control.

ii) **Collaborative & Swarm Robotics:** Future systems will leverage multiple robots working together, including the combined use of ground-based units and aerial drones for comprehensive site inspection.

iii) **Advanced Sensor Fusion:** Combining technologies like LiDAR, advanced cameras, and acoustic sensors to improve defect detection accuracy and environmental mapping.

iv) **Digital Twins & Cloud Integration:** Robots will feed data into digital twin models for instant, virtual representations of infrastructure, enabling enhanced predictive maintenance.

v) **Increased Autonomy in Hazardous Areas:** Enhanced capabilities for specialized environments like oil, gas, and power grid inspection to replace humans in dangerous locations.

vi) **Lightweight & Energy-Efficient Design:** Developing smaller, more robust, and energy-efficient units to increase operational uptime.

IV. CONCLUSION

The proposed wheeled type IPIR and the current wheeled type IPIR are compared in this paper. The three wheels are positioned 120 degrees apart in the current configuration. Both the suggested and conventional wheeled forms of IPIR are replicated. The most effective angles are 120°, 135.12°, and 104.88°. Each wheel's force and velocity study findings demonstrate how this design results in the wheels colliding with the pipelines. The created robot did not experience the unequal force encountered by the robot with a wheel mounting angle of 120° when traveling the curved pipeline [67]. Additionally discussed are the consequences of the in-pipe wheel robots [69,71].

REFERENCES

1. Baballe MA, Magashi UY, Garko BI, Umar AA, Magaji YR, Surajo M. Automatic gas leakage monitoring system using MQ–5 sensor. Review of Computer Engineering Research. 2021 Dec 6;8(2):64–75.
2. Baballe MA, Bello MI. A comparative study on gas alarm detection system. Global J Res Eng Comput Sci. 2022;2(1):6–12.
3. Baballe MA, Bello MI. Gas Leakage Detection System with Alarming System. Review of Computer Engineering Research. 2022 May 6;9(1):30–43.
4. Adegboye MA, Fung WK, Karnik A. Recent advances in pipeline monitoring and oil leakage detection technologies: Principles and approaches. Sensors. 2019 Jun 4;19(11):2548.
5. Carvalho AA, Rebello JM, Souza MP, Sagrilo LV, Soares SD. Reliability of non–destructive test techniques in the inspection of pipelines used in the oil industry. International journal of pressure vessels and piping. 2008 Nov 1;85(11):745–51.
6. M.B. Ahmad, A.S. Muhammad, "A general review on advancement in the robotic system. Artificial & Computational Intelligence.2020 1(2): 1–7. http://acors.org/ijacoi/vol1_issue2_04.pdf,
7. Cavas M, Ahmad MB. A Review on Spider Robotic System. International Journal of New Computer Architectures and Their Applications. 2019 Jan 1;9(1):19–25.
8. Kakogawa A, Ma S. Robotic Search and Rescue through In–Pipe Movement. InUnmanned Robotic Systems and Applications 2019 Aug 12 (p. 1). Intech Open.
9. Chen Z, Qiu X, Yang L. Deformation and stress analysis of cup on pipeline inspection gauge based on reverse measurement. Energy Science & Engineering. 2022 Jul;10(7):2509–26.
10. Zhang H, Gao MQ, Tang B, Cui C, Xu XF. Dynamic characteristics of the pipeline inspection gauge under girth weld excitation in submarine pipeline. Petroleum Science. 2022 Apr 1;19(2):774–88.
11. Tu Q, Liu Q, Ren T, Li Y. Obstacle crossing and traction performance of active and passive screw pipeline robots. Journal of Mechanical Science and Technology. 2019 May;33(5):2417–27.
12. Tourajizadeh H, Rezaei M. Design and control of a steerable screw in–pipe inspection robot. In2016 4th International Conference on Robotics and Mechatronics (ICROM) 2016 Oct 26 (pp. 98–104). IEEE.
13. Yamamoto T, Sakama S, Kamimura A. Pneumatic duplex–chambered inchworm mechanism for narrow pipes driven by only two air supply lines. IEEE Robotics and Automation Letters. 2020 Jun 19;5(4):5034–42.
14. Kusunose K, Akagi T, Dohta S, Kobayashi W, Shinohara T, Hane Y, Hayashi K, Aliff M. Development of inchworm type pipe inspection robot using extension type flexible pneumatic actuators. International Journal of Automotive and Mechanical Engineering. 2020 Aug 6;17(2):8019–28.
15. Hayashi K, Akagi T, Dohta S, Kobayashi W, Shinohara T, Kusunose K, Aliff M. Improvement of pipe holding mechanism and inchworm type flexible pipe inspection robot. International Journal of Mechanical Engineering and Robotics Research. 2020 Jun;9(6):894–9.
16. Fang D, Shang J, Luo Z, Lv P, Wu G. Development of a novel self–locking mechanism for continuous propulsion inchworm in–pipe robot. Advances in Mechanical Engineering. 2018 Jan;10(1):1687814017749402.

17. Khan MB, Chuthong T, Do CD, Thor M, Billeschou P, Larsen JC, Manoonpong P. icrawl: An inchworm–inspired crawling robot. IEEE Access. 2020 Nov 4; 8:200655–68.
18. Aliff M, Imran M, Izwan S, Ismail M, Samsiah N, Akagi T, Dohta S, Tian W, Shimooka S, Athif A. Development of Pipe Inspection Robot using Soft Actuators, Microcontroller and LabVIEW. International Journal of Advanced Computer Science and Applications. 2022;13(3).
19. Yang J, Xue Y, Shang J, Luo Z. Research on a new bilateral self–locking mechanism for an inchworm micro in–pipe robot with large traction. International Journal of Advanced Robotic Systems. 2014 Oct 28;11(10):174.
20. Guanhua FE, Wenhao LI, Zhang H, Zhigang LI, Zhen HE. Development of a wheeled and wall– pressing type in–pipe robot for water pipelines cleaning and its traveling capability. Mechanics. 2020 Apr 20;26(2):134–45.
21. Brown L, Carrasco J, Watson S, Lennox B. Elbow detection in pipes for autonomous navigation of inspection robots. Journal of Intelligent & Robotic Systems. 2019 Aug;95(2):527–41.
22. Brown L, Carrasco J, Watson S. Autonomous elbow controller for differential drive in–pipe robots. Robotics. 2021 Feb 2;10(1):28.
23. Wahed MA, Arshad MR. Wall–press type pipe inspection robot. In2017 IEEE 2nd International Conference on Automatic Control and Intelligent Systems (I2CACIS) 2017 Oct 21 (pp. 185–190). IEEE.
24. Jang H, Kim TY, Lee YC, Song YH, Choi HR. Autonomous Navigation of in–Pipe Inspection Robot Using Contact Sensor Modules. IEEE/ASME Transactions on Mechatronics. 2022 Apr 19.
25. Savin S, Jatsun S, Vorochaeva L. State observer design for a walking in–pipe robot. InMATEC Web of Conferences 2018 (Vol. 161, p. 03012). EDP Sciences.
26. Savin S. RRT–based Motion Planning for In–pipe Walking Robots. In2018 Dynamics of Systems, Mechanisms and Machines (Dynamics) 2018 Nov 13 (pp. 1–6). IEEE.
27. Jackson-Mills GH, Shead BA, Collett JR, Mphake M, Fry N, Barber AR, Boyle JH, Richardson RC, Jackson AE, Whitehead S. Non–assembly Walking Mechanism for Robotic In–Pipe Inspection. InClimbing and Walking Robots Conference 2021 Aug 30 (pp. 117–128). Springer, Cham.
28. Savin S, Vorochaeva L. Footstep planning for a six–legged in–pipe robot moving in spatially curved pipes. In2017 International Siberian Conference on Control and Communications (SIBCON) 2017 Jun 29 (pp. 1–6). IEEE.
29. Zagler A, Pfeiffer F. "MORITZ" a pipe crawler for tube junctions. In2003 IEEE international conference on robotics and automation (Cat. No. 03CH37422) 2003 Sep 14 (Vol. 3, pp. 2954– 2959). IEEE.
30. Zhao W, Zhang L, Kim J. Design and analysis of independently adjustable large in–pipe robot for long–distance pipeline. Applied Sciences. 2020 Jan;10(10):3637.
31. Wu Z, Wu Y, He S, Xiao X. Hierarchical fuzzy control based on spatial posture for a support– tracked type in–pipe robot. Transactions of the Canadian Society for Mechanical Engineering. 2019 Jun 24;44(1):133–47.
32. Ciszewski M, Buratowski T, Giergiel M. Modeling, simulation and control of a pipe inspection mobile robot with an active adaptation system. IFAC–PapersOnLine. 2018 Jan 1;51(22):132–7.
33. Abidin AS, Chie SC, Zaini MH, Pauzi MF, Sadini MM, Mohamaddan S, Jamali A, Muslimen R, Ashari MF, Jamaludin MS. Development of in–pipe robot D300: Cornering mechanism. In MATEC Web of Conferences 2017 (Vol. 87, p. 02029). EDP Sciences.
34. Consumi V, Merlin J, Lindenroth L, Stoyanov D, Stilli A. A Novel Soft Shape–shifting Robot with Track–based Locomotion for in–pipe Inspection. arXiv preprint arXiv:2202.10840. 2022 Feb 22.
35. Hadi A, Hassani A, Alipour K, Askari Moghadam R, Pourakbarian Niaz P. Developing an adaptable pipe inspection robot using shape memory alloy actuators. Journal of Intelligent Material Systems and Structures. 2020 Mar;31(4):632–47.
36. Li H, Li R, Zhang J, Zhang P. Development of a pipeline inspection robot for the standard oil pipeline of China national petroleum corporation. Applied Sciences. 2020 Apr 20;10(8):2853.
37. Zheng D, Tan H, Zhou F. A design of endoscopic imaging system for hyper long pipeline based on wheeled pipe robot. In AIP Conference Proceedings 2017 Mar 13 (Vol. 1820, No. 1, p. 060001). AIP Publishing LLC.
38. Islas–García E, Ceccarelli M, Tapia–Herrera R, Torres–SanMiguel CR. Pipeline inspection tests using a biomimetic robot. biomimetics. 2021 Mar 9;6(1):17.
39. Roussialian M, Al Zanbarakji H, Khawand A, Rahal A, Owayjan M. Design and development of a pipeline inspection robot. InMechanism, Machine, Robotics and Mechatronics Sciences 2019 (pp. 43–52). Springer, Cham.
40. Elankavi RS, Dinakaran D, Jose J. Developments in in pipe inspection robot: A review. J. Mech. Cont. Math. Sci. 2020; 15:238–48.
41. Kwon YS, Yi BJ. Design and motion planning of a two–module collaborative indoor pipeline inspection robot. IEEE Transactions on Robotics. 2012 Jan 31;28(3):681–96.
42. Kim JH, Sharma G, Iyengar SS. FAMPER: A fully autonomous mobile robot for pipeline exploration. In2010 IEEE International Conference on Industrial Technology 2010 Mar 14 (pp. 517–523). IEEE.
43. Kazeminasab S, Banks MK. A localization and navigation method for an in–pipe robot in water distribution system through wireless control towards long–distance inspection. IEEE Access. 2021 Aug 24; 9:117496–511.
44. Elankavi RS, Dinakaran D, Doss AS, Chetty RK, Ramya MM. Design and Motion Planning of a Wheeled Type Pipeline Inspection Robot. Journal of Robotics and Control (JRC). 2022 Jul 1;3(4):415–30.

45. Atsushi K, Yuki K, Shugen M. Shadow–Based Operation Assistant for a Pipeline–Inspection Robot Using a Variance Value of the Image Histogram. Journal of Robotics and Mechatronics. 2019 Dec 1;31(6):772–80.
46. Zhao W, Kamezaki M, Yoshida K, Yamaguchi K, Konno M, Onuki A, Sugano S. A coordinated wheeled gas pipeline robot chain system based on visible light relay communication and illuminance assessment. Sensors. 2019 May 20;19(10):2322.
47. Yeh TJ, Weng TH. Analysis and Control of an in–Pipe Wheeled Robot with Spiral Moving Capability. Journal of Autonomous Vehicles and Systems. 2021 Jan 1;1(1):011002.
48. Yan F, Gao H, Zhang L, Han Y. Design and motion analysis of multi–motion mode pipeline robot. In Journal of Physics: Conference Series 2022 Apr 1 (Vol. 2246, No. 1, p. 012029). IOP Publishing.
49. Bandala AA, Maningo JM, Fernando AH, Vicerra RR, Antonio MA, Diaz JA, Ligeralde M, Mascardo PA. Control and mechanical design of a multi–diameter tri–legged in–pipe traversing robot. In2019 IEEE/SICE International Symposium on System Integration (SII) 2019 Jan 14 (pp. 740–745). IEEE.
50. M. Tanaka, K. Tanaka, and F. Matsuno. Control of an articulated wheeled mobile robot in pipes. Advance Robotics. 3(20). 2019. doi: 10.1080/01691864.2019.1666737.
51. Zhou J, Deng T, Peng J, Liang G, Zhou X, Gong J. Experimental study on pressure pulses in long–distance gas pipeline during the pigging process. Science progress. 2020 Mar;103(1):0036850419884452.
52. Zhang H, Dong J, Cui C, Liu S. Stress and strain analysis of spherical sealing cups of fluid-driven pipeline robot in dented oil and gas pipeline. Engineering Failure Analysis. 2020 Jan 1; 108:104294.
53. C. Liu, Y. Wei, Y. Cao, S. Zhang, and Y. Sun, “Traveling ability of pipeline inspection gauge (PIG) in elbow under different friction coefficients by 3D FEM,” J. Nat. Gas Sci. Eng., vol. 75, no. December 2019, p. 103134, 2020, doi: 10.1016/j.jngse.2019.103134.
54. Jiang J, Zhang H, Ji B, Yi F, Yan F, Liu X. Numerical investigation on sealing performance of drainage pipeline inspection gauge crossing pipeline elbows. Energy Science & Engineering. 2021 Oct;9(10):1858–71.
55. Dong J, Liu S, Zhang H, Xiao H. Experiment and simulation of a controllable multi–airbag sealing disc of pipeline inspection gauges (PIGs). International Journal of Pressure Vessels and Piping. 2021 Aug 1; 192:104422.
56. Ren T, Zhang Y, Li Y, Chen Y, Liu Q. Driving mechanisms, motion, and mechanics of screw drive in–pipe robots: a review. Applied Sciences. 2019 Jun 20;9(12):2514.
57. Tourajizadeh H, Boomeri V, Rezaei M, Sedigh A. Dynamic Optimization of a Steerable Screw In– pipe Inspection Robot Using HJB and Turbine Installation. Robotica. 2020 Nov;38(11):2001–22.
58. Li T, Liu K, Liu H, Cui X, Li B, Wang Y. Rapid design of a screw drive in–pipe robot based on parameterized simulation technology. Simulation. 2019 Jul;95(7):659–70.
59. Tourajizadeh H, Rezaei M, Sedigh AH. Optimal control of screw in–pipe inspection robot with controllable pitch rate. Journal of Intelligent & Robotic Systems. 2018 Jun;90(3):269–86.
60. Li P, Tang M, Lyu C, Fang M, Duan X, Liu Y. Design and analysis of a novel active screw–drive pipe robot. Advances in Mechanical Engineering. 2018 Oct;10(10):1687814018801384.
61. Kwon YS, Lee B, Whang IC, Kim WK, Yi BJ. A flat pipeline inspection robot with two wheel chains. In2011 IEEE International Conference on Robotics and Automation 2011 May 9 (pp. 5141–5146). IEEE.
62. Mohd Aras MS, Md Zain Z, Kamaruzaman AF, Ab Rashid MZ, Ahmad A, Mohd Shah HN, Mohd Tumari MZ, Khamis A, Ab Azis F. Design and development of remotely operated pipeline inspection robot. In Proceedings of the 11th National Technical Seminar on Unmanned System Technology 2019 2021 (pp. 15–23). Springer, Singapore.
63. Zhang Y, Yan G. In–pipe inspection robot with active pipe–diameter adaptability and automatic tractive force adjusting. Mechanism and Machine Theory. 2007 Dec 1;42(12):1618–31.
64. Xu L, Zhang L, Zhao J, Kim K. Cornering algorithm for a crawler in–pipe inspection robot. Symmetry. 2020 Dec 6;12(12):2016.
65. Prasad EN, Kannan M, Azarudeen A, Karuppasamy N. Defect identification in pipe lines using pipe inspection robot. Int. J. Mech. Eng. Robot. Res. 2012 Jul; 1:20–31.
66. Chang WC, Huang YC, Chang PY. Development of a 3d pipe robot for smart sensing and inspection using 3d printing technology. Smart Science. 2017 Jul 3;5(3):123–31.
67. Elankavi RS, Dinakaran D, Doss AS, Chetty RK, Ramya MM. Design and Motion Planning of a Wheeled Type Pipeline Inspection Robot. Journal of Robotics and Control (JRC). 2022 Jul 1;3(4):415–30.
68. Easy-Sight. The Principle and Advantages of Using Robots for NDT Pipeline Inspection [Online]. Available from https://www.pipedetect.com/the–principle–and–advantages–of–using–robots–for– ndt-pipeline-inspection.html.
69. Muhammad Ahmad Baballe, Mukhtar Ibrahim Bello, Adamu Hussaini, Usman Shuaibu Musa. Pipeline Inspection Robot Monitoring System. Journal of Advancements in Robotics. 2022; 9(2): 27–36p.
70. https://www.pipedetect.com/what-are-the-problems-faced-by-customers-regarding-pipeline-inspection-robots.html.
71. Isa, A. I., Muhammad, A. B., Industry 4.0 Pipeline Inspection Robots: Challenges, Opportunities, and Innovative Solutions. Global Journal of Research in Engineering & Computer Sciences. 2024., 04(05).