Pipeline Monitoring by using Unmanned Aerial Vehicles: A Review

Sourav Pal[1] Shriya Gupta[2] Saikat Banerjee[3] Ankur Neog[4]
[1,2]Student [3]Director [4]Assistant Professor
[1,2]Department of Aerospace Engineering [4]Department of Petroleum Engineering
[1,2]University of Petroleum & Energy Studies, Dehradun-248007, India
[3]Wingbotics, Kolkata-700092, India [4]Chandigarh University, Mohali, Punjab, India

Abstract— Inspection of onshore oil and gas pipelines for gas leaks and thermal insulation is an expensive undertaking due to the costs for personnel and equipment. Conventional methods like Ultrasound, Fiber glass and Infrared Thermography are being replaced by optical imagery and satellite data from RADAR. Aerial inspection by drones enhances Photogrammetry, Spectrometric Techniques and Thermographic Techniques with lower operational cost and more flexibility. The confinement for UAV Application is the absence of dedicated regulations and specific protocols for air traffic management for UAVs. Three different scenarios are discussed to enhance the contribution of UAVs under pipeline surveillance.

Key words: Pipelines, UAVS, Aerial Inspections, Sensors, Leak Detections

I. INTRODUCTION

In today's global gas and oil market scenario, pipelines play an extremely vital role in their transportation. From the perspective of safe and secure transportation of oil and gas, inspection (leak detection, thermal insulation) of pipelines is an issue of paramount importance. Factors such as over age structure and material failure, natural ground movement and third party (accidental, incidental, intentional) interference can cause equipment failure such as breakage or leaks[1]. Improper inspection may lead to insufficient maintenance or repair job, which might result to leakages. Depletion of products in the form of gas, petroleum or basic petrochemicals imposes a serious threat to the environment. It can cause contamination of water bodies, air quality disturbance, land contamination and atmosphere damage [2].

With a specific end goal to work the pipeline foundation effectively and securely, standard inspections should be carried out requested by national law, yet additionally by the operator's advantages to decrease money related misfortunes brought about by spilling gas [3].

Conventional methods of pipeline monitoring include visual inspection and aerial inspection by planes or helicopters. Visual inspection is time consuming and can cause errors due to human involvement. In aerial inspection the cost of monitoring is very high.

The best alternative to these methods is the use of an Unmanned Aerial Vehicle, operated remotely or autonomously for inspection. Along with an array of on-board sensors, it provides real time data which can be processed in a very short span of time with reduced operational cost. In recent years the use of an UAV based aerial inspection of pipelines has increased.

II. BACKGROUND

Pipeline networks normally have branches that have different lengths, reaching hundreds or thousands of kilometers. Generally pipeline installations are situated in remote places which are difficult to access for monitoring purpose. Loss of revenue and adverse impact on the ecology can cause due to damage or attacks on such installations[4]. In such places the use of drones are efficient for its flexibility in deployment and ease of retrieving data. As stated earlier, traditional methods of pipeline includes visual inspection, aerial inspection by light aircraft and sometimes by satellite observation. Also, incorporation of various in-line sensors along the pipeline structures are used extensively. The most common methods of pipeline inspection have been stated along with their advantages and disadvantages in Table 1.

Methods	Advantages	Disadvantages
Gas indicator	High authenticity of leakage detection	Slow process. Necessary to test the air sample from prospective place of leakage
Visual inspection		This method can be applied only where the vegetation is clean looking. Authenticity depends on soil humidity and at the time of vegetation growth.
Pressure decrease	Real time	For outflow more than 1.25% to 1.5% of an pipeline flow
Bubbling	Visibility	Utilization of soapy water for show of leakage on surface
Ultrasound	Real time	The compressor motor creates ultrasound that produces false alarms.
Fiber glass	Real time	It is very difficult for buried ducts and in ducts operations
Infrared thermography	Exact localization of the leakage. High productivity	It is not real time

Table 1: Existing Approaches For Pipeline Inspection [2]

Optical images and satellite data from radar (e.g. ERS, RADARSAT-1, and ENVISAT) are used to detect oil spills in water bodies and marine environment [5]. Advancement in high resolution remote sensing and image processing technology has given the reason for outlining pipeline checking frameworks utilizing remote sensors and setting focused image processing software [6]. Satellites are

equipped with high definition cameras in both the obvious and infrared ranges, however most importantly they can carry hyperspectral or multispectral that makes it conceivable to analyze particular spectral band [1]. The advantage that this technique gives is the probability of using particular sensors, likewise of significant weight that covers vast area of investigation. In the meantime, in any case, this is a disadvantage for determination at ground level, which does not allow details to be acquired in images. As compared to satellite imagery techniques, On Board Infrared Equipment (OBIE) gives better solution with less cost. During oil leakages, the radiation factor of oil in thermal spectrum is different from its surrounding surface. Thus it is easily detected by any aircraft carrying OBIE [2].

An inspection of pipes of 800 km was carried out during 1991-1996 in western and northeast Siberia with the help of OBIE. The figure below shows the thermal defects in the pipelines over four years. The right hand side indicates defects in three months and in left its showing number of defects in four years

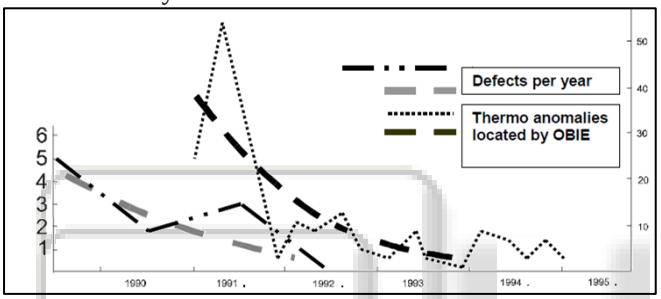

Fig. 1: Thermal Defects as Recorded by OBIE [2]

III. Application of Unmanned Aerial Systems

The use of UAVs or drones can give significant advantages as regards to both feasibility and speed of operations in inspecting oil and gas pipelines. The multiple sensors situated onboard the aircraft helps to study a wide variety of spectra. Also due to its less mass it allows to carry out lengthy scans and from the point of view of conceivable effects of flight accidents it is completely safe [7].

Pipelines extend several kilometers and in some areas it is difficult to reach for human operators for inspection purpose. To overcome this restriction drones are being used where it is operated either remotely or autonomously [8]. With basic direct visual assessments, without ensuing handling of the information gathered, the camera mounted on the drone transmits images specifically to a video terminal where an expert checks the condition of the framework being analyzed.

Nonetheless, not a wide range of UAVs are similarly appropriate as platform. Specifically the flight dynamics is an essential choice foundation. Vertical take-off and landing (VTOL) arrangements empower deployment in muddled conditions without the requirement for extra foundation and for the most part enable slower flying velocities in contrast with wing-based arrangements [7]. Additionally, additional time over a specific range can be utilized for dull estimations, which in the long run prompts higher detection rates and less false cautions [3].

One fundamental property is the size of the UAV. While bigger UAVs for the most part give more payload limit, longer mission lengths and are less affected by turbulence, their heavier weight expands dealing with intricacy and in addition the danger of harms to the pipeline and different frameworks if there should be an occurrence of unforeseen flight occasions [9].UAVs are typically categorized into fixed wing UAV and Multi-rotor UAV. Fixed wing UAVs generally have a simple structure influencing them to stable stages simple to control amid autonomous flights. Productive streamline features empowers longer flight term and higher velocities which make them suitable in applications like aerial survey of large areas by capturing geo-referenced images. On the other hand, multi-rotor UAVs have more complex structures and have less velocity and shorter flight range. The advantages of using multi-rotor platform for inspection is its vertical take-off and landing (VTOL) capability and hovering around a specific location at a particular height. This makes multi-rotor UAVs suitable in clumsy spaces where the drone can maneuver with great ease [10].

Two types of sensors to be mounted on the UAV-RGB camera i.e. a normal photo/video camera for obtaining data in visible spectrum and spectral camera which allows the analysis of particular spectra in both visible and infrared. Additionally, thermographic cameras can be used for analyzing the far infrared (IR) spectrum [1].

A. Aerial Inspection Techniques by Drones

1) Photogrammetry

Photogrammetry is a mapping technique based on the central perspective model, which makes it conceivable to acquire three dimensional metric data on the shape and position of the target to be analyzed. It is carried out on two dimensional acquired images. For photogrammetry technique, traditional RGB cameras are used as sensors or payloads [11].

2) Spectrometric Technique

The term spectrometry shows the arrangement of estimation techniques and systems did utilizing spectrometers, which are instruments that measure the electromagnetic range as a component of wavelength. Spectrometry, which makes it conceivable in our particular case to examine the infrared range, depends on the cooperation that each and every atom has with electromagnetic radiation: when radiation strikes a substance or material, some portion of it can go through it, another part is consumed by the substance, and part of it is reflected. Spectrometry is a passive technique since the instruments/sensors associated with it receive the radiation, not emit it. A spectral camera is used as a payload in the UAV to monitor the pipelines [11].

3) Thermographic Technique

The utilization of a thermographic camera helps to analyze the pattern of far infrared spectrum and along these lines the pattern of the surface temperatures of the bodies being analyzed. Also it permits to identify hydrocarbon gases that interact with infrared spectrum, which in this case are methane, LPG and gas vapours [11].

IV. Oil & Gas Pipelines Monitoring Scenarios

Three monitoring scenarios have been proposed where UAVs can contribute and provide necessary support to the whole monitoring framework [10].

A. Scenario1: Proximity survey/visual identification of pipe damage

In this scenario, for examining proximate pipelines, a small light weight UAV is required for short distance flights to get detailed data in difficult positions.

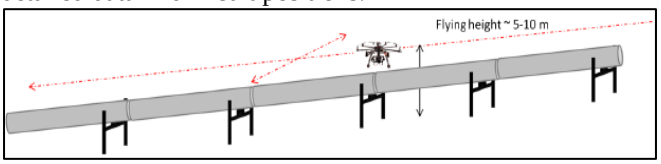

Fig. 2. Proximity Survey for identification of structure condition [10]

B. Scenario 2: Short Distance Survey/Visual Identification of Leak

For short distance visual detection of leak, an UAV with service ceiling of 100 m is appropriate. This situation speaks to a periodic checking and will profit by autonomous flying plan dictated by number of waypoints. Fixed wing UAVs are best suited for this role.

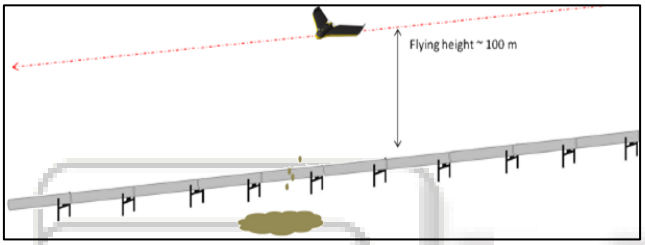

Fig. 3: Short Distance Survey for Detection & Monitoring of Leak [10]

C. Scenario 3: Long Distance Survey/Automatic Sensing of Soil Properties

In monitoring long pipelines spanning several kilometers, periodical surveillance is required to detect any malfunctions. For this a large UAV is required, powered by engine or motor. Here, the UAV is operated above 100-150 m and a radar (SAR) should be mounted accompanied by optical/IR sensors.

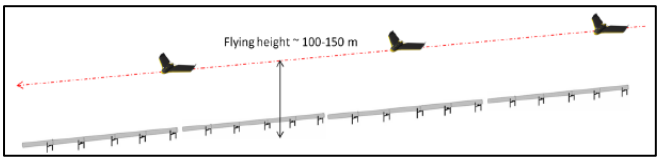

Fig. 4: Long Distance Survey with Automatic Sensing of Soil Properties [10]

V. Advantages & Limitations of UAVs for Pipeline Monitoring

Preferences of UAVs over other means of inspection incorporate a lower cost, higher operational safety and high mission adaptability. Ground and manned aerial survey are more costly, being manned aerial survey also less secure and flexible. Climatological factors like winds, mist, clouds limit the use of conventional manned platforms [12]. The only limitation it faces is the requirement of dedicated regulations to operate the UAVs and specific air traffic management procedures.

VI. Conclusion

The overall system of oil and gas transmission pipelines makes up a gigantic framework for safe transport of a regularly expanding volume of hydrocarbons. Pipelines are liable to weakening what's more, inevitable disappointment, and episodes and mishaps happen, also as vandalism, imperiling the security of the energy infrastructure and the environment .Oil and gas pipelines require consistent observing for upkeep, wellbeing and security. Conventional observing systems based on foot patrol and helicopter can be upheld and supplemented by UAVs, especially in remote and troublesome regions, where this innovation may give mission adaptability and cost-viability [13]. Cutting edge level of computer facilities, radio electronics, aerodynamics and materials permits to make the drone fit in a programmed mode to make long flights on substantial separations. It is expected that the quantity of UAV arrangements for pipeline monitoring will increase in the following years.

References

[1] Ramalli, G., Giovani, M., Pacchiacucchi, F. and Manneschi, M., "Pipeline Monitoring With Drones" in Studia UbbAmbientum, Italy, pp. 105-118, 2016.
[2] Sadovnychiy, S., "Unmanned Aerial Vehicle system for pipeline inspection" in Instituto Mexicano del Petroleo, Mexico, 2005.
[3] Bretschneider, T. R., Shetti, K.R., "UAV based gas pipeline leak detection" in 35th Asian Conference of Remote Sensing, Mayanmar, pp. 27-31, 2014.
[4] Sadovnychiy, S., Bulgakov, I., Subramaniam, V., "Pipeline right-of-way remote inspection system" in WSEAS Transactions on Circuits and Systems, Vol 3, pp. 805-809, 2004.
[5] Brekke, C., Solberg, A.H.S., "Oil spill detection by satellite remote sensing" in Remote Sensing Environment, Vol 95, pp. 1–13, 2005.
[6] Hausamann, D., Werner, Z., Schreier, G., Strobl, P., "Monitoring of Gas pipelines- a civil UAV application" in Aircraft Engineering and Aerospace Technology: An International Journal, Vol 77, pp. 352-360, 2005.
[7] Austin. R., "Unmanned Aircraft Systems: UAV design, development and deployment". Wiley, Chichester, 2010.
[8] Alawode, A.J., Ogunleye, I.O., "Maintenance, security, and environmental implications of pipeline damage and ruptures in the Niger Delta region" in Pacific Journal of Science and Technology, Vol 12, pp. 565–573, 2011.
[9] Mcfadyen, A., Mejias, L., "A survey of autonomous vision-based see and avoid for unmanned aircraft systems" in Progress in Aerospace Science, Vol 80, pp. 1–17, 2016.
[10] Gómez, C., Green, D.R., "Small-Scale Airborne Platforms for Oil and Gas Pipeline Monitoring and Mapping" in AICSM – UCEMM – University of Aberdeen, 2015.
[11] Everaerts, J., "The use of unmanned aerial vehicles (UAVs) for remote sensing and mapping" in The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Beijing, Vol XXXVII, 2008.

[12] Murvay, P.S., Silea, I., "A survey on gas leak detection and localization techniques", in Journal of Loss Prevention in the Process Industries, Vol 25, pp. 966-973, 2012.
[13] Hayes, B., Jones, C., Töpfer, E., Eurodrones Inc. Transnational Institute and State watch, Amsterdam, 2014

