Analysis of safety early warning technology for the myanmar-china oil and gas pipeline (myanmar section)

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Abstract. On the basis of engineering data of Myanmar-China oil and gas pipeline (Myanmar section), combined with years of pipeline operation experience, According to the characteristics of safety early warning technology at home and abroad, In this paper, a distributed optical fiber early warning system is proposed as an early warning technology for the third party damage of the pipeline and In Myanmar, UAV monitoring and early warning is proposed as a technical scheme for pipeline geological hazards and large and medium-sized crossing projects.

Key Words: Myanmar-China Oil and Gas Pipeline (Myanmar Section), Distributed Optical Fiber Early Warning System, UAV (Unmanned Aerial Vehicle), Safety early warning.

1. Introduction of the myanmar-china oil and gas pipeline (myanmar section)

The Myanmar-China crude oil pipeline (Myanmar Section) originates from Made Island on the west coast of Myanmar and enters China from Namkham through Rakhine, Magway, Mandalay and Shan States of Myanmar. The total length of the line in Myanmar is about 770.5 km, the diameter of the pipe is 813 mm, the design pressure is 8-14.5 MPa. The X70 spiral submerged arc welded steel pipe and the straight submerged arc welded steel pipe are used for the pipeline. The buried pipeline is laid and the outer wall of the pipeline is protected by three layers of PE. There are five process stations along the pipeline, including four pumping stations (Made Initial Station, Sinkontai Pump Station, Mandalay Pump Station, Hsipaw Pump Station) and one metering station (Namkham metering station). There are 31 line cut-off valve rooms along the pipeline, including 7 monitoring valve rooms, 12 check valve rooms and 12 manual valve rooms [1].

The Myanmar-China natural gas pipeline (Myanmar Section) begins at the Kyaukpyu initial station about 6.7 km southwest of the city of Kyaukpyu, Ramree Island, on the west coast of Myanmar. It is laid parallel with the crude oil pipeline at the Made initial station of Oil Pipeline through Rakhine, Magway, Mandalay and Shan States of Myanmar and enters China from Namkham. The line in Myanmar is 792.5 km in length, pipe diameter 1016 mm, designing pressure 10 MPa. X70 spiral submerged arc welded steel pipe and straight submerged arc welded steel pipe are used for pipe buried laying, three layers of PE are used for external anti-corrosion, and drag reduction inner coating is applied for inner wall. There are six process stations along the pipeline, Kyaukpyu initial station, Yenangyuang Distribution Pressure Station, Dangda Distribution Station, Mandalay Distribution Station, Maymyo
Pressure Station and Namkham Metering Station. There is no compressor unit in the first phase of the pipeline project, only the land for it is reserved. There are 28 line cut-off valve chambers along the pipeline, including 7 monitoring valve chambers and 21 common valve chambers[2].

The Myanmar-China oil and gas pipeline (Myanmar section) optical cable line lays a silicon core pipe in the same ditch with the natural gas pipeline in the ordinary section and injects a 24-core pipeline optical cable into it, Laying a 24-core directly buried water-line optical cable with natural gas pipeline in high groundwater level areas such as beach, gully and paddy field. Crude oil and natural gas pipelines share this optical cable, each accounting for 12 core optical fibers. Optical cables in the lead-in section from the trunk line to the oil transmission stations and the control valve chamber are laid separately with one silicon core pipe and one 24 core pipe cable is blown into it.

2. Current situation of pipeline safety early warning at home and abroad
Since 1990s, domestic and foreign pipeline companies have adopted traditional civil air defense measures, such as manual patrol, warning signs and telephone alarms, and often installed leak detection technology that can detect fluid characteristics changes caused by media leakage, and then alarm and locate leak detection technology. In recent years, with the third-party damage, pipeline aging and natural disasters occurring frequently, how to use new methods to give early warning and accurate positioning before pipeline leakage, so as to prevent leakage accidents in the future, is a major challenge facing pipeline safe operation. From the analysis of the factors inducing safety incidents affecting the safe operation of pipelines, pipeline safety early warning technology can be divided into two categories: one is for the early warning of third-party damage such as mechanical excavation, force attack and man-made destruction, the other is for the early warning of geological disasters such as earthquakes, landslides and debris flows[3].

The early warning technology for third-party pipeline damage mainly identifies the incidents threatening pipeline safety such as man-made damage and mechanical excavation during pipeline operation. Through remote real-time monitoring of state changes along pipelines and signal recognition, alarm and positioning can be carried out in order to timely detect and stop the occurrence of pipeline damage events. At present, there are mainly distributed optical fiber early warning technology, pipeline acoustic early warning technology, seismic geophone early warning technology, electromagnetic early warning technology and intelligent sensor protection belt early warning technology for third party damage of oil and gas pipelines at home and abroad.

Oil and gas pipelines have long distances and complex geology and geomorphology. They often pass through mountain areas, permafrost areas, fault zones and so on. Therefore, pipelines often face natural disasters such as landslides. Early warning of geological hazards in pipelines mainly monitors the deformation or activity characteristics and related factors of pipelines under the action of disasters, studies the activity law of geological hazards and the stable development trend of pipelines under the action of disasters, at the same time, establishes monitoring accounts for frequent geological hazards areas and large and medium-sized crossing projects, and provides information for pipeline protection and disaster prevention engineering investigation, design and construction[4]. At present, global positioning system, fiber Bragg grating sensing technology, rock acoustic emission detection technology and UAV detection technology are often used as early warning technology for pipeline geological hazards at home and abroad.

3. Design of distributed optical fiber early warning system for the myanmar-china oil and gas pipeline (myanmar section)
Distributed optical fiber early warning system mainly consists of three parts: light source, light source driver and protection circuit, photoelectric detection circuit. The light source is mainly used to send light wave to the sensor. The light source uses semiconductor laser diode. The generated light is simulated light wave and the frequency is the natural frequency of the light source itself. The drive and protection circuit monitors the output of the laser through a photodiode and generates control signals. The photoelectric detector can convert the phase change of the sensor into electrical signals, and then amplify
the detection signals of the two photoelectric detectors by using two preamplifiers. The system software design includes the following functions: controlling the data acquisition card to collect vibration and sound signals along the pipeline, displaying the detected signal waveform on the computer display for real-time monitoring of the signal, and processing and judge the waveform data which is stored manually or by the system[5] [6].

Crude oil and natural gas stations or monitoring valve rooms are distributed every 60 km along the Myanmar-China oil and gas pipeline (Myanmar section), At the same time, a silicon core pipe is laid along the same ditch and a 24-core pipeline optical cable is blown into it, of which 12 cores are used and 12 cores are spared. The pipeline has the hardware condition of deploying distributed optical fiber early warning system. Distributed micro-vibration sensor based on Mach-Zehnder fiber interferometer principle is constructed by using three single-mode fibers. Two of the fibers constitute the test fibers OF1 and OF2 of the optical fiber interferometer, which are used to test the vibration signals along the pipeline, and the other fibers OF3 is used to transmit the signal [7]. The continuous light wave emitted by the light source (LD) is divided from one end of the sensor into two beams of light intensity of 1:1, which propagate in two optical fibers at the same time. The interference signal is formed at the other end of the optical fiber sensor. The interference signal is transmitted to the photoelectric detector (D) by the third optical fiber. The optical signal is converted into electrical signal, and then the transmitted signal is processed by amplifying and filtering circuit and converted to the computer for further analysis and processing of signals. When the disturbance signal occurs along the pipeline, the length, diameter and refractive index of the optical fiber will change due to the effect of acoustic pressure. The vibration signal of the pipeline accessories can be obtained by measuring the phase change of the optical wave in the sensing optical fiber. Further analysis and processing of the detected vibration signals can detect leakage or endanger the safety of pipelines along the pipeline. The detection schematic diagram is shown in Figure 1.

![Figure 1. Distributed optical fiber early warning detection schematic diagram](image)

When the test cable is subjected to the vibration signal along the pipeline, the two test fibers in the cable will produce stress and strain under the external force, and the two coherent light waves propagating in the two sensor fibers will produce phase change respectively. The phase modulation of light wave produced by two sensing fibers affected by vibration signal is respectively $s_1(t)$ and $s_2(t)$. The two coherent light waves propagating along two sensing fibers are harmonic oscillations, so the modulated wave equations propagating in the fibers can be expressed as follows:

\[ y_1 = A_1 \cos[wt + s_1(t) + \varphi_1] \]  
\[ y_2 = A_2 \cos[wt + s_2(t) + \varphi_2] \]
Formula: $\gamma_1$ and $\gamma_2$ —— Field Intensity of Two Coherent Beams of Light,
$A_1$ and $A_2$ —— Optical field amplitude,
$\omega$ —— Angular Frequency of Light Wave,
$\varphi_1$ and $\varphi_2$ —— Initial Phase of Two Beams of Light.

Superimposed light field $A$:

$$A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos[\varphi_1 - \varphi_2] \quad (3)$$

Suppose that the intensities of two coherent beams of light are respectively $I_1$ and $I_2$, so $I_1 = A_1^2$, $I_2 = A_2^2$, $\Delta s(t) = s_1(t) - s_2(t)$, $\Delta \varphi = \varphi_1 - \varphi_2$.

The intensity of interference between two coherent beams of light is as follows:

$$I = I_1 + I_2 + 2\sqrt{I_1I_2} \cos[\Delta s(t) + \Delta \varphi] \quad (4)$$

Suppose $I_0$ is the total light intensity input into two sensing fibers; $\propto$ is the mixing efficiency of two coherent light waves, so:

$$I(t) = I_0[1 + \propto \cos[\Delta s(t) + \Delta \varphi]] \quad (5)$$

If only AC light intensity is considered, and the light intensity signal is converted into current signal by photoelectric detector, so the alternating current of photocurrent is:

$$i(t) = KI_0 \propto \cos[\Delta s(t) + \Delta \varphi] \quad (6)$$

Formula: $K$ —— Photoelectric conversion coefficient.

$\Delta \varphi$ is a constant(\(\pi\)/2), called DC bias. At the bias, the photoelectric current and the detection phase change slope are the largest, and the detection sensitivity is the highest. The displacement positions of the two sensing fibers are different. When the cable receives external force, the stress and strain are different, and the phase changes of two coherent light beams in the two sensing fibers are also different, so $\Delta s(t)$ is a variable. In practice, the micro-vibration signal along the distributed optical fiber sensor can be detected only by real-time detection of the change of interferometric optical signal, so that the events leading to pipeline vibration along the pipeline can be monitored in real time. The system locates events along pipelines through two distributed sensors based on Mach-Zehnder fiber optic interferometer. The two sensors share optical fiber OF1 and OF2 to ensure that the two locating optical paths are subject to the same effect. The location formula is as follows [8]:

$$x = \frac{L-v(t_1-t_2-L)}{2} \quad (7)$$

Formula: $t_1t_2$ —— the time when two detectors detected the same event,
$x$ —— the position of Optical Cable Subjected to External Action,
$v$ —— the propagation Velocity of Light Wave in Optical Fiber, m/s,
$L$——the speed of Light Propagation in Vacuum(\(3\times10^8\)m/s),
$n$——the refractive Index of Optical Fiber.

4. Monitoring and early warning technology of unmanned aerial vehicle for myanmar-china oil and gas pipeline (myanmar section)

In recent years, with the development of UAV technology, UAV is widely used in pipeline monitoring abroad (Unmanned aerial vehicle (UAV) applications are limited to varying degrees according to the air
traffic control of each country.). UAV has the ability of high altitude, fast and long-distance operation. It can traverse complex terrain such as trench, beach, river and mountainous area. It can track, locate, monitor and transmit views to pipeline lines and surrounding environment. It has fast patrol inspection, timely information feedback and high monitoring efficiency. Professional analysis of data acquired by aerial photography provides basic data support for pipeline disaster monitoring and pipeline maintenance management.

The large and medium-sized crossing projects of Myanmar-China oil and gas pipeline (Myanmar Section) are as follows: 8 large-scale crossings, 9 medium-sized crossings, 2 medium-sized crossings and 2 mountain tunnels. Among them: Karaba Trench, Yexuchun Trench, 1 #~6 trench, Ayeyarwady River are crossed by directional drilling; Mitange River is crossed by truss; other rivers are crossed by large excavation. Geological hazard-prone areas along pipelines and key cross-region projects are shown in the following table:

### Table 1. Geological hazard-prone areas and large and medium-sized crossing projects of Myanmar-China oil and gas pipeline (Myanmar Section) (a part)

| No. | Pipeline mileage | Line description | Engineering characteristics |
|-----|-----------------|------------------|-----------------------------|
| 1   | G16.8-G18.2     | Karaba Trench Crossing | Large-scale projects |
| 2   | G22.4-G27.9     | submarine pipeline | Large-scale projects |
| 3   | G27.9-G31.7     | 1# Tidal flat | High incidence of geological disasters |
| 4   | G41.7-G42.96    | 1# Trench crossing | Large-scale projects |
| 5   | G43.12-G43.81   | 2# Trench crossing | Large-scale projects |
| 6   | G51.24-G52.09   | 3# Trench crossing | Large-scale projects |
| 7   | G52.77-G54.23   | Yexuchun Trench crossing | Large-scale projects |
| 8   | G57.99-G58.75   | 4# Trench crossing | Large-scale projects |
| 9   | G58.7-G60.6     | 2# Tidal flat | High incidence of geological disasters |
| 10  | G60.65-G62.15   | 5# Trench crossing | Large-scale projects |
| 11  | G62.8-G63.5     | 3# Tidal flat | Large-scale projects |
| 12  | G63.54-G64.42   | 6# Trench crossing | Large-scale projects |
| 13  | G98-G99         | Daayo River crossing | Large-scale projects |
| 14  | G97-G161.3      | Rakhine Mountain Areas | High incidence of geological disasters |
| 15  | G231.93-G233.46 | Ayeyarwady River crossing | Large-scale projects |
| 16  | G472.3-G472.76  | Mitange River Stride crossing | Large-scale projects |
| 17  | G569.14-G570.17 | Nantang River Tunnel and Valley Bottom Crossing | Large-scale projects and High incidence of geological disasters |
| 18  | G790.47-G791.32 | Ruili River crossing | Large-scale projects |

Due to technical constraints, the flight time of UAVs on the market at present generally does not exceed half an hour, the maximum remote control distance does not exceed 10Km, and the maximum flight altitude is about 5Km. According to the flight characteristics of UAV and the actual situation of pipeline line, the layout of UAV release monitoring points requires pipeline line managers to carry out actual survey of the release monitoring points in combination with previous pipeline patrol experience,
and to select appropriate locations for regular monitoring of pipelines. The layout of UAV monitoring points for Myanmar-China oil and gas pipeline (Myanmar Section) is shown in the following table:

**Table 2. Layout of UAV monitoring points for Myanmar-China oil and gas pipeline (Myanmar Section) (a part)**

| No. | Take-off point 1 | Take-off point 2 | Pipeline mileage | Line Length and Key Areas |
|-----|-----------------|-----------------|-----------------|--------------------------|
| 1   | Kyaukpyu initial station | G5 | G0-G5 | 5Km, G5 Located at the intersection of highway |
| 2   | G5 | G8 | G5-G10 | 5Km, G8 Located at the intersection of highway |
| 3   | Karaba Trench | G10 | G10-G16.8 | 6.8Km, Karaba Trench |
| 4   | Karaba Jet | 1# Gas valve chamber | G16.8-G22.4 | 5.6Km Karaba Trench, Oceanic pipe entrance |
| 5   | 1# Oil valve chamber | 2# Trench Wharf | G27.9-G43.8 | 15.9Km, Oceanic pipe export, 1# trench |
| 6   | 2# Trench Wharf | 2# Gas valve chamber | G43.8-G54.2 | 10.4Km, 2#/3# Trench |
| 7   | 3# Oil valve chamber | / | G54.2-G58.7 | 4.5Km, Yexuchun Trench, 4# Trench |
| 8   | 2# Tidal flat Jet | / | G58.7-G62.1 | 3.4Km, Tidal flat, 5# Trench |
| 9   | ... | ... | ... | ... |
| 10  | G132 | G134 | G132-G136 | 4Km, Key areas G132+200, G132+300, G133+800 |
| 11  | 5# Gas valve chamber | G143 | 5# Gas valve chamber -G145 | 5Km, Key areas G141+850, G144+100, G144+300 |
| 12  | G145+800 | G147 | G145-G148+300 | 3.3Km, Key areas G145+200, G145+400, G146+900, G147 |
| 13  | Ayeyarwady River west side | Ayeyarwady River east side | G231.93-G233.46 | 1.53km Ayeyarwady River crossing |
| 14  | ... | ... | ... | ... |
| 15  | Ruili River west side | Ruili River east side | G790.47-G791.32 | 0.85km Ruili River |

The UAV flight monitoring route (part) is shown in the following figure: [9]

![Flight Monitoring Route of Unmanned Aerial Vehicle at Karaba Wharf and 1# Oil Valve Chamber](image)

**Fig 2.** Flight Monitoring Route of Unmanned Aerial Vehicle at Karaba Wharf and 1# Oil Valve Chamber

In the process of UAV flight monitoring, the operator should grasp the weather conditions and visibility of the day, and choose the open and flat ground as the UAV release point as far as possible. Line managers judge the line situation according to timely video, and judge the position...
according to GPS positioning and record. Aerial photographs of the same area should maintain the same shooting angle, height and GPS position in different periods, so as to facilitate analysis and comparison. The UAV is hovering around sensitive and high-risk sections of pipeline routes such as trench crossing, submarine pipeline, beach, large-scale hydraulic engineering, mountain slope trench bottom and cliff, water damage and geological hazards (videos and pictures). The shooting area is within the working zone of pipeline and the nearby area of 100m, and the shooting angle is the normal plane and both sides of the working zone; the pipeline line in the general area is shot directly and frontally (video). After the flight, video and image data are exported, and line managers review and screen the shooting content, and record the data.

UAV monitoring and early warning mainly identifies the risk of mechanical damage and natural and geological hazards around pipelines, prevents and controls the construction behavior threatening pipeline safety in time, and discovers the change of topography and landform in time, so as to take measures to prevent pipeline damage. UAV mainly inspects whether pipelines and optical cables are exposed or floating, inspects whether the ground markings of the three piles and warning signs are damaged or dumped, inspects the completed hydraulic protection and whether new gullies are damaged, inspects whether there is illegal pressure on the top of pipelines, inspects whether there are third-party construction operations such as channel opening, electric power, communications, sand excavation and soil extraction, etc. within 5 meters of the operation belt. No mechanical excavation, etc. At the same time, in the pipeline emergency operation, UAV can easily and quickly enter the scene to investigate the damaged location, grasp the damaged situation and secondary disasters in the surrounding environment, and transmit real-time data to the emergency command center to provide data support for pipeline maintenance and emergency repair program. After the UAV flight monitoring is completed, line managers should fill in the UAV patrol record form and save and file with the image data. The contents of the record sheet should include image data comparison of key areas, risk analysis, three piles, illegal occupancy, third-party construction and other information.

5. The conclusion and suggestion

Based on the engineering data and pipeline operation experience of Myanmar-China Oil and Gas Pipeline (Myanmar Section), combined with the characteristics of safety early warning technology, this paper puts forward the design idea of distributed optical fiber early warning system as an early warning technology for third-party pipeline damage in Myanmar-China Oil and Gas Pipeline (Myanmar Section), and puts forward UAV monitoring early warning technology as a early warning technology for pipeline geological hazards and large Scheme. The application of distributed optical fiber early warning system in Myanmar-China oil and gas pipeline (Myanmar section) is just around the corner. With the development of UAV technology, it is suggested that pipeline line managers further optimize and optimize the flight route, improve the early warning scheme and comprehensively improve the pipeline safety early warning management in the process of UAV monitoring and early warning according to the aviation management regulations of the host country.

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