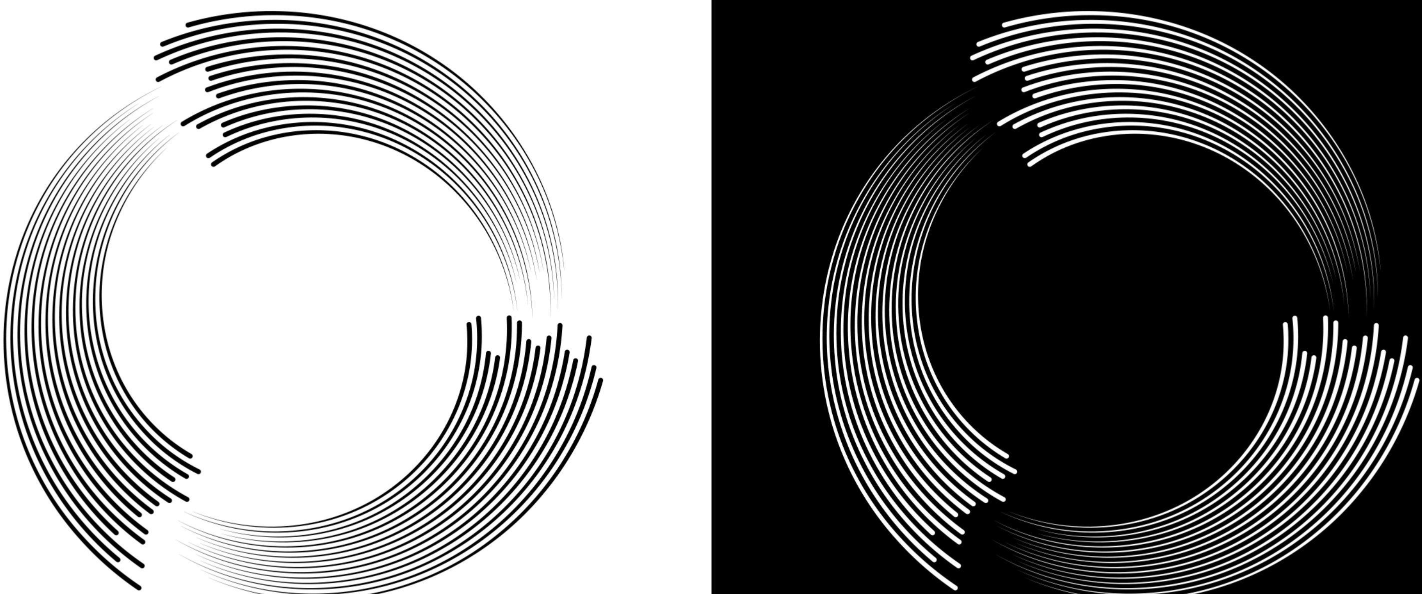
Monitoring pipeline movement



Daniel Bahrenburg and Roland Palmer-Jones, ROSEN, UK, explore new tools for managing pipeline integrity in areas affected by landslides.

The recent atmospheric river events in California that have been in the news across the world brought widespread flooding, scour and landslides.[1] In 2022, exceptionally heavy monsoon rain and glacier melt caused devastating floods and landslides in Pakistan.[2] According to the US Environmental Protection Agency, it is likely that climate change is resulting in an increase in extreme rain events.[3] The UK Meterological Office points out that warmer air can hold more water; so, as the climate warms, rainfall is increasing on average across the world.[4]

These increases in extreme rainfall, and the associated scour, landslides and floods, create more and more challenges for the pipeline industry. Geohazards are however, not a new phenomenon. As an industry, we have built and safely managed pipelines in geotechnically difficult terrain such as the Andes, Rocky Mountains, or Caucuses, in areas of subsidence caused by historic coal mining and in geological fault zones for decades. Good practice in design, construction and integrity management can prevent failures. An example is the recent massive strike-slip earthquake in Turkey and Syria, which was devastating for the population with many buildings destroyed and lives lost. While there were pipeline failures where design and integrity management actively consider geohazard threats, TANAP and BTC survived with no loss of containment.

It is now widely recognised in the pipeline industry that good practice in the integrity management of pipelines subject to geohazard threats includes a combination of remote sensing (e.g. LiDAR), ground survey, internal geometry and mapping inspection, and site assessment.[5,6]

In recent years the inline inspection (ILI) tool equipped with an inertial measurement unit (IMU) has proven itself to be indispensable for the detection and monitoring of geohazard-induced bending strain and pipeline movement. Typically, IMUs are integrated into ILI systems that include magnetic flux leakage sensors for detecting and sizing metal loss, and calipers for geometry measurement. The combination of these ILI technologies provides relevant information for geohazard threat evaluations; however, complex tools and expert resources are required for deployment. Utilising a dedicated IMU platform offers a simple efficient option for monitoring geohazard threats at high frequency and short notice.

To make pipeline movement monitoring easier, ROSEN has developed the RoGeo PD (PipeDrift) system. This system integrates an IMU with a robust utility tool designed for excellent run stability and tolerance to high speeds, allowing an operator to deploy an IMU inspection with much less effort than would be required for a typical MFL/Geometry combination set-up, or even a stand-alone geometry inspection. The PipeDrift system was run multiple times in 2021 and 2022, proving the reliability and benefits of the approach, and has since been adopted as the primary platform for routine geohazards monitoring of a high-visibility natural gas pipeline system.

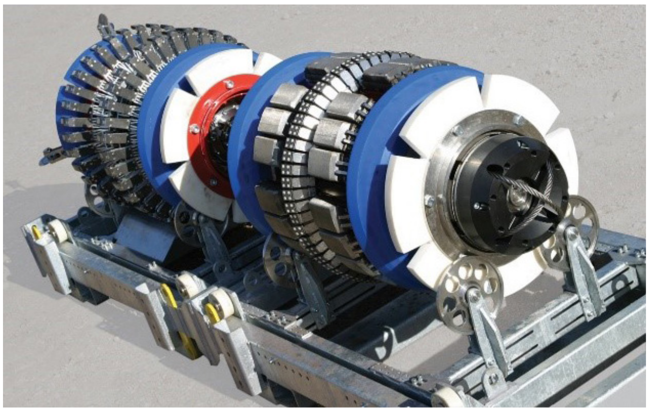


Figure 1. XT tool.

Figure 2. Landslides may affect pipeline integrity, making monitoring or stresses essential.

How it works

A baseline inspection with a minimum of high-resolution geometry and IMU technologies, together with accurate differential GPS surveyed above ground marker points is required for reference. This gives the most reliable picture possible of the position and shape of the pipeline. Subsequently, the dedicated IMU system can be deployed and, using the start and end points, along with characteristic patterns produced by inertial responses of pipeline features, the two datasets (baseline and IMU-only) can be distance aligned. This is needed as the IMU-only tool does not have odometer wheels and above ground markers will not be in place.

With the two datasets aligned, the rate of change of pitch and azimuth can be reviewed. Where there has been no movement between the two inspections, these rates of change will be consistent. There will of course be some variations due to noise in the data, typically caused by vibration of the tools as they travel through the pipeline. If there has been any movement, the rate of change of pitch and azimuth will not be the same between the baseline inspection and the following IMU-only run. In these cases, it is possible to calculate the new trajectory where it deviates from the original, typically considering a limited length of pipe, possibly 150 m (500 ft).

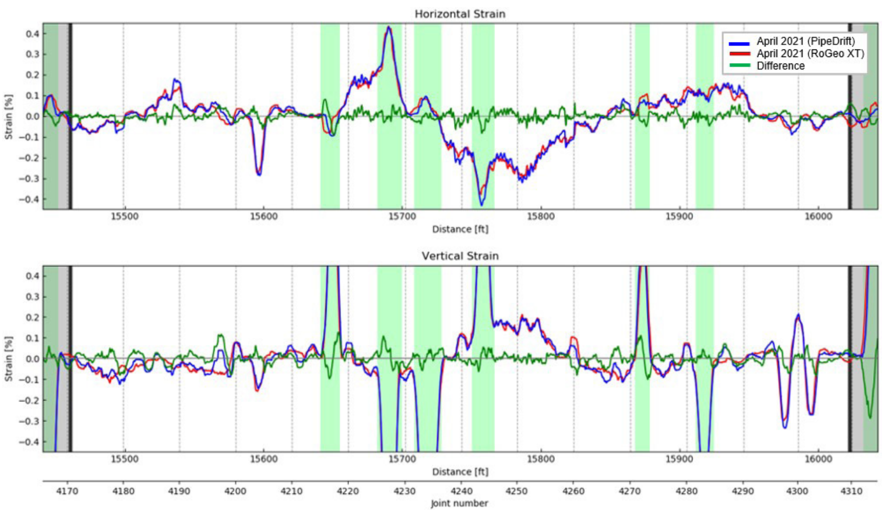


Figure 3. Bending Strain comparison XT vs PipeDrift for a known area of pipeline movement.

Case study

ROSEN has been working with multiple operators around the world helping them to identify active or incipient geohazard threats, and develop appropriate monitoring and mitigation plans. In one particular case, numerous combined geometry and IMU inspections were completed and a few locations of active pipeline movement were being monitored.[7] The maximum strain levels in the sections being monitored remained low, and movement was slow. Sections with higher strains and faster movement had been mitigated by either stress relief and slope stabilisation, or re-routing away from the areas of active movement. The repeat inspection frequency for monitoring the pipeline was approximately every 2 or 3 months. PipeDrift was implemented as a trial with the aim of increasing the efficiency of monitoring and allowing an

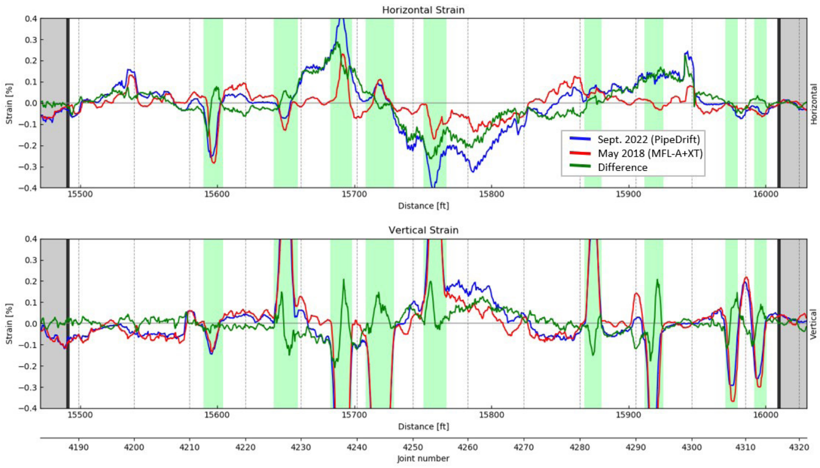


Figure 4. **Bending strain comparison using PipeDrift for a pipeline movement area.**

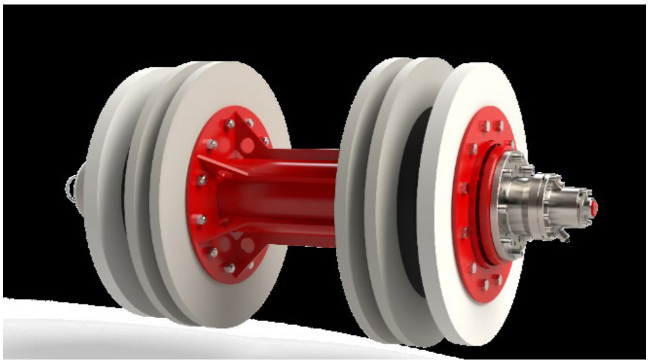


Figure 5. **PipeDrift tool.**

increased monitoring frequency if required. A geometry and IMU combination service (RoGeo XT) was performed first, immediately followed by an inspection with the dedicated PipeDrift IMU system. The post-processed datasets were analysed and compared to assess the accuracy of the PipeDrift monitoring system.

High quality IMU, when deployed in a geometry tool or MFL/geometry combination, has been shown to deliver very consistent results with high repeatability.[8] Some reduction in accuracy was considered likely when using a less sophisticated tool, without distance measurement. However, the results were very reassuring, showing a close correlation with minimal differences in horizontal and vertical bending strain, as illustrated in Figure 3.

Since confirmation of the system's feasibility, several additional PipeDrift monitoring inspections have taken place to observe this area of historical movement. Each inspection has consistently detected the displacement occurring between the first IMU-equipped inspection of the pipeline and the most recent ILI. This is clear to see in Figure 4, which reflects a total maximum strain change of 0.26% (corresponding to 5.2 ft of total movement) between a combined MFL-A/XT inspection and a PipeDrift inspection.

The dedicated IMU-only bending strain monitoring system was shown to give results consistent with a more traditional sophisticated combined high-resolution geometry and IMU inspection systems. Changes in bending strain were identified, and movement was quantified, allowing the operator to make relevant integrity management decisions.

Some challenges were noted, in particular, any areas of re-routing between inspections need to be carefully checked as weld counts will be different and linear alignment can be difficult. Utilisation of third-party datasets should also be approached with caution and the reliability of provided coordinates and inertial measurements should be verified with the ILI vendor.

Conclusions

Energy pipeline operators have been utilising IMU tools to aid in the management of geohazard threats for many years. This has required the use of combination technologies, which are valuable tools requiring significant set-up, mobilisation and deployment effort. PipeDrift is a dedicated IMU platform with a simple and robust design that can be deployed in piggable segments with less operational impact than conventional ILI technologies. A particular advantage is that performance is good at high velocities (e.g. 7 m/sec.), meaning that gas flow rates can be maintained. The viability of this system for routine monitoring of geohazard threats has been demonstrated.

The datasets produced compare very well to both proven technologies and repeat PipeDrift inspections. IMU data quality was maintained even with average run velocities of up to 7 m/sec., and it is expected that higher velocities are achievable. The robust tool design also allowed for rapid redeployment of the system. Challenges associated with characterising trajectory deviations have been overcome by utilising the pitch and azimuth data with appropriate post-processing.

Efforts are ongoing to improve the efficiency of data processing and evaluation of PipeDrift inspection data in support of pipeline movement identification, monitoring and assessment. Signal matching algorithms have recently been implemented as an enhancement for data alignment. Research into tool dynamics and interrogation of various post-processing methodologies have delivered more efficient and repeatable practices. The service will continue to improve, both the technology and process will evolve to maximise ease of deployment, efficiency, accuracy, speed of results delivery, and value to pipeline integrity.

References

1. www.cbsnews.com/news/california-flooding-landslides-as-atmospheric-river-power-outages (Accessed on 20/03/2023).
2. www.worldweatherattribution.org/climate-change-likely-increased-extreme-monsoon-rainfall-flooding-highly-vulnerable-communities-in-pakistan (Accessed on 20/03/2023).
3. www.epa.gov/climate-indicators/climate-change-indicators-heavy-precipitation (Accessed on 20/03/2023).
4. www.metoffice.gov.uk/weather/climate-change/effects-of-climate-change (Accessed on 20/03/2023).
5. THURAIRAJAH, A., *Integrity Management Guidelines for Pipes in Potentially Unstable Soils*, Paper 86987, International Pipeline Conference (September 2022).
6. BAHRENBURG, D., YOUNG, A, EDWARDS, J., SINGH, A., *Above and Below: A Holistic Geohazard Monitoring Solution*, Paper 53, Pipeline Pigging and Integrity Management Conference (February 2023).
7. BAHRENBURG, D., TAYLOR, J., FIGGAT, C., CAMPBELL, P., *Catch my Drift? The Big Implications and a Smaller IMU Platform*, Pipeline Pigging and Integrity Management Conference (February 2022).
8. DOTSON, R., BROWN, A., TAYLOR, J., JACOBS, L., *Beware the Shapeshifter: A Repeatability Study on Pipeline Movement and Bending Strain Assessments*, Pipeline Pigging and Integrity Management Conference (February 2021).