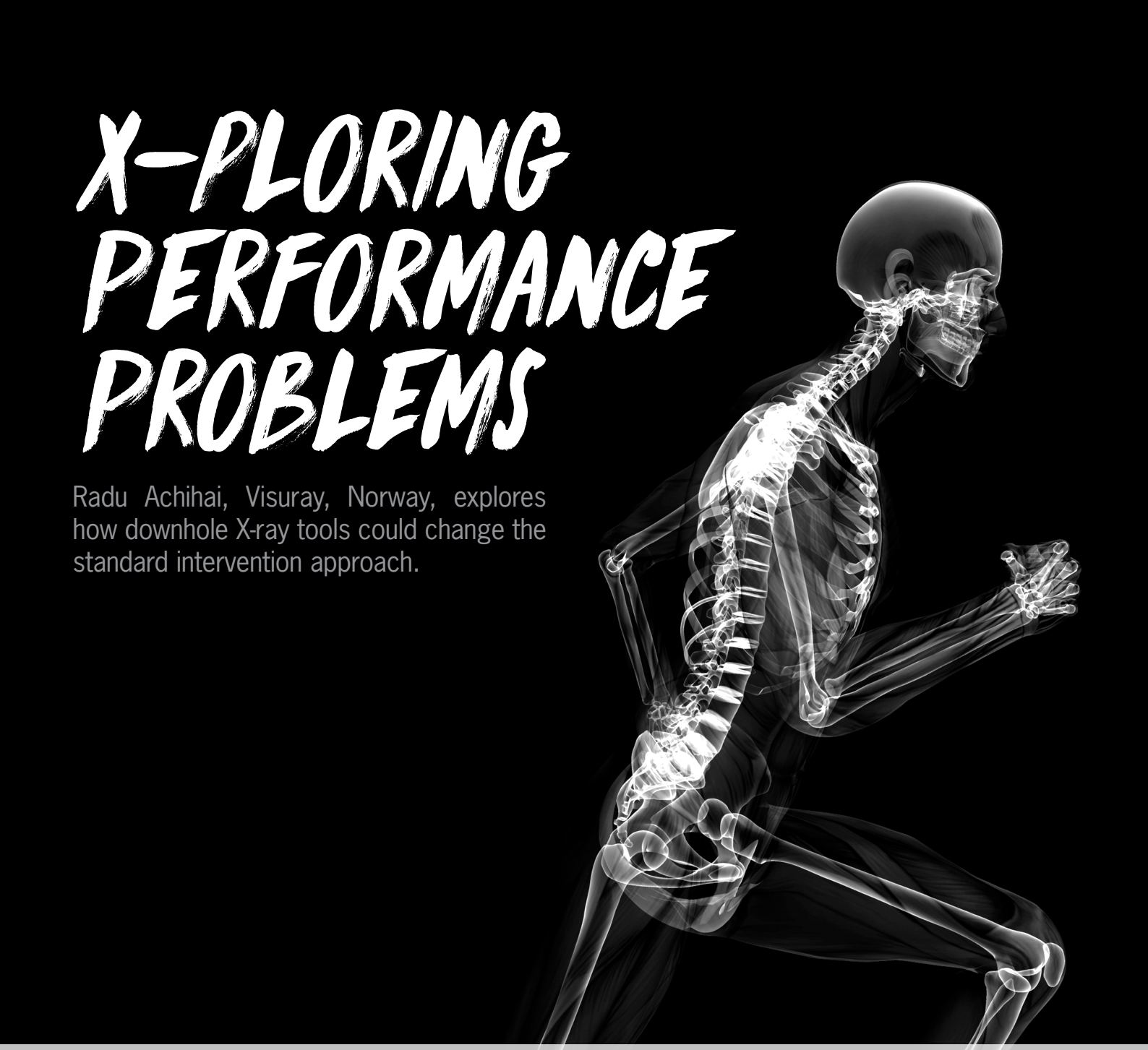
X-PLORING PERFORMANCE PROBLEMS

Radu Achihai, Visuray, Norway, explores how downhole X-ray tools could change the standard intervention approach.



Operators' budgets always include significant amounts assigned to well intervention operations. Addressing well performance issues and downhole hardware failures is costly, time-consuming and, in many cases, marred by operational uncertainty.

This uncertainty has, at its core, a lack of clear, reliable information regarding the condition of the downhole equipment. Efforts to get accurate information have resulted in the use of lead impression blocks, which, despite low costs, present difficulties in interpretation. Video cameras are also used, however they still need a transparent well environment, despite advances in lens coatings. More recently, ultrasonic imagers have been used. This technology assumes well-fluid homogeneity, the absence of gas bubbles or suspended particles, and accurate fluid information.

One of the challenges of well interventions and workovers is the trial-and-error approach typically employed whenever there is an operational issue. The cycle of estimating the problem, attempting a solution, and then in many cases failing to correct the problem is seen at well sites around the world. The key to breaking the cycle is reliable diagnostic imaging whatever the conditions downhole, opaque or otherwise. To address this challenge, scientists at Visuray developed a diagnostic method based on X-rays.

X-rays as a reliable way forward

The conventional way of performing X-ray imaging – for example in security or medical applications – involves placing the scanned object in between the source and the detector, with the detector sensing variations in transmitted X-ray intensity caused by variations in the density of the object. This method is not applicable inside oil wells as, generally, access to both sides of the target objects is not possible.

Visuray developed an alternative solution called 'fluid-based surface imaging' that uses an X-ray source and detectors positioned on the same side of the target object. The technique relies on X-ray scattering from the fluid in the well. These fluids generally scatter very strongly and when a greater amount of fluid

is present, a greater number of scattered X-rays are registered by the detectors. Thus, as demonstrated in Figure 1, a detector pixel that views a part of an object farther away from the detector will register more X-rays than a pixel that views a part of an object closer to the detector. This creates contrast in the images and can be used to reconstruct the surface topography of the object in 3D.

Downhole X-ray diagnostics

Using topographical reconstruction, Visuray has established downhole X-ray diagnostics. The company's first offering, the VR90 Downhole X-ray Diagnostic Service, has a proven record on three continents; to date, the 3 ⅝ in., 100˚C rated system has performed jobs in North America, Europe and the Middle East.

The newly improved version of the VR90 service is called the VR90s Advanced Diagnostic Service. The VR90s tool has a higher temperature rating of 125˚C, complies with NACE MR0175/ISO 15156 for sour well operations and has a slimmer outer diameter of 3 ⅜ in. which allows passage through restrictions as small as 3 ½ in.

A challenge faced when running the VR90s service was the accurate positioning of the tool above the scanning targets. In order to address this, Visuray has added an anchored positioning module (VPM) to the VR90s tool. The VPM permits up to 50 cm of controlled vertical movement, allowing closer inspection of in-well debris and damage, with enough detail to thoroughly evaluate the integrity of the downhole well components.

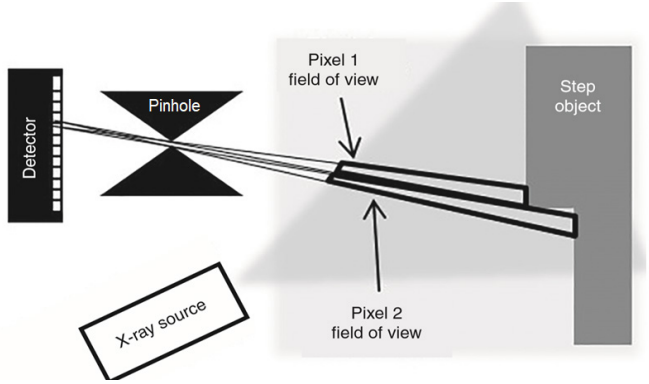


Figure 1. *Topographical reconstruction model comparison for two pixels of the X-ray detector.*

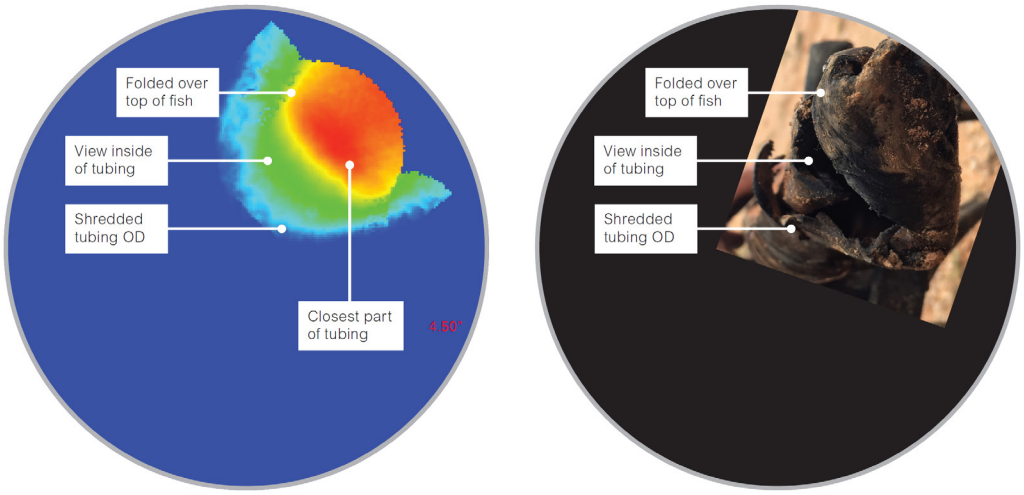


Figure 2. *The image on the left is a false-colour representation of the tubing top. The colours are used to highlight the shape of the tubing; red areas correspond to parts of the tubing sticking up, while green to blue areas correspond to parts of the tubing deeper in the well. On the right is a photograph of the mangled, crushed, and folded top of the tubing, taken after it was pulled. This is consistent with the VR90 service's scan results.*

One of the concerns shared by operators when using an anchor device relates to casing/tubing wear and the potential of the anchoring arms to damage the completion. In order to prevent this, the anchoring force of the VR90s tool's VPM can be set on the fly according to client specifications, while at the same time allowing for accurate tool positioning.

Case study 1 – Northern Europe

An offshore gas well owned by a major operator had been offline for several years due to a stuck fish. Multiple depth determination attempts and video camera runs had not provided the information required to take informed decisions on the operations needed to put the well back into production. One of the main questions to be answered was the location of the fish relative to a nipple, which would dictate the fishing approach.

The VR90s Advanced Diagnostic Tool was run in hole until it tagged an obstruction. The real time X-ray scans revealed the 2.9 in. nipple with some sand-like debris on the low side of the well, proving that the fish was below the nipple and that a standard fishing approach could not be used.

The VPM was also run for the operation, and used as a stick-mitigation device. As the VR90s tool saw overpulls when coming off the scanning depth, the VPM was anchored and used to lift the tool, allowing for a smooth pull out of hole.

By running the VR90s service, the client was finally able to obtain measurable information despite the conditions within their well, and ascertain the location of the fish. The diagnosis provided the client with a clear foundation for decision-making, allowing them to successfully complete the fishing operation.

Case study 2 – North America

A Permian Basin operator was removing tubing string from a producing well when a section of the tubing became stuck in a known tight spot in the casing.

Multiple remediation efforts were made, including washing over, milling, and pulling, but a section of the pipe was twisted off during the process. The operator was unable to pass additional tooling through this section, and they wanted to know specifically if the obstruction encountered was due to twisted-off tubing or collapsed casing.

The VR90 service was run to examine the obstruction in the dirty, oily well fluids without any costly and time-consuming circulation of the well. The real time results (Figure 2, left image) revealed the twisted-off tubing and provided key information about the size, position, and condition of the tubing top. The client was able to see immediately that the tubing top lay towards the high side of the well. It also showed that the tubing top was thoroughly mangled, and crucially, that a section of the tubing had folded over.

Based upon this diagnosis, engineers recommended a fishing strategy to retrieve the tubing, including specifying a particular type of grapple to

grab the fish. The operator and fishing company followed Visuray's suggestion and fished the tubing the next day.

Case study 3 – Middle East

In an onshore, brine-filled multilateral well, the operator had installed a whipstock to facilitate milling a window for a new lateral hole. During installation and milling, they suspected that the whipstock was not seated properly and subsequently spent weeks attempting to drill the lateral and then retrieve the whipstock from the well.

The client wanted to know the state and position of the whipstock to guide their fishing operation. The VR90 service was conveyed using a wireline tractor and obtained representations at several stations around the depth-of-interest.

The position and orientation of the whipstock with respect to the high side of the well were immediately identified during the first run. Furthermore, the well was determined to be filled with fine debris interspersed with larger pieces resulting from milling. Extended investigation revealed that the whipstock had been severely damaged by milling.

This information convinced the operator to forego other fishing attempts and go ahead with sidetracking the well, thus avoiding delays associated with a risky fishing operation.

Case study 4 – North America

A major independent E&P company needed to image the top of stuck tubing in order to determine the most suitable option of fishing it. The opaque well fluid ruled out using a video camera, but the VR90 service clearly showed a tubing top that had sustained milling damage that significantly altered the fishable dimensions on both the outer and inner diameters.

The results also provided the relative location of the tubing inside the surrounding casing. This information gave the operator the possibility of moving forward with a targeted fishing plan and putting the well in production with minimal delay.

Case study 5 – North Sea

A North Sea operator was considering converting an injection well into a producer, but the procedure was held up by a malfunctioning downhole safety valve (DHSV). Following a suite of evaluation runs, they suspected that the DHSV was stuck in a partially open position, which would prevent the placement of a wireline retrievable insert safety valve. This left them with having to choose between the significantly more expensive options of attempting to mill out the flapper or recompleting the well in order to change the DHSV.

The VR90 service was mobilised in order to get more information about the DHSV. The VR90 tool performed scans in several positions, showing the flapper open at different angles, and thus proving that, contrary to expectations, the valve was not stuck open. Most importantly, the VR90 service proved that the flapper should open wide enough for an insert DHSV to pass through.

By using the VR90 service, the operator was able to confidently proceed with installing the insert safety valve, making significant time and costs savings, while minimising operational risk.

Conclusion

These downhole X-ray diagnostic services were able to provide proven and actionable real-time information that allowed operators to understand the nature of malfunctioning downhole hardware. This understanding directly translates into reduced rig time, significantly improving the overall cost and decreasing the risk of the operation. This technology means that decision makers will have essential information even in the most opaque and troublesome well environments, allowing them to see with certainty and act with confidence.