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Robots, pigs and pipes

Groundbreaking robots in the UK eliminate the logistical and environmental impacts of gas line excavation by taking measurements from inside the pipe. To withstand the extreme conditions there, 2507 super-duplex stainless steel was chosen for the robots' chassis.

Understanding the immense value of Project GRAID (Gas Robotic Agile Inspection Device) requires a look back in time. Building the National Transmission System began in the 1960s. By 2030, over 60% of the system will be older than its projected lifespan, raising the risk of both corrosion and leaks. Until now, the only way to assess the condition of pressurized pipe sections inaccessible by traditional Pipeline Inspection Gauges or Pigs was through above-ground surveys and asset life modeling. Such techniques led to costly and environmentally-damaging excavations. Hence, there was a need for a remotely controlled robotic inspection device that could check the condition of these pipes without purging them.

Work on the £6.3 million project started in 2015 with Network Innovation Competition funding from the UK Office of Gas and Electricity Markets. The aim was to design an agile robotic inspection device, capable of surveying the 350 kilometers of unpiggable pipelines that connect the 200 high-pressure installations in the UK Gas Transmission Network. The pioneering robotic platform must operate in extremely demanding physical conditions, including high velocity, live gas, and pressures of up to 100 barg – equivalent to more than five times the maximum pressure experienced by a typical submarine.

This in-line inspection project posed many complex engineering challenges. Once launched into the high-pressure pipe, a challenge in itself, the robot has to negotiate its way through meandering pipe systems. These systems are fraught with obstacles, including sharp bends, inclines, declines and diameter changes. Within this high-pressure labyrinth, flowing with live gas, the robot takes visual and wall-thickness measurements of the deeply-buried pipes. The data is then translated into meaningful pictures for analysis.

Conserving costs and carbon

National Grid collaborated with three companies to deliver the project: Premtech Ltd, who mapped the sites, created a GPS for the robot to follow underground and designed the launch and retrieval device and testing facility; Pipeline Integrity Engineers, who translated the measurements into relevant data via a series of complex calculations and Synthotech Limited, who designed and built the special robots for this world's-first project.

GRAID gives the UK National Grid a detailed understanding of the pipework's condition. It provides reliable data that makes managing, maintaining and replacing pipes more cost-efficient and less disruptive to the community. Now in operation, GRAID is expected to deliver cost savings of more than £60 million over 20 years. In addition to conserving fiscal resources, GRAID also saves an estimated 2,000 tons of carbon emissions annually – equivalent to the emissions from almost 500 UK households.

Extensive testing was carried out to ensure the GRAID robot could operate in the harsh environment experienced within the pipe.

The challenges of developing the robot

Designing the innovative robotic platform took over two years. The final design was influenced by the conditions it must withstand inside high-pressure gas pipework. Natural gas acts like a liquid at high pressure, so fluid dynamics are critical. And when gas flow peaks, an equivalent 200 kilogram force pushes against the robot, so being strong and resilient was also essential.

Project Engineers initially took inspiration from nature – the dolphin – to create the most dynamic form for the robot, with a special skin for use in high flow conditions. However, as the project progressed, the team realized that the agility of the robot was impaired by having one large chassis. Following a re-design, a twin chassis module approach was taken, which allowed all of the electronics to be protected in two custom built chassis. This allowed the device to navigate the tight geometry found on site. The robot uses patent-pending magnetic tracks to adhere to the pipe wall, enabling it to navigate up the side of the pipe, avoiding obstacles, rather than just moving along its bottom.

Project GRAID would not have been possible without the super-strong metal chassis that holds all of the control systems, electronics, and cameras. It was critically important that the robot could withstand whatever conditions it

encountered, especially as it was towing a specially-designed 100-meter umbilical cord that contained all the necessary cables to allow it to operate and feedback real-time images. Synthotech's Senior Principal Engineer and Head of Research & Development on the project, John White, explains the challenges of developing the robotic system. He also answers why a super-duplex grade of stainless steel, containing 3.6% molybdenum, was chosen for the chassis.

"No-one in the world has designed a robot for use in an environment where it faces pressures of up to 100 barg, with live gas inside the pipes, so it was a big challenge for us. The strength of the chassis holding the robot was perhaps the key to its success".

"There were many materials out there, but we chose a particular grade of super-duplex stainless steel – 2507 – for a number of reasons. Molybdenum's inclusion in this grade of super-duplex steel also gave it the strength we were looking for. The grade is more expensive, but the benefits justified the additional cost".

The project team considered alternatives, such as carbon steel materials. But in terms of meeting the demanding criteria, the chosen molybdenum-containing duplex stainless steel grade came into its own and performed as expected throughout the extensive testing.

A pipe dream come true

Following the successful testing of the custom-made launch and retrieval vessel in 2017, testing the robot to exacting criteria accelerated. This testing included working under the pressures of 100 barg and traveling distances of 100 meters while collecting visual inspection and wall thickness measurements – definitely not a simple task considering the robot's varied functions. GRAID has sophisticated electronics and control systems, including four individual drive motors, an umbilical management system, seven cameras that transmit live images, and a moveable arm with electromagnetic sensors. It is these sensors on the moveable arm that measure the thickness of the pipe wall and identify any corrosion.

The GRAID robot's front chassis in development.

Specially built test rig, with 90-degree bends, equal tee and reducing diameter sections, and a 45-degree incline.

Also, in 2017, the Project GRAID team reached another major milestone. The GRAID robot successfully navigated a specially built test rig, with 90-degree bends, equal tee and reducing diameter sections, and a 45-degree incline. After every test, the robot was brought back to the launch vessel for visual checks. The robot must return to the launch vessel, sometimes against the flow in the pipe, to avoid any costly retrieval missions involving digging up significant stretches of pipeline. In the latter months of 2018, extensive testing on various transmission sites by National Grid Gas confirmed that the system, especially the robot, was fit for purpose and ready to be put to work.

Project GRAID began as a pipe dream, but through the collaboration of specialist companies and the use of molybdenum-containing duplex stainless steel, this elegant robotic system became a reality. And most importantly, it is helping National Grid to run a safer, more reliable, and efficient gas transmission system. So far, this technology has only been implemented in the UK. However, the robot inspection devices could be used in other installations around the world with unpiggable sections of pipe. The implications for resource conservation in the gas and water industries may be substantial. Wherever these ingenious, pipe-dwelling robots end up, molybdenum will serve an important role in guaranteeing performance in the face of challenging conditions. (Stratia)