UNIQUE AUTONOMOUS PIPELINE MAPPING SYSTEM: AN OVERVIEW

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ABSTRACT

The need to develop an accurate, autonomous, and economical pipeline mapping system capable of use within a wide range of pipeline sizes, configurations, operating pressures and specific uses was addressed by Reduct, NV, a Belgium technology company, resulting in the development of a series of unique inertial based smart probes.

This paper attempts to review the need, technical capabilities and applicability of mapping various pipeline systems with smart probe technology.

INTRODUCTION

The pipeline industry is divided into numerous industry segments which have over the years dictated the installation of various types and sizes of underground pipelines. The materials which we have used to manufacture these various pipelines have changed. As the technology progressed, new methods were developed to install these pipelines, thus the “trenchless” industry evolved as we know it today.

Whether it is fiber, water, sewer or gas lines in an urban environment, or oil, gas and telecom distribution lines running across vast stretches of open territory, one fact about our pipeline industry remains true. The amount of installed pipelines is huge and growing quickly.

For many years, the need to know the exact location of these pipelines was not considered to be necessary. As our underground became more congested, and as it became more evident that these older pipelines were in need of both condition assessment and rehabilitation, it became increasingly more important to know exactly where these existing and new pipelines were located. The advent of pipeline “asset management” programs and the development of more and more sophisticated GIS based data bases reaffirmed to the pipeline operator, the value that could be derived from accurate “x, y & z” spatial centerline data for their entire pipeline system.

Although some progress has been made within the energy industry toward obtaining this data, the smart pigs that existed are primarily designed as assessment tools that are expensive, only marginally accurate (particularly on the “z” or depth capability) and because of their large size, are only capable of maneuvering through larger diameter pipelines that have been designed to be “piggable” and built with large sweeping bends.

THE SMART PROBE TECHNOLOGY

The smart probe technology consists of two main components. The first is an array of data collection instruments which include accelerometers, gyroscopes and odometers located within each of the probe bodies. The second is a proprietary software package which extracts and interprets the collected data and allows for the seamless transfer of the collected data into various GIS data bases.

As the smart probe moves through the pipeline it records all changes in inclination, heading and velocity at a rate of 800 times per second. This information is held on a hard drive within the probe. The probe is autonomous, meaning that it is not tethered via a data cable to the surface. In fact the probe does not communicate with the surface at all. This means that the probe is not restricted by the depth of ground cover over the pipeline nor is it subject to possible interference derived from other pipeline or metals located within the soil. There is no requirement to “trace” the movement of the probe from above ground.

The smart probe is provided with its starting coordinates and its ending coordinates, and the internal data collection instruments along with the software record everywhere that the probe travels between those known coordinates. By transferring the starting and ending points into CADD or a GIS database, you then have the accurate “x, y, & z” centerline coordinates depicted in either a 3D or “plan & profile” view.

A key goal in developing the smart probe technology was to design the instrumentation in such a way that it is capable of being utilized within a series of different probe body styles that would allow for the use of the technology within the widest range of pipeline types, sizes and environments. To this end, the initial instrumentation was miniaturized with a goal of developing a smart probe capable of operating within a 3.8 cm (1.5 inch) diameter pipeline. An articulating body on this probe allows for movement through a pipeline with as small as a 43.18cm (17 inch) radius bend.

Figure 1.   A 3.8 cm (1.5 inch) Diameter Smart Probe.

To map larger diameter pipelines, the same data collection instrumentation and software were utilized, and the probe bodies were modified to allow for movement through the pipeline while still allowing the probe to track the pipeline centerline. Depending on the pipeline interior surface and condition, various wheel-sets with protruding carrier legs are used to assure the positioning of the probe body within the pipe.

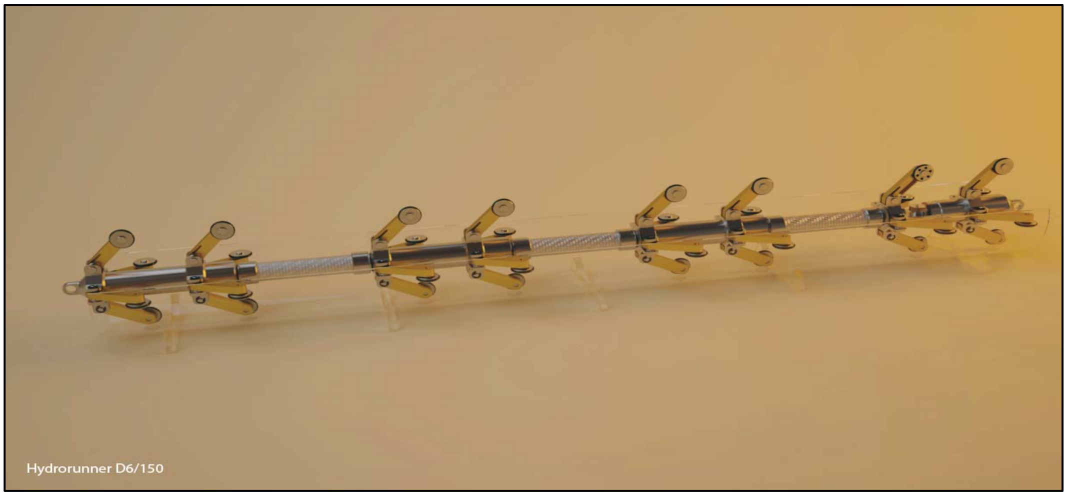

Figure 2. - A 15.24 cm (6 inch) Diameter Smart Probe Capable of Negotiating a 2 D Bend Radius.

Figure 3. - A 30.48 cm (12 inch) Diameter Smart Probe Capable of Negotiating a 1.5 D Bend Radius.

Figure 4. A 122 cm (48 inch) to 152 cm (60 inch) Diameter Smart Probe

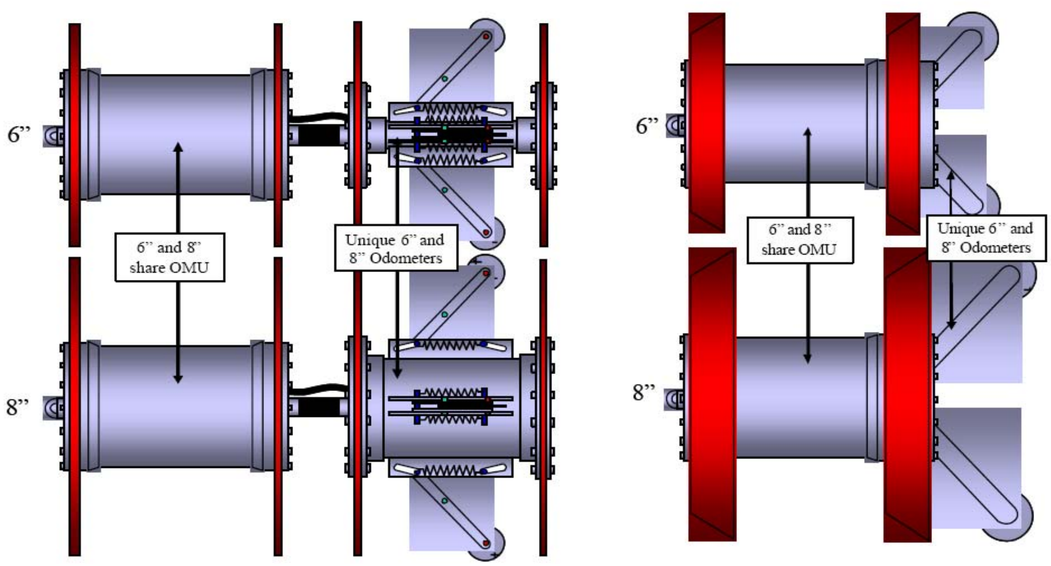

Figure 5. Prototype High Pressure Smart Probe 241 Bar (3500 psi) Design Pressure.

The ability to economically design and develop multiple specifications for the smart probe bodies or carriers and utilize the same instrumentation modules is a key element to the smart probe technology. Modifying the probe bodies allows operations in high pressure, high temperature and many caustic environments.

The basic smart probe is designed for use within non-pressurized pipeline environments. A full line of second generation smart probes have been designed and are in use in pressurized environments up to 6.55 bar (95 psi).

The newest line of high-pressure smart probes designed primarily for the oil & gas industry which are capable of operating in environments up to 241 bar (3500 psi) with battery and memory capacities allowing for very long distance runs are in design and will be available in June, 2008. Limitations on length of run are strictly dependent on battery and memory life and each probe can be modified to increase these components as needed.

DATA OUTPUT

Over thirty instruments within the smart probe collect approximately 800 accurate readings per second as the probe moves within the pipeline. This data is saved on a hard drive within the smart probe and then download at the end of the run onto a laptop computer. The technician can then review the data in the field or send the data via the internet to a centralized server to be processed. Depending on the needs of the client, the data can be provided in one of several formats ranging from intricate detail of each of the data points to a summary report providing a simple CADD plan and profile view of the pipeline run. Data can be provided in a format which integrates with all current GIS platforms.

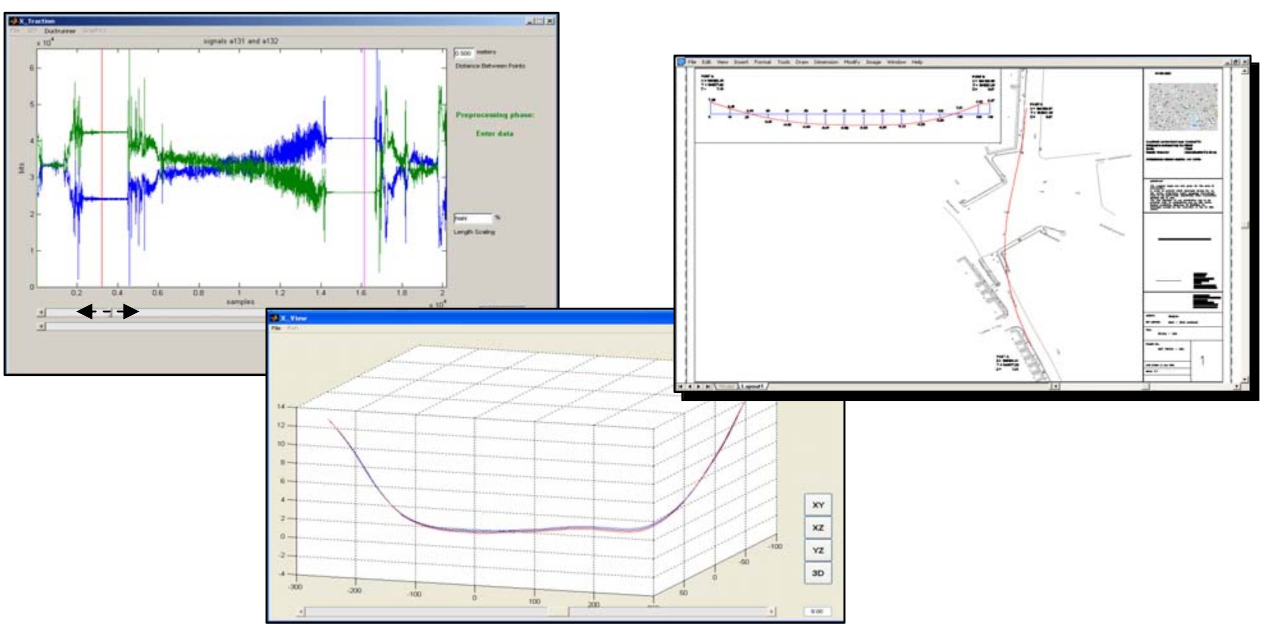

Figure 6. Various Formats of Data Output.

PROPULSION THROUGH THE PIPELINE

The smart probes are either pulled or pushed through the pipeline. The most common method to utilize a probe to map pipelines that are accessible on both ends with lengths up to approximately 3 to 4 kilometers (2 + miles) is to insert a pull rope through the pipeline, attach the probe to the pull rope and utilize a winch to pull the probe through the pipeline. For pressurized lines that need to stay in service or for much longer pipe runs, the smart probes are attached to foam pigs and they are pushed through the pipeline with either compressed air, water or the pipeline product itself.

ACCURACY AND DEVIATION

The smart probes are designed to be extremely accurate although all gyroscopically based instruments are subject to deviation. It was important to understand this deviation and to develop specified tolerances that could be used as a safe guide when evaluating the completed pipeline mapping data.

Over time it has been determined that the smart probes produce data with a maximum deviation that is within 0.25% of the distance between two known coordinates on the “X & Y” horizontal plane (plan view) and within 0.10% of the distance between known points on the “Z” vertical plane or the depth. Since we know that the starting and ending coordinates of each run are exact (because we surveyed them prior to the run), then we know that the maximum deviation can only occur at the midpoints of each run.

Assuming that we were mapping a pipeline with 305 meters (1000 foot) between known coordinates, then our maximum deviation in the “X & Y” or plan-view at the midpoint would be 73 centimeters (28.7 inches). The maximum deviation on the “Z” coordinate or depth at the midpoint would be 25 cm (9.8 inches).

On long runs, required accuracy is obtained by adding above ground markers at known coordinates along the pipeline. The deviation can also be reduced by running multiple runs of the smart probe back and forth through the same pipeline.

APPLICATIONS FOR THE TECHNOLOGY

The smart probe technology allows pipeline owners, operators and engineers to obtain accurate and economical centerline data from most types of underground and above ground pipelines and seamlessly download that data into all CADD and GIS software data bases.

For both existing pipelines and new construction the smart probe technology is an efficient method to create accurate as-built pipeline drawings. The seamless integration of this centerline data into powerful GIS databases is a compelling addition to all pipeline asset management programs.

The smart probe technology allows you to obtain accurate as-built drawings from pipelines installed via horizontal directional drilling. Not only is the accurate centerline mapped, but the software is capable of calculating the actual installed bending radius at every point along the pipeline. By overlaying the smart probe's centerline data over existing grade information, depth of cover above the pipeline is established.

With data from the smart probe all pipeline joints whether welded joints, ring joints or gasketed slip joints are easily detectable and assigned a coordinate. By reviewing the output data, the quality of certain joints can be reviewed and poorly installed offset joints can be discovered.

The autonomous nature of the smart probe technology allows the smart probes to be easily "coupled" with most other pipeline assessment tools and very efficiently add important positioning capabilities to these tools. Video cameras, leak detection equipment, sonar and laser evaluation tools as well as magnetic flux leakage (MFL), and caliper tools can be added in tandem to the smart probe for multiple assessment tasks.

CONCLUSION

The smart probe provides an efficient and economical methodology to obtain accurate "X, Y & Z" centerline mapping data for most pipelines, in most industries and should become an increasingly important technology in the rapidly growing pipeline assessment industry.