Dynamic Speed Control In High Velocity Pipelines

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Editor's Note: *High-velocity pipelines often require significant cutbacks in production to achieve safe operating parameters for routine pig runs or ILI programs. P2D/Inline introduces their latest development in intelligent speed control, designed to maintain acceptable pigging speeds for routine pigging and intelligent cleaning for flow assurance management with minimal impact on production.*

This article discusses development of the dynamic speed control system, initial field trials, operational success and its application for maintenance pigging, intelligent cleaning, debris mapping, and black powder removal as part of an operator's pipeline integrity management strategy.

Pipeline cleaning and dewatering is most effective when a cleaning pig is traveling at no more than 11 mph (5 m/s). Above this speed the pig's cleaning performance is adversely affected, meaning the pipeline will no longer be cleaned effectively. There are also pig receipt issues when running pigs at high velocities. In most cases pig speed is not an issue as product flow velocity does not exceed the optimum pig speed and a standard cleaning pig such as a BD6 steel mandrel pigs.

However, there are an increasing number of gas pipelines which have "ultra-high velocity flow" in which the product can be flowing at speeds of up to 24 mph (11 ms-1). These pipelines tend to be large-diameter (36-42-inch) trunk pipelines covering large distances. The usual procedure for pigging these high-speed pipelines is to reduce pressure and flow to suitable levels to allow the cleaning pig to run close to the magic 11 mph (5 m/s) value. From an operator's perspective this is a costly exercise as flow often has to be reduced for several days. This needs extensive planning and leads to lost revenue from reduced gas flow.

Speed control pigs have been used for some time to provide inline inspection (ILI) companies with a stable platform to tow inspection tools. However, there has been very little use of speed control for cleaning pipelines. So a speed control pig (SCP) that is suitable for cleaning of these high-velocity pipelines was the way to go. This tool has now been run in several pipelines with great success.

By using a cleaning pig capable of speed control it is possible to very effectively and safely clean a high-velocity pipeline with very little operational disruption, negligible change in gas flow and minimal loss of revenue.

History Of The Speed Control Pig

The original SCP, then called a Variable Speed Pig (VSP), was designed by Apache Industries in the early '90s following a request from a large Middle East oil and gas company for a pig that could run with a variable velocity compared to the product flow. The client had been venting off large volumes of gas to slow down the pig's velocity, but found that even at these reduced speeds the pig was traveling too fast for efficient cleaning and the safe, controlled receipt at the receiver. Past attempts to slow down the pig with fixed bypass ports had failed. Fixed bypass ports in the mandrel body either caused too many speed excursions or prohibited the pig from obtaining enough differential pressure to launch.

The VSP designed to meet the above requirement had several runs which proved successful and showed that this was an effective method for pigging these excessive flow pipelines. Through a series of acquisitions this tool and technology became the property of an ILI vendor who was not interested in developing it from the stage it had reached in the early '90s.

In 2009 a major gas transmission pipeline operator approached us with a view to using a speed controlled pig in their new 36- and 42-inch pipeline network. They also had encountered the problem of lost revenue when using standard cleaning pigs. The purchase of the technology and patents was done to develop this into a system suitable for use in high-velocity gas transmission networks.

Theory Of Operation

It has long been understood that a pig's speed can be controlled by introducing bypass through the pig body. Usually pig speed reduction is accomplished by introducing a fixed amount of bypass through the body of the pig which will then have a 'fixed' effect upon speed reduction.

The SCP operates by allowing variable bypass through the body of the pig. Using an electronic control system, the bypass can be adjusted to control the speed of the pig. Bypass is controlled by rotating one disc with three vanes, whose area is half of the disc area, against a fixed disc of similar shape. Figures 2.2 and 2.3 show the vanes in the open and closed positions. In this way the bypass can be adjusted from 0-50% of the cross-sectional area. The rotating disc is moved using a motor, gearbox and shaft sealing assembly.

Figure 2.2: Vanes closed.

Figure 2.3: Vanes opened.

Updating And Improving The System

The original speed control mechanism was built circa 1990. At an early stage it was decided to completely update the electronic control and logging system, taking advantage of the experience already gained from previous experiences and implementing newer technology. The original system used a simple feedback mechanism to control vane position, very little logging capability was incorporated and there was no ability to log environmental variables. The electronics were completely redesigned with an FPGA processor at the heart of the logging and control. As the system is battery-powered for the duration of any run, power consumption was a major concern during the design process.

To provide speed input to the system two or three odometer wheels are used. A signal system is then used to choose the fastest signal from these odometers. This is then used to calculate and log the distance traveled by the SCP and calculate speed. In addition to this pressure, differential pressure, temperature, linear and rotational (6-axis) acceleration sensor data is logged. The acceleration data can then be resolved into pitch and roll information.

In a system like this failure of the electronics is a major concern. To reduce the risk of electronic failure causing pipeline operational issues critical parts of the electronics are duplicated. Should the main electronics fail a backup system can then take control and put the vanes into a failsafe position, either fully closed or fully open. This will ensure either the pig traverses the pipeline safely or that flow is not interrupted.

Control Method

The system is a basic closed-loop control system with one feedback sensor. Two methods of controlling the system were investigated.

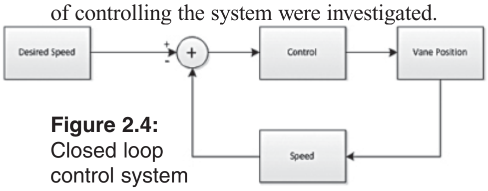


Figure 2.4: Closed loop control system

The first, a quasi-fuzzy logic system uses a number of states to determine the vane action required. System set-up would then require a set speed and speed band that the tool was required to operate within. The control electronics will then endeavor to keep the pig within the speed band around the given speed. Having a dead band reduces power consumption as in this region the electronics do not try to control the speed, hence the motor is active for less time.

The second, a PID control system, would undoubtedly offer more precise speed control once it had been tuned correctly, but this can often take significant fine tuning and time. This control method results in the motor being active whenever the pig velocity is not equal to the desired speed. This would result in increased power consumption ultimately affecting the length of pipeline that could be run.

The first option was chosen as the most appropriate for the reasons given.

Field Trials

As part of the development of the SCP, a development contract with a major gas transmission operator was done to clean several of their LD trunk lines. This five year contract would take the form of yearly cleaning programs on each of the designated pipelines. This would allow the SCP to be developed using the same pipelines and meet the operator's regulatory requirements to clean the pipelines, while not affecting flow. Figure 3.1 shows the LD SCP used in the initial runs of the tool.

Figure 3.1: Initial Speed Control Pig

Initial Runs

The first runs of the newly developed SCP were carried out in fall 2010 in three sections of pipeline, a 42-inch gas trunk pipeline running for over 200 miles. These sections ranged in volume from 300 MMcf/d to 1.4 Bcf/d which equated to gas velocity of between 6-24 mph. For these runs the tool was set to try and achieve a pig speed of between 6-8 mph. The tool successfully cleaned all the sections of pipeline but several areas for improvement were identified.

Improving On performance

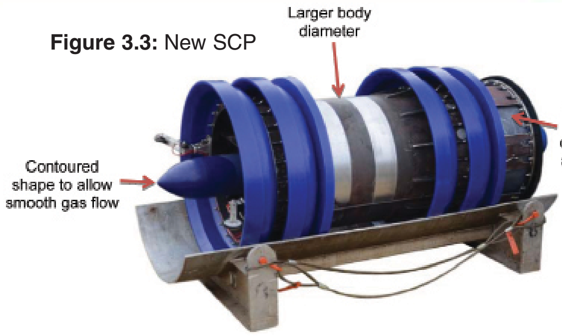
Although the SCP was able to reduce the speed of the pig compared to the gas flow it was not able to reduce the velocity to the desired 6-8 mph when gas velocity was above 12 mph.

There is a reduction in pig speed compared to gas speed but once pig speed goes above 12 mph and the vanes are fully open the tool is no longer able to keep the pig speed below 8 mph. The main cause of this inability to control the speed was a lack of bypass area, even when the vanes were fully open.

To try and accomplish this additional bypass capability a new, larger diameter, pig body was designed, figure 3.3. This included some features designed to facilitate smooth gas flow through the body of the pig.

A control issue was also identified in these initial runs. This arose when the pig was slowing down either after the vanes had opened slightly or a change in terrain. In this circumstance the

Figure 3.3: New SCP



electronics did not react quickly enough and allowed the SCP to stop before the vanes started to close. To rectify this issue the control firmware was changed to speed up the reaction time.

Case Study


Figure 3.4: Launch

A case study has now undertaken eight SCP runs with a major gas operator in both 36-inch and 42-inch sections of their network. The next section looks at one part of pipeline that was cleaned using the SCP in December 2011.

The SCP utilizes the client's approved pigging procedures and requires no special equipment for launching. In the runs carried out with the major gas operator a backhoe was used to lift the SCP, in its tray, into position and to insert it into the launcher.

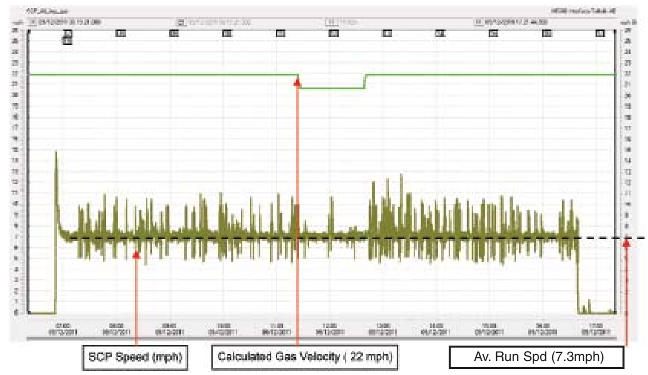


Figure 3.5: Gas Speed Velocity, SCP Speed

The SCP uses two pressure switches to turn on the electronics; this occurs after the unit has been loaded into the launcher and the pressurization process has started. After pressure equalization has been completed the SCP can be launched in the standard fashion. Typically about 14 PSI (1 bar) differential pressure is required to kick the SCP into the pipeline.In this pipeline section the SCP was configured to try and control its speed to between 6-8 mph.

The above section of line is 71.1 miles of 42 inch pipeline. The figure above shows the tool performance in this section.

Figure 3.5 details the SCP speed for the entire run (gold) plotted along with calculated gas flow velocity (green). Gas flow velocity calculations are based on information given by the operator. Unfortunately, few pressure and flow details were available to plot for this section, therefore, the graph essentially shows an average gas velocity for the entire run. It is known that the flow did not change drastically for the duration of the run. The conversion is based on a .427-inch (10.8-mm) wall thickness assumption; however, actual gas flow velocity will be higher in all heavier wall thickness sections, of which there were many. The average SCP tool speed for the entire run is around 7.3 mph indicated with the black dashed line.

Figure 3.6 shows data for the full run length. It can be seen that the vane position is effectively adjusted to keep the pig speed to within the desired set band.

Figure 3.7 shows SCP speed (gold), differential pressure (cyan), pipeline pressure (dark

Figure 3.8: Receipt.

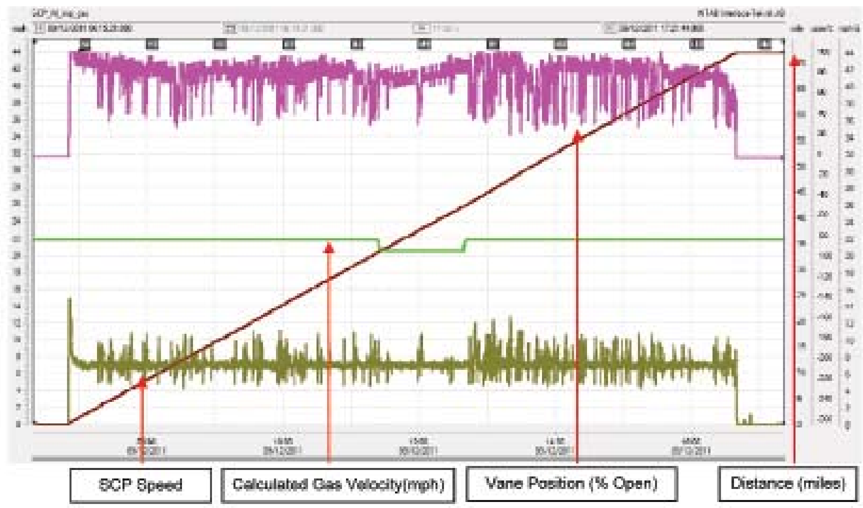


Figure 3.6: SCP Speed, Calculated gas flow velocity, Vane position and Distance

The average vane position for the whole run is 77% open.

Figure 3.6 shows in more detail the conditions experienced by the SCP as it transited this section. Figure 3.6, shows SCP speed (gold), calculated flow velocity (green), vane position (pink) and distance traveled (red).

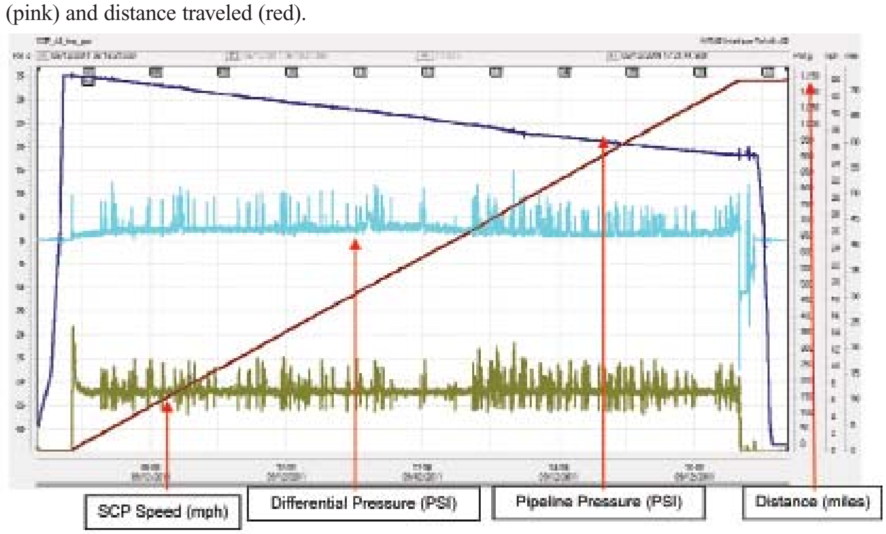


Figure 3.7: Pig Speed, Differential Pressure, Pipeline Pressure, Distance.

blue), and distance traveled (red).

It can be seen that the differential pressure required to drive the pig is approximately 2.2 psi (0.15 bar) for the whole run.

Receipt of the SCP, again, requires no special equipment and the receipt procedure is the same as with any other pig.

Performance Of Tool Controlling Speed

As can be seen from figure 3.5 the SCP was very effective at reducing its transit velocity. For the whole run the average speed reduction compared to gas velocity was 15 mph. and the average tool speed was 7.3 mph, well within the set speed of 6-8 mph. It is very difficult to completely avoid speed excursions where the tool goes well outside its control parameters. This is always the case in gas pipelines and unfortunately there is very little that can be done to completely eliminate the problem. However, during the run there were minimal speed excursions which were controlled quickly by the electronics.

By managing to control the pig speed, pipeline cleaning is much more effective. The chances of the cleaning pig hydroplaning over any water in the pipeline are also minimized and the maximum debris removable is possible due to high velocity bypass acting as a forward jet to keep particles in suspension. This, combined with a minimal loss in revenue, makes the SCP a very valuable tool.

Future For Tool

After every run the performance of the tool is evaluated and a continuous program of development is in place to continue to improve the performance. The SCP has already been fitted with a 6-axis IMU to give accurate pitch and roll information and this will eventually be improved to include slope information. It will be possible to identify any low points in the pipeline that are likely to collect liquids — useful additional information from an SCP run.

Black Powder Removal

Black powder can be found in both dry and wet gas pipelines along with other contaminates like liquid hydrocarbons, water and sand etc. Typically made up from a combination of iron, sulphur iron oxides, corrosion inhibitors and solvents, in wet conditions it can form a sticky tar-like substance. In dry condition it forms a powder which can have a significant impact on gas flow. It can also be abrasive and have a longer term impact on the operation and performance of valves, flow measuring equipment and other process instrumentation, along with excessive wear on pig seals.

With high flow bypass through the SCP body, by design, the tool can be used for the removal and management of black powder in dry gas pipelines as part of the operator's flow assurance strategy.

Polyurethane guide discs provide an effective scraping and bulldozing action ideal for pushing out loose debris. However, there is a risk that debris can build up in front of the pig and potentially block the line. Bypass through the SCP body creates turbulent flow in front of the pig, keeping the black powder in suspension, mitigating the risk of pipeline blockage by preventing it from building up into a solid mass.

Black powder removal can be further enhanced by the addition of jetting nozzles and heavy-duty pencil brushes and high-strength magnets.

Other Cleaning Options

The SCP has substantial unused space on the body where other cleaning options can be fitted. The SCP has now been proven as a standard cleaning pig and these other options can be explored as client requirements dictate. Already the SCP has been fitted with high-power Neodymium magnets with great success at removing metallic debris. It would be possible to fit other cleaning options such as brushes, ploughs, pin wheels or scrapers.

Bypass provides a significant benefit with any cleaning application, especially where there is a potential for debris buildup. The SCP design is such that it can be easily configured to suit a wide range of applications.

- In standard configuration (4 cups and 2 guides) the SCP can be used for the removal of loose debris such as black powder, dust, sand and soft pipewall deposits (wax).
- The addition of brushes increases cleaning performance further by improving the sweeping effect, brushing debris directly from the pipewall and also cleaning into corrosion pits. Brushes can be fixed or spring-mounted.
- The addition of de-scaling pins or scraper blades can be considered for the removal of hard pipewall deposits such as scale and wax.
- The addition of high-strength magnets will enable the SCP to clean and pick up ferrous debris such as pipeline cuttings after tie in or hot tapping work scopes.
- 'Smart' pipeline gauging. Used to confirm minimum bores and indicate pipeline damage, gauge plates can be easily added. In the event of a gauge plate being damaged, background data already collected by the SCP, in particular ride profile and linear distance, will enable the operator to accurately pinpoint the location where the damage occurred.
- Other more advanced innovative technologies such as debris mapping and pipeline profiling options could also be added.

Mounting Of Caliper And Debris Sensors

As well as the potential for using the SCP as a cleaning pig it could also be used as part of an intelligent cleaning program in high-velocity pipelines. Again, as there is significant unused space on the SCP body it is possible to add calipers and debris-mapping sensors. This would allow an initial survey to be carried out as part of operational pigging to assess the volume of debris in a given pipeline. A tailored pigging program would then be conducted and a final survey carried out to assess the effectiveness. This could all be done using speed control pigs which would have a minimal effect on product flow and therefore cost.

A variety of items have been developed and successfully launched a range of innovative, ATEX-certified technologies that add intelligence to pipeline cleaning, removing the mystery, eliminating uncertainty and mitigating the risk of a failed inspection, or even worse, a blocked line as a result of debris buildup such as wax, scale and sand in a pipeline.

These new technologies can be used to measure, monitor and record pig performance, providing a real-time view on the effectiveness of any mechanical cleaning strategy or campaign by confirming and qualifying the actual level of internal cleanliness attained. The same technologies can also be applied to chemical-cleaning performance management.

These new technology tools are typically used ahead of pipeline cleaning campaigns, either production pigging programs or pre-inspection cleaning, to provide a baseline indication on internal cleanliness or periodic pig performance monitoring. These tools provide information on debris thickness (wax, scale, sand, black powder etc.), location, orientation and volume. The initial data collected is used as the basis for pig selection and to determine the optimum pigging program. A run midway through the program is used to assess the effectiveness of the cleaning pigs being used.

The program and/or pigs being used can be modified as necessary, depending on the results. A final run at the end of the program is used to confirm that the required standard of cleanliness has been achieved or in the case of production pigging, is being maintained. More often this approach is used to qualify line cleanliness ahead of an inline metal loss inspection, eliminating the risk of a failed inspection run as result of a dirty pipeline.

When installed on board cleaning, scraper, or more specialized pigs like the SCP, it will give a pipeline ride profile that provides an accurate indication on the pipeline's cleanliness and geometric configuration. When fitted on a gauging pig the data recorded will identify exactly where any gauge-plate damage occurred in the pipeline, i.e. 'smart gauging'.

The debris mapping tool, DMT, can be fitted to an operator's production pig or it can be supplied as a stand-alone unit. The DMT uses the same electronics module as the PET and gathers the same data set. However, depending on the nominal pipeline diameter, it can accommodate up to 96 debris measurement sensors. The DMT sensors provide 360° coverage, are in direct contact with the pipewall and are used to accurately measure hard or soft pipewall deposits and or debris. The DMT will identify the thickness, linear location, clock position and the volume of debris deposited along the length of the pipeline.

The pipeline profiling tool provides a comprehensive pipeline profile, measuring and recording pipeline operating parameters, such as pressure, temperature, velocity etc. debris mapping and a detailed geometry (calliper) survey. It is basically a combination of the PET and DMT technologies with the addition of a geometric survey capability. It uses the Advanced Geometry Tool (AGT) as the lead module or tow pig. Fitted with an array of caliper sensor arms, providing full 360° coverage, in addition to the above, the PPT will identify the location, orientation and measurement of dents, ovality, bends and diameter changes.

Comparison of the AGT and DMT data sets provides clear differentiation between pipeline anomalies or features and debris or pipe wall buildup. This provides the operator with a comprehensive and detailed pipeline profile survey.

Mechanical cleaning programs can be effective in the removal of sand, wax and hard pipewall deposits subject to the anticipated volumes of debris and the length of the line. Adding 'intelligence' confirms the effectiveness and provides confirmation that a pipeline has been cleaned to an acceptable standard either for metal loss inspection (MFL, UT, EMAT, etc.) or the implementation of a regular production pigging program. Periodic use of tools like the PET, DMT and PPT, either as stand-alone tools or combined with the SCP, will confirm that the level of cleanliness originally established is monitored and maintained as part of an operator's flow assurance strategy.

Ability To Tow Other Tools

The SCP also has the ability to tow other pigs, either as part of a more advanced cleaning program or for an inline inspection. No changes need to be made to the control electronics to allow this to happen and the only requirement for the pig being towed would be that it has substantial bypass.

Conclusions

The SCP is ultimately a 'vehicle of opportunity': it can be specifically configured and tailored to suit the client's application and satisfies many requirements on one run. ***P&GJ***

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