COMBINING INFORMATION FROM PIGGING WITH DATA LOGGER WITH OPERATIONAL AND PIPELINE DATA FOR WAX ZONE ESTIMATION

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Abstract

Data from cleaning pig runs with data logger has been combined with operational data i.e. flow rate and pipeline information e.g. joint length. Main parameters from the data logger are acceleration in three directions, differential pressure and temperature. From the data wax deposition zones can be estimated and pig speed for each pipe joint, joint speed, can be calculated. By comparing the calculated joint speed with calculated speed based on differential pressure, DP speed, it is possible to conclude if the bypass set up has been fully open during the run. This information is a useful input to the wax cleaning program. The analysis is performed in MATLAB partly with MATLAB built in code partly with in-house written code.

Introduction

Equinor started the analysis of collected data during cleaning pig runs in 2012. The data was used to determine wax deposition zones and to optimise the cleaning pig frequency. The time-based data was converted to distance by average speed assumption. With a varying differential pressure this is not the case as the speed is dependent on the differential pressure. Thus, work was initiated to calculate an accurate pig speed and distance scale which also enables comparison of multiple pig runs in the same pipeline.

PDL acceleration data and joint lengths from the pipe tally were used to calculate the joint speed. This can be compared to the flow speed and the DP speed to get a good description of the bypass in the different pipeline sections. This paper will describe the different steps in achieving the different pig speeds and the conclusions that can be drawn.

The data used for the work originates from three different sources. Process data and pipeline system data was retrieved from various Equinor internal data bases. In addition, data from cleaning pig runs in the pipelines were collected. The data logger collect data for pressure, differential pressure, temperature and acceleration in three orthogonal directions. From the data logger data, rotation, inclination and bends is calculated.

Pig speed calculations

The first two approaches for pig speed calculations proved to be inaccurate. One assumes constant speed throughout the whole pipeline and the other used the flow speed and differential pressure to calculate the pig speed. The only parameter in the calculation using differential pressure that is not measured is the flow coefficient, c, in the equation for the bypass flow, ϕ,

$$\phi = A * c * \sqrt{2 * DP/\delta} ,$$

where A is the total bypass area and δ is the density of the fluid. For instance, in data logger runs in a pipeline with a wye the value of the flow coefficient had variable value to match the essential parameters, e.g. total pig time and time to wye passage. However, in wax rich pipelines where there is a risk for bypass ports getting clogged and the analysis showed that the mismatch was due to changes in bypass area and not in the flow coefficient.

The final approach was to calculate the joint speed based on the time between girth weld passes and a calculated average length of the pipe joints. The average joint length is from the pipe tally and the time between girth weld passes is obtained from data logger acceleration data. Figure 1a shows acceleration data for the whole pipeline length and Figure 1b shows the same data zoomed. Looking at the whole distance, the acceleration data seems to consist of noise. By zooming in, a regular pattern of peaks can be seen originating from girth weld passes. In this example all three acceleration directions have clear peaks. However, this is not always the case. Sometimes peaks are only shown in one direction. Wax rich sections can create high noise levels equal to or higher than the signal from girth welds or the girth welds may be masked by the wax layer, making it difficult or impossible to detect the girth weld passes.

It can be noted that every second peak height is high, and every second peak is low. This is explained by different welding methods during laying of the pipeline.

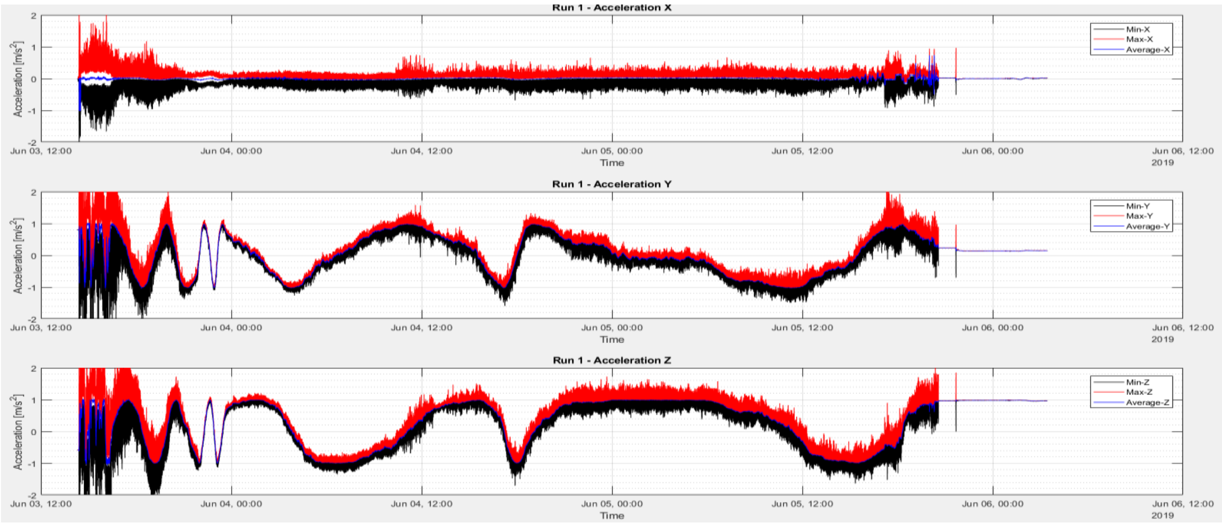

Figure 1a. Acceleration in three orthogonal directions for the whole run.

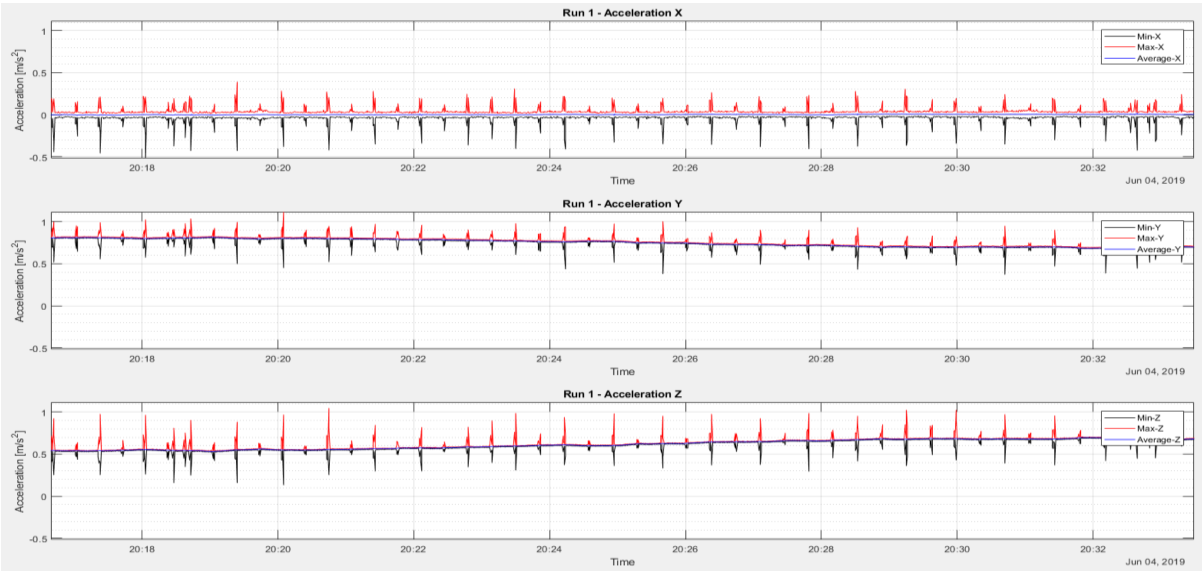

Figure 1b. Acceleration in three orthogonal directions in a zoomed in section.

The number of girth welds in a pipeline requires a digitalised recognition of the girth weld peaks. MATLAB provides several digital filters. After tests of several filters an adequate solution was found. The chosen filter can select all peaks in pipeline sections with low noise level. From the detected peaks the joint speed is calculated using inhouse written code. With all data, process data, system data and from data logger, MATLAB provides the possibility, trough inhouse written code, to calculate and display useful data e.g. percentage bypass open and plot the data on a selected format, e.g. time based, distance based and multiple runs in the same plot. Additional code to the MATLAB library were developed inhouse to be able to perform the desired analysis.

Figure 2 shows the result after processing the acceleration data in the MATLAB filter for peak indication. The indicators at the top of the peaks indicate that the software has identified the peak. In this section of the run all peaks were identified. To make the peaks more pronounced the, minimum acceleration value, a negative number, was subtracted from the maximum acceleration value resulting in more distinct positive peaks. The time for each girth weld pass is extracted and used to calculate the pig speed by using the average pipe joint length.

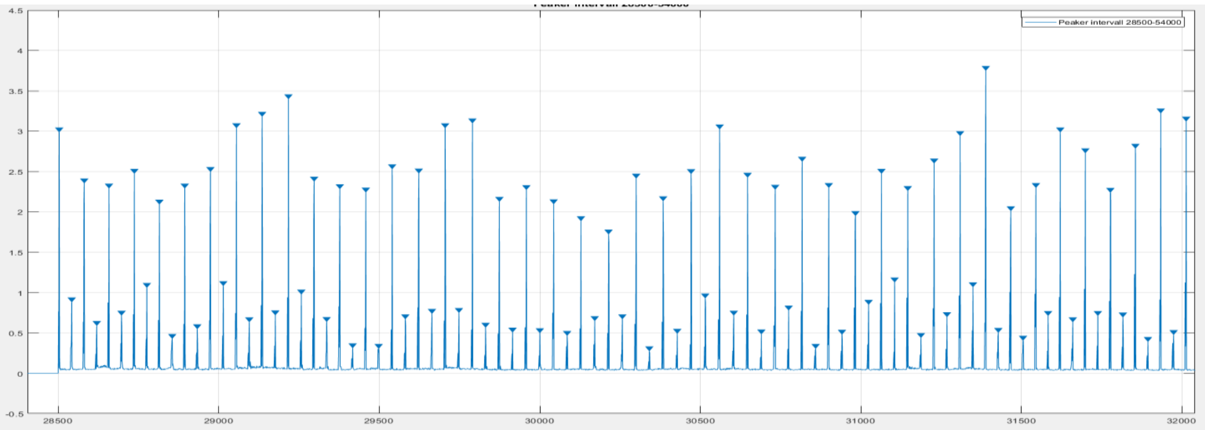

Figure 2. Girth weld pass identification by MATLAB filter.

Pig speed verification

To verify that the calculated joint speed and distance are correct the data can be compared with known features in the pipeline, e.g. buckle arrestors, pipeline depth etc. For this pipeline buckle arrestors were used. The roughly 12 m long buckle arrestors consist of 3 pieces, 4 m long welded together. In a plot, joint speed vs distance where the 4 m long sections will be registered with a higher joint speed. Figure 3 and 4 shows the joint speed graph vs distance with the position of the buckle arrestors. As can be seen there is a good match between the position of the buckle arrestors and the location of the peaks indicating shorter distance between welds. This verify that the calculated distance data and the joint speed data are correct.

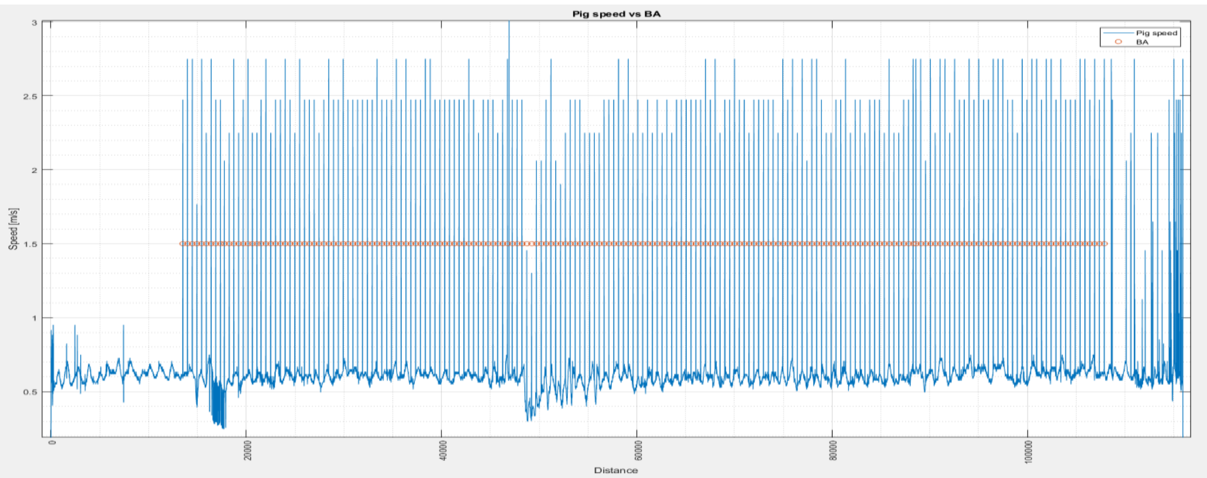

Figure 3. Joint speed plot with peaks for buckle arrestors and location of buckle arrestors.

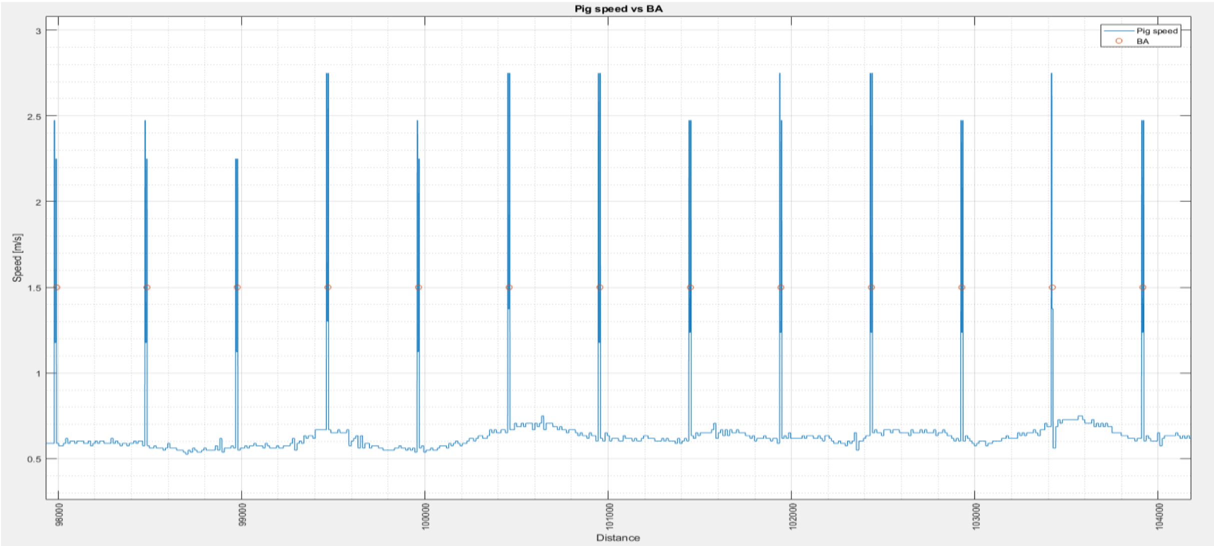

Figure 4. Zoomed in section of figure 3.

Flow speed correction

The flow speed is obtained from the flow measured either at the launching site or the receiving site. A change in flow propagates through the pipeline with the speed of sound of the liquid, causing an off-set when comparing the peaks in joint speed for a certain location in the pipeline with the peaks of the flow speed, measured at one end of the pipeline. To be able to perform the desired comparisons of different speeds it is necessary to perform an adjustment of the flow speed with respect to the joint speed. This can be done by applying a linear correction of the measured flow data. This is verified by plotting joint speed and corrected flow vs time.

Figure 5 shows three curves. The black curve is the measured flow, the blue is the corrected flow and the red is the calculated joint speed. After the correction, the joint speed and flow peaks appear at the same time which is expected from a physical point of view.

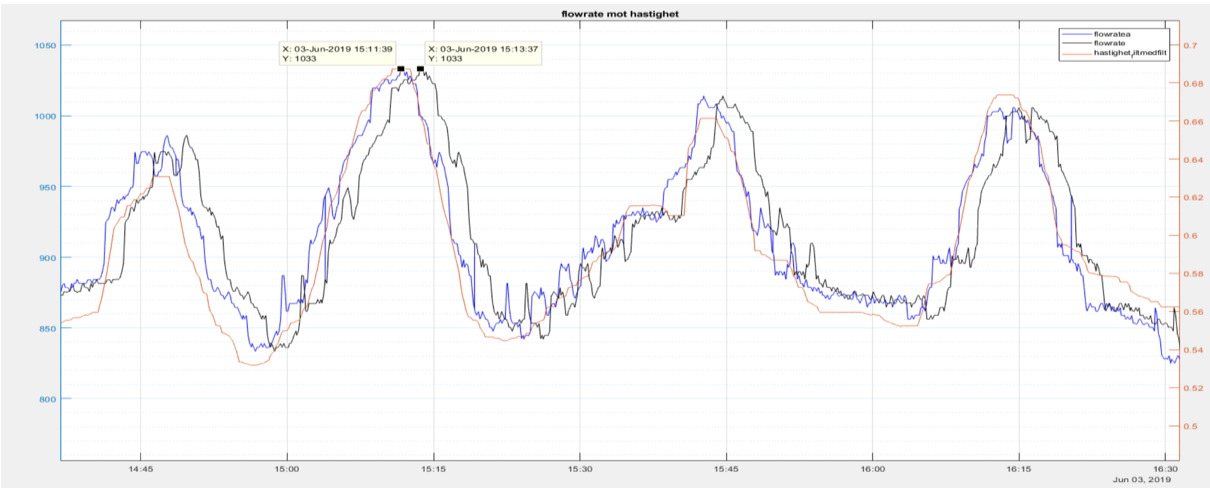

Figure 5. Correction of flow speed. The black curve is the measured flow, the blue is the corrected flow and the red is the calculated joint speed.

Data analysis

With the data processing described above, it is now easy to plot all data vs distance and to compare different runs. This is done in figures 6 and 7. The top graph in figure 6 shows three different speeds, flow speed in red, joint speed in black and DP speed in blue. A wye is located at roughly 43 km and flow from another location is added, resulting in speed increase.

Before the wye piece the two calculated pig speeds have the roughly the same value. DP speed oscillates as it enters a relatively short section of wax, from about 25 km and all the way to the wye.

About 20 km after the wye there is a separation of the two pig speeds. The joint speed approach the flow speed and the DP speed remains at a lower level and varies as expected with the variation in differential pressure, see the middle graph of figure 6. The difference in speeds and the increase in the differential pressure data indicate that there is second wax zone.

The pig is set up with bypass to prevent wax build up in front of the pig. However, as the pig enters the second wax zone we believe that the bypass area is partly blocked with wax. The bottom graph in figure 6 shows the percentage bypass area open. Before the pig enters the wye the percentage bypass area is stable apart from the very beginning and in parts of the first wax zone. As the pig enters the second wax zone it builds up to a permanent blocking of bypass area and levels out at about 30 percent open.

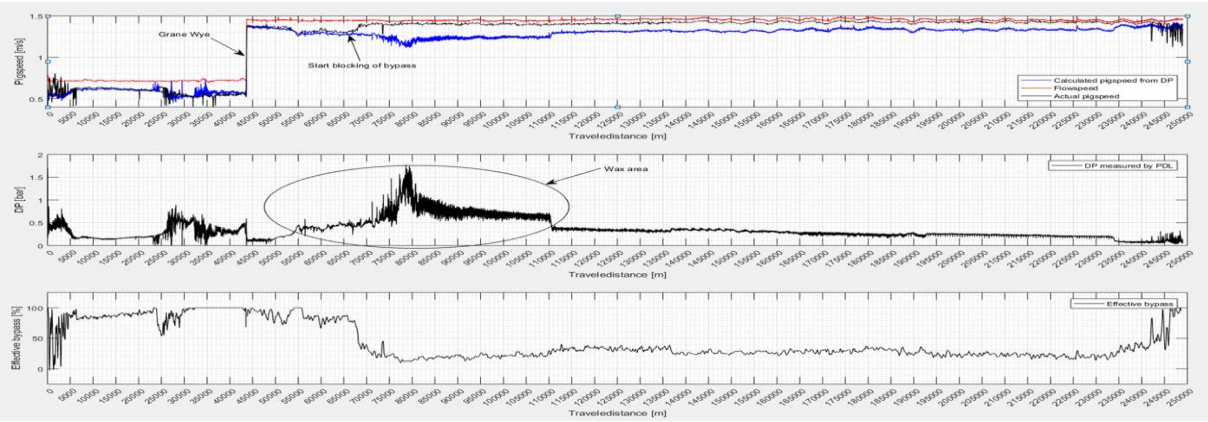

Figure 6. The figure shows three plots. At the top are the speed graphs, flow speed in red, and joint speed and DP speed, black and blue respectively. The middle graph shows the measured differential pressure and the bottom graph shows the percentage of open bypass area.

Figure 7 shows three different runs in the same pipeline. All three graphs show the same curves, maximum, minimum and average acceleration in the x direction, axial, together with temperature and differential pressure. The colours of the curves are green, yellow, red, black and blue. The top graph also includes a calculated wax deposition curve, pink. The pig in run 1 had under sized guide discs, 7 mm smaller than the pipeline ID and the pigs in runs 2 and 3 had over sized guide discs, 4 mm larger than the pipeline ID.

The differential pressure curve in the three graphs indicate a wax zone starting at about 18 km. This is also supported by the similarities in shape of the differential pressure curve and the wax calculation even though the calculation states that the wax deposition occurs in a wider zone than indicated by the increase in differential pressure. The wax layer is calculated to be maximum 2 mm thick. An accurate wax layer thickness estimation cannot be done based on the differential pressure data.

The shape of the differential pressure curves as well as the accelerations does not fully correspond between the runs. Part of it can be explained by the different diameters of the guide discs, e.g. the difference in shape between run 1 and runs 2 and 3. Runs 2 and 3 show similar shape for the first 30 km. From there and onwards the acceleration data in run 2 differ substantially from the two other runs. The cause of that is not fully understood. There is nothing in the wax model that predicts deposition in that section.

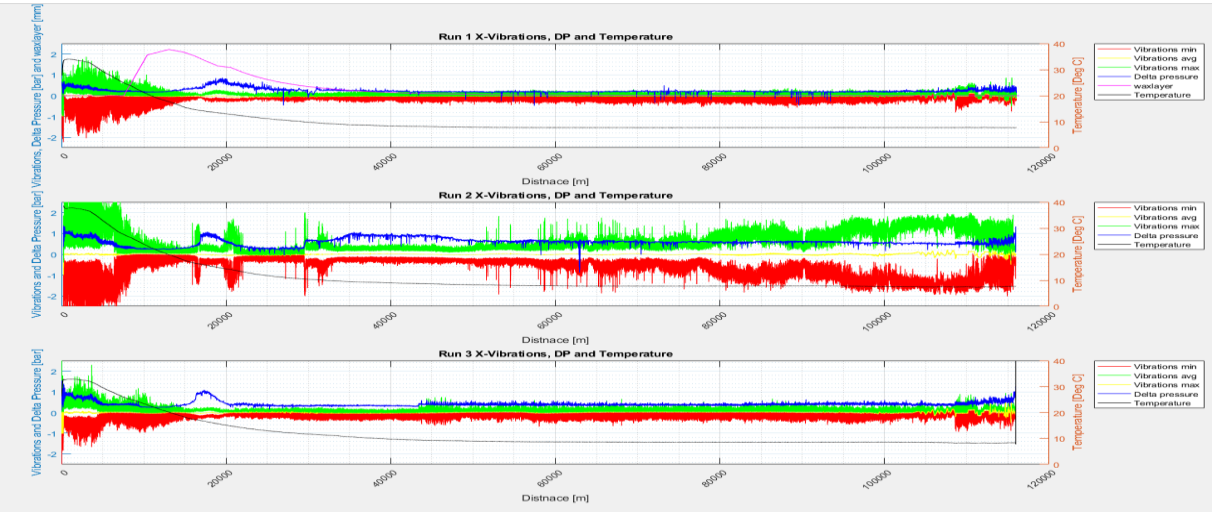

Figure 7. The figure shows three different runs in the same pipeline. All three graphs show the same curves, maximum, minimum and average acceleration in the x direction, axial, together with temperature and differential pressure. The colours of the curves are green, yellow, red, black and blue. The top graph also includes a calculated wax deposition curve, pink.

Monitoring of operational data is an important part of pipeline integrity management. Figure 8 shows a plot of the variation in pressure drop as a result of pigging. The pipeline is pigged with 14 days interval and the curve shows that there is a pressure increase of about 0.7 bar between pigging. This shows the need for pigging and in combination with data analysis mentioned above it is possible optimise pigging frequencies and pig design.

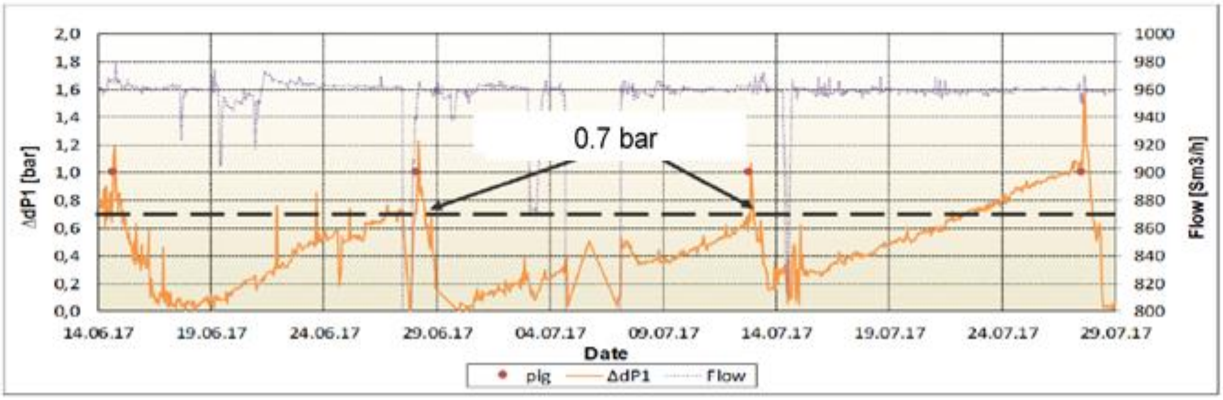

Figure 8. The graph shows 0.7 bar pressure build up between two pig launches.

Discussion

The paper shows the possibility of extracting useful information about the pipeline by combining datalogger data, pipeline system data and process data. Data that can be extracted is joint speed, effective bypass which is derived from flow speed, joint speed and differential pressure. This is made possible as the data is shown as a function of distance rather than time.

The combination of information from different data bases is shown to be a useful tool in understand more about the wax appearance and pig performance. With more detailed information of the pig behaviour, e.g. accurate pig speed for the whole pipeline, it is possible to identify wax zones and it gives a basis for improved pipeline integrity. It also contributes to a well-founded selection of cleaning pigs and set-up of cleaning pig program prior to an inline inspection.

Even though a lot of information has been extracted already there is a potential to obtain more. Further work will focus on software development and interpretation and understanding of the data.