PUSHING THE BOUNDARIES OF DUAL DIAMETER PIG DESIGN

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INTRODUCTION

As the demand for dual diameter pipeline systems grows, the demand to develop a range of dual diameter pigs becomes ever more acute. This paper has been produced to aid the selection process for dual diameter pigs.

The paper presents current technology and describes the advantages and disadvantages of the various designs of dual diameter pig in the market. It also goes into detail of the function requirements of pigs and the validation process, which should be undertaken, prior to using a pig in a real life pipeline.

Pipeline Engineering and Supply Company Limited is has been designing pigs for specialist applications for more than 30 years. They are Europe's largest suppliers of pigs and associated pipeline pigging equipment.

Background – why the need for dual diameter pigs

For many years the industry standard for offshore oil and gas pipelines, has been to design pipelines with a constant internal diameter and minimum bend radii of 5 times pipe diameter. The internal inspection companies, who needed tight clearances between their inspection vehicles and the pipe wall, predominantly drove this requirement.

It was clear however, that if these requirements could be relaxed, then large savings could be made to the overall pipeline system cost. For example, if the riser and associated top side pipe work could be made of smaller pipe ID to that of the main pipeline, then weight and space could be reduced, which in turn could have considerable cost reduction impact.

For obvious reasons these savings become ever more apparent as pipelines moved into deep water.

Hence the offshore pipeline industry needed to push forward the boundaries of dual diameter pigging technology.

Dual diameter utility pig design selection

By utility we mean the pig can be used for pre-commissioning exercises such as flooding, cleaning and gauging, and dewatering and also for routine pigging tasks such as liquid hold-up removal and pipeline cleaning.

A description of the alternative types of pigs available, which can negotiate the different, pipeline percentage changes are presented. These include: –

Butterfly or petal disc support type pig;

Paddle Pig (patent applied for);

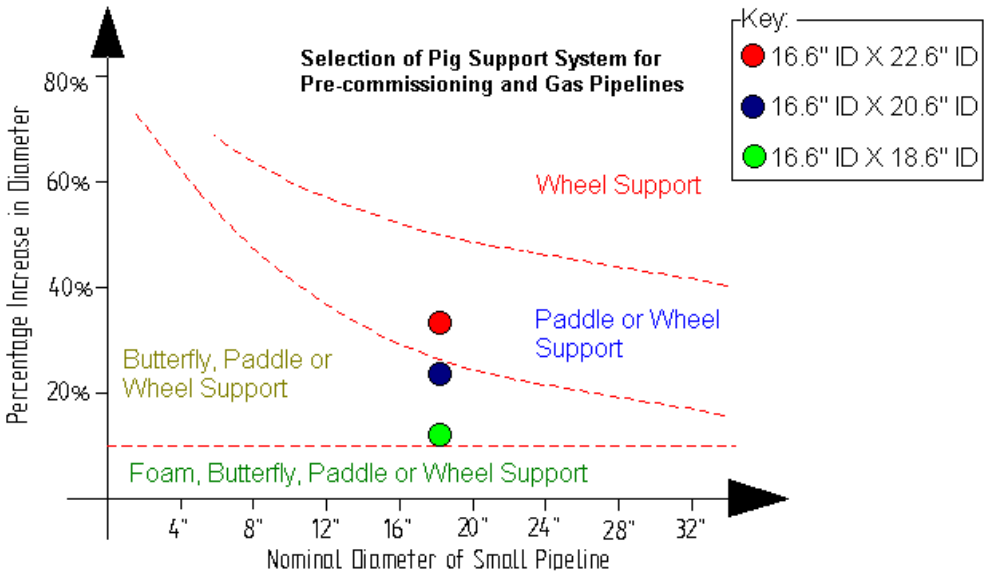
Wheel or spring suspension pig.

Dual Diameter Pig Selection

The Dual Diameter pig selection process is based on a worst-case scenario involving high friction pigging in dry environment. This can be during pre-commissioning for example. Figure 1.1 shows the selection graph for this: -

Figure 1.1

Dual Diameter Pig Selection



Pig Selection guide based on small diameter and percentage increase for higher friction lines. If better lubrication is present, such as in Oil lines then there may be more scope for using Foam and Butterfly supports

The graph shows four operating envelopes plotted on the following axes: -

X-axis: Nominal diameter of smaller pipeline.

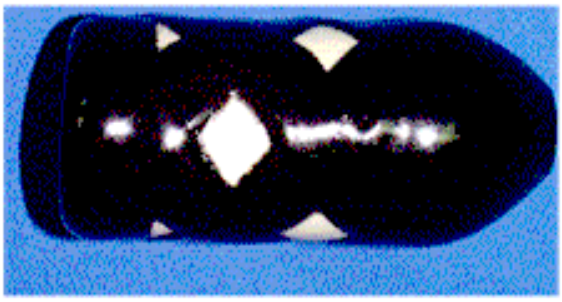
Y-axis: Percentage increase in diameter.

There are four possible main pig types available. These are described below. As the pipeline diameters increase and the percentage increase in diameter increases then the pig types available reduce. This is since the weight of the pig increases with the pipe diameter and the flexibility reduces with increased step change. This is seen in the graph in Figure 1.1.

Foam Pigs

Figure 1.2

A typical Foam Pig



Foam pigs have been used for many operations where it is uncertain what the state of the pipeline is. For example when pigging an old line for the first time, a foam pig can be used to check out the line, as it is unlikely to get stuck. For this reason, they have also been thought of as dual diameter pigs by default. However, the dual diameter capability is limited, as they tend to twist in the line, break-up and get damaged. For this reason they are not recommended for large diameter and percentage changes.

Advantages: Cheap, very unlikely ever to get stuck.

Disadvantages: Inadequate seal, not efficient and may get damaged or destroyed.

Butterfly Pigs

Most dual diameter pigs now separate the functions of sealing and support. That is they have one set of elements whose function is to support the pig in the large line and then collapse into the small diameter. They then have a separate set of seals to provide drive and perform useful function in the pipeline.

Figure 1.3

Butterfly Type Pigs

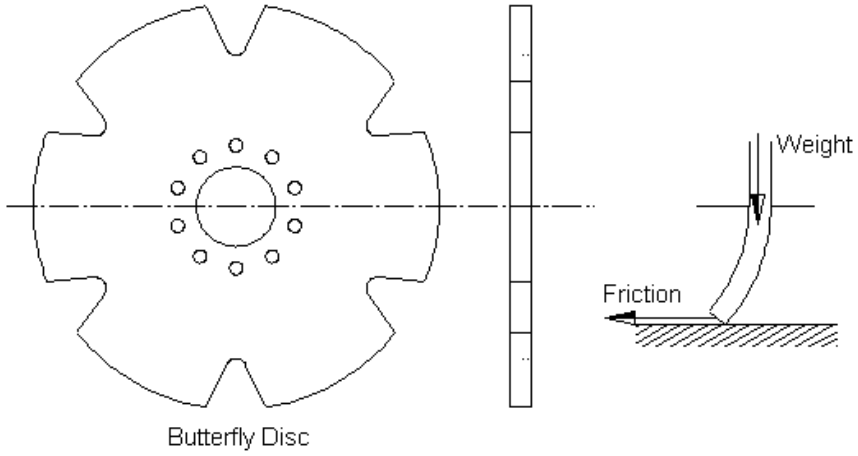
Butterfly pigs are typified by a slotted guide disc which is used to support the pig in the large diameter and which folds up into the small diameter line. There is usually a fine balance between getting adequate support and enough flexibility. However, for medium range dual diameter scenarios, these have been used successfully now by a number of pipeline operators to solve the problem. If designed and tested correctly they will do the job.

Advantages: As cheap as normal pigs, high efficiency in small diameter line

Disadvantages: Tendency to nose down (See Figure 1.4), difficult balance between support and flexibility, High friction in small diameter line. Probably require longer test program, more difficult to design.

Figure 1.4

Friction causes Butterfly Pig to Nose down



Paddle Pig as developed by Pipeline Engineering

The Paddle Pig has been developed to exploit the advantages of the Butterfly pig while overcoming the main dis-advantage, that of lack of centralisation in the large diameter pipeline.

The paddles support the pig by overcoming the main problem with the butterfly pig, friction as demonstrated above in Figure 1.4. The walls of the pipeline also lend to the support as it is always at right angles to the paddle arms.

Collapse into the small diameter line is achieved by rotation that is induced by chamfers on the paddles.

Sealing is performed by Buckle Inducer type seals. These seals act as normal seals in the large diameter line and are very efficient. Buckle Inducers are then used to fold the seals up in a uniform and repeatable manner in the small diameter line. Separate small diameter seals then take over the drive and sealing function.

Advantages: Very good centralisation, very good sealing and functionality

Disadvantage: High friction in small diameter line.

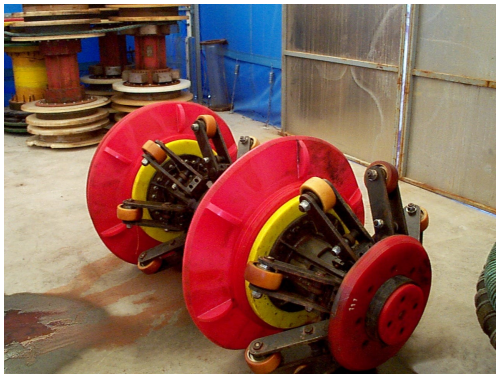
Spring Suspension Pig (Wheel Pig)

The wheel pig centralises the pig exactly on the centreline of the pipeline. The suspension modules consist of a number of suspension arms each of which is linked to a central shaft, (Figure 1.5), in such a way that when one wheel arm is deflected, the other seven are also deflected. The shaft resists the deflection using springs. Mechanical advantage is provided by the way the arms are linked to the central shaft.

The basic principle of operation is that the total spring force in the cylinder is greater than the weight acting on the module. The pig rides on the centreline since if it were to drop, the restoring force would be greater than the weight. The contribution to pig friction and differential pressure from the wheel module is negligible in both line sizes as it is merely rolling friction from the wheels.

Figure 1.5

Spring Suspension System



Buckle inducer discs are again used for the sealing function.

Advantages: Very high efficiency, very low friction, excellent centralisation.

Disadvantages: Very expensive compared with normal pigs (up to 8 times as expensive)

Pig Wear and Seal Permanent Set considerations

When negotiating the small diameter lines the following can occur: -

Driving seals, or the small diameter seals can wear in the small diameter line as a result of large pressure drops increasing the load on these seals. This will lead to seal flip (or loss of capacity to support the pressure) and ultimately the pig will stall.

As a result of being left in the small diameter line for some time, there can be a problem with the seals recovering shape. This is known as permanent set. This could

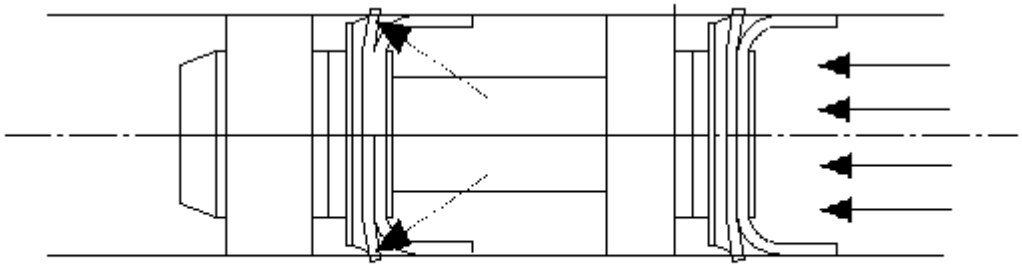
be a problem even on the small section from the riser. However, this problem has been encountered before and has been successfully overcome.

Seal Wear

The wear performance of the pig in most cases is not in question. However, the pig traveling in the smaller pipeline section can result in large differential pressure across the small diameter driving discs for the duration of the travel. This imparts a high load on the drive discs and may cause the discs to fail.

Figure 2.1

Wear of Drive Discs in Small Diameter Pipeline



If it is likely that the line condition will deteriorate then it is prudent to line the pipe with epoxy or similar in order to allow pigging to proceed. Additionally, during testing, attempts to reduce the differential pressure could be investigated, as this will further extend the piggable distance.

Permanent Set

Permanent set is as a result of compressive stresses in the PU material over time. Compressive stresses cause the deformed material to remember its shape and therefore when the pig emerges into the large diameter line, a full seal is not recovered immediately.

To mitigate against this it is necessary to select the correct seal material hardness. For diameter changes in the region of 2" it is not expected that there will be a major problem with permanent set. This has been observed before. For larger diameter

changes 4" plus, the hardness of the material used for the large diameter seals will be selected lower than normal at around Shore 65 A.

Selection of low hardness materials means that the compressive stresses in the material when the seal is folded into the small diameter line are greatly reduced. This reduces the effects of permanent set. In the case where only the riser is to be negotiated, then the time spent in the small diameter line is short and this has a significant effect also. Permanent set would not then be a major problem. Finally, even if there is an effect on the seals, the resulting flow of fluid past the seals should ensure that they recover and begin to seal again. Once there is differential pressure across the seal, then all effects of Permanent Set should be alleviated.

Functional Requirements

It is worth baring in mind that the pig is being put into the line to perform a certain scope of work. The measure of success is more than just simply getting the pig to travel from one end of the line to the other. The selection of pig design should be based on (and measure against) a set of functional requirements.

These criteria may be proven by test, CAD or calculation as agreed and deemed necessary.

Negotiate pipeline without excessive nose down or wear of seals, and no metal contact with the pipe wall. A positive seal shall be maintained at all times;

Adequate provision for wear of the seals.

Negotiate bends, with a positive seal at all times and avoiding metal contact with pipe wall;

Negotiate transition pieces with full recovery of seals.

Span and negotiate any wye pieces while maintaining a positive seal at all times;

Negotiate longitudinal and circumferential welds without destroying the sealing action;

Consistently span and negotiate all tees in line, without loss of seal;

Provision of adequate bumper noses front and rear to avoid problems if pigs contact in the line;

Avoid through body and bolthole leakage.

Running differential pressure, straight and bend to be kept to a minimum;

Flip pressure, straight and bend to be kept to a maximum;

No visible forward leakage through pig or past seals in each pipe size with all seals working. No leakage when pig is stopped;

No visible reverse leakage through pig or past seals in all pipe sizes.

Ability of seals to recover completely after reversal of pig;
Ability of pig to accommodate magnets and gauging plate correctly positioned on pig;

Ability of pig to take data logger;

Ability to take isotopes and pig tracking devices such a transponder.
Ability of pig to accommodate magnets and gauging plate correctly positioned on pig;

Acknowledgements

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