DEVELOPMENTS IN MECHANICAL PRODUCTION CLEANING OF PIPELINES

By Peter Fretwell, Pipeline Engineering, Richmond, UK

ABSTRACT

PE has over 30 years experience in production cleaning of pipelines. This presentation will focus on the latest developments in pigging philosophy and the importance of tool design for specific production cleaning requirements. The presentation will also cover a number of case histories highlighting production cleaning issues.

WHY PIG A PIPELINE

Pigging is an operation to remove debris or unwanted deposit build-up in a pipeline. Debris and deposits in a pipeline will result in a pressure build-up and if no pigging programme exists the debris and deposit build-up could continue to rise which will create greater back pressure on the line, causing higher maintenance on pumps and the line could eventually become blocked.

If no production pigging programme exists, the main concern is the risk involved in pigging at all. The Operator knows that pigging is a solution for removing the debris and deposits, but is also concerned that in attempting to solve the problem, the situation could become worse, as aggressive cleaning could result in a blocked line. The longer the pipeline is left producing without pigging however, the worse the situation could become.

DATA GATHERING

Once a decision has been taken to clean a pipeline (by pigging), it is necessary to gather as much operational data as possible to determine the nature and amount of debris which could be present. Data, such as temperature, profile, pressures, flow rates, product chemistry, pipeline geometry features and any operational pigging history all help to be build a picture of what may be in the line. This early evaluation is normally conservative in its approach i.e. there is a tendency to over estimate the amount of debris.

PROGRESSIVE CLEANING

A specialist contractor is then asked to develop a “progressive” cleaning program. Most cleaning programs can be broken down into two distinct operational phases. The first phase is to prove that the line is capable of being pigged with aggressive cleaning tools. The second phase is then to carry out this aggressive cleaning.

PROGRESSIVE CLEANING PHASE 1

In Phase One, it is normal to run foam pigs of various foam densities. These, should they meet with obstructions or restrictions in bore will collapse or break up with an increase in pressure differential across them, hence allowing production to continue. In the case of crude oil lines with heavy wax deposits, even performing this task, can have some associated risks. The act of running a low density foam pig for instance, can push soft wax ahead of it which can in some cases result in causing a wax plug or candle. The problem with wax is that, once plugged, an increase in pressure can lead to wax compaction, whereby the lighter paraffins and asphaltines are squeezed out of the wax, creating a harder plug or candle. Hence for waxy lines it is wise to carry out initial chemical treatment prior to commencement of the pigging program. Once the first pig has been launched and received it proves there is a path

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through from one end of the pipeline to the other. It is these initial stages of a Progressive Cleaning Operation that are the most important.
The First Phase is a confidence building exercise and starts with the receipt of the initial pigs no matter what type. The pigs often used at this stage are simply 1 to 2 lb/ft^3 foam swabs, the type used for drying pipelines. They are very soft and will compress very easily to approximately 20% of their original size. They can either be bare with an impervious backing or coated with polyurethane. It should also be remembered that foam pigs of any type will not necessarily remove wax from a pipeline. They simply spread it more evenly along the pipewall moving it from one place to another and smoothing out the peaks and troughs in the wax deposits. They are also very good at doing exactly what you do not want them to do such as disappearing down branches when they come into the receiver trap should the necessary precautions not be taken.

A number of these would be sent initially and then foam pigs of a higher density and diameter would continue to be run until such time that enough confidence has been gained to move on to the next phase. It should be remembered that this, Phase One of the Progressive Cleaning Operation is the most important. It is not the same as reading a book where you start at the beginning and go though to the end, you have to be prepared to make adjustments and deviations to the procedure on the way. For instance, it might be decided after running a few pigs, it would be more beneficial to continue running more of the same type of pig than was originally planned or possibly less of another. There has to be flexibility in the procedure to allow for this type of deviation. One thing that should be remembered is this is a process that cannot be rushed and is, to some degree impossible to put a time scale on.

These initial stages set the parameters for Phase Two, when far more aggressive cleaning tools will be used to achieve the cleanliness required. It should be remembered that when the Progressive Cleaning Program is completed the cleanliness of the pipeline needs to be as near to what it originally was when first commissioned.

PROGRESSIVE CLEANING PHASE 2

The Second Phase involves the use of cleaning tools that gradually become more and more aggressive. Their design will generally consist of a metal body with either cups or discs attached to them or a combination of both. In the final stages they may have studs, pins, scraper blades or metal discs attached to them to remove the deposits from the pipewall. The type used will, to some degree be dependent on the contractor used for the operation, as there are companies that have patents on certain types of attachments that mount to the metal tubular body section of the cleaning tool. All are designed to aggressively remove wax or scale deposits from the pipewall.

In the initial stages of Phase Two proving will continue using flexible type drive cups attached to a metal tubular body; this is to ensure that it is possible for the aggressive cleaning tools to traverse the pipeline section without becoming lodged. Often tracking devices such as electromagnetic transmitters or acoustic pingers are used to enable the tools to be located in the event of them becoming lodged while traversing the line.

DATA GATHERING REMAINS A TOP PRIORITY

It is important to remember at this juncture that historical data regarding the pipeline plays a major part in the construction of the cleaning tools as does any previous pigging history if any has been carried out. Data regarding bend radius, tees, i/d variations, valve type and bore, 'wye' sections, pig trap dimensions, lengths of individuals sections making up the pipeline such as flexible jumpers and risers, flow rates and product type all play a critical part as to how the cleaning tool will finally be constructed and dressed to ensure it can safely negotiate the pipeline.

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It is in Phase Two that debris will start to be removed from the pipewall and quantities of wax and debris will start to pass through the system including separators, filters and the like. Deposits/Debris will also be evident in the receiver trap when the cleaning tools are removed and great care should be exercised to ensure that the tool is fully entered into the oversize barrel and not sitting in the trap isolation valve because of debris that has been pushed ahead of the tool stopping it entering fully into the oversize barrel. Again, as with Phase One and the foam pigs, the way forward should be one of extreme caution. Removing too much wax and debris at any one time can create major problems. For instance, the cleaning tool can become lodged in the line as a result of removing too much debris, or it can build up a "wax candle" in front causing handling problems and disposal problems. The process cannot be rushed and enough caution cannot be exercised during the operation. It is far better to take longer by removing a little at a time and complete the operation than to rush and create problems which generally means that the down time and loss of production are much more protracted.

PLANNED PRODUCTION CLEANING IS A GOOD INVESTMENT

The majority of lines that suffer with blockages or reductions in bore due to wax and debris build up are generally smaller in diameter more often the 6", 8", 10" and 12" sizes. Quite often they are short in length and form part of a production loop to a subsea manifold. Lines of this type have to be taken out of production to enable any cleaning tool to traverse the two sections and this is something that the operator is reluctant to do for obvious loss of production reasons. Wells need to be shut in, the pigging valve requires opening and the cleaning tool is generally pumped round using dead crude. All this adds up to additional work and a days downtime and loss of production and revenue. However, the penalties for not pigging regularly can and do far outweigh the downtime and production losses at the end of the day. Companies spend millions of dollars building a platform or FPSO facility, initially drilling the wells and putting down subsea manifolds. They also spend millions of dollars on maintenance of both, but neither of these is any good without the pipeline that connects them together.

Initially chemicals will be used to try and alleviate the problem, but in the main they will only soften the wax and not necessarily remove it in the quantities required. Chemicals are also expensive so the recommended quantities being injected are often reduced to try to once again lower costs. Chemical suppliers will agree that if wax inhibitors are used initially then they will prevent wax formation, but asking them to disperse wax that has been building up for years is not what these chemicals are designed to do. To resolve the problems adopting a Progressive Cleaning Program is normally the only means of removing large quantities of wax from a pipeline. The large cost resulting from the use of certain types of the chemical could have been saved if a simple Maintenance Pigging Program had been carried out in the first instance.

There are other problems just as demanding as removing wax and debris from crude oil production and export pipelines. For instance the removal of sand from any oil line is also very demanding and even more so from gas lines. Black Powder is probably the most demanding to remove and is generally found in dry gas lines.

The combination of high flow rates, dry conditions and the abrasive nature of the Black Powder does not create a user friendly environment for the polyurethane components used in the construction of any cleaning tool. Both Sand and Black Powder are very aggressive and the best way to remove them is with a combination of pigs and pick-up gels. The gel is contained between a number of cleaning tools which also cause the sand or black powder to be lifted thus enabling them to be collected and suspended in the centre of the gel slug. The cleaning tool again has to be designed correctly to ensure that the debris is first lifted to enable them to be collected by the gel and also give a very high seal against the pipewall.

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All the above represent a challenge and it is these types of challenges that make actual pig/tool design vital for specific production cleaning requirements.

FACTORS AFFECTING CLEANING TOOL DESIGN

The main factors affecting cleaning tool design are quite basic and generally revolve round the following:

- Pipe size
- Length of the pipeline section
- The minimum bend radius used in the construction of the line
- The product being transported by the pipeline
- How many changes of I/D are there in the pipeline due to wall thickness changes
- Valve types
- Is the pipeline subsea or cross country
- Pig trap design
- What debris is the cleaning tool being asked to remove from the pipe wall and subsequently the pipeline

The above are the main items that have to be considered.

Pipe size is a critical factor as smaller diameter pipelines are more difficult to design cleaning tools for. While the principles of design remain the same, the simple fact is there is far less room to play with in a smaller diameter line than a larger one. Attachments to the tool become smaller and therefore they become less effective than on larger diameter tools. The spring arm, for instance, on to which brushes are mounted, become such a problem that on smaller diameter tools they have to be substituted with circular brushes as it is not practically possible to mount effective spring arms and brushes to smaller diameter tools.

Wear of the polyurethane components such as discs or drive cups is always substantially higher on smaller diameter tools than on larger tools due to the increased frictional resistance generated in smaller diameter lines. Larger diameter tools suffer with a different problem. High friction seen with smaller tools is not the major issue, but is overtaken by that of weight. As the tool size increases the weight of the metal body tube and any other attachments mounted to it has a significant impact on the longevity of the polyurethane components.

Pipeline length is also very important. The longer the pipeline section the more is being asked of the polyurethane components used for the discs or cups. These, in conjunction with size, are two out of the three most critical factors of the design of a cleaning tool.
The third is bend radius. This determines a number of things in the design of the cleaning tool for instance its maximum overall length, the diameter of the body tube, the distance between the disc/cup packages and the overall sealing length. All these aspects are determined by the bend radius.

Pipelines are constructed to transport product of one type or another. It can either be liquid or gas. This will also greatly impact on the longevity of the polyurethane components. In a liquid line there is lubrication and while some liquids are far better than others it has to be said that some lubrication is better than none at all. In a gas line there is little or no lubrication whatsoever. Even in wet gas lines condensate for instance is not what can be called a good lubricator. So friction becomes an issue in gas lines and is not such an issue in liquid lines.

Changes in I/D due to wall thickness changes impacts on the design of the discs or drive cups. This will result in compromises having to be made to give optimum seal capabilities in the different I/D’s.

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If pipelines have been designed to be pigged then there are two types of valve that are generally used, these are the full bore ball valve and a through conduit valve. Other types of valve such as clapper type check valves will impact on the overall length of the cleaning tool and so minimum bend radius once again becomes an issue.

The issue of whether the pipeline is subsea or cross country also has to be considered. Subsea pipelines generally have a number of things that would never be seen on cross country pipelines, for instance, subsea manifolds, pigging loops, flexible jumpers, 'wye' pieces, tie in sleds to name but a few. While on a cross country pipeline major features would be block valve stations, check valves and 'tee' pieces and there are very occasionally 'wye' pieces.

Pig trap design also has to be considered. Is the launcher and receiver designed to accept the cleaning tool that is finally produced. Is the receiver long enough to accept more than one cleaning tool or will an extension be required to accommodate more than one cleaning tool?

All these and others are aspects which have to be considered when designing a cleaning tool. However, what never has to be forgotten in all of this, is that the tool has to efficiently remove from the pipewall and subsequently the pipeline the debris and deposits present in the line. After all that is the object of the exercise.

THE PROCESS REQUIRED TO DESIGN AND DEVELOP THE RIGHT CLEANING TOOL

To design and develop a cleaning tool that is 'fit for purpose' you first need all the information regarding the pipeline. No longer is it possible to say that because a cleaning tool performs well in one pipeline that the same pig will perform well in another. Each pipeline is individual, no two are the same. Acquiring detailed information with regard to an individual pipeline is, it has to be said, probably the most difficult part of designing a cleaning tool.

So once all the information is to hand it is discussed within the team and from there an initial concept is developed for further discussion. From there detailed drawings are prepared of the individual components of the cleaning tool. Once the design is finalised a prototype is manufactured ready to carry out trials in a test loop.

The test loop will have been designed and constructed to contain all the individual features in the pipeline i.e. changes in I/D, bend radius, tee's, valve I/D's, check valve bowls and lengths, 'wye' sections all are included in the test loop. This way it is possible to prove the design of the tool to ensure that it will safely traverse the features contained in the actual pipeline and at minimum differential pressure.

At this stage it is possible to make changes to the design and modify the tool as necessary to ensure it is fit for purpose. Once the design is finalised and any necessary modifications have been made to the prototype the client will be invited to witness further trials in the test loop.

It has to be said that all this is confidence building to ensure that all the features contained within the pipeline have been taken into consideration during the initial stages of the design. Everyone has to be satisfied that the tool works as it should and will perform the task it was designed to carry out.
As previously stated pipelines are individual. Designing cleaning tools this way ensures that every aspect of the pipeline has been taken into consideration and that the tool is fit for purpose before it is deployed in the actual pipeline. This minimises risk and maximises tool performance.

DEVELOPMENTS IN PIGGING PHILOSOPHY - WHAT'S NEW

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Developing something new is not always easy. Most aspects of the cleaning tool have been designed, re-designed, copied by everyone else, so one way or another, and development becomes very much a variation on the same theme.

Occasionally however something new appears very much by accident and often from failure. A typical example of this is the Annular Cleaning Tool. For years jetting heads on cleaning tools have been a heavy clumsy arrangement at the front of a cleaning tool with a series of small plugged holes. The idea being that the more plugs that were removed increased the percentage of bypass to the front of the tool and the deposits being removed from the pipewall would be kept in suspension. In theory this should have worked, but in practice it did not and for the following reasons: The plugged holes were always too small and when the plugs were removed they easily became blocked with wax and debris. Very often the plugs were never removed because the operators loading the cleaning tools were not aware what they were for through lack of training.

One of the most important aspects of removing deposits from the pipewall and subsequently the pipeline is to ensure the deposits and debris are put into and kept in suspension. This minimises the risk of debris building up in front of the cleaning tool and forming a wax plug or candle. The Annular Cleaning Head gives a jetting action through 360º and the bypass is variable. If you also increase the differential pressure across the tool you get even more product passing through the tool which gives an even better jetting action and creates far more turbulence. It also works very well at low flow rates.

Brush design and attachment to the tool body is another area that has in the past been a bone of contention. Brushed pads attached to spring arms attached to the tool body between the disc or cup packages has never worked well. The reason for this is quite simple, the debris being removed from the pipewall builds up in the centre of the body between the disc or cup packages and becomes compacted. The brushes then become totally ineffective and the tool slides down the pipeline like a piston doing nothing. The same goes for plough blades, in fact probably more so with scrapper blades because the wax they initially remove just builds up and has nowhere to go.

Developments are currently underway to take a new look at the design of the brush and plough cleaning and rather than attach them to the cleaning tool body, make a brush or plough blade module that is towed behind. By so doing, the leaf spring that the brush pad or polyurethane blade would normally be attached to can be totally replaced with something far more efficient and greatly more effective.

The brushes themselves are also undergoing re-design. The grips which form the bristles of the brush have historically been inserted on to the perforated plate by hand; then fastened off at the rear to avoid them becoming detached. This is a very time consuming operation, not to mention hazardous to the person who was building the brush.

By towing the brush unit behind the cleaning tool not only can the leaf spring be replaced, but far more modern bush technology can be utilised. Bristles that have a memory and do not bend as the old grips did and springs that keep the brush pads in contact with the pipewall 100% of the time. Far more import, their efficiency as a cleaning tool will be far higher than the traditional spring arm and brush attached to the centre of the cleaning tool body.

One of the most hazardous operations when carrying out pipeline cleaning operations is the opening and closing of the pig trap door to both load the cleaning tools and to receive them and an automated launching system would reduce the risk in this area limiting the number of times the launcher had to be opened and closed. In the past pins have been used and have had a limited amount of success. Using modern technology developments are underway where simply depressurising the launcher will arm the next cleaning tool ready to launch.

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CASE STUDIES

It always creates a sense of satisfaction when things go right, the new tool works and the client is satisfied. It makes all the head scratching and hard work worthwhile. Two such cases in the recent past are a large crude oil pipeline and an 8" pipeline totally unrelated to the oil and gas industry.

The large pipeline is a trunk line and carries crude oil. The crude is waxy and therefore the pipeline has to be cleaned on a regular basis. The cleaning tool was developed to remove the wax deposition from the pipewall and because it was a large diameter it also had to support its own weight over the distance it had to travel. Temperature was also a factor so the choice of the polyurethane system the discs were manufactured from was also important.

As it turned out there was an unknown factor which was to have a far greater impact on the design of the cleaning tool than just the wax it had to remove, its size and the temperature. When the line had been laid the line pipe had not been fitted with end caps subsequently sand deposits had accumulated in them. When the line was commissioned the first cleaning tools traversed the line. On their arrival at the receiver what was seen when the pig trap was isolated and the closure door fully opened was totally unexpected.

The receiver was full of not only wax but sand mixed with the wax. The debris was heavy, difficult to remove and handle. The photograph below shows how robust the design of the cleaning tool was.

This was not only a problem on the one section of pipeline but the other sections also. The cleaning tool was designed to be robust with the amount and density of debris it was being asked to remove from the pipeline.

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The 8" line is more unusual as it transports a rock paste. It is 4.5 km long and runs from above ground to below ground. The ore is mined and transported to the surface by conveyor then crushed into a fine powder. The minerals are then removed and the residue rock paste and water stored in a holding tank. After being mixed with approximately 3-4% cement it is then pumped back down the mine and allowed to solidify.

Because the pipeline is not in use all of the time the paste falls out of suspension and subsequently builds up on the bottom of the pipe. Over time only ⅓ of the pipe bore was open the remainder being filled with hard deposit. While the deposit was hard it was wet which made its removal easier.

Cleaning tools were designed to remove the deposit. While the drive cups remained the same the cutting head of the cleaning tool was gradually increased in diameter until the full bore of the pipe was open. The pictures below show the tools and the deposit.

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IN CONCLUSION

It has to be said that tools cannot be designed and be fit for purpose unless their is cooperation between all parties. The most important factor is having all the information regarding the pipeline the cleaning tools are to run in before the project starts.

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