INNOVATIVE METHOD TO PROTECT PIPELINES MADE OF COMPOSITES WHEN EXCAVATING TO BUILD A CROSSING PIPELINE

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ABSTRACT

This paper is sharing the details of deploying a new method and equipment to protect existing nonmetallic pipelines when excavating to build a crossing pipeline or cable that generally passes underneath the existing pipe. Thermosetting composite pipes made using filament winding process are the easiest to manufacture, cheapest and provide the required pressure and temperature specifications for many piping applications. On the other hand, those pipes are vulnerable to damage when exposed to mechanical impact by excavation equipment, tools, or falling rocks. Due to the brittleness of the cured resin (epoxy, vinyl ester, or polyester) low velocity and relatively small load impacts can cause microcracks in the matrix that lead to a complete failure as fluid under pressure persistently pushes itself through those cracks. This scenario makes the need to protect composite pipes during excavation activities very essential.

This paper presents detailed description of the protection technology, benefits, field deployment, and implementation in Pipeline Projects saving significant project time and money. The protection method consists of a covering tool of 1.5 meter or longer as needed, placed firmly over the existing pipe to protect it from impact while excavation is in progress. The cover consists of two halves, on the top and bottom of the pipe fastened together using stud bolts. The weight of this cover is supported independently from the pipeline being protected. The two ends of the cover sit on the ground and steel dowels can be used to hold the cover in place around the pipe and to resist any horizontal movement. This method provides a very stiff cover that does not deform under normal operating conditions and provides a wide innovative crumple zone that gives an extra protection window. This technology is a Saudi Aramco protected Intellectual Property under US patent Number 11549633 B1. Detailed summary of the innovative solution and deployment in the field is presented in the following pages.

1. INTRODUCTION & BACKGROUND

The challenge that faces constructing new pipelines is the need to work close to existing piping systems that are live and carrying flammable hydrocarbon fluids. Recently, there has been a need to also work near nonmetallic pipelines that are more vulnerable to damage than steel pipes. On-demand shutdown of a pipeline system is usually very difficult to obtain from the respective area responsible operation department. Industry standards and work procedures mandate that when a new pipeline is crossing an existing pipeline, the new line should cross below the existing line with a minimum clearance of 600 mm between the bottom of the existing and the top of the new pipe [1]. This method of construction becomes very challenging when the existing ground consists of solid rocks that require heavy machinery to excavate. Project management records show that there are thousands of pipelines crossings are encountered every year.

To protect the pipeline and for safety reasons when pipelines carry flammable or toxic fluids, construction Safety Manual (CSM) Vol. ll [2] mandates that no work with heavy excavation machines should be allowed near live lines within 3 meters of either side. This means that excavation of the new crossing trench shall be done using manual or hand-held tools for 3 meters on each side of the existing pipeline, Figure 1. This requires more resources and is significantly time consuming. It will also result in a delay in critical construction activities and will cause a slippage or delay in project milestones and time schedule. However, the temporary solution now is to have most of the pipes crossing above the existing lines, but there are scenarios where it is not practical to cross above and, in most cases, it is not allowed by the area responsible operation department. Therefore, alternative methods need to be adopted. The invention presented here provides a perfect solution for situations like this one [3].

Figure 1: Pictures showing current status; manual excavation near existing pipes and protection with wood pieces

Oil and gas steel pipes still need protection against impact for safety reasons and to prevent any possible interruption of supplies [4, 5]. When those pipes are made of composites, we have more pressing challenge to protect them even from smaller loads and impacts. Nonmetallic pipes can be damaged much easier than steel and need to be protected urgently, whether during live operation of the nonmetallic pipeline or during shutdowns. Nonmetallic pipe, and more specifically the pipes made with thermosetting resin (e.g. epoxy, polyester), are vulnerable to being damaged by low speed impact and relatively small loads that may cause microcracks of the resin matrix leading to a failure in service. This invention as detailed below serves perfectly to the purpose of protecting nonmetallic pipes because it does offer a condition where no load or force is transferred to the pipe body in the event of impact force.

2. DESCRIPTION OF THE PROTECTION TOOL

The protection method described here recommends the use of a pipe covering of 1.5 meters long, or longer as needed, placed firmly over the existing pipe to protect it from any direct impact resulting from external forces while excavation is in progress. The impact can result from a direct hit by excavation machine or falling rocks. The cover consists of two halves, on the top and bottom of the pipe fastened together using stud bolts. This cover provides a three-zone protection system to the pipe as shown in Figure 2 and is detailed below. Figure 3 is a schematic drawing showing a longitudinal view of the protection tool on the pipe and showing the location of the crossing pipe underneath it. Figure 4 presents pictures of the tool assembly components, inner shell and outer shell. Figure 4 presents a picture of the actual tool after it was manufactured and set up on a trial pipe. The weight of the cover itself is also supported independently from the pipe as shown in Figure 3 and 5.

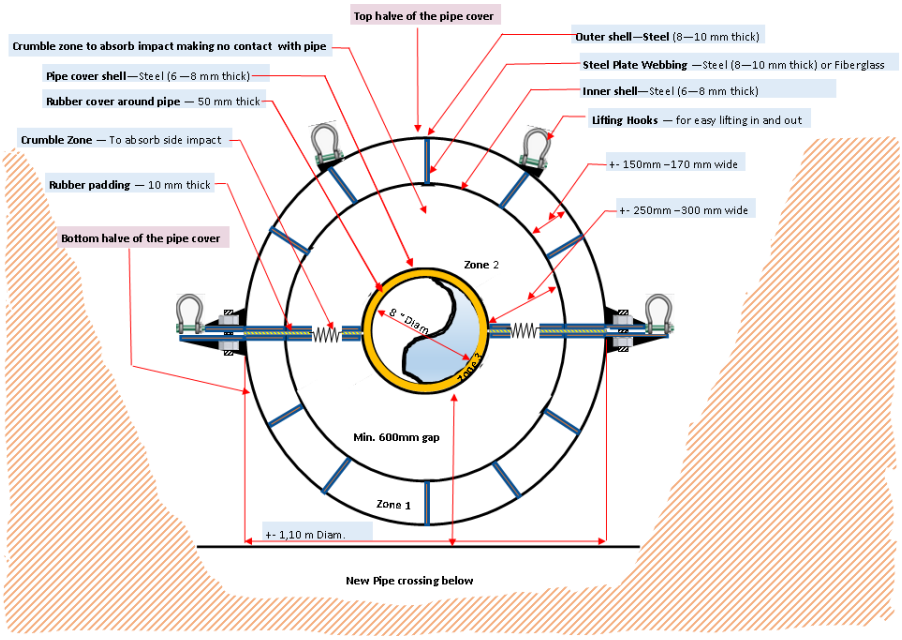

Figure 2: Cross sectional schematic drawing of the pipe protection cover

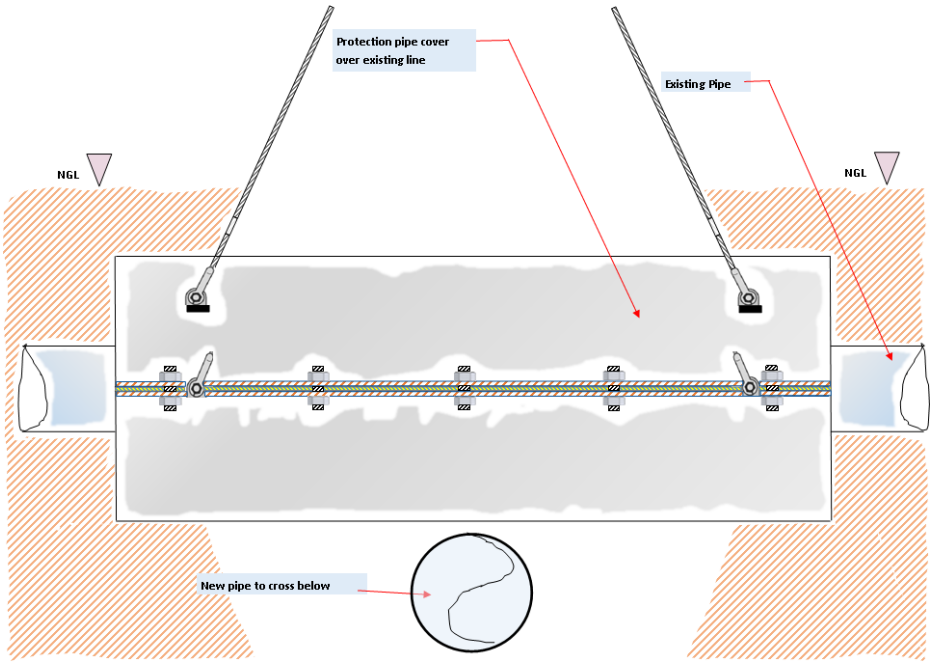

Figure 3: A drawing showing the cover on top of existing pipe and showing where the new pipe will be constructed underneath

Figure 4: Protection tool inner shell and outer shell

Figure 5: Experimental setup of the protection tool on an aboveground pipeline

The cross-sectional schematic shown in Figure 2 points to the three protection zones that are also shown by the actual tool assembly picture, Figure 5, and described as:

Zone 1: 100-150 mm, outer layer, protection zone made of 8-10 mm two steel shells separated and reinforced by plate webbing of 8-10 mm thick. This is designed to be very stiff and will take the bulk of any external impact including an accidental direct hit by an excavation machine, rock breaking machine, or by falling rocks.

Zone 2: 150-200 mm, middle layer, this is designed to be a crumple zone that will deform without affecting or putting force on the live pipeline. This zone can be hollow separating the external zone (zone 1) from zone 3, or can be filled with low density foam structure or weak/soft metal webs that will crumple without transferring any significant force to the pipe wall. The benefit of this zone is giving a cushion in the event that the external force is big enough and persistent to deform zone 1 or to penetrate through it.

Zone 3: Is the final layer of protection, consists of pipe cover shell of 6 mm thick steel lined with a 20 mm rubber pad that will absorb any residual forces, which could not be absorbed by the first and the second zone of protection.

The two sides of the cover will be tightened together with stud bolts to ensure it will act as one unit and will not separate or transfer loads to the pipe during the excavation activities close to the line. Finally, there are lifting lugs fitted to each half of the pipe cover to ensure easy lifting into and out of the trench.

The weight of this cover will not be carried by the pipe. The two ends of the cover will sit on the ground and steel dowels can be used to hold the cover in place around the pipe and resist horizontal movement that may apply load on the pipe if it was hit on the end side of the protection tool.

3. BENEFITS AND ADVANTAGES

This invention offers a two-piece solution to protect the pipe during the use of heavy machines excavation. The two halves are placed around the pipe locked together with bolts and nuts, the top half is supported by the bottom half and the bottom half is supported by solid ground or other mechanical support as shown in some of the attached pictures. Any impact force or load applied on it will transfer to the ground or to the supporting structure. The weight of the fixture itself is also supported and not lift to sit of the pipe.

Currently, there is no proven method or tools that make excavation near a live pipe line or nonmetallic pipeline a risk free by providing good protection which justifies this new invention. This invention is easy to make and easy to use to provide the needed protection. This invention provides a very stiff cover that will not deform under normal operating conditions and provides a wide crumple zone that will give the extra protection window before reaching the pipe body. The significant importance of this invention comes and becomes crucial when the existing pipe is a nonmetallic, which is more vulnerable and can be damaged by a minute impact or penetrating force compared to a steel pipe.

The advantages and benefits of this invention over prior methods or means of protection can be summarized in the following lines:

1. The invention has a tough and hard outer shell that takes most impacts.
2. This device does not transfer loads to the pipe due to the presence of a crumble zone.
3. The weight of the fixture is independently supported and not applied to the pipe.
4. This invention (device) is a perfect solution to protect nonmetallic pipes when excavating in a rocky area for a crossing pipe or cable. Nonmetallic pipes are easy to be damaged when left without good protection due to the brittleness of the resin that may sustain microcracks due to impact that lead to a failure in service.
5. Provides protection when excavating to cross live steel pipes. This protection is not matched by others.
6. Represents a time and schedule saving (around 70% schedule saving for each pipeline crossing), especially when there are so many crossings to be executed on a project.
7. Thousands of pipeline crossings take place every year and this technology offers a significant cost saving for each pipeline crossing
8. Allows for better planning of crossing excavations and project activities.
9. Protects the environment and safety of people in the vicinity of crossings.
10. Provides an opportunity to use heavy excavation equipment where otherwise they would not be allowed or prohibited within 3 meters of existing pipelines by Construction Safety Manual and Safety Management Guide.

4. FIELD DEPLOYMENT

The protection device was manufactured by a local manufacturer as shown by the pictures in Figure 4, and was delivered to the pipelines construction contractor who worked with us to test it in the field. Two field trials have successfully been done to date; the first trial was on an aboveground 10” pipeline to demonstrate using the protection device, prove the concept, and to troubleshoot any problems or missing elements

(Figure 5, above). The second trial was done on a buried pipeline, which exactly represents what this invention is intended for. The photograph in Figure 6 below shows the setup of the protection tool on a buried 8" pipe. The pipe was 100% covered either by the protection device or buried under the sand, which enabled heavy excavators and rock breakers to go close to the existing pipeline and cut the ground next to the pipe making a trench underneath it without the risk of damaging the pipeline (Figures 7 & 8 below). It can also be seen in the photographs below that the weight of the protection tool was supported by a steel dowels substructure, which was erected for this purpose around it.

Figure 6: Protection tool assembled in place around the pipeline at the crossing location

Based on the success of this trial, more trials will be conducted and more tools with different lengths and diameters to suit different crossing angles and different pipeline sizes will be manufactured and deployed. Commercializing steps and process of this invention will follow.

Figure 7: An excavator was used to remove sand and soft soil around the pipe to dig a crossing trench

Figure 8: A rock breaker was used to dig a crossing trench for the new pipeline

5. CONCLUSIONS

In conclusion, the authors would like to emphasize on the following points:

1. This protection device technology, as described in this paper, is a Saudi Aramco's intellectual property and has been granted as a US patent number 11,549,633.
2. The protection tool or device was successfully manufactured by a steel workshop following inventors' instructions and was assembled in the field as planned with no issues.
3. Field trials were successfully conducted as planned with no issues.
4. Using this protection method is estimated to save a significant amount of labor-related costs at each pipeline crossing.
5. Using this protection method cuts excavation time at each pipeline crossing by more than 3 weeks because heavy excavation and rock breaking machines can be used as oppose to manually operated tools.
6. Based on the results of the field trials that were conducted so far, different sizes of this protection device will be manufactured and used in the field. This will cover different pipeline sizes and will accommodate different crossing angles.
7. This innovative pipe protection device and method is being considered for commercialization by Saudi Aramco.

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