Cold Welding Repair Based on ASME PCC-2-2018, and The Effectiveness for the Applied Repair

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ABSTRACT

As pipelines and tanks are used in continuous process of industry, it is inevitable that it will encounter corrosion and leads to the weakening of the strength. Cold Welding is an alternative repair of a pipeline and tank. It consists of a combination of metal filler and composite wrapping material/FRP (Fiber Reinforced Polymer). ISO 24817 and ASME PCC-2 are the standards we referred for this repair system design. ASME PCC-2 gives the standard for the composite wrapping and filler material specification. This repair method has been done on pipeline and tank of PT. Pertamina EP Tambun, an oil and gas company, done by PT. TAM Victory Cemerlang. These results are then observed and tested to determine the effectiveness of the newly repair method. Results show that the applied repair is indeed shows a satisfactory result, which determined cold welding repair can be applied to a variety of cases of defected and leaked pipe and tank to regain the functionality and the lost strength.

Keywords

Pipelines, cold welding repair, metal filler, composite wrapping.

1. Introduction

Pipelines and Tanks of industry will experience internal and/or external metal degradation because of corrosion. This process can occur because of corrosive fluid transfer inside or a corrosive environment. Metal pipe and tanks used to carry water, oil, gas, etc. are at a risk of destruction. Repair of theses pipelines in the shortest possible time is economically, technically, and environmentally important [1]. Conventionally, the repair system of most pipeline is by removing the corroded part of a pipe and replacing it with a new pipe or based on API Recommended Practice 12R1 Section 7 [2], Shell plate of the same material is needed with the minimum thickness of original standard used for construction and not be less than greatest nominal thickness of any plate in the same course adjoining the replacement pipe. It also may be repaired without welding or hot-work by using forms of patching such as epoxy or fiberglass-reinforced plastic.

In the last decades, laminated composites have been widely applied for repairing the damaged metallic pipes [3,4]. Many researchers already used the laminated composites to repair metallic pipes. Zarrinadeh et al [5] investigated the fatigue crack growth in a cracked aluminum pipe repaired by laminated composites. Watanabe junior et al [6] repaired the corroded circumferential welds using a polymer-based laminated composites system. Repair design most of the time is designed based on the experimental study including mathematic formula with an addition of many years of real-life application.

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Based on definition of repair system ASME PCC-2-2018 [7] in Point 401-1.1.2, stated that repair system is a combination of a. substrate, b. surface preparation, c. filler material, d. primer layer adhesive, and e. composite material. filler material and composite material is introduced to be an alternative repair system called Cold Welding. **Cold welding is a cold applied repair, which does not need heat or high temperature to cure the material**. Properties of composite material also stated in Point 401-1.1.3, composite material include but are not limited to glass, aramid or carbon fiber reinforcement in a thermoset polymer (e.g., polyester, polyurethane, phenolic, vinyl ester, or epoxy) matrix. Fibers shall be continuous and not be randomly oriented. while filler material in definition is a material used to repair external surface imperfections prior to the application of composite laminate. In one comparative study, it was found that FRP repair was 24% cheaper than the welded steel sleeve repair and 73% cheaper than replacing the defected pipe section [8]. **So Cold Welding, especially considering the cost of FRP (fiber reinforced polymer)/ composite wrap material is more economical than conventional method**. Cold welding also has an advantage of **reducing downtime of process** by live repairing rather than shutdown the process to replace the designated pipe, additionally it will reduce the risk of work accidents, as well as to saves time.

Stated in ISO 24817 [9], Attention shall be given for the potential of bimetallic (galvanic) corrosion of the substrate. The choice of fiber based upon this statement used in this repair system is E-Glass.

The damages may be happened in the different part of the steel pipelines/tanks and with various type of steel pipe/tank strength of which related to the pressure it can withhold. These defects caused by the damages were then repaired by the cold-welding method.

2. Methods

2.1 Material Properties

2.1.1 Composite Material

The composite wrapping used in this journal is manufactured at PT. TAM Victory Cemerlang in Indonesia, material properties of this product is designed and comply based on ASME PCC-2-2018 standard and shown in Table 1 and Table 2, depending on the thickness provided. These specifications are needed to verify the quality of the composite material so it can be used as a repair component in various cases. The repair laminate was using a E-Glass which is an alumino-borosilicate glass that mainly consist of SiO_2 with a very low thermal expansion and more resistant to thermal shock whilst also showing an extremely high chemical resistance in corrosive environments [10].

Table 1
Weight % of Typical Glass Fiber Compositions

Component	E-glass %
SiO_2	52-62
CaO	16-25
Al_2O_3	12-16
B_2O_3	0-10
MgO	0-5
Na_2O+K_2O	0-2
TiO_2	0-1.5
Flourides	0-1
Fe_2O_3	0-0.8

The matrix used in this laminate is polyamine epoxy. Polyamine epoxy has a maximum operating temperature above 120°C. The results are done on verified 3rd party Indonesian lab, such as STP Lab (Center of Polymer Technology BPPT) and Sucofindo Lab (PT Sucofindo SBU Laboratorium).

Table 2
Composite Wrapping (FRP) Properties

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Properties	Requirement ASME PCC-2	Results	Laboratory
Tensile Strength	None	531.5 ± 4.09 MPa	STP Lab no. 1603770822
Tensile Modulus	None	22.71 ± 4.38 GPa	STP Lab no. 1603770822
Elongation at Break	Strain to failure must be >1%	3.85 ± 0.71 %	STP Lab no. 1603770822
Per Ply Thickness	None	1250 microns	STP Lab no. 1603770822
Adhesion	4 MPa	182.6 MPa (26,477 psi)	Sucofindo No. 17995/FNBPAO
Flexural Modulus	None	20.93 ± 0.37 GPa	STP Lab no. 1603770822
Flexural Strength	None	520.07 ± 13.65 MPa	STP Lab no. 1603770822

Based on Standard ISO 24817, for Class 3 repair system, which has a typical service of produced water, hydrocarbons, flammable fluids, and gas systems, the thickness equivalent needs to be <D/12 for the system to be qualified for repair.

Additional tests to show the performance as an anti-corrosion material agent is further needed. the specifications for this kind of criteria are Dielectric Strength and Volume Resistivity. As such, the result is shown below in Table 2.

Table 3
Composite Wrapping (FRP) Additional Properties

Properties	Method	Results	Laboratory
Dielectric Strength	ASTM D 149	<5000 V Ac; No breakdown	Sucofindo Lab No. 42467/DBBPAN
Insulation Resistance	ASTM D 257	>500 G ohm (500 V Dc)	Sucofindo Lab No. 42467/DBBPAN

2.1.2 Filler Material

The Filler Material used in this journal is manufactured at PT. TAM Victory Cemerlang, which is called Metal Adhesive. Material properties of this product are designed based on ASME PCC-2-2018 standard and shown in Table 3. These specifications are also needed to verify the quality of the filler material. The results are done on verified 3rd party Indonesian lab, such as STP Lab (Center of Polymer Technology BPPT) and B4T Lab (Balai Besar Bahan dan Barang Teknik).

Table 4
Filler Material Properties

Properties	Requirement ASME PCC-2	Results	Laboratory
Adhesion	4 MPa	114.34 MPa (16,580 psi)	Sucofindo No. 42279/DBBPAN
Heat Distortion Temperature	None	195.3 °Celcius	Sucofindo No. 42279/DBBPAN

Additional tests to show the performance as an anti-corrosion material agent is also needed. the specifications for this kind of criteria are Dielectric Strength and Volume Resistivity and shown below in Table 4.

Table 5
Filler Material Additional Properties

Properties	Method	Results	Laboratory
Dielectric Strength	ASTM D 149	<10000 V Ac, No Breakdown	Sucofindo Lab No. 42279/DBBPAN
Insulation Resistance	ASTM D 257	142 G ohm (500 V Dc)	Sucofindo Lab No. 42279/DBBPAN

2.1.3 Main Component of Material

The main chemical component structures of the adhesive component used in the FRP as well as filler material are using a combination of Epoxy Bisphenol A with a polyamine shown below in Figure 1 and Figure 2. These reacted components would create a high performance of corrosion resistance, high adhesive strength as well as resistant against high temperature.

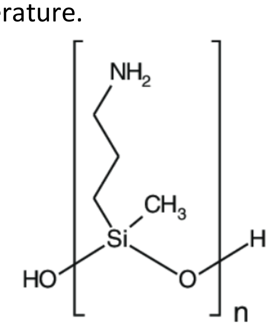

Figure 1. Polyamine [11]

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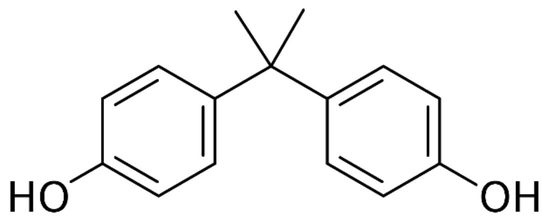

Figure 2. Bisphenol A [12]

2.2 Application Method

For the repair of any material defects such as non-leak thin surface as well as leaked defects, Cold welding could be used and the repair method is stated as follows:

A. Metal adhesive and Patching Application

1. The first stage of the repair is to prepare and carry out the fabrication of reinforcement plate for patching in accordance with the attached drawings or according to the field pipe.

2. Surface Preparation is carried out which includes cleaning the pipe surface and patching material from all kinds of dust, oil/grease, dirt from the environment (spatters, tack weld residue etc.) and rust and from old paint, based on SSPC-SP2/SP3 standard.

3. Mix Metal Adhesive Base with Activator using a spatula for 2-3 minutes on a mixing mat.

4. Apply the fully mixed Metal Adhesive and Activator to the leaking pipe furthermore apply the coated patch which is a patching plate that has been adjusted to the size of pipe and coated by metal adhesive mix. Wait for 2-3 hours to dry completely (full curing time). Then Install the Bolts on Patching. Make sure there is no more leakage from the pipe.

B. FRP (Composite Wrapping) Application

5. Primer Coating Application: Primer coat is applied to the surface using a paint roller or any other auxiliary tools. Wait for it to cure for 4-5 hours.

6. Application of FRP: Saturate Coating Material into Glass Fiber, then apply the FRP to the surface of the tank or pipeline evenly, making sure the FRP is evenly distributed and there are no air bubbles.

7. Finishing Application: After a minimum of 4-5 hours, apply the coating again using a finishing coating as the outermost layer with a paint roller or other tools.

3. Repair Application on Real Cases

3.1 Application on Pipeline

3.1.1 Previous Condition

A real case of repair using cold welding method was used on the hole defects on pipeline in PT. Pertamina EP Tambun. The condition of the pipeline was empty inside as they were using an alternate pipe for continuation of the production process of the plant, thus the repair does not need to determine any precaution on previous flowing component. The hole defects documentation is shown on Figure 3.

Figure 3. Hole in the Pipeline

3.1.2 Repair of the defects

Following the application method stated above, the repair progression was documented below.

A. Surface Preparation

Figure 4. Surface Preparation

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B. Metal Adhesive and Patching Application

Figure 5. Adhesive and Patching Application

C. FRP (Composite Wrapping) Application

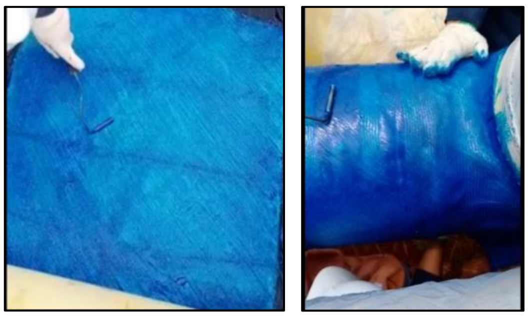
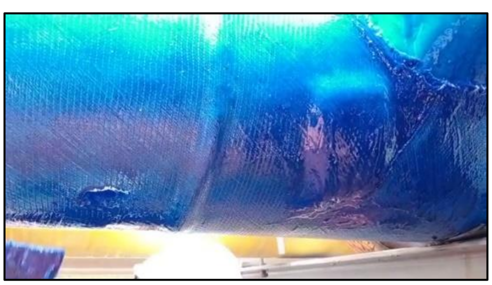


Figure 6. FRP (Composite Wrapping Application)

3.1.3 Final Results

(a)



(b)

Figure 7. Results of Cold Welding on Pipeline

(a)

(b)

Figure 8. Finish Coating on Cold Welding Works

3.2 Application on Tank

3.2.1 Previous Condition

Cold welding repair method was also used for hole defects on the storage tank in PT. Pertamina EP Tambun. The condition of the tank was empty of which the repair could be done conventionally without the need to take the possibility of leaking fluid into account. The hole defects on tank marked by a piece of wood documentation are shown on Figure 9.

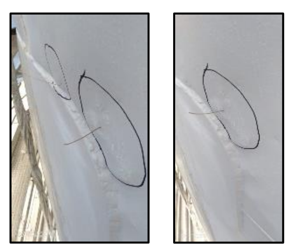


Figure 9. Holes on Tank

3.2.2 Repair of the defects

Following the application method stated previously, the repair progression was documented below.

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Figure 10. Surface Preparation

Figure 11. Metal Adhesive and Patching Preparation

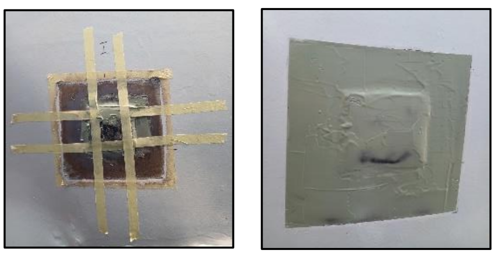

Figure 12. Applied Patching and Metal Adhesive Finish

Figure 13. Epoxy Preparation

Figure 14. FRP (Composite Wrapping) Preparation

Figure 15. Applied FRP (Composite Wrapping) on Tank

3.1.3 Final Results

Fig 16. Applied Cold Welding works on all Tank Defects

Fig 17. Finish Coating on Cold Welding Works

4. Results

After the previous cold-welding repair on the pipeline and tank has been done, the repaired area is carefully checked. The system connected to the object is then turned on and thoroughly observed for over 1 month period of time. There was no sign of any repair break down and no leakage was found. It is concluded that the cold welding did repair the holes or the defects effectively.

This cold-welding repair method now can be used as an alternative to repair any holes or any defects rather than replacing the object entirely, as long as the repair material meets the condition of the defected area.

5. References

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