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Economic Analysis of Using E-Glass Composite Wrap Repair System for Pipelines in Malaysia

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ABSTRACT

One of the biggest problems faced by the oil and gas industries is transmitting gas when there is a damaged pipeline. This damage may be a result from corrosion, crack or a burst pipe. Damaged pipelines need a safe, quick and efficient repair mechanism to prevent any further extensive damage. There are various methods and repair systems that offer different advantages and limitations to the oil and gas industries. Composite wrap repair system is a new technology that is being used in the United States of America and some European countries. However, this technology has not penetrated into the South East Asian region yet. This study is done with the aim of determining the feasibility of implementing this repair system into the Malaysian oil and gas industries. E-Glass fiber was selected since it is the most suitable and appropriate type of composite that can be adapted for the composite wrap. Then, cost analysis was done for this composite repair system and compared with the welding repair and pipeline replacement methods. Calculations for the result of every repair system were performed to compare the most efficient method. E-Glass fiber composite wrap has shown to be the most economical technique when compared with the welding and pipe replacement methods.

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INTRODUCTION

The most common problem in oil and gas pipeline system is leakage. This problem can lead to the reduction of the oil production. Usually, the leakage part will be welded to cover the leak as a temporary solution. However, if the leak is huge the whole part would need to be removed and changed with a new part that may take longer time and more cost.

A leaking pipeline must undergo immediate repair to ensure safety and minimize losses. The type of leak will be identified first to setup precautionary and repair solution. There are few types of conventional and unconventional repair system for the minor leakage in pipelines. The leakage can be welded to cover the leakage using Welding Procedure Specification (WPS) as shown in Fig. 1(a). The weld part will then be examined using Non Destructive Test (NDT). There is also repair system that is call mechanical clamp. Two half shell of housing will be tight around the pipe by bolting or welding it to cover the leakage (Fig. 1(b)). There is another method called wrapping (Fig. 1(c)) can also be applied to repair the leakage. This method is new where the solution is not widely used in Malaysia. This method does not require welding to attach the wrap to the pipelines.

These processes are usually expensive due to many equipments and manpower needed to accomplish the welding process. Moreover, huge amount of time is needed to perform this operation. Not to forget, the amount of unproductive time spent during shutdown if pipeline repair is concerned.

Composite wrap repairs on the other hand are light and easy to mobilize. They are quick to install, but they are not proven for leaking damage, or severe damage such as combined dents and gouges. A composite wrap repair is generally installed by wrapping several layers of a composite material around the damaged area. The composite, and any adhesive, will take a short time to cure, and then the repair is complete. The main advantages of composite wraps for emergency repair are the speed of installation, and the limited working space required. The pipeline also can continue operate while repair is being applied (Saeed, 2012).

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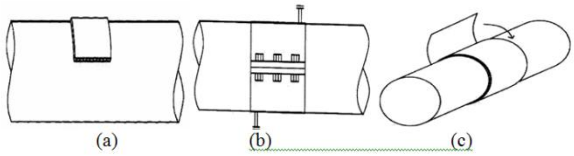

Fig. 1: Types of pipeline repair systems (a) Welding (b) Mechanical clamp (c) Wrapping(Alim, 2011).

There are no risks of fire and explosion in composite repair due to welding and cutting process were completely eliminated. This method is also was 24% cheaper than the welded steel sleeve repair and 73% cheaper than replacing the defected pipe section. Repair system can retard the growth of external corrosion by isolating the external defect from corrosive environment so it can be considered as a lifetime repair, while in the case of internal damage, an additional way of stopping or de-rating the corrosion or erosion process is required in order to perform a life time repair (Saeed, 2012).

In the design of a composite repair system for offshore pipes, fatigue loads, impact and the potential for galvanic corrosion form the basis for additional consideration. Factors such as wave motion and contact with other structures, such as ships and other pipeline are realistic sources for impact damage (Alexander and Ochoa, 2009). Fig. 2 shows a composite repair system being applied on the pipeline. 1 and 2 show the fiber reinforcement sleeve polymer and interlayer adhesive respectively. While 3 shows the infill (resin) that bind the composite to the pipeline.

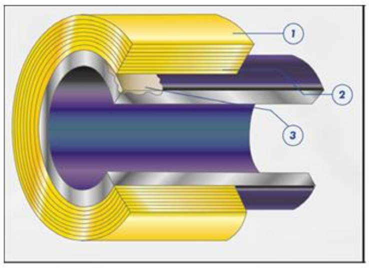

Fig. 2: Composite wrap process (Shamsuddoha et. al, 2013).

An alternative repair method using composite wrap needs to be studied for the implementation of this system in Malaysia. This research is intended to study the feasibility of applying composite wrap as an alternative method for pipeline repair system. Cost analysis is done to compare which method would be more practical in terms of usage, cost and durability.

MATERIALS AND METHODS

Material Selection:

Glass fiber is cheap, easily available and more compatible with resin systems. It has low modulus of elasticity and more susceptible to fatigue, creep and stress rupture. Most glass fibers consist of E-glass, a term which once stood for electrical grade glass. E-Glass is a low alkali glass. Usually the composition of E-glass is built from 54% of SiO_2, 14% of Al_2O_3, 22 % of CaO+MgO, 10% of B_2O_3 and less than 2% of Na_2O+K_2O. This glass is a super-cooled mixture of metallic oxides. It is brittle and transparent but has a very high tensile strength; 3400 MPa (500 ksi) (Porter and Silva, 2001).

E-Glass is a material that is mainly used in composite wrap repair system. This material was known as electrical grade glass which initially developed as insulators for electrical wiring application. However,this material then was identified to have excellent fiber forming capabilities and is used in the material commonly known as fiberglass. E-glass fibers are also cheaper and more economical than other fiber composites that are used for wrap.

Cost Calculations:

This calculation estimates 0.15 m leaking defect on 0.61 m diameter of pipeline, operating at 2.5 MPa. The shut off valves include 16 km of pipeline. These calculations are based on replacing 1.8 m length of pipeline. Assuming the task wasperformed in 40 hours and consist of 25% of management and planning cost.The equation and information for following cost calculations are taken from Natural Gas partner (n.d) and Oil and Gas Journal (1995). The following data in Table 1 were used in the subsequent calculations for pipeline replacement, welding and composite repair systems.

Table 1: Items of labor and equipment cost.

Cost of Labor	Cost of Equipment
Welder = RM47/hr Operator = RM46/hr Pipeliner = RM42/hr Apprentice = RM30/hr	Crane/ Boom Truck = RM135/hr Welding Rig = RM141/hr Backhoe = RM135/hr Steel Pipe = RM203/m Coatings = RM1124

Pipeline Replacement. Using Eq. 1-2, Total Labor Cost (C_{labor}) (Eq. 3) is calculated. Then, followed by the Cost of Equipment (Total Equipment and Material Cost), as indicated by Eq. 4.

Cost of Field Labor = (Welder + Operator+ Pipeliner + Apprentice)/hr * 40 hr (1)

Engineering Management Cost = 25% * Cost of Field Labor (2)

C_{labor} = Cost of Field Labor + Engineering Management Cost (3)

C_{equip} = (Crane/ Boom +Truck Welding +Rig Backhoe)/hr * 40 hr (4)
+ Steel Pipe/m * 1.8 m + Coatings

Indirect Cost which includes the cost of permits, cost of inspection services and right of way related expenses is found using Eq. 5.

$C_{indirect}$ = Assume 40% of total equipment and labor cost
$= 0.4 * (C_{labor} + C_{equip})$ (5)

Total Cost is expressed in Eq. 6 which includes all the calculated labor cost, equipment cost and indirect cost. Finally, the cost of natural gas wasted during pipeline replacement is found using Eq. 7-9. Taking the natural gas market price ($P_{naturalgas}$) as RM 0.74 /m^3 for nitrogen,

$C_{Total} = C_{labo}r + C_{equip} + C_{Indirect} + C_{Purge\ Gas}$ (6)

Volume of natural gas emission ($V_{natural\ gas}$) = $0.372* D^2 *P* L$ (7)

Value of natural gas = $V_{natural\ gas} * P_{natural\ gas}$ (8)

Cost of Natural gas wasted = Value of natural gas * 40 hr (9)

where D = diameter of pipeline (meter), L = length of pipeline between shut-off valves (meter) and P = pipeline pressure (Pa).

Welding:

Eq. 10 is used to find the engineering management cost involved for the preparation work of welding repair system. Taking the cost of material to be RM 57.75 / m and assuming the total time taken for preparation is 4 hours, the cost of preparation is calculated using Eq. 11.

Engineering Management Cost = 40% * [(Welder + Pipeliner + Apprentice Pipeliner) * 4 hr
+ Material *(dimension of leak)] (10)

$C_{preparation}$ = (Welder + Pipeliner + Apprentice Pipeliner) * 4 hr + Material
*(dimension of leak) + Engineering Management Cost (11)

Engineering management cost (Eq. 12) for the installation includes the total time used for the installation work. Here, the time taken for installation process is assumed to be 9 hours. Using this 9 hours into the calculation, the cost of installation and labor cost for welding is calculated using Eq. 13 and 14 respectively.

Engineering Management Cost = 40% * (Welder + Pipeliner + Apprentice Pipeliner) * 9 hr (12)

$C_{Installation}$ = (Welder + Pipeliner + Apprentice Pipeliner) * 9 hr
+ Engineering Management Cost (13)

$C_{labor} = C_{preparation} + C_{Installation}$ (14)

By adding the machinery cost (Eq. 15) and the material cost, the cost of equipment can be found using Eq. 16. Then, the indirect cost (Eq. 17) for the welding is calculated based on 50% of the labor cost and equipment cost. Therefore, the total cost for welding is calculated using Eq. 18. Finally, the cost of natural gas wasted (Eq. 19) is calculated by including the total time taken for the preparation and the installation which is 13 hours.

$C_{Machinery}$ = (Backhoe + Welding rig) * 13 h (15)

$C_{equipment} = C_{Machinery} + C_{material}$ (16)

$C_{indirect} = 50\% * (C_{labor} + C_{equipment})$ (17)

$C_{total} = C_{labor} + C_{Equipment} + C_{indirect}$ (18)

Cost of natural gas wasted = Value of natural gas saving * 13 hours (19)

Composite Wrap. The field labor cost (Eq. 20) for the composite wrap repair system is calculated. Then, by taking 25% of the field labor cost, the engineering management cost for composite wrap repair system is found (Eq. 21). Then, the labor cost for composite wrap repair system can be found using Eq. 22.

Field Labor Cost = hourly rate * time required to complete work (20)
= (Operator + Pipeliner +Apprentice) * 16
Engineering management cost = 0.25 * Field Labor Cost (21)
C_{labor} = Engineering management cost + Field Labor Cost (22)

Taking the composite wrap kit as RM 3261 for 1 kit, the sandblasting equipment as RM 12/hr, and the pipeline coating as % of the composite which is RM 54, the cost of equipment can be calculated (Eq. 23). The indirect cost for the composite wrap repair system is found using Eq. 24. Finally, the total cost for the composite wrap repair system is calculated using Eq. 25.

C_{equip} = Cost of consumable materials (composite wrap kit and coatings)
+ Cost of renting / using equipment on-site
= composite wrap kit + coatings + (backhoe * 16 hr) + (Sandblasting Equipment* 16 hr) (23)
$C_{indirect}$ =Cost of permit, Inspection services and related expenses, assume 50 %
= 0.5* (C_{labor} + C_{equip}) (24)
$C_{total} = C_{labor} + C_{labor} + C_{indirect}$ (25)

Results:

Table 1 shows the calculated labor cost, equipment cost, indirect cost and the total cost for pipeline replacement, welding and E-Glass composite wrap system. The total cost of pipeline replacement is higher because the process of replacing the new pipeline part needs more expenses for procedure, labor, machineries and material. However, this pipeline can withstand for long time before defects occur again. According to James (2008), the pipeline replacement will be only preferred if the damage is severe due to many processes, equipment, facilities and crew involved.

Table 1: Calculated labor cost, equipment cost and indirect cost for different repair systems.

Type of repair systems	Labor Cost	Equipment Cost	Indirect Cost	Total Cost
Pipeline replacement	RM 8150	RM 17929.4	RM 9779.8	RM 35879.2
Welding repair	RM 2182	RM 4005	RM 2002.5	RM 8189
E-Glass composite wrap	RM 2320	RM 5657	RM 3993.5	RM 11970.5

Table 2 shows the cost of natural gas wasted during the repair system, the estimated repair time and the total hours of shutdown during repair. The highest amount of natural gas wasted is for pipeline replacement where the cost is RM 157245. In addition, it also contributes to the longest repair time (40 hours) which results in the pipeline being forced to shutdown for the same duration of time (40 hours). Welding repair takes about 13 hours of repair time with 13 hours of shutdown time as well. However, E-Glass fiber composite wrap system takes the least amount of time for repair (6 hours) and during this process, the pipeline does not require it to be shutdown. Furthermore, there is no gas wasted during this repair process.

Table 2: Cost of natural gas wasted, estimated repair time and shutdown time.

Type of repair systems	Cost of natural gas wasted	Estimation of repair time (hours)	Shutdown of pipeline (hours)
Pipeline replacement	RM 157 245	40	40
Welding repair	RM 51104.7	13	13
E-Glass Fiber Composite Repair system	RM 0	16	0

Discussion:

The pipeline replacement has the highest labor cost due to more time and manpower needed to replace the entire pipeline section due to defects that could not be repaired (Natural Gas Partner, n.d). The second highest labor cost is from using composite wrap repair system. The E-Glass fiber composite wrap repair system is still new in the pipeline repair system. There is insufficient skillful labor in this work that could lead to high demand. While the lowest labor cost is from welding since it is widely used since ancient times, and has enough skillful labor to execute the welding process.

The equipment cost of pipeline replacement is the highest (RM 17929.4) because it uses many heavy machineries and equipments for digging, moving and replacing the pipelines. Composite wrap using E-Glass fiber has the second highest cost (RM 5657). The material and equipment used are expensive and the process is still new in this industry where the company that produces and supplies the material is still growing and charges high price. The lowest equipment cost is the welding repair system (RM 4005). This is because the equipment and the material of welding repair are cheaper and easily available in the market.

The pipeline replacement has the highest indirect cost (RM 9779.8) due to many standard operating procedures involved and work needed to replace the entire pipeline section. This cost also consists of maintenance operation for machinery and material that applied in this repair system. The second highest cost is E-Glass fiber composite wrap repair system (RM 3993.5). The repair using composite wrap involves many steps and has a standard operating procedure as well to follow. Meanwhile, welding repair has the lowest cost (RM 2002) because the cost of maintenance of machinery is lower for it is a very traditional method of pipeline repair (Bruce, 2007).

Overall, the pipeline replacement has the highest total cost (RM 35879.2) followed by E-Glass fiber composite wrap system (RM 11970.5). The labor, material, equipment and process involved are expensive and the process is still new in this industry. However, composite wrap can eliminate the need for shutdown of damaged pipeline. The production of gases through the pipeline to the plant can cover the cost of the repair procedure. This process also easy, quick and can be done in limited space (Jones et. al., 2008).

The lowest total cost of the repair is the welding repair operation. The procedures, labor powers and equipments of welding repair were already available and being used vastly in the field (Bruce, 2007). This lead to lower total cost for welding repair (RM 8189). The welding repair also did not have any technical limitation for repair process (Bruce, 2004). However, welding repair has drawbacks where the pipeline needs to be shutdown during the repair. For companies, the cease of pipeline operation of pipeline can lead to losses because they cannot produce the gas while most of the operations cost are still running. The welding repair is also risky, dangerous and time consuming (Alexander, 2007).

The E-Glass Fiber Composite Repair system is the most efficient and productive method for the pipeline repair system. The pipeline operation can be continued for transmitting the gas for production. The cost of this method is also reasonable. Even though, the total cost of using E-Glass fiber composite repair is expensive than the welding method, the continuous production of gas with zero hours of shut down can cover the repair cost different from the welding process and pipeline replacement where shut down operation of gas production through the pipeline are needed.

Conclusions:

Considering the outstanding properties of E-Glass composite, it serves as a wiser and more economical option compared to carbon fiber and Kevlar without sacrificing its mechanical and chemical properties as a material for pipeline repair. E-Glass composite wrap offers a faster and safer method compared to other repair methods like welding repair and pipeline replacement. It can eliminate the hassle and danger possibilities of using equipments that produce electrical spark and contribute to explosion. E- Glass composite wrap also offers a more productive and efficient repair system by preventing shutdown and eliminating methane gas emissions during the repair.

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