Journal of Vocational Studies on Applied Research

Failure Analysis at Stem Valve Fire Hydrant in LNG Plant

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Abstract- *Hydrant is one of fire extinguisher fix system that use pressure water and flowed through the pipes and fire hose. There are more 250 Hydrant in this LNG Plant and based on finding at the field, many stem valve of outlet hydrant in fracture condition, therefore the author wants to analyze about the problem from this material, this reserch aims to find out root cause dan conduct failure analysis, method of reserch that conducted is visual check to predict possible cause from failure of stem valve fire hydrant and then conducted fractographic analysis to find out what type of fracture that happen to this material and Tensile Strenght Test to Find out the the actual strenght of the material..*

Keywords *–Hydrant, stem valve, , failure analysis*

Submission : March 22, 2018 Correction : October 21, 2019 Accepted: November 19, 2019

Doi: http://dx.doi.org/10.14710/jvsar.1.2.2019.5-10

[How to cite this article: Subari, A., Fauzi, A.(2019). Credit Transfer System (CTS) Design in Academic Information System of Diponegoro University.*Journal of Vocational Studies on Applied Research,* 1(2), 5-10. doi: http://dx.doi.org/10.14710/jvsar.1.2.2019.5-10]

1. Introduction

As one of world class LNG processing Company, safety aspect is highest priority in it's production, Fire & Safety as one of section in operation department to ensure process of production working safely with using Fire Protection and Detection System that integrated with remote system, one of fire protection that used is fire hydrant, the function is as source of water if any emergency situation even in plant or non plant, to ensure this hydrant in good condition as periodic must conducted flushing twice a week, to remove deposit of sludge contained in pipe line. But there are some obstacles that often occur in the field. Such as many hydrant found in passing condition and stuck close, after conducted disassembly to outlet hydrant, founded stem valve in fracture condition.

Fracture is one of problem that many happening in this LNG Plant, one of component is outlet hydrant especiallystem valve fire hydrant and there are more 250 fire hydrant in this company, it mean many possibility of fracture at the future

2. Materials and Methods

2.1 Flushing Hydrant Activity

To ensure hydrant in ready condition if any emergency situation, this company make a standing order for flushing

Figure 1. Flushing hydrant

hydrant activity, with that schedule, cycle for open and close the outlet valve definitely occur. with that high intensity, stem valve of fire hydrant usually experience a fatique condition, and from that condition many founded stem valve of outlet hydrant has a fracture condition [1].

2.2 Documentation

Figure 2. Stem valve that experience a fracture condition

2.3 SEM Test

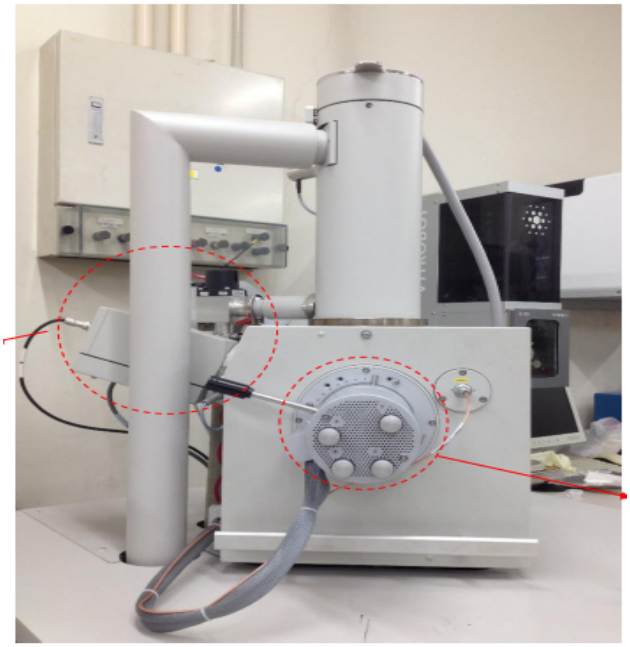

Figure 3. Scanning Electron Microscope

This tool has function to analyze structure of sample face with magnification up to 1.000.000 times, this tool has 2 operational mode, low vacum (for non conductive sample) and high vacum (for conductive sample). This tool is equipped with EDAX, it's tool can used to analyze elemental content to material, distribution of elements in material can be detected in the form of surface area, line and mapping.

2.4 Chemical Composition Check

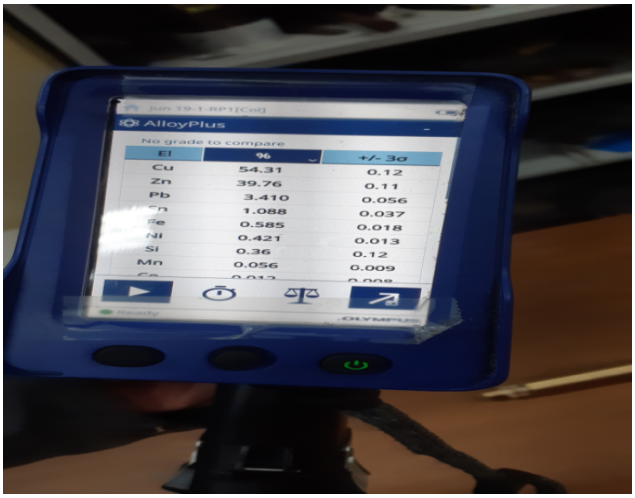

Figure 4. Alloy Analyzer Tool

There are some tools can used to check chemical composition, in this paper the author use facility owned by this company, that is alloy analyzer, this tool can check the chemical composition roughly, this tool is fully field portable analyzer based on energy dispersive X-Ray fluorescence (EDXRF) techology And use an x-ray tube as their excitation source. When energized, the instrumentation generate low energy X-Rays.

3. Result and Discussion

3.1 Macro Visual Observation

Figure 5. Fracture at Thread of Stem Valve

This menu is used to entry the CTS course schedule. In this case the schedule-making process is done outside the system and after the schedule has been established, the schedule will into the academic information system. The design of the scheduling menu interface is shown in Figure 4.

3.2 Result of Chemical Composition Examination

Chemical composition testing with Alloy Analyzer to component stem valve that conducted for observe

composition at material stem valve and compare to it's standard.

Table 1. Composition data of stem valve

Cu	Zn	Pb	Sn	Fe
54.37	39.76	3.410	1.088	0.585
SI	NI	MN	CO	
0.36	0.421	0.056	0.012	

This data was got from measurement by Alloy analyzer.

Table 2. Requirement of Material Composition Based on Standard ANSI/AWWA C502-94

Grade Of Bronze	Copper Minimum Percent	Zinc maximum Percent
A	79	16
B	57	Unspecified
C	57	Unspecified
D	79	16
E	79	16

Table 3. Grade of Bronze for Component Fire Hydrant According to Standard AWWA C502-94

Component	Grade of Bronze
Drain Valve Parts	A, B, D, E
Packing Glands	A, B, D, E
Packing Gland Bushings	A, B, D
Outlet Nozzles	A, B, D
Stem or Threaded Portion Of Stems	A, B, D, E
Stem Nuts	A, B, C, D, E
Suffing Boxes	A, D
Valve Seats or Valve-seat Rings	A, B, D, E

According Table 1. result of chemical composition test, measurement by alloy analyzer that chemical composition from stem valve is not accordance with requirements AWWA C502-94, from data, it shown the material is brass whereas according the standard ANSI / AWWA C502-94,requirements for material is bronze so that quality from material is lower than the standard [2].

3.3 Result of SEM Testing

Ductile fracture is characterized by tearing of metal and significant plastic deformation. The ductile fracture may have a gray, fibrous appearance. Ductile fractures are associated with overload of the structure or large discontinuities. This type of fracture occurs due to error in design, incorrect selection of material, improper manufacturing technique and/or handling. Ductile metals experience observable plastic deformation prior to fracture. Ductile fracture has dimple, cup and cone fracture appearance.

The research was done by Scanning Elecron Mycroscopy at Material Engineering Material Characterization Division ITS Surabaya, observation was conducted in the inner section of the thread, and on the threaded cross section with magnification until 1500 times, so that it can be observed the root cause of the fracture.

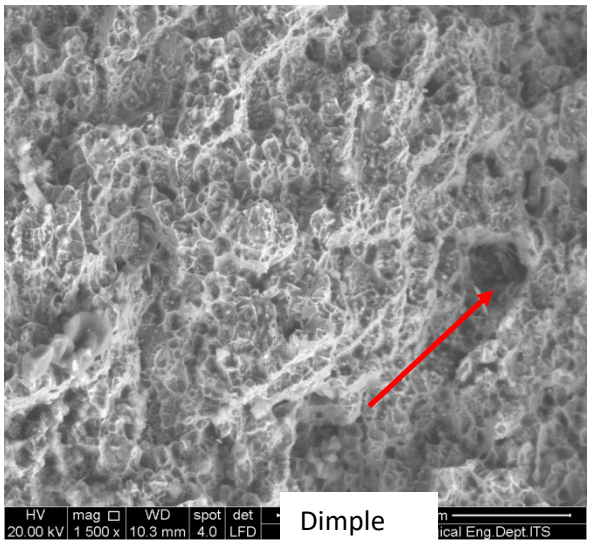

Figure 6. SEM Test

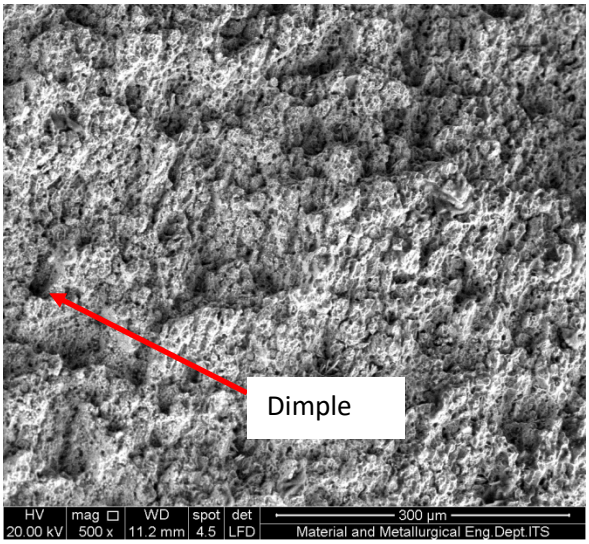

Figure 7. Dimples on the Face of Fracture

One of factor affecting the fracture of a material is stress concentration. A crack in brittle material will have quite pointed tip and hence a small radius. Such a crack thus produces a large increase in stress at its tip. One way of arresting the progress of such a crack is to drill a hole at the end of the crack to increase its radius and reduce the stress concentration. A crack in ductile material is less likely to lead to failure than a brittle material because a high stress concentration at the end of notch leads to plastic flow and so an increase in the radius of the tip of the notch. The result is then a decrease in the stress concentration.

3.4 Result of Tensile Strength Test

In the Stem Valve Fire Hydrant Material, tensile testing is carried out to determine the actual condition of the yield strength of the material at the time of the fracture.

Results of Tensile Test

Standard and method : ASTM E8 – Tensile Test of Metal

Specimen No.	Ø (mm)		Area (mm²)		Gage Length (mm)		Δℓ	Ultimate Load (N)	Yield Point (N)	Ultimate Strength (N/mm²)	Yield Strength (N/mm²)	Elongation (%)	Reduction of Area (%)
	Ø	Ø'	A	A'	ℓ	ℓ'							
1 (kondisi baik)	6.32	5.53	31.38	24.03	25.00	31.60	6.60	14400	10146	**458.84**	323.29	26.40	23.44
2 (ULIR RUSAK)	6.32	6.08	31.38	29.05	25.00	26.80	1.80	13400	9552	**426.98**	304.37	7.20	7.45

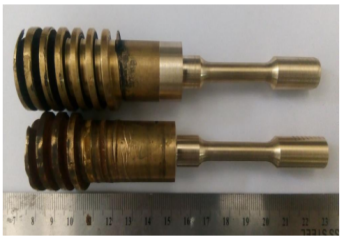

Fig. 1. Specimen before test

Fig. 2. Specimen after test

Figure 8. Tensile Test at Stem Valve

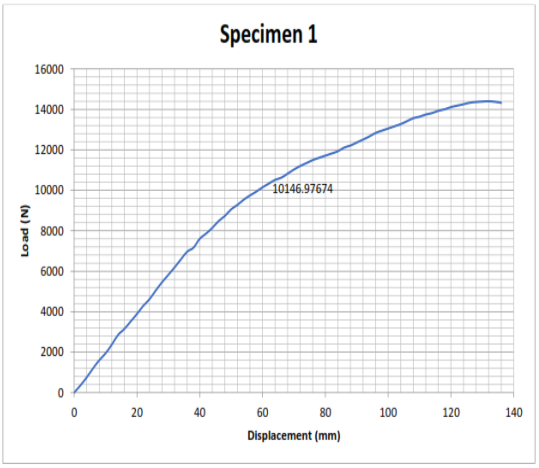

Figure 9. Graphic Tensile Test Speciment 1

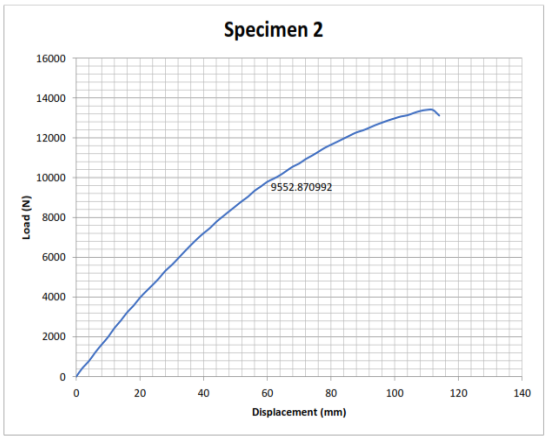

Figure 10. Graphic Tensile Test Speciment 2

From the data, it can be seen that there is difference between the stem valve which has been broken with the new stem valve, this show that there has been decrease in tensile strenght at the material [4].

3.5 Stress Corrosion Cracking

Although Copper Alloy has good corrosion resistance but there are several problems that often occur in Copper material, for example Corrosion Failure such as Dezincification, Pitting and Stress Corrosion Cracking often occur, there are factors that cause these failures including environmental factors and direct media touching the material. From a number of these factors, do a test to find other causes of the failure of the Stem Valve Fire Hydrant. Extensive analysis has been carried out to determine the specific characteristics of Stress Corrosion Cracking including only a few special characters regarding the environment that can affect this type of Failure against Metal or Alloy, pure metals are slightly more susceptible to failure compared to impure metals such as Copper-Zinc. Copper-Gold and Magnesium-Aluminum Alloys, other aspects such as the Metalurgical Structure (grain size) affect the susceptibility of mixed metals which can cause Stress Corrosion Cracking given by the environment.

3.6 Grain Size

Although it is not specific to measure grain size changes, it can be ascertained that there is a change in grain size, it is known from the results of SEM (Scanning electron Microscopy) testing that there are Microvoids or Dimples which indicate that Shear Over Stress results in changes in grain size.

3.7 SEM & EDX Test

In the Stem Valve material SEM and EDX were tested to determine the Crack that occurs on the surface of the Stem Valve. The following results are tested on the cross section of the inner surface of the thread.

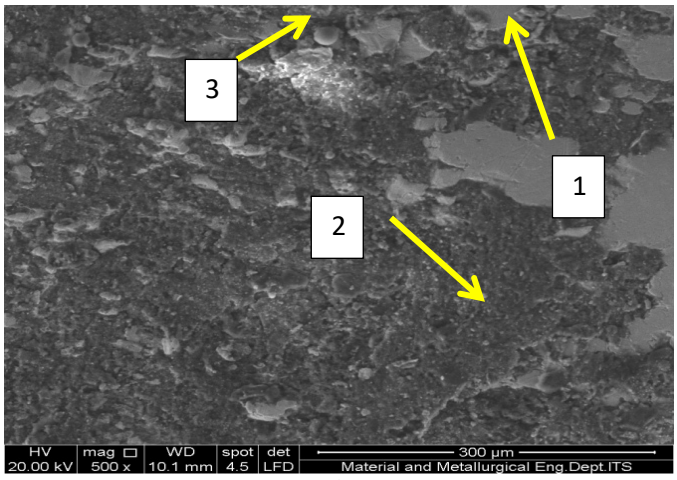

Figure 11. Special sign for stress corrosion cracking

Special sign:

1. The intergranular path of the basic fault shown, appears to be an irregular fracture display
2. Multiple secondary intergranular cracking
3. Corrosion products that appear on the surface

From the characteristics contained in the SEM test results it can be said that SressCorrotion Cracking occurs in the Stem Valve Fire Hydrant material.

3.8 Effects of Environment on SCC

There are several ions and substances that are known to cause Stress Corrosion Cracking and also some impurities which can cause corrosion. The following substances that can cause Stress Corrosion Cracking.

Table 4. EDX Result

Element	Wt%	At%
CK	34.36	63.17
OK	12.55	17.32
AlK	00.88	00.72
SiK	01.96	01.54
PbM	05.03	00.54
ClK	00.70	00.43
KK	00.53	00.30
CaK	03.40	01.88
FeK	02.77	01.09
CuK	23.65	08.22
ZnK	14.17	04.79
Matrix	Correction	ZAF

From the EDX test data, it was found that the oxygen content in the Crack area is quite high, where oxygen is one of the elements that can cause Corrotion in Copper Alloy Materials, besides that there is also Fe content on the Crack surface which is one of the elements that can cause corrosion . And from all the elements detected there is a fairly high carbon element thought to originate from erosion in the internal Fire Water pipe, the carbon element was one of the biggest contributors as Impurities [3].

At the sampling point at the other fault location it was also read that there was a high enough carbon content, in many literature it was also mentioned that one of the most found Impurities caused by Corrosion Cracking was carbon and sulfur content following SEM and EDX data at the other fault location:

Table 5. EDX test result at another location

Element	**Wt%**	**At%**
CK	40.91	67.57
OK	17.04	21.12
SiK	01.77	01.25
PbM	13.08	01.25
ClK	00.91	00.51
FeK	03.86	01.37
CuK	13.08	04.08
ZnK	09.36	02.84
Matrix	Correction	ZAF

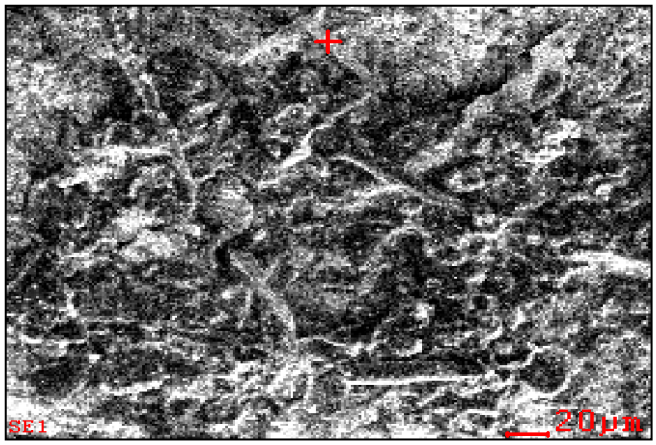

Figure 12. SEM test result at another location

Figure 13. Internal surface condition of fire pipe

4. Conclusion

a. Based on chemical composition examination with Alloy Analyzer tool that found material no suitable with the standard ANSI / AWWA C502-94 about fire hydrant chapter 3.2.5.1 “the operating threads of the hydrant shall be designed to avoid the working of any iron or steel parts againts either iron or steel. The threaded portion of the stem or it’s threaded stem nut (or sleeve) shall be made of bronze”, from the testing was found composition from material is copper 54 % and Zinc 39 % it mean the material is Brass, any differential with the standard where it’s should be from bronze material.

b. From the results of tensile tests, it is known that there has been a decrease in tensile strength in the material, it is known based on the results of tensile tests that have been carried out, by comparing the results of tensile test material that is broken with material that is still in new condition.

c. The selection of the right material is a mandatory requirement for a system to support the smooth operation, in terms of atmosphere / environmental factors the equipment works and the condition of the media that is in direct contact with the material is also a special concern for selecting suitable material types, one of which often occurs in Copper Alloy material is Stress Corrosion Cracking, from the data obtained based on SEM and EDX testing that the surface of the Stem Valve is intergranular and multi intergranular cracks besides

corrosion products on the inner screw surface are reinforced with EDX results where there is oxygen and Fe content large enough to be able to make corrosion on the surface of the Stem Valve and added to the amount of carbon content as one of the Impurities that plays a major role in the formation of Stress Corrosion Cracking on this Fire Hydrant Stem Valve.

5. Acknowledgment

This work was supported in part by Vocational School of Diponegoro University.

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[1] Manual Book Operation Fire & Safety, Fire Protection & Detection System.

[2] American Water Works Association ANSI/AWWA, Standard for Dry-Barrel Fire Hydrants.

[3] Metal Handbook Eight Edition Vol. 10, Failure Analysis and Prevention.

[4] Tobi, A.L., Zaman, M.S., Mustapa, W.A., Case Study: Techniques for Material Characterisation of Brass Tensile Testing Fracture Sample, ARPN Journal of Engineering and Applied Sciences.