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Failure Analysis on Leaked Tube of Furnace Boiler

Sukandar[1,a)], Triwibowo[2], Aswandi[2]

[1]*Mechanical Engineering Department, Universitas Pamulang, Tangerang Selatan, 15417, Indonesia*
[2] *Research Center for Structural Strength Technology, Research Organization for Energy and Manufacture, National Research and Inovation Agency, Indonesia*

E-mail: [a)] dosen00164@unpam.ac.id

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Abstract: Furnace in oil companies is functioned to heat raw oil in process to produce various fuels, and outlet gas from the furnace is used for heating water in Furnace Boiler. Failure took place on tubes of Furnace Boiler. The purpose of this failure analysis is to find the root cause of failure. Methods conducted in this failure analysis are through examination and testing of fractography, metallography, chemical composition, hardness, and bulging measurement. Examination on the fracture surface by fractographic method revealed leakage due to excessive bulging and existence of excessive deposit/scale. Condition of bulging gave indication of long-term overheating due to excessive deposit/scale. Examination by metallographic method revealed that microstructure of ferrite and pearlite having grain growth due to exposed by local heating. However, result of chemical composition examination and hardness test showed that material of the furnace tubes were in accordance with ASTM A-192. Bulging measurement gave indication of excessive bulging up to 15% for the leaked tube. Therefore, failure of leaked tube of Furnace Boiler was caused by long-term overheating due to excessive deposit/scale which were formed in the location of bulging.

Keywords: Furnace Boiler Tube, ASTM A-192, Excessive Bulging, Excessive Deposit/Scale, Long-term Overheating.

Abstrak: *Furnace pada perusahaan minyak berfungsi untuk memanaskan minyak mentah dalam proses produksi berbagai jenis bahan bakar, dan gas buang dari furnace digunakan untuk memanaskan air pada Furnace Boiler. Kegagalan terjadi pada pipa-pipa Furnace Boiler. Tujuan dari analisis kegagalan ini adalah untuk mengetahui akar penyebab kegagalan tersebut. Metode yang dilakukan dalam analisis kegagalan ini meliputi pemeriksaan dan pengujian melalui fractografi, metalografi, komposisi kimia, kekerasan, serta pengukuran deformasi (bulging). Pemeriksaan permukaan patahan melalui metode fractografi menunjukkan adanya kebocoran akibat deformasi berlebih (bulging) dan terbentuknya deposit/skala yang berlebihan. Kondisi bulging mengindikasikan terjadinya overheat jangka panjang akibat adanya deposit/skala yang berlebihan. Pemeriksaan metalografi menunjukkan bahwa mikrostruktur ferit dan perlit mengalami pertumbuhan butir akibat paparan panas lokal. Namun, hasil pengujian komposisi kimia dan kekerasan menunjukkan bahwa material pipa furnace sesuai dengan standar ASTM A-192. Pengukuran bulging menunjukkan deformasi berlebih hingga 15% pada pipa yang mengalami kebocoran. Dengan demikian, kegagalan pada pipa Furnace Boiler disebabkan oleh overheat jangka panjang akibat terbentuknya deposit/skala yang berlebihan pada lokasi bulging.*

Kata kunci: *Pipa Furnace Boiler, ASTM A-192, Bulging Berlebih, Deposit/Skala Berlebih, Overheat Jangka Panjang.*

INTRODUCTION

It is given a tube sample of furnace boiler (Figure 1). In oil companies, furnace is one of some sequence processes to produce fuel. In the furnace, tubes contained raw oil is heated by gas. Gas outlet from furnace is then used for heating boiler to heat water tubes. So that is why the construction is named of furnace boiler [1].

Figure 1. Tube sample of Furnace Boiler

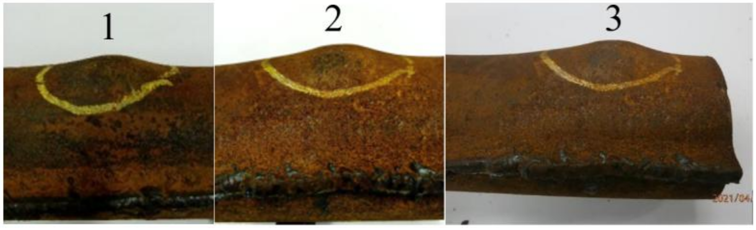

Figure 2. Bulging 1, 2 and 3 on tube of furnace boiler

Condition of bulging on the tube is shown in Figure 2. The purpose of this failure analysis is to find out the root cause of failure on furnace tube and to provide recommendations in order to prevent similar failure in the future.

Figure 3. Leakage took place at bulging 1 and 3

METHODS

The sample is taken from the leaked tube as shown in Figure 1 to 3. Material of the tube is carbon steel ASTM A-192. Technical data and operational data are listed in Table 1.

Table 1. Technical and operational data of tube

Specification	Value
Unit	Furnace Boiler
Year of start operation	1993
Tube OD / thickness	76.1 mm (OD) / 4 mm
Tube Material	ASTM A-192
Operation temperature of tube Boiler	448 ^oC
Operation pressure of tube Boiler	60 kg/cm^2

Failure analysis on tube is conducted based on examination and testing as follow:

Chemical Composition

Examination of chemical composition is conducted to verify the tube material specification by OES (optical emission spectrometer) whether it is in accordance with ASTM A-192.

Hardness

Hardness test is conducted to verify the tube material specification by hardness tester Frank Finotest whether it is in accordance with ASTM A-192.

Fractography and Metallography

Examination of fractography and metallography is conducted to observe fracture modes on the fracture surface, and metallography is to observe the microstructure and defects [2].

Bulging (circumferential) measurement

Bulging measurement is conducted to find the percentage of bulging.

RESULT AND DISCUSSION

Chemical Composition and Hardness

Examination result of chemical composition of the tube is in accordance with the standard of ASTM A-192 [3] as shown in Table 2. Hardness test result of the tube is in accordance with the standard of ASTM A-192 [3] as shown in Table 3.

Table 2. Chemical composition examination result of tube (% weight)

Elements	Tube	ASTM A-192
Fe	98.9	Remaining content
C	0.117	0.06 – 0.18
Si	0.197	Max. 0.25
Mn	0.460	0.27 – 0.63
P	0.0485	Max. 0.035
S	0.0144	Max. 0.035

Table 3. Hardness test result of tube (HV)

No	Bulging 1	Bulging 2	ASTM A-192
1	114	111	Max. 144
2	111	100	
3	105	110	
4	107	116	
5	111	106	
6	113	105	

Results of chemical composition examination and hardness test indicated that the material of tube is in accordance with ASTM A-192 specification [3], therefore failure of tube is not caused by wrong material selection.

Fractography and Metallography

Examination result of fractography on the fracture surface of tube shows longitudinal stretch lines on the bulging 1 and 3 as shown in Figure 3. On the top of bulging it can be seen stretch line that has leakage. As shown in Figure 4, it can be seen thick deposit on inner surface of tube at bulging side.

Figure 4. Thick deposit can be observed on inner surface of tube

As can be seen in the Figure 4 that the deposit can act as local stress riser due to local high temperature. Examination result of metallography shows that the microstructure of tube is ferrite and pearlite. But grain size on bulging position is greater than that of normal position as can be seen in Figure 5 and 6 [2].

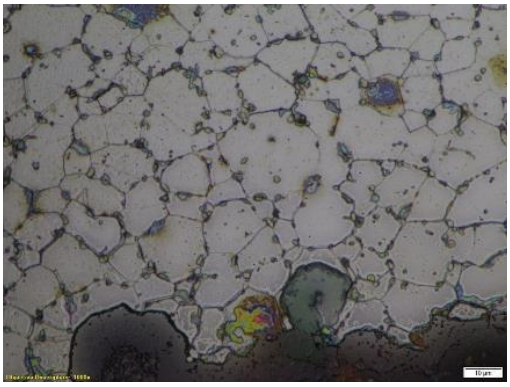

Figure 5. Grain growth microstructure on bulding 1, 500x

Figure 6. Normal size microstructure, 500x

Results of fractography and metallography examination show that the leakage took place at top of bulging, and inner side of bulging is inhabited by excessive deposit, also at lateral section of bulging shows grain growth. Combination of these findings gave a clue of long-term overheating [4], [5]. Formation of deposit should be related to flow pattern and operation system and water quality. Since deposit formed, heat received from gas could increase local heat because the heat is absorbed by the deposit, and not transferred to water. Long-term overheating induced high local stress and slowly created bulging. When the bulging is not detected early, it will continue to cause leakage [6]–[12].

Bulging (circumferential) measurement

Result of bulging (circumferential) measurement can be seen in Figure 7-9. Bulging (circumferential) measurement gave information that leakage is not taking place at 2.68% of circumferential, the leakage took place at 11.61% and 15.12% of circumferential. So it is necessary to find out how critical percentage of circumferential before tube leakage.

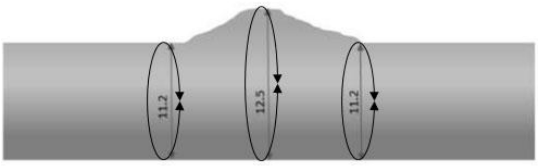

Figure 7. Circumferential of bulging 1 is 11.61%

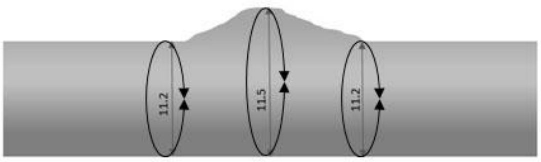

Figure 8. Circumferential of bulging 2 is 2.68%

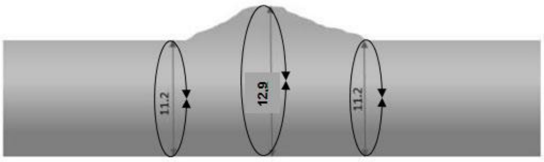

Figure 9. Circumferential of bulging 3 is 15.12%

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Calculation of circumferential is conducted as follow:

It is taken bulging 1 to represent bulging measurement:

- Normal circumferential: 11.2 mm
- Bulging circumferential: 12.5 mm
- Circumferential bulging:
  100% x (12.5 – 11.2) / 11.2 % = 11.61%

Bulging (circumferential) measurement gave information that leakage is not taking place at 2.68% of circumferential, the leakage took place at 11.61% and 15.12% of circumferential. So it is necessary to find out how critical percentage of circumferential before tube leakage.

CONCLUSIONS

From all examination and testing, it can be concluded that the cause of tube leakage is long-term overheating. Long-term overheating is created by formation of deposit/scale on inner surface of tube. This long-term overheating is also created bulging, when it is excessive or undetected, it is causes leakage. Deposit formation that taking place could be caused by flow pattern, operation system, and water quality.

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