FRACTURE ANALYSIS OF GANTRY CRANE GEAR TOOTH BY NONDESTRUCTIVE EVALUATION METHOD

Mai Noipitak*, Sittisak Charunetratsamee

Ratchaburi Learning Park, King Mongkut's University of Technology Thonburi

***Corresponding authors: mai.noi@kmutt.ac.th**

ABSTRACT

Preventive maintenance properly conducted is necessary for the gantry crane located at sea port where it work 24 hours to transfer the container goods. However, crane breakdown is likely to occur due to random causes. If such root causes that results in severe component damages are identified, any premature failure that may occur could be prevented or mitigated. This paper presents an analyzed technique to investigate the root cause of fracture and reports the cause of failure in gantry crane gear tooth driving the hoist drum. The onsite Non-Destructive Evaluation (NDE) was used to investigate the cause of failure. First of all the visual examination of the fracture surface was used, the liquid penetrant examination was also used to evaluate the crack propagation and the replica testing was used to evaluate the microstructure at the surface of tooth. Then, films of replica and some chip of tooth were collected to analyze in the laboratory. The microhardness of tooth was measured and the chemical composition also was analyzed by spectrometer. The results showed that the type of fracture is brittle and the characteristic of fracture at the surface is intergranular fracture. The cause of fracture occurred at the top tooth area as contrast to other areas, is the stress concentration, and had the sensitive microstructure of surface due to the hardening process. The grain boundaries at the tooth surface were weaken by heat treatment process and non-uniform of chemical composition also lead to the weakness than other area.

1. INTRODUCTION

The performance of gantry crane for transferring the container goods at the sea port has been always monitored and maintained under condition of design and operating factors to avoid sudden breakdown. The main operation point of gantry crane to transfer the container goods is set of gear driving the hoist drum because this drum drive the wire rope to lift the container goods. If this gear has some problem, this effect not only results in gear box replacement but also in shutdown as well as significant consequences. In this case, the gantry cannot operate full time during the replacement of gear box, leading to low productivity and loss of profit income. The techniques were used to investigate the root cause of fracture in gear of gantry crane for the corrective action and preventive plan in the future.

Many case of gear failure were studied. An accessory gear box of a turbojet engine was reported the fracture of a drive bevel gear by tooth-bending fatigue caused by improper casehardening (Park, 2003). The investigation of the effect of carburizing was studied in relation to the mechanism of failure and a case nitriding can be used in place of carburizing and it could be a good solution in order to avoid the failure phenomena (Boniardi, et al., 2006). The crack failure of the two gears were investigated and confirmed to occur during the carburizing-quenching process (Xu, et al., 2008). The failure of helical gear was made by 18CrNiMo steel which found the fracture surface exhibited fatigue fracture characteristic and there were inclusions of iron oxide surrounded by (FeMo)3C carbide in the microstructure of gear material (Netpu & Srichandr, 2013). The fatigue crack propagation in the gas turbine compressor blades was investigated that is greatly influenced by surface treatment and cyclic loading (Mokaberi, et al., 2015).

In previous papers the main causes of the fracture of gear were concluded by microstructure susceptibility on the surface and cyclic loading. The objective of this presented study is to investigate the root cause of fracture and reports the cause of failure in gantry crane gear tooth driving the hoist drum. The benefit of this paper is providing the guideline to investigate the root cause of fracture and would help prevent or minimize the reoccurrence of similar failures in the future.

2. BACKGOUND

A gantry crane gear driving the hoist drum failed after approximately three years of service. The temperature of gear during service is approximately between 25 to 60^{o}C. In the first year, lubricant in gear box was replaced and then every next three year lubricant will be replaced. During service there was no problem associated with the gear. After three years the vibration of gear became unusual and increasingly severe. A gantry crane temporarily stopped for inspection. It was found that one tooth of the gear were broken. Before installation, this gantry crane was tested the shock load (40 tons) to confirm the system of gear driving the hoist drum.

3. INVESTIGATION PROCEDURE

To investigate the cause of failure, the onsite nondestructive evaluation was used. First of all the visual examination of the fracture surface was used, the liquid penetrant examination was also used to evaluate the crack propagation and the replica testing was used to evaluate the microstructure at the surface of tooth. Then, the films of replica and some chip of tooth (fragment) were collected to analyze in the laboratory. In the laboratory, the microhardness of tooth chip was measured by Vickers Hardness tester (Wilson Wolpert, 432 SVD(V32D219)). A total of 28 points were measured to establish the hardness profile. The chemical composition was analyzed by spectrometer ARL3460 and the films of replica were analyzed by Optical Microscopy (LEICA DM 2500M).

4. RESULTS

4.1 Visual Examination

The location of damage and the apparent fracture at top tooth are shown in Fig. 1 and Fig. 2, respectively. It was found that the fracture on the gear tooth face is the brittle type. The fracture surface revealed the tooth damage including four distinguishable zones (zones A, B, C, D). Zone A in Fig. 2 showed the broken tooth face area and the surface was relatively smooth to rough area. Zone B and C showed the shrinkage and the extension areas while zone D presented the brighten surface which was scratched.

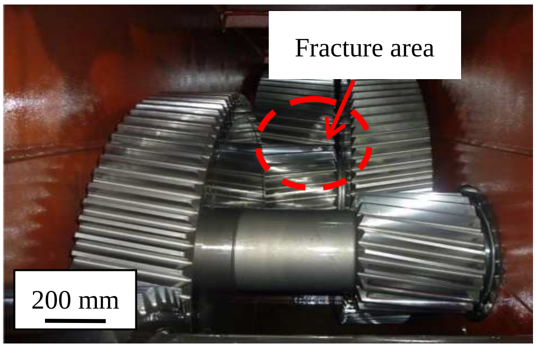

Fig. 1 Location of damage

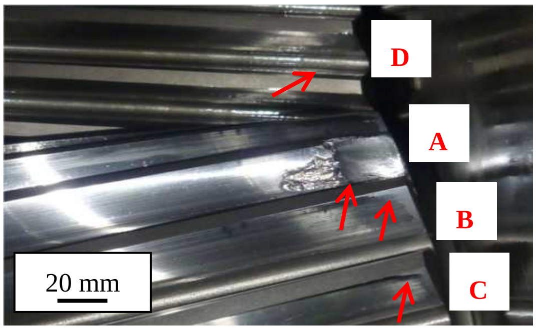

Fig. 2 Fracture appearance of the failed gear tooth

4.2 Liquid Penetrant Examination

The surface crack opening that may occur from fracture propagation was investigated by liquid penetrant examination. The test result is shown in Fig.3. The result found the fine crack at the top tooth. The direction of crack growth was parallel in the exit of gear.

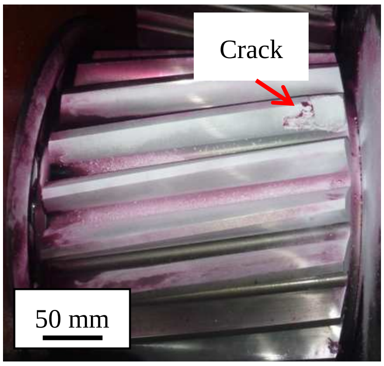

Fig. 3 Liquid penetrant examination

4.3 Chemical Composition and Hardness Analysis

Some chips that broken out form the gear tooth were analyzed for the chemical compositions to identify the material of gear. The result is shown in Table 1.

Table 1 Chemical composition (%wt)

Elements	Case	Core
C	0.688	0.183
Mn	0.550	0.538
Si	0.229	0.220
P	0.129	0.015
S	0.012	0.014
Ni	1.558	1.551
Cr	1.686	1.683
Mo	0.282	0.280

The chemical compositions indicated that the gear was made from low alloy CrNiMo steel and exhibited high carbon content at the case surface. The average carbon content at surface was 0.688 %wt. This means that gear tooth was performed case hardening steel by carburizing process according to the microhardness profile that is shown in Fig. 4. The highest hardness value at the case surface was 510.9HV (49.9HRC) and the hardness decreases with the distance from the surface down to the value of about 218.8HV (15.3HRC) at the case core interface at the distance of about 4.6 mm from surface.

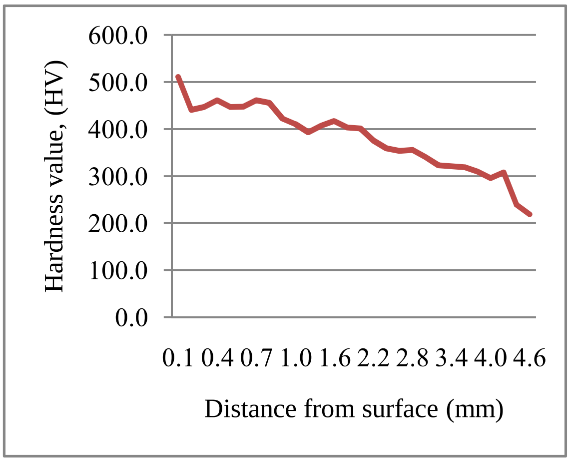

Fig. 4 Microhardness profile

4.4 Replica Testing

To verify fracture propagation and microstructure susceptibility, the replica testing was used to investigate a metallographic image of the material directly on the component examined. The replica testing was used to analyze the two regions (A and B) as shown in Fig. 5.

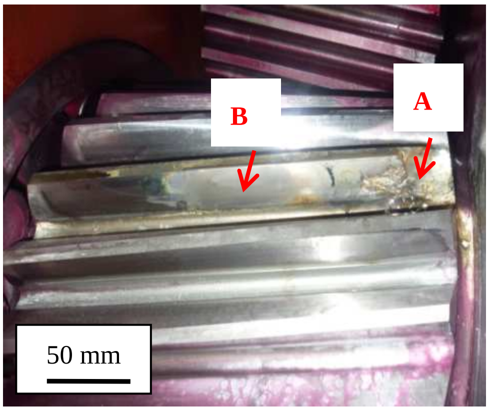

Fig. 5 Location for replica testing

The microstructure of gear material was found to be tempered martensite that conforms to the hardening process mention above. The microstructure of the failed gear is shown in Fig. 6. At the surface of failed gear, the intergranular cracks were found. Region A was the fractured area and the microstructure at 25x and 100x were shown in Fig. 7 and Fig. 8, respectively. It was observed that the crack originated from the edge of fracture which was intergranular fracture type. The region B is the middle area of gear tooth. By visual testing, there were no apparent damages in this area and there were no surface crack opening by liquid penetrant testing. However, the micro crack along with gear tooth was found after analysis of the replica film. The microstructure of region B is shown in Fig. 9.

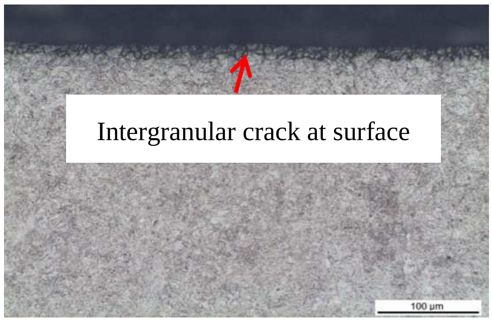

Fig. 6 Microstructure of the failed gear (200x)

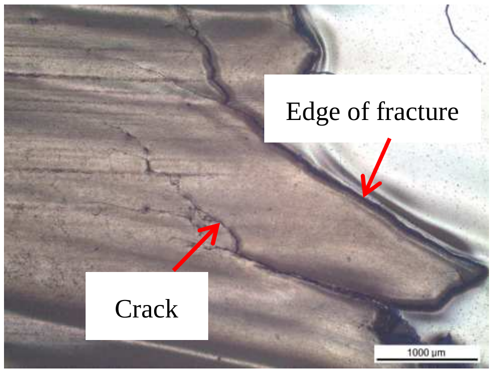

Fig. 7 Microstructure at region A (25x)

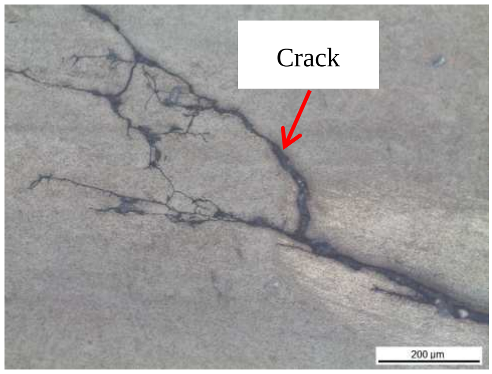

Fig. 8 Microstructure at region A (100x)

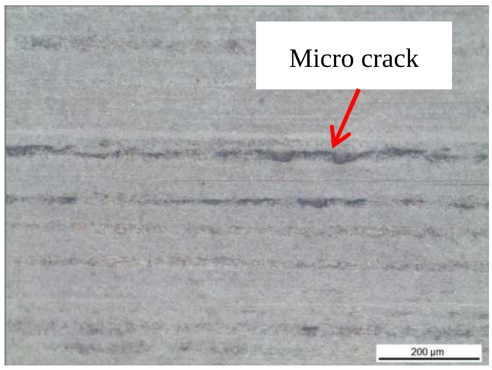

Fig. 9 Microstructure at region B (100x)

5. CONCLUSION

The fracture of gear tooth in a gantry crane was investigated. The following conclusions can be summarized from the investigation:

1. The type of fracture is brittle, the characteristic of fracture at the surface of top tooth is intergranular fracture and the microstructure at the surface of tooth is tempered martensite. The fracture has occurred at the carburizing area.

2. The crack growth is started from surface to core of tooth and the micro crack found along with gear tooth.

3. Stress concentration is the cause of fracture occurred at the top tooth area and this was happened more often than other areas. The fracture area had the sensitive microstructure of surface due to the hardening process.

REFERENCES

Park. M., Failure analysis of an accessory bevel gear installed on a J69 turbojet engine, *Eng Fai Anal*., vol. 10, pp. 371-382, 2003.

Boniardi. M., D'Errico. F., Tagliabue. C., Influence of carburizing and nitriding on failureof gears – A case study, *Eng Fai Anal.,* vol. 13, pp. 312-339, 2006.

Xu. X., Yu. Z., Gao. Y., Wang. T., Crack failure of gears used in generating electricity equipment by wind power, *Eng Fai Anal.,* vol. 15, pp. 938-845, 2008.

Netpu. S., Srichandr. P., Failure of a helical gear in a power plant, *Eng Fai Anal.,* vol.32, pp.81-90, 2013.

Mokaberi, A., Derakhshandeh, R.,Haghighi, Abbaszadeh. Y., Fatigue fracture analysis of gas turbine compressor blades, *Eng Fai Anal.,* vol. 58, pp. 1-7, 2015.

Mai Noi[pitak received the B.E. (2004), M.E. (2007), and Ph.D. (2011) degrees in manufacturing and system engineering from King Mongkut's University of Technology Thonburi, Thailand.

He is a lecturer, Ratchaburi learning park, King Mongkut's University of Technology Thonburi. His research current interests non-destructive testing technology, welding technology, materials technology and destructive testing in materials.

Sittisak Charunetratsamee received the B.E.(2009), and M.E.(2012) degree in welding engineer from King Mongkut's University of Technology Thonburi, Thailand

He is a researcher assistance, Ratchaburi learning park, King Mongkut's University of Technology Thonburi. His research current interests non-destructive testing technology, welding technology and destructive testing in materials.