



An Investigation of a Helical Gear Crack Used in a Crop Shear

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Abstract

This paper reports the results of an investigation into the crack of a helical gear used in a crop shear. Standard investigative procedures were employed in the analysis. It was found that the longitudinal running through the bore gear face width after quenching process. The chemical compositions indicated that the failed gear was made from low alloy Cr-Mo steel to AISI 4140 standard. The microstructure near the crack zone was a martensite phase. The micro-hardness values measured from the crack surface region to inside decreased from 729 HV to 489 HV at the depth of 2.5 millimeters respectively. And it was found that the hardness of inside the gear was almost the same at 486 HV.

It was, therefore, concluded that the cracks were caused by the casting process. The lesson learned from this case is that one must inspect the casting defect before machining station.

Keywords: Helical gear, Helical gear cracks, Longitudinal crack, Casting defect

1. Introduction

Gears are extensively used in numerous engineering applications including crop shear gearboxes. Crop shears are key equipments and extensively used in steel industry. Failures of gears not only result in replacement cost, but also an effect on late delivery. In the case being investigated, for example, the late delivery was one and haft month due to make gear by start from casting process again.

According to literature, the cause of gear failure may include faulty designs, improper application or manufacturing errors. Design errors include such things as improper gear

geometry, wrong material selections, poor materials quality, inappropriate lubrication system, or several others. Application errors include things such as improper mounting and installation, poor cooling, lubrication, and poor maintenance. Manufacturing errors could be poor machining or faulty heat treatments [1]. Gears fail from a variety of reasons. Gears failure modes include (in decreasing order of frequency) fatigue, impact fracture, wear, stress rupture. Tooth bending fatigue, contact fatigue, and thermal fatigue are among some of the types of fatigue failures in gears. Abrasive wear and adhesive wear are common modes of wear

failure of gears. Faulty material selection, poor manufacturing and engineering practices, hostile service environment are important causes that could also lead to gear failures [2, 3]. Gear failures can even occur before the gears are placed in service due to excessive stress. The very best design, on paper, can be a total disaster if it is not properly executed in manufacturing phase. Process related failure can be of following types: quench cracks case/core separation, grinding cracks, nicks, scratch, electric arcing and tool marks [4]. Human errors were also found to be a major cause of roll failures. Such errors are of three general types (1) errors of knowledge (usually involve insufficient knowledge, education, training and experience) (2) errors of performance (lack of sufficient care or from negligence), and (3) errors of intent (very commonly involve greed) [5].

This work was aimed at investigating and to identify cause of the helical gear failure in a crop shear so that the re-occurrence of similar failure can be avoided in the future.

2. Background

The failed helical gear being investigated was used in a crop shear for hot rolling mill. The failed gear has 45 teeth and the face width of 90 mm. The module of the gear is 12 mm, the helix angle is 10 degrees. A crack of gear was reported after heat treatment process. Relevant photo of the crop shear and layout of gear as shown in Fig. 1.

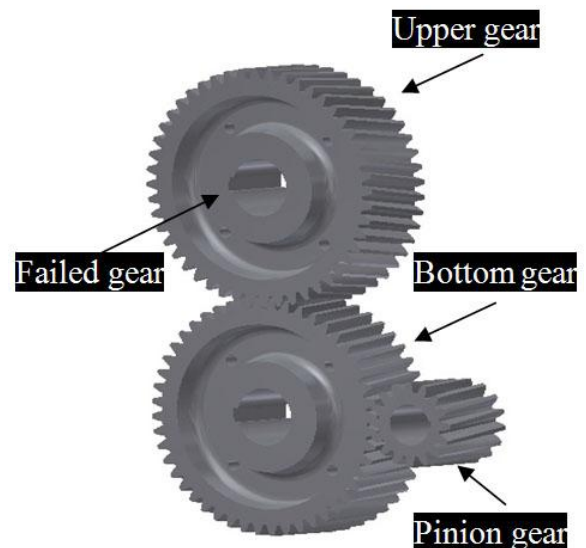


Fig. 1. The crop shear and layout of the failed helical gear

Approximation of critical time of making gear was 50 days as shown in Fig. 2. The maximum time was casting process.

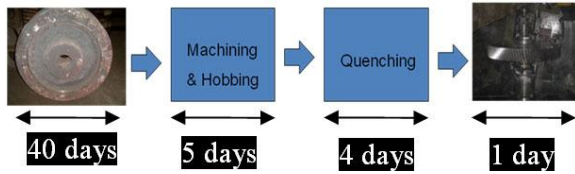


Fig. 2. Critical time of making gear

3. Investigation procedure

The failed gear was first inspected visually then macroscopically. Samples of the material in the vicinity of the crack zone of the failed gear were taken and metallographic samples were prepared for optical microscopy examination, and for microhardness measurement.

Dye-penetrant technique (DPT) was employed to enhance visual inspection of the crack and to fully reveal the nature of the crack. Microhardness measurement at various distances from the crack origin of the gear hub to the interior were carried out on a polished specimen using a Mitutoyo model ARK 600 microhardness tester (steel ball diameter 1/16") with a load of 10 kgf. Chemical analysis of the gear material was performed in order to identify the type of steel used. The chemical composition of the failed gear material was analysed using a spectrolab spectrophotometer (Model: M8, Type: LAVWA 18A). The samples were taken from the failed gear for microstructure investigations. Standard metallographic specimen preparation procedures were employed. The specimens were metallographically prepared by cut, grinding, polishing, and then etched by 2 % Nital. After etching, the microstructure of specimens was studied, and micrographs were

taken using an optical microscope (LECO: IA32-Image analysis system).

4. Results and discussion

4.1 Visual examination and Dye penetrant

The appearance of the failed helical gear from various perspectives is as shown in Fig. 3. It can be seen that the cracks of the failed gear from heat treatment are long and passed through the gear hub. Dye penetrant technique was employed to enhance visual inspection of the crack and to reveal the nature of crack more fully.

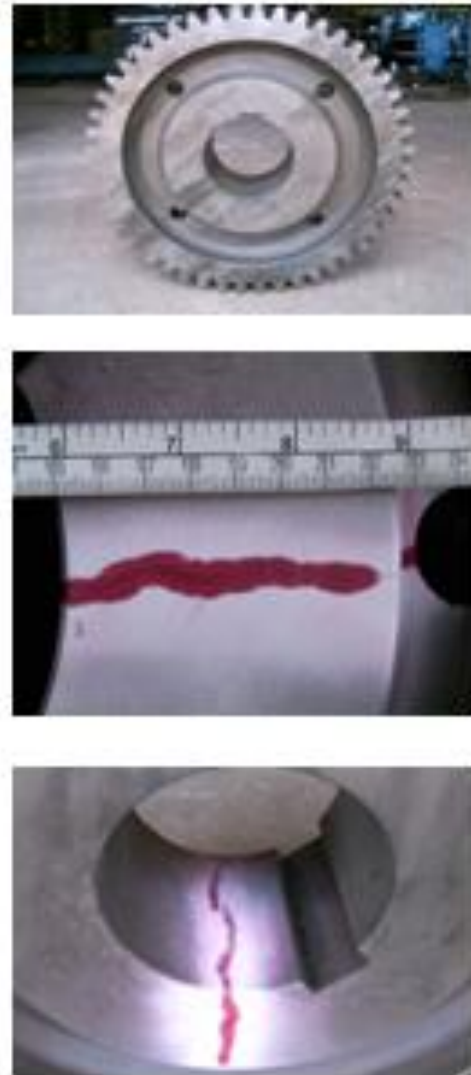


Fig. 3. Crack occurrence in the failed gear

4.2 Hardness profile

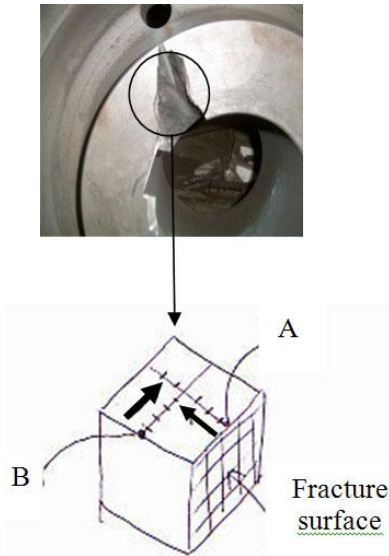


Fig 4. Hardness testing of the sample

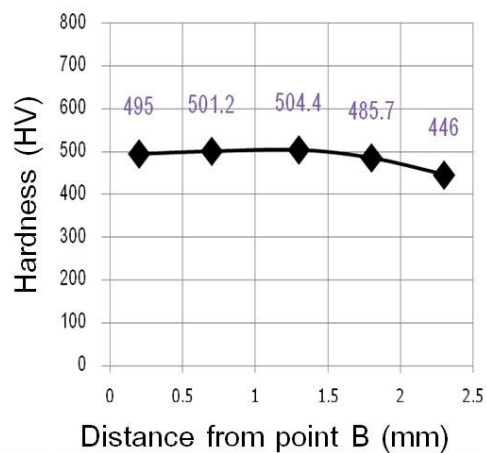
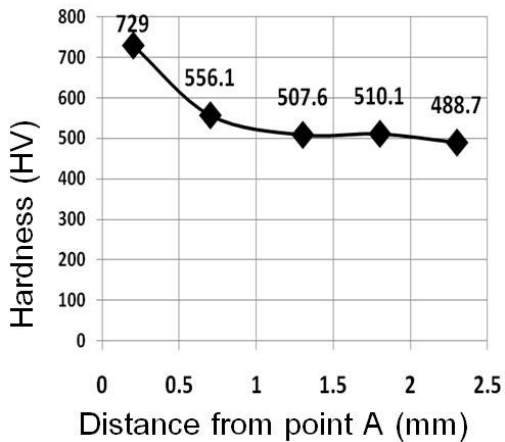


Fig 5. Microhardness profile of the failed gear

Fig. 4 shows the position that was cut from the cracked area for hardness testing.

Fig. 4 shows the measurement of hardness at different positions along the arrow lines. Result of hardness testing are shown by graph as in Fig. 5 that shows the following results. When measuring from the crack at Position A towards the center of the failed gear, the hardness diminished from 729 HV down to 488.7 HV at the dept of 2.25 mm. But if measured inside the failed gear starting at Position B and went deeper, the hardness was similar: at Position B, the hardness was 595 HV and at the dept of 2.25 mm the hardness was 446 HV. It can be seen that the cracks of the failed gear happened before heat treatment because if the cracks happened during the process of heat treatment the hardness would be similar when measured from the crack towards the inside.

4.3 Composition analysis

The average values of the analysis are shown in Table 1. The compositions indicated that the failed gear material was made from low alloy steel to the standard AISI 4140 [6], commonly and widely used in making gears in surface hardened conditions [7].

Table 1 Chemical composition of the failed helical gear material and AISI 4140 (%wt)

Materials	Failed gear	AISI 4140
C (wt%)	0.311	0.38-0.45
Si(wt%)	0.619	0.4(max)
Mn(wt%)	0.784	0.60-0.90
Cr(wt%)	0.860	0.90-1.20
Mo(wt%)	0.193	0.15-0.30

4.4 Heat Treatment and Microstructure examination

The heat treatment of the failed gear used the austenitizing temperature of 880°C and tempered at the temperature of 250°C as shown in Fig. 6 according to the standard of heat treatment of AISI 4140 steel.[8]

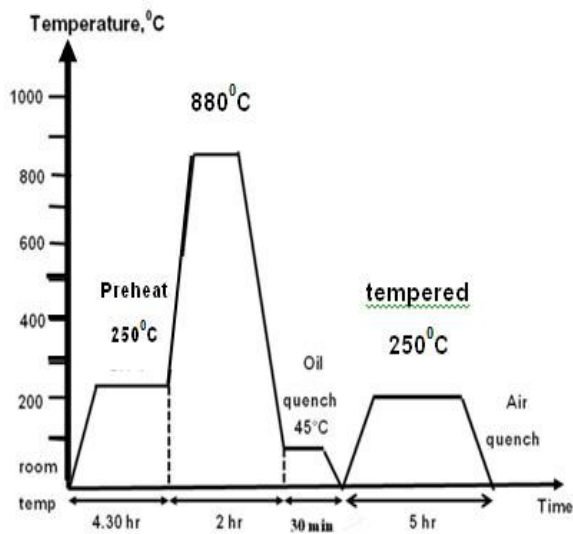
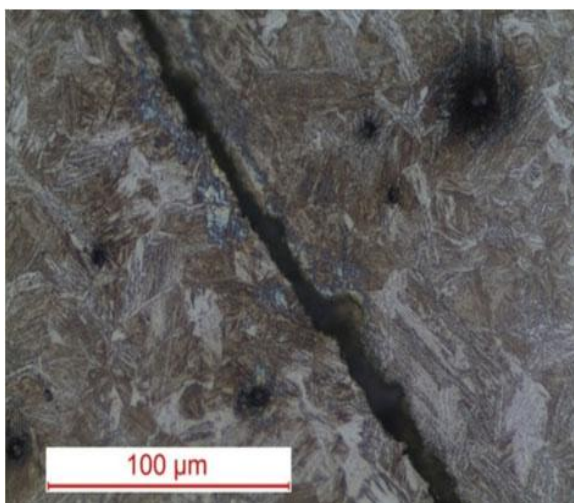
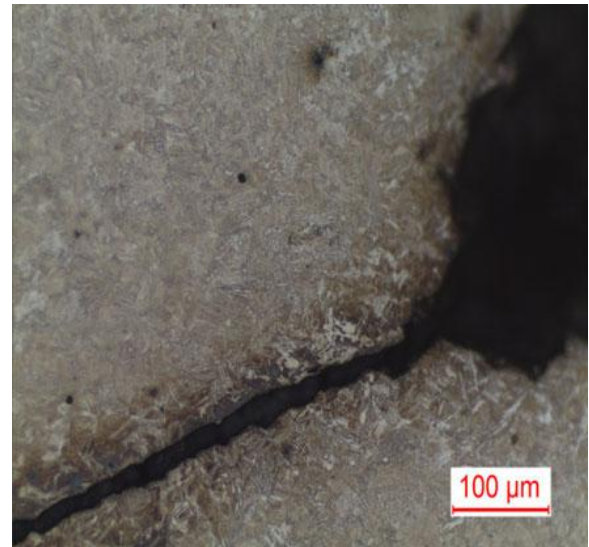


Fig. 6 Schematic of heat treatment



a)



b)

Fig. 6. Optical micrograph showing martensite structure in the vicinity of the crack along the fracture surface of failed gear

5. Conclusions

From the studies conducted to understand the failed gear, it could be concluded that:

1. The cracks of the failed gear happened at the process of the casting.
2. It is recommended that extreme care must be inspected the casting defect before machining station.

6. Acknowledgement

The author thanks Mr.Krit Deelokcharoen, Managing Director of S.H.K. Engineering Co., Ltd., for his help in the history of the failed gear.

7. References

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