Failure Analysis Procedure of Steel Wire Drawing Fracture

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Abstract Failure analysis procedure of steel wire drawing fracture process was introduced, which includes background information collection, visual inspection and low magnification test, microscopic analysis, metallographic examination, etc. The importance of each step on fracture failure analysis results was also explained. In accordance with the stress condition in drawing process of steel wire, the typical characteristics of the mainly drawing fracture failure modes including pencil-point shaped, plane shaped and inclined shaped were investigated. The process of microscopic analysis and metallographic examination were optimized with macro morphology characteristics, and a faster and more precise analytical approach of metallic wire drawing fracture failure was proposed which was of important engineering significance and practical value to improve product competitiveness.

Keywords failure analysis, fracture, drawing, SEM, metallographic examination

1. Introduction

This is a template to prepare the full paper manuscript for the 13th International Conference on Fracture, which will be held at Beijing, China, June 16–21, 2013.
Fracture failure was inevitable during steel wire drawing which was affected by equipment, weather, operation, etc [1]. Many researchers had made great efforts to investigate the causes of fracture failure, the major fracture morphology included pencil-point shaped, plane shaped, and inclined shaped fracture [2]. And microstructure of wire rod, drawing die, lubrication and other factors which lead to fracture were analyzed.

An optimized procedure of circle section steel wire fracture failure analysis which was depended on macroscopic fracture morphology was proposed. The importance of every step of failure analysis was emphasized, and failure analysis of the pencil-point shaped, plane shaped, and inclined shaped fracture were introduced respectively.

2. Failure Analysis Procedure

The main procedure failure analysis procedure of steel wire drawing fracture was: background information, visual inspection and low magnification test, microscopic analysis, metallographic examination, chemical analysis and mechanical tests if necessary [3].

2.1. Background Information

The object of failure analysis was not only the fracture wire but an integration of wire, equipment, environment and person. Failure analysis should consider the relationships include: fracture wire and normal wire of the same batch, fracture wire and drawing equipment, fracture wire and production environment, fracture and operating person.

First of all, make sure the location of fracture wire, number of drawing pass, reduction of fracture pass and other relevant information as much as possible. Generally, fracture wire located in drawing die hole, around the reel, post-straightener, or take-up device. That information was used to judge the stress condition of fracture. Secondly, find out the fracture frequency of the same batch and

other similar fracture samples. Then, make sure whether the drawing equipment was well, such as broken of drawing die, hole eccentric of die, water shortage of die case would lead to wire fracture. Because the influence of temperature and humidity on wire drawing performance, production environment and operating person would not be ignored.

2.2. Visual Inspection and Low Magnification Test

The purpose of visual inspection and low magnification test were to determine the fracture mode by the macro morphology and surface defects, and photo with relevant information should be recorded. For circle section steel wire fracture, visual inspection and low magnification test included: (1) Original surface defects, such as fold and pitting. (2) Surface defects caused by drawing, such as broken of drawing die, hole eccentric of die, water shortage of die case, etc. (3) Color of wire surface, such as corrosion and welding joints.

2.3. Microscopic Analysis and Metallographic Examination

The purpose of microscopic analysis and metallographic examination was to find microstructural characteristic which caused wire fracture.

Scanning electron microscope (SEM) was used to observe fracture and surface morphology. The feature of wire fracture could be divided into two categories: (1) Dimple character, which was composed of round or oval holes with different sizes, sometimes inclusions or second-phase particles could be found in dimple. (2) Cleavage character, which included river pattern, scallop pattern, grainy pattern and intergranular fracture character.

Metallographic examination was used to analysis internal cracks, grain size, decarburized layer, defect microstructure, etc. And typical defect microstructure included: martensite, net carbide, widmanstatten, etc.

3. Drawing Fracture Analyses

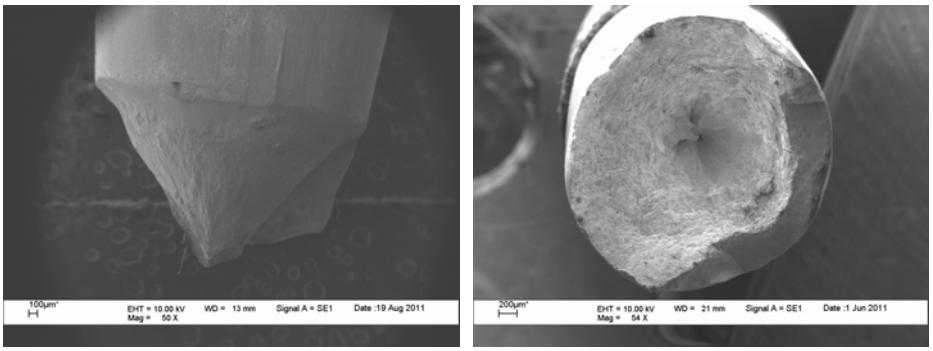
Steel wire was under drawing force, pressure and friction during the drawing that was a plastic deformation. If the drawing equipment had poor lubrication, shortage of cooling water, or die eccentric, wire drawing would be caused to fracture. Fracture and surface morphology were very important to failure analysis of wire drawing fracture. Generally, fracture modes were corresponded to macro fracture morphology and surface state of wire.

Failure analysis procedure of typical macro fracture morphology was optimized, such as, pencil-point shaped, plane shaped and inclined shaped fracture.

3.1. Pencil-point Shaped Fracture

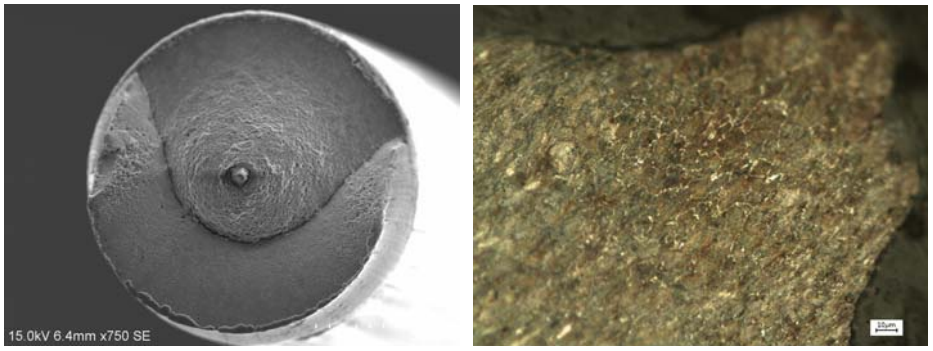
One end of the pencil-point shaped facture was conical tip, and the other conical hole which was matched with each other. The conical surface was angel of 45° to drawing direction and its morphology was shown in Fig. 1. Many investigations showed that the cause of pencil-point shaped fracture was central brittle phase. During wire drawing, brittleness microstructure in center could not be well deformed with outer steel wire, cracks firstly initialized surround the brittle phase, then the cracks which extended along 45° direction to wire axis leas to fracture [4,5]. Central brittle microstructure of wire that was shown in Fig.2 consists of inclusion, net carbide, martensite, etc.

The above research showed that defects of pencil-point shaped fracture usually in center of wire, therefore the procedure of microscopic analysis and metallographic examination should be: (1) SEM was used to search inclusion or pin of it in conical tip. (2) Longitudinal metallographic examination was used to seek central brittle phase. Transversal metallographic examination was also used by some researchers to judge brittle microstructure. Longitudinal metallographic examination was suggested that could found brittle phase and its discontinuous deformation (shown in Fig. 3) more easily.

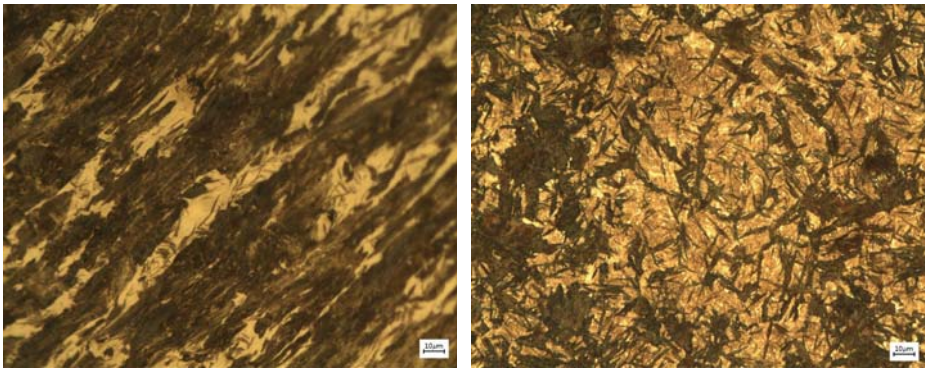


(a)conical tip (b) conical hole

Figure. 1 Morphology of pencil-point shaped fracture



(a) Inclusion (b) net carbide



(c) martensite (longitudinal) (d) martensite(transversal)

Figure. 2 Central brittle microstructure of pencil-point shaped fracture

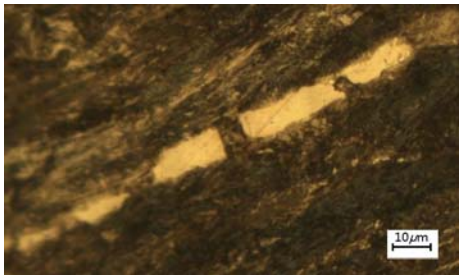


Figure. 3 Discontinuous martensite in center of steel wire

3.2. Plane shaped fracture

There was almost no necking or significant surface defects of plane shaped fracture, whose fracture surface was likely a plane shown in Fig. 4, so called as plane shaped fracture. Generally, the cause of plane shaped fracture was abnormal microstructure or larger grain which increased brittleness of wire [6]. Cleavage character and its microstructure of a plane shaped fracture were shown in Fig. 5.

Bad welding zone could lead to plane shaped fracture as well [7], and the unusual color of blue or white could be the proof of joint. There were cleavage character, inclusion and dimples of different region of fracture, and longitudinal metallographic examination could show variation tendency of grain size which were shown in Fig. 6.

Therefore microscopic analysis and metallographic examination procedure of plane shaped fracture should be: (1) wire surface should be inspected whether had defects or unusual color. (2) SEM was used to observe cleavage character, dimple, inclusion or other microstructural feature. (3) Transversal metallurgical examination should be adopted if cleavage character was found. Longitudinal metallurgical examination should be adopted if there were more than one microstructural character or unusual color of wire surface.

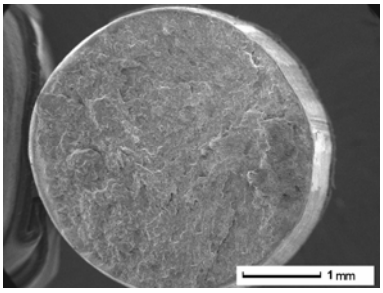
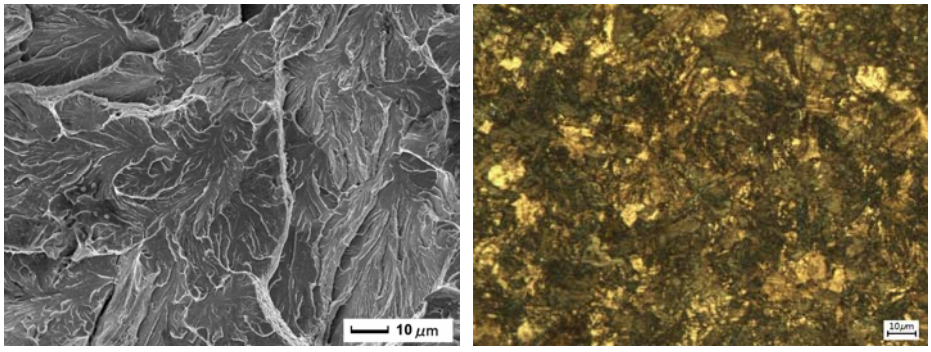


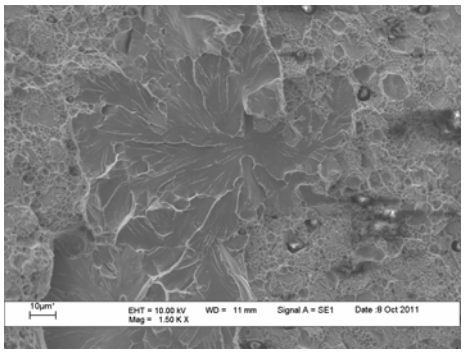
Figure. 4 Morphology of plane shaped fracture

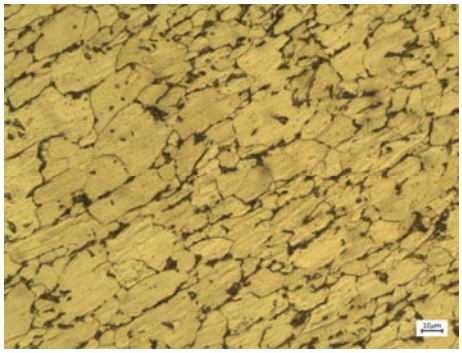


(a) Cleavage Character (b) Metallurgical analysis

Figure. 5 Cleavage character and Metallurgical analysis of plane shaped fracture

(a) Unusual color





(b) Microscopic character (c) Variation trend of grain size

Figure. 6 Plane shaped fracture of bad welding

3.3. Inclined shaped fracture

The fracture surface of inclined shaped was an angle to wire drawing direction, and crack, little hole or other defects would be found nearby fracture. Different wire surface defects corresponded to fracture cause which included scratching, abrasions, die broken, poor lubrication, etc [8]. Morphology of inclined shaped facture and a typical surface defect was showed in Fig. 7 and Fig. 8, respectively.

Microscopic analysis of inclined shaped fracture was brittle fracture feature, shown in Fig. 9. Trend of surface crack and poor deformability microstructure would be observed by longitudinal metallographic examination, shown in Fig. 10.

Microscopic analysis and metallographic examination procedure of inclined shaped fracture should be: (1) Wire surface of fracture should be examined to find defect of crack, scratches and so on. (2) SEM would be used to identify microstructural character and defect mode. (3) Longitudinal metallurgical examination would be used to observe trend of crack and poor deformability.

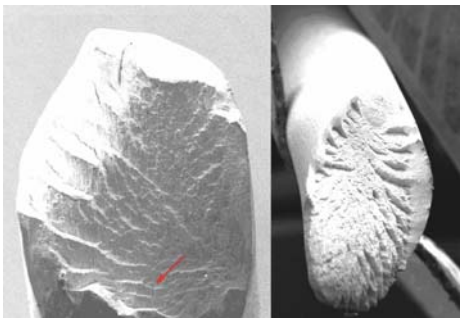


Figure. 7 Morphology of inclined shaped facture

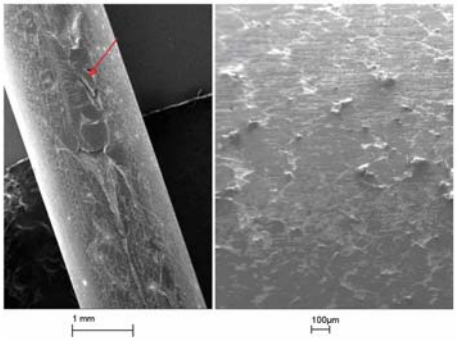


Figure. 8 Surface defect of inclined shaped facture

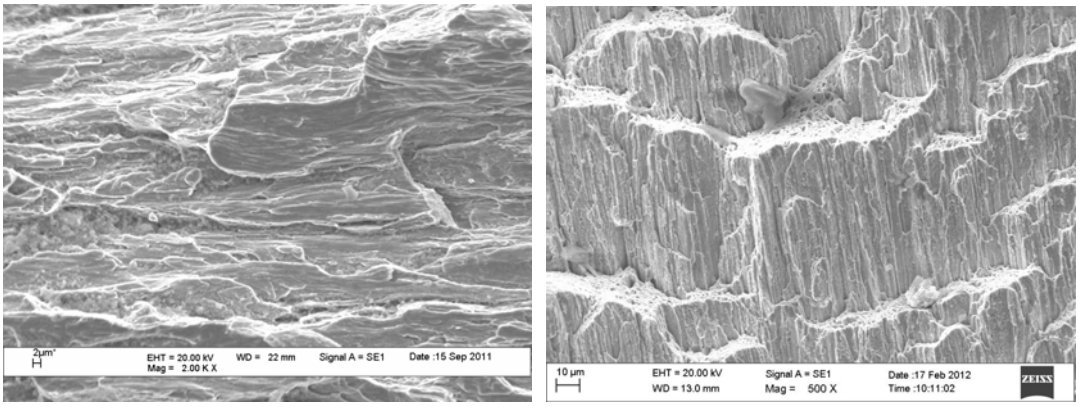


Figure. 9 Micro-morphology of inclined shaped facture

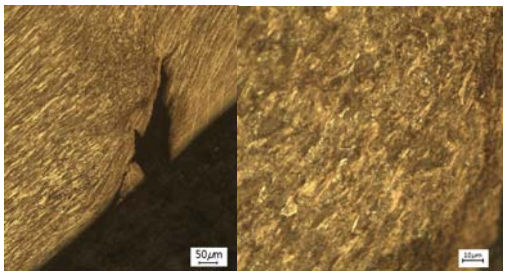


Figure. 10 Poor deformability microstructure of inclined shaped facture

4. Conclusion

Failure analysis procedure of steel wire drawing fracture was proposed and the significance of every step was explained. Microscopic analysis and metallographic examination of pencil-point shaped, plane shaped and inclined shaped fracture were optimized by fracture modes and investigation of fracture failure.

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