

Case study

Metallurgical investigation of wire breakage of tyre bead grade



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ABSTRACT

Tyre bead grade wire is used for tyre making application. The wire is used as reinforcement inside the polymer of tyre. The wire is available in different size/section such as 1.6–0.80 mm thin Cu coated wire. During tyre making operation at tyre manufacturer company, wire failed frequently. In this present study, different broken/defective wire samples were collected from wire mill for detailed investigation of the defect. The natures of the defects were localized and similar in nature. The fracture surface was of finger nail type. Crow feet like defects including button like surface abnormalities were also observed on the broken wire samples. The defect was studied at different directions under microscope. Different advanced metallographic techniques have been used for detail investigation. The analysis revealed that, white layer of surface martensite was formed and it caused the final breakage of wire. In this present study we have also discussed about the possible reason for the formation of such kind of surface martensite (hard-phase). Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Tyre bead grade with Cu-coating was conventionally used for tyre making application [1]. During tyre making operation at tyre manufacturer company, wire failed frequently during bending operation at brittle manner. During bending operation such kind of breaking was also happened at wire mill. Different breakages as well as defective samples have been collected from different coils. The wire manufactured by drawing process from 5.5 mm wire rod [2,3]. Two stage of drawing process is involved to making of final wire. After the drawing operation stress relieving and Cu–Sn coating of wire was carried. The process details are mentioned in Fig. 1.

2. Visual observation

Two pieces of breakage wire samples were collected from the drawing mill for investigations. The samples were cleaned with acetone to remove dirt for visual examination prior to metallographic sample preparation. Visual examination is carried out in stereoscope. Surface appearance of the defects in all wire samples was of similar in nature. The fracture surface revealed finger nail type (Figs. 4 and 5). Crow feet like defects including button like surface abnormalities were observed on

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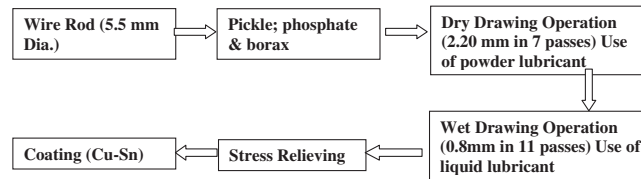


Fig. 1. Flow diagram of wire rod to wire drawing process.

the broken wire samples. The defect was observed near the fracture end and which was very much localized in nature (Figs. 2 and 3).

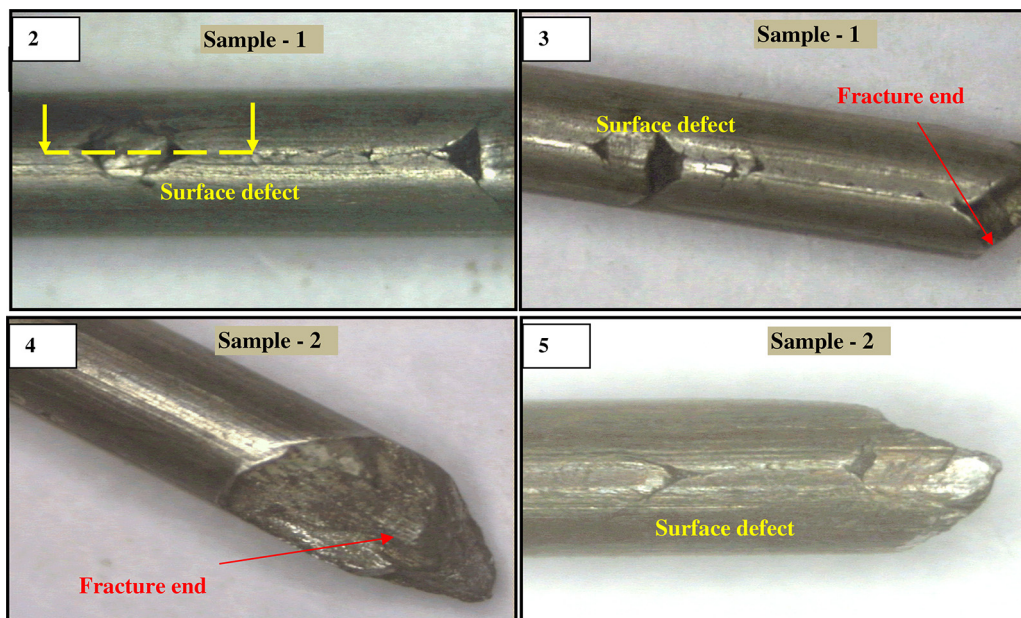
3. Chemical analysis

Chemical analysis of wire samples was carried out using combustion infrared technique (LECO, TC600) for carbon and sulphur contents. An inductively coupled plasma atomic emission spectroscopy (ICP-AES) instrument was used to determine amounts of rest of the elements. The chemistry of wire sample confirmed to high carbon steel grade (C-70). Chemical analysis result is presented in Table 1.

4. Metallography analysis

4.1. Microstructural analysis

Micro specimens were prepared from the fractured end as well as defect location of wire samples for conducting light optical microscopic examination and scanning electron microscopy (SEM). These samples were individually mounted in conductive mounting and polished by conventional metallographic techniques for scratch free surface. The polished samples were etched in 3% nital solution (3 mL HNO_3 in 97 mL ethyl alcohol), and both un-etched and etched samples were examined in a light microscope to observe microstructural constituents. Un-etched sample shows surface defect in longitudinal as well in transverse direction (Figs. 6 and 8). Etched microstructure of the longitudinal samples revealed presence of brown layer near the defect location. The thickness of the brown layer is around 30–40 μm (Fig. 7). From microstructure analysis the brown layer appeared to be of martensite (which was further verified by micro hardness value and SEM analysis; Table 2). Severe grain flow was observed along the defect location. The microstructure of the matrix revealed cold drawn pearlite structure (Figs. 9–11).



Figs. 2–5. (2, 3) Closer view of surface defects of failed wire samples #1. (4, 5) Closer view of surface defects of failed wire samples #2.

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