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Fracture Fatigue and Wear

Wear characteristics and residual bending fatigue life of wire ropes in acidic environments

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Introduction

During ultra-deep mine hoisting, wire ropes are subjected to harsh conditions including sulfate-containing acidic environments (pH 3–5) and temperature variations (normal to high temperature), while simultaneously bearing tensile, bending, torsional and contact pressures. The coupled effects of corrosion, wear and fatigue seriously threaten hoisting safety.

However, existing studies mainly focus on single environmental factors or normal temperature conditions, and a systematic understanding of the friction and wear characteristics, corrosion-wear mechanisms and residual bending fatigue life of wire ropes under the coupled action of high temperature and sulfate-containing acidic environments is still lacking. The influence of lubrication conditions also remains to be revealed.

Therefore, taking 6×19+FC hot-dip galvanized fibre-core wire rope as the research object, this paper simulates a sulfate-containing acidic environment and carries out friction-wear tests and bending fatigue tests under different corrosion times, wear times and lubrication conditions at 30 °C and 60 °C, aiming to clarify the tribological behaviour, damage mechanisms and fatigue life degradation laws of wire ropes in temperature-corrosive environments, and to provide a theoretical basis for life prediction and maintenance of mine hoisting wire ropes.

Methods

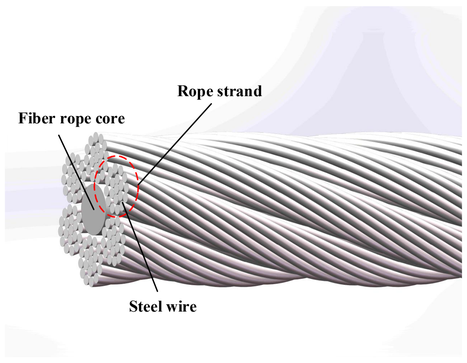

Figure 1 Test wire rope construction

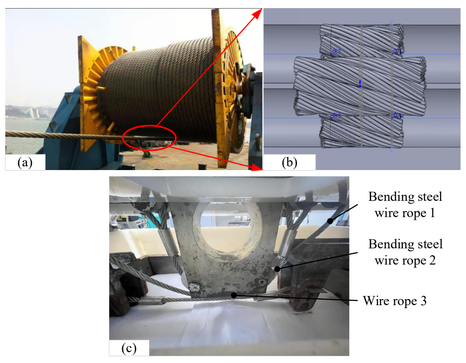

Figure 2 Contact diagram of wire rope in the winding stage

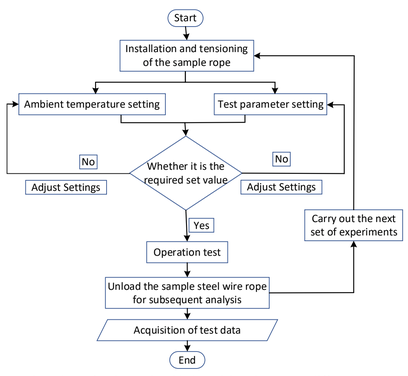

Figure 5 Flow chart of reciprocating friction of the wire rope at different temperatures

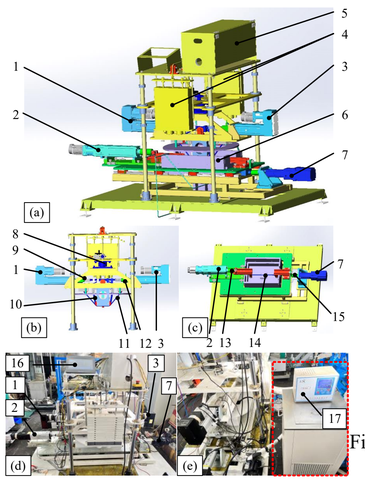

Figure 4 Friction and wear test device for hoisting steel wire rope in harsh environment

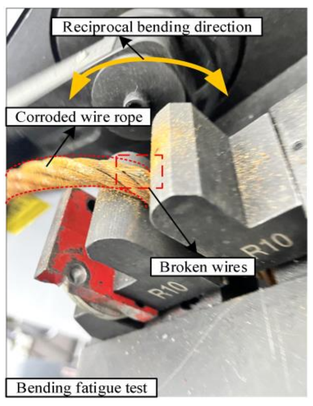

Figure 6 Bending fatigue test of wire rope

Graphics / Images

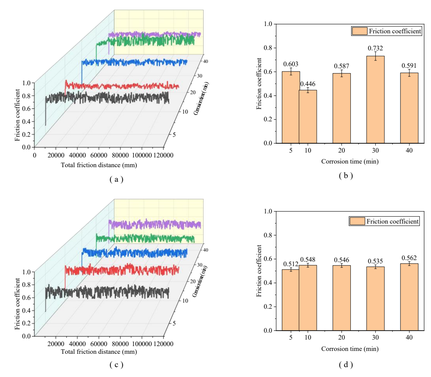

Figure 12 Friction characteristics of steel wire rope with different corrosion time under acidic environment containing sulfate at room temperature

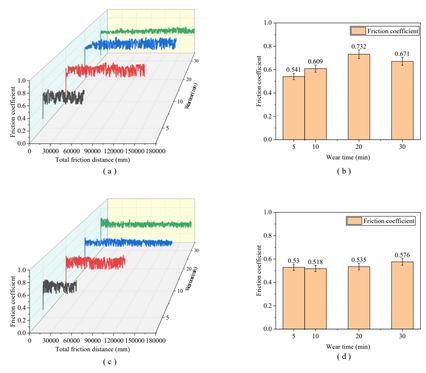

Figure 13 Friction characteristics of steel wire rope corroded in acidic environment containing sulfate at room temperature under different wear times

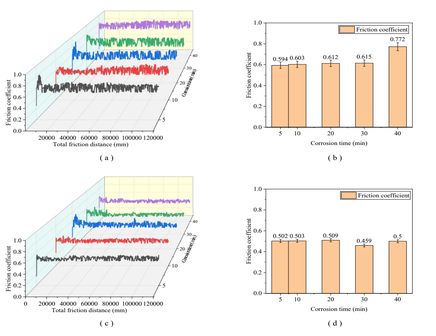

Figure 14 Friction characteristics of steel wire rope at different corrosion times under acidic environment containing sulfate at high temperature

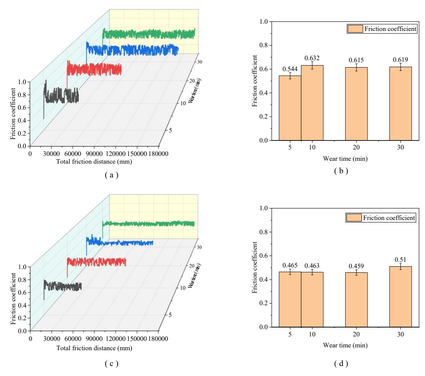

Figure 15 Friction characteristics of steel wire rope corroded at high temperature and sulphate-containing acidic environment under different wear times

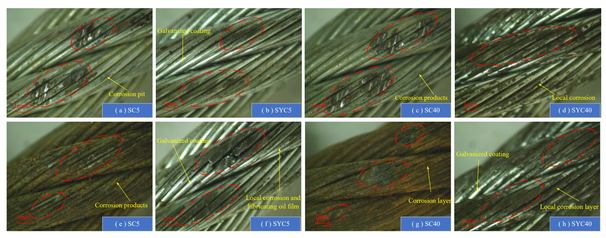

Figure 17 Wear morphology of steel wire ropes under different temperatures and corrosion times: (a-d) at room temperature, (e-h) at high temperature

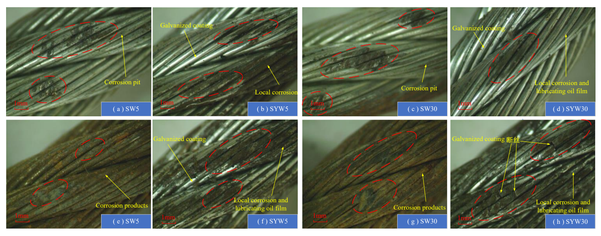

Figure 18 Wear morphology of steel wire ropes under different temperatures and wear times: (a-d) at normal temperature, (e-h) at high temperature

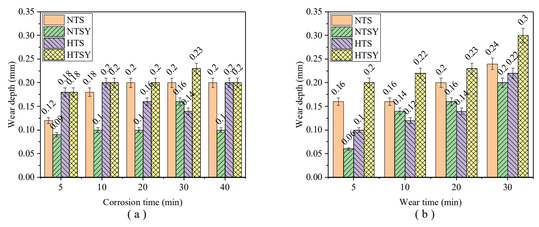

Figure 19 Wear depth of steel wire ropes under different temperatures and corrosive environments: (a) Different corrosion times, (b) Different wear times

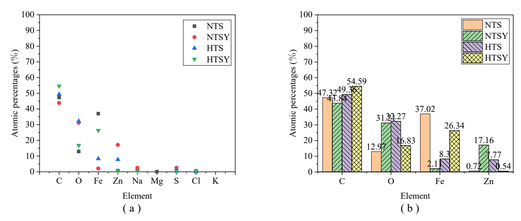

Figure 20 Analysis of wear surface elements of steel wire ropes under different temperatures and corrosive environments: (a) Element distribution, (b) C, O, Fe and Zn elements

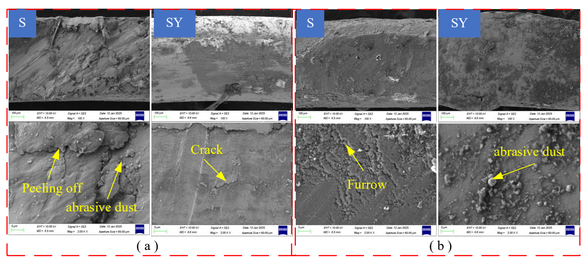

Figure 21 Corrosion and wear mechanisms of steel wire ropes under different temperature and corrosion conditions: (a) normal temperature, (b) high temperature

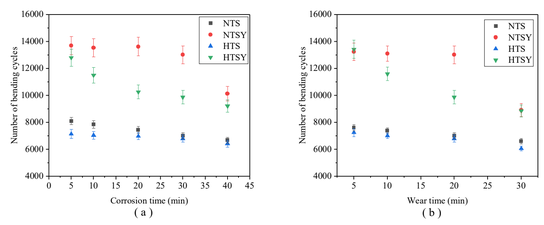

Figure 26 The bending fatigue life of steel wire ropes under different temperatures and corrosive environments: (a) Different corrosion times, (b) Different wear times

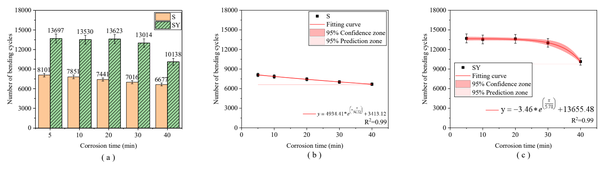

Figure 22 The bending fatigue life of wire rope varies with corrosion time under acidic environment containing sulfate at room temperature: (a) bending fatigue times when reaching scrap standard, (b) without lubrication, (c) lubrication

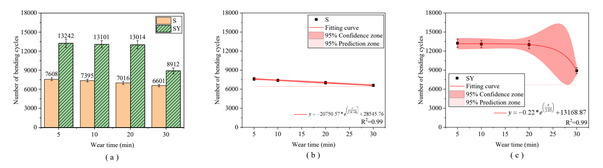

Figure 23 The bending fatigue life of the wire rope varies with the wear time under acidic environment containing sulfate at room temperature: (a) the bending fatigue number when the scrap standard is reached, (b) without lubrication, (c) lubrication

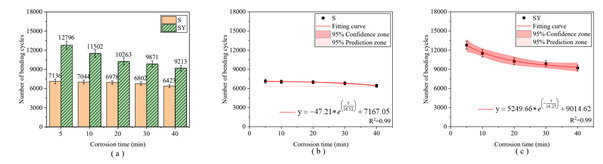

Figure 24 The bending fatigue life of the wire rope varies with the corrosion time under the acidic environment containing sulfate at high temperature: (a) the bending fatigue number when the scrap standard is reached, (b) without lubrication, (c) lubrication

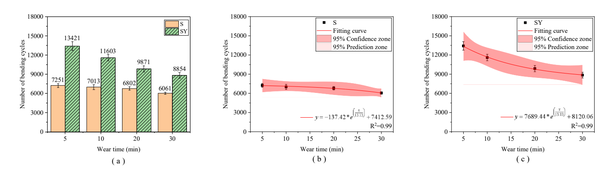

Figure 25 Bending fatigue life of steel wire rope changes with wear time in acidic environment containing sulfate at high temperature: (a) bending fatigue times when reaching scrap standard, (b) without lubrication, (c) lubrication

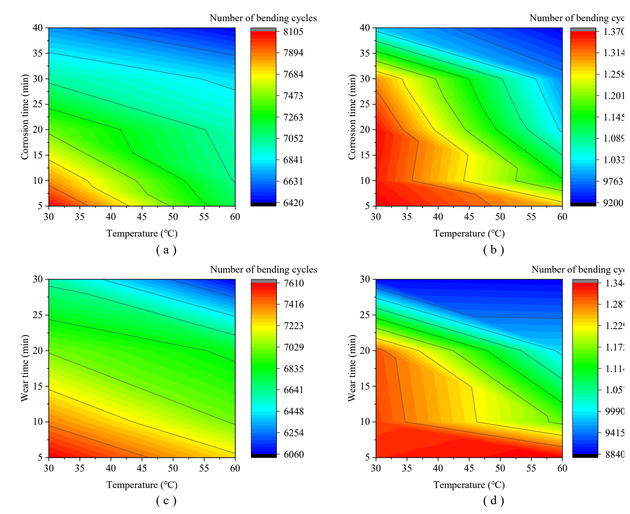

Figure 27 The influence of temperature-corrosion environment on the bending fatigue life of corroded steel wire ropes: (a) No lubrication for different temperature-corrosion times, (b) Lubrication for different temperature-corrosion times, (c) No lubrication for different temperature-wear times, (d) Lubrication for different temperature-wear times

Conclusions

1. At normal temperature, the friction coefficient of non-lubricated wire rope fluctuates and increases with corrosion time, while lubrication significantly reduces the friction coefficient and keeps it stable; at high temperature, the friction coefficient of non-lubricated wire rope increases overall, and lubrication still maintains a relatively low friction coefficient.

2. In the sulfate-containing acidic environment at normal temperature, lubrication effectively reduces corrosion pits and wear marks; at high temperature without lubrication, a thick corrosion layer and furrow-like wear appear on the surface, and lubrication partially fails due to thermal degradation of the oil film but still performs better than non-lubricated condition.

3. As corrosion time increases, the wear depth at high temperature is larger than that at normal temperature; at normal temperature, the wear depth of non-lubricated wire rope is larger than that of lubricated wire rope, but at high temperature lubrication does not significantly reduce the wear depth.

4. The carbon and oxygen contents on the worn surface of non-lubricated wire rope increase while the iron content decreases at high temperature, indicating that high temperature aggravates oxidative corrosion and iron loss, and lubrication can mitigate the loss of elements.

5. The bending fatigue life decreases exponentially with increasing corrosion time or wear time; lubrication greatly prolongs the fatigue life, but under high temperature the fatigue life reduction of lubricated wire rope is greater than that of non-lubricated wire rope because local corrosion becomes a source of fatigue cracks.

6. In the sulfate-containing acidic environment, lubrication is effective in inhibiting corrosion-wear and extending fatigue life, but high temperature accelerates lubrication failure; therefore, enhanced protective measures should be taken with consideration of temperature and acidic environment in practical engineering.