Nondestructive Assessment of Full Locked Coil (FLC) Ropes in Cage and Skip Winders

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Abstract Magnetic nondestructive evaluation is being used to assess the condition of full locked coil ropes used in cage and skip winders. Four locked coil ropes were studied for a period of 4 years. This paper focuses on the determination of the in situ condition of full locked coil ropes in cage and skip winders throughout this 4-year period.

Keywords Flaws · Full locked coil · Nondestructive evaluation

Introduction

Visual inspection is the most conventional inspection method for wire ropes. Assessment of rope condition either by visual examination or even by drawing a specimen rope length and subjecting it to destructive evaluation seldom speaks about integrity of the entire rope length in the installation. Electromagnetic and visual wire rope inspections complement each other. Both are essential for safe operation, and both methods should therefore be used for maximum safety [1].

Magnetic nondestructive evaluation is the process in regular use for assessment of rope condition. Equipment recently used for nondestructive evaluation of steel wire ropes generally use "permanent magnet method" [2]. This technique enables detection of (a) localized flaws e.g., broken wires (quantitative inspection) and (b) distributed flaws, namely, corrosion, abrasion, wear nicking, pitting, and so forth (qualitative inspection).

A complete documentation of gradual rope deterioration throughout rope's entire service life by periodic inspection after the rope installation would enable the operator to arrive at a decision to prevent rope failure under adverse conditions or to extend rope life in deserving cases.

Rope Condition Assessment

Full locked coil (FLC) and half locked coil ropes are made of a spiral strand as its main core and finally covered with one or more layers of shaped wires (trapezoidal, round, and rail sections as in half locked coil or full locked sections). The final cover layer is made of full locked sections of wires that interlock each other and present a smooth surface. The outermost layer or cover is always laid in the opposite direction to the inner layers to make the rope "non-rotating" [3].

Two ropes of cage and two ropes of skip each of 28 mm diameter full locked coil construction (Fig. 1a), right-hand Lang's lay, galvanized, used on a multirope friction winder in uranium mines in India were considered for nondestructive evaluation using a magnetic defectograph for

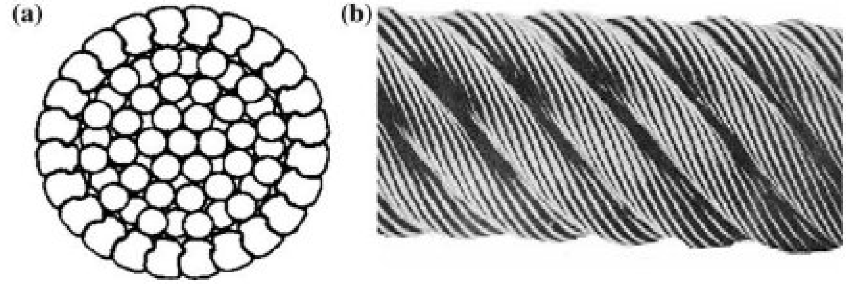

Fig. 1 (a) Cross section of full locked coil rope. (b) Right hand Lang's lay of rope

monitoring their suitability for continued use. Construction of 28 mm diameter full locked coil is such that one round wire forms the inner central core. The second layer consists of 5 round wires; the third layer consists of 10 round wires. Ten round and 10 rail wires form the fourth layer, and in the fifth and outer layer there are 26 formed wires. Lang's lay ropes have the wires in the strands laid in the same direction as the strands in the rope. Right-hand Lang's lay (Fig. 1b) shows final twisting of strands in the rope in the right-hand direction, that is, strands laid right and wires laid right. The choice of a "lay" in rope depends on the nature of particular application. The laylength or pitch is the distance, measured along the rope starting from one shaped wire on the outer layer of rope and ending on the same point along the length. The laylength charts for cage ropes (C-1 and C-2) and skip ropes (S-1 and S-2) as measured during the last investigation, that is, after 20 months for cage ropes and after 5 months for skip ropes, are shown in Figs. 2 and 3, respectively. The wire rope defectograph was calibrated each time by 80 and 20 mm^2 rod for Hall Effect channel for comparison of metallic cross-sectional area. For calculation of relative loss in cross-sectional area, it has been taken into consideration that steel cross-sectional area for locked coil rope is about 85% of the full (nominal) cross-sectional area [4].

This nondestructive evaluation on four winder ropes was carried out over nearly 4 years, that is, 48 months at regular intervals. The wire rope defectograph was suitable for wire ropes varying in diameter from 20 to 60 mm. Average rope speed during investigation of winder ropes was 1.0 m/s. The internal and external (inner and outer) inductive sensor coils registered the defects characterized by stepwise changes in rope cross section, that is, broken wires (localized flaws), and the Hall effect sensor registered the relative variation in loss in metallic cross-sectional area due to distributed flaws such as wear, corrosion in longer length, and abrasion [5, 6].

The cage ropes were replaced after 36 months in the installation. During the span of investigation, the skip ropes were replaced first after 26 months and then after 24 months from the date of installation.

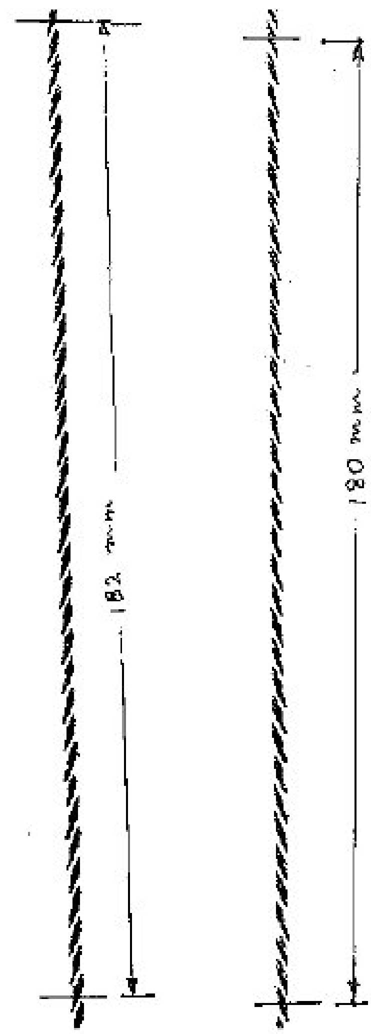

Fig. 2 Laylength charts for cage ropes (C-1 and C-2) during the fifth investigation

Evaluation and Discussion

It is necessary to take into account the state of the rope and the service conditions to determine if the rope should continue to be used or be discarded. A rope that shows some deterioration but that has done little work may be suitable for continued use, whereas another rope with the

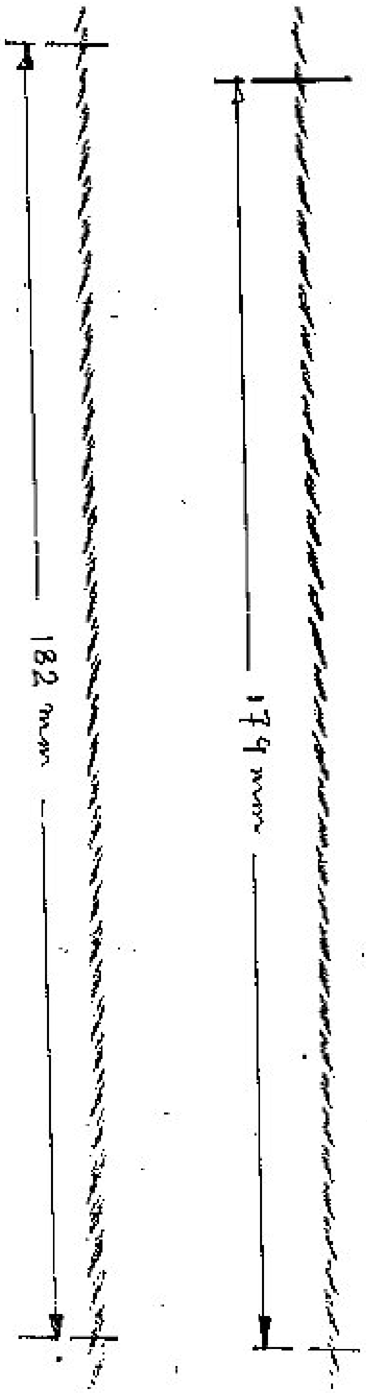

Fig. 3 Laylength charts for skip ropes (S-1 and S-2) during fifth investigation

same degree of deterioration, but which has done a great deal of work may have reached the end of its useful life, as the onset of fatigue or corrosion-fatigue will be much more likely in the busy rope [7]. Broken wires are only one way wire ropes wear out. Other conditions of rope removal are: (a) corrosion, (b) evidence of kinking, crushing, cutting, bird-caging, and so forth, (c) severe reduction of diameter of the rope, (d) evidence of heat damage, (e) significant increase in laylength, (f) loss of about one-third (or 33%) of outer wires in their depth as a result of any form of deterioration, (g) loosening and displacement of outer wires, and (h) overwinding or overloading or shock loading of rope, and so forth. Comparative studies of all the four ropes were carried out and number of flaws per 100 m length and relative percentage loss in metallic cross-sectional area of the rope are shown in Tables 1 and 2.

From Tables 1 and 2, the following was observed:

- Cage rope C-2 showed more flaws/100 m, and it is evident that in all ropes the number of flaws increases with time. In the initial study after 32 months, this value was 2.020 and it was 1.530 in the later case (20 months after replacement of earlier rope).
- Relative loss in metallic cross-sectional area compared with a healthy portion of rope was observed in each

Table 1 Flaws/100 m and Percentage Loss for Cage Ropes

Time of Investigation	Rope C-1		Rope C-2	
	Flaws/ 100 m	Loss, %	Flaws/ 100 m	Loss, %
10 months after installation	0	0	1.023	1.3
26 months after installation	0.253	5.6	1.515	5.5
32 months after installation	0.506	6.47	2.020	6.86
Ropes replaced after 36 months and new ropes installed				
8 months after installation	0.518	0	1.034	0
20 months after installation	0.760	0	1.530	0

Table 2 Flaws/100 m and Percentage Loss for Skip Ropes

Time of Investigation	Rope S-1		Rope S-2	
	Flaws/ 100 m	Loss, %	Flaws/ 100 m	Loss, %
10 months after installation	0.483	1.3	0.242	1.3
25 months after installation	1.519	5.7	0.718	5.46
Ropes replaced after 26 months and new ropes installed				
5 months after installation	0.239	0.76	0.719	0.8
17 months after installation	0.24	1.05	2.671	1.02
Ropes replaced after 24 months and new ropes installed				
5 months after installation	0.48	0	0.96	0

investigation. This value was nearly equal in each observation in cage or skip winder ropes. The trend of relative reduction in material of rope was the same for both cage and skip winder ropes.

- Laylengths were observed in each interval for all the four ropes. From Fig. 2 and 3, laylengths are 182 and 180 mm for cage ropes and 182 and 179 mm for skip ropes during the fifth investigation. Its values ranged from 6.3 to 6.7 times the nominal diameter of the rope (normal values are within the range of 6*d* and 8*d*, where *d* is the nominal diameter of rope).
- Locked coil ropes have constant cross-sectional area. Comparatively less effect of corrosion was noticed during study.

The wire rope lengths of about 6 to 10 m each from both cappel ends were not subjected nondestructive evaluation due to positional disadvantage. It was determined through destructive study with the 3 m samples of ropes from cappel ends that generally broken wires are not observed throughout this length. Localized flaws in the form of broken wires generally concentrate near the points that cross and halt in the pulley whenever the cages and skips stop at boarding-deboarding/loading-unloading stations. Localized flaws of cage ropes (C-1 and C-2) during the third investigation and skip ropes (S-1 and S-2) during the fourth investigation are shown in Fig. 4 and 5, respectively.

Conclusion

The study showed the rope damage is generally progressive and that nondestructive techniques can be used to assess the condition of ropes. The measurements can be made to identify rope wear and other deterioration so that a rope is removed from service before it becomes hazardous to use.

Application of nondestructive evaluation procedures makes it possible to improve the reliability of detecting broken wires over the available rope length for evaluation.

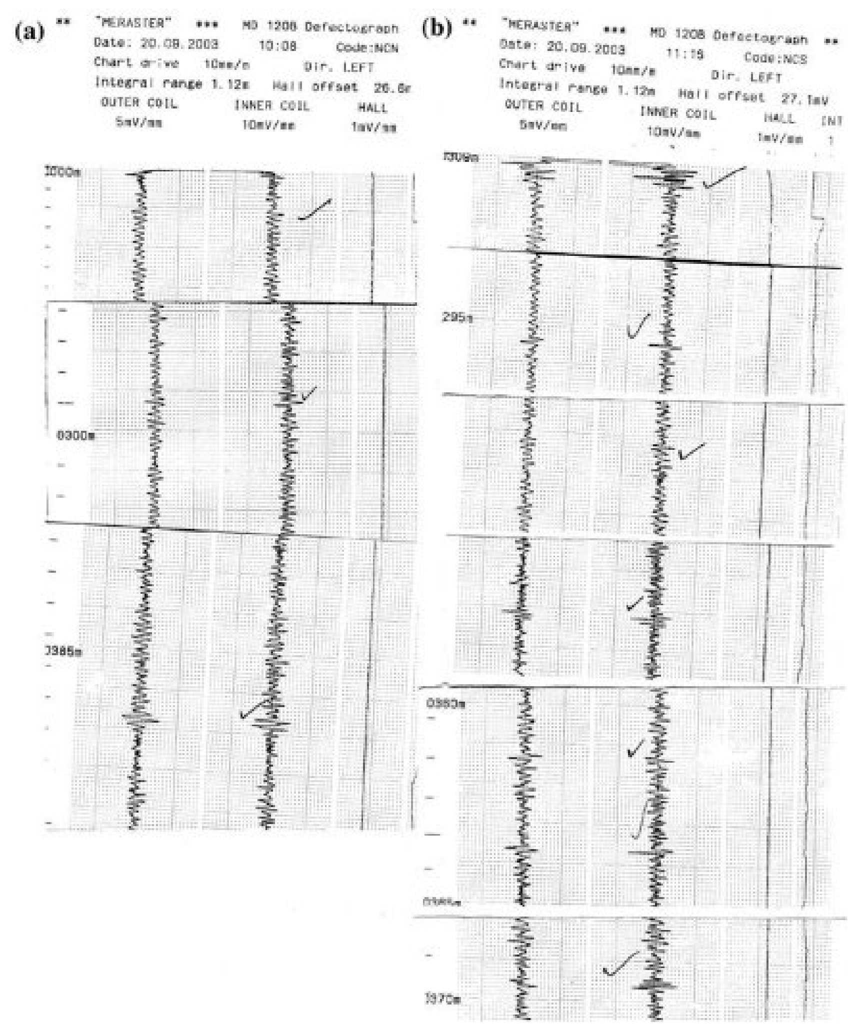

Fig. 4 Localized flaws of (a) cage rope C-1 and (b) cage rope C-2 during third investigation (32 months after installation)

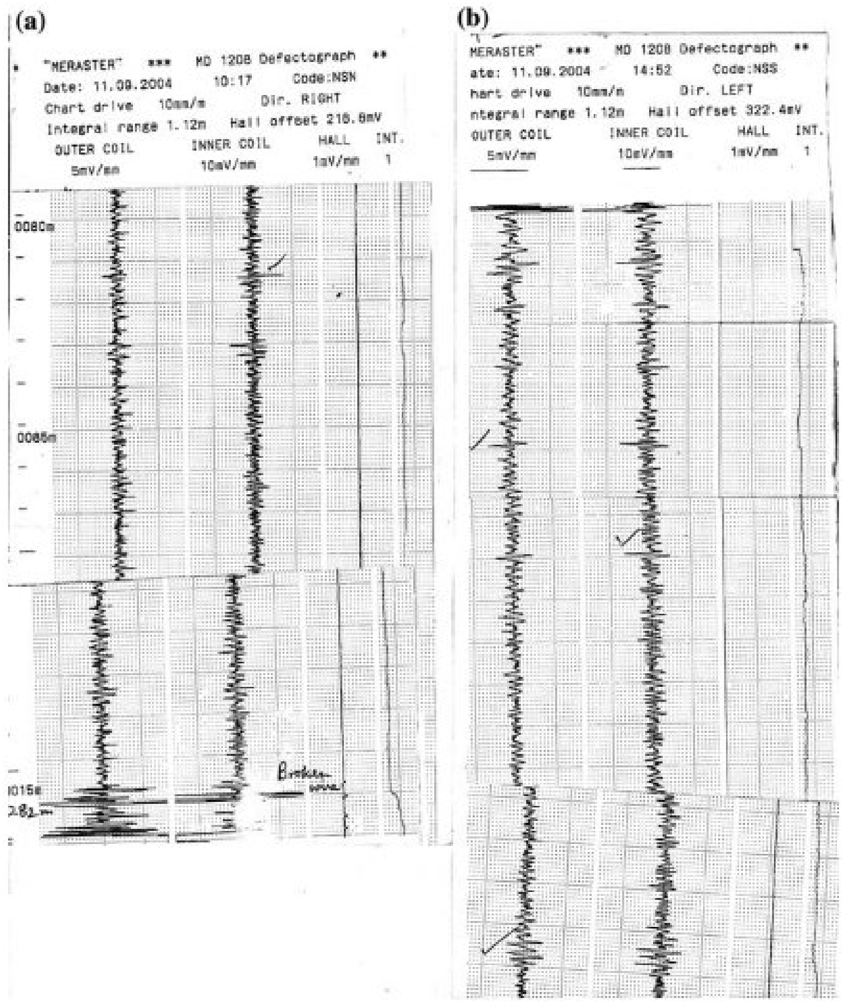

Fig. 5 Localized flaws of (a) skip rope S-1 and (b) skip rope S-2 during fourth investigation (17 months after installation)

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