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Nondestructive Evaluation of a 6X25 FW Haulage Rope in a Monocable Continuously Moving Passenger Cable Car Installation

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Abstract—**Electromagnetic nondestructive evaluation (NDE) of wire rope has been in use for over fifty years. Regular NDE inspections provide a powerful tool in monitoring the rate of degradation of a rope. Wire defects and condition of a haulage rope (construction 6X25 FW) have been studied and presented in this paper.**

Index Terms— **discard criteria, nondestructive evaluation.**

I. INTRODUCTION

Wire rope is a vital machine element for transmitting tensile forces and motion. Carbon steel wire ropes are by far the most abundant, due to their high strength and relatively low cost. Wire rope service is typically categorized as static or dynamic. Static or stationary wire rope services include tower supports, guy wires, suspension bridge supports and electrical power transmission lines. Dynamic wire ropes are used for pulling or lifting, and applications include elevators, aerial cable cars, cranes, hoists, dredges and control cables. Dynamically stressed ropes are flexible and easily pass over sheaves and drums.

Construction is the design configuration of a wire rope. It denotes number of strands in a rope and number and arrangement of wires in a strand (e.g. 6X25). Construction of rope is designed to suit the exact working conditions e.g. (i) Load, (ii) Abrasion, (iii) Bending, iv) Crushing, (v) Corrosion etc. Filler wire (FW) constructions contain auxiliary interior wires to support the rope's geometrical configuration under loading. 6X25 FW wire is used in Mobile and Heavy Duty Cranes, Hoisting, Logging Winches, Slinks, Oil Well Drilling Lines, Mine Winding. To most wire rope users, 6X19 means 6X25 filler wire. It is the most common rope in the 6X19 classification. This rope has a good balance between both abrasion resistance and fatigue resistance in relation to other ropes. The wires under the outside layer of the Filler Wire rope are made up of a combination of main wires of the same size, and smaller filler wires also of the same size nested between the main wires. The outside layer of wires, therefore, is supported partly by the main inside wires and partly by the filler wires.

The 'Lay' is the pattern in which the wires in the strands and the strands in the rope are laid to form a finished rope e.g. Ordinary or Regular lay and Lang's lay. Lang's lay ropes have the wires in the strands laid in the same direction as the strands in the rope. Each of the above types of lay may be Right-hand or Left-hand depending on the direction of final twisting of strands in the rope. The choice of a 'lay' in rope depends upon the nature of particular application.

II. EVALUATION OF ROPE CONDITION

Steel wire ropes are most significant part of ropeways [1]. Frequent inspection of wire ropes is required to attain maximum service life avoiding costly, and possibly inconvenient, replacement. It is necessary to observe excessive wear on the outside wires resulting in marked reduction of rope diameter, broken wires, corrosion and pitting, state of lubrication, core condition, etc.

The reduction in rope diameter due to excessive wear of outside wires should be thoroughly investigated and its cause determined. In case of broken wires, their number and distribution over a distance should be taken into account to calculate their effect. Where corrosive conditions exist, the inside wires and core should be controlled by correct and sufficient lubrication.

Visual inspection is the simplest nondestructive examination (NDE) method for wire ropes [2-4]. Unfortunately, visual inspection can only include the exterior strands. Core damage may be invisible, including IWRC or WSC fatigue cracking, internal corrosion attack, insufficient lubrication, and other potentially serious types of degradation. Wire rope Defectograph is used now-a-days to scan the ropes in-situ to assess the condition of ropes.

Safe use of the ropeways depends directly on the rope condition, and on the in-time and reliable rope inspection. The principle of magnetic flux detection technique is based on the measurement of three phenomena [5], namely: (a) leakage flux around a local fault (LF) in a damaged rope section, (b) change in the rope's magnetic impedance, due to a loss in the magnetic cross sectional area (LMA), and (c) change in the magnetic flux value of the magnetic circuit in the sensor head. Recently used method is based on magnetization of the rope with permanent magnets and detection of the changes of magnetic field around the rope

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and total magnetic flux. Discontinuity in the rope such as broken wires or corrosion pit creates radial magnetic flux leakage and sensor detects it as rope passes through the sensing head. Other sensor measures information about loss of steel due to missing wire, continuous corrosion or abrasion [6, 7].

III. CASE STUDY

A haulage rope of 41 mm diameter, 6X25 FW [6(1+6+6+12)] (Fig. 1), polypropylene core, rope grade 1960/galvanised right hand LANG lay (Fig. 2) manufactured by FATZER, Switzerland on Continuous Monocable with Automatic Grips of Passenger Cable Car was considered for nondestructive evaluation over a period of more than 6(six) years [8]. As stated, the ropeway was put into service with technical assistance of Dopplamayr, Austria. There are 34 cabins including 3 freight cabins attached to haulage rope with automatic grip. The speed of rope movement varies from 0 to 6 meters per second. There are 20 (twenty towers in between lower and upper terminal points to support the haulage rope [9].

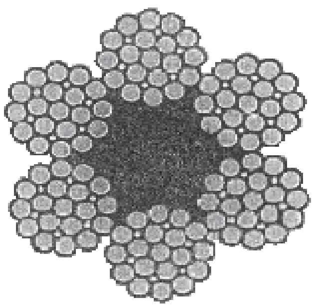

Fig. 1. Construction of 6X25 FW haulage rope.

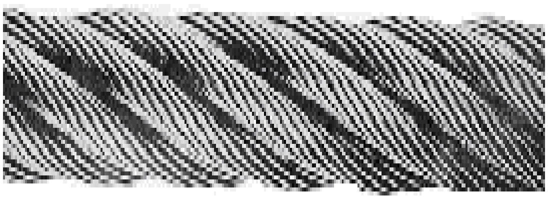

Fig. 2. Example of a Right Hand Lang's lay

Meraster MD 120B Magnetic Defectograph of Polish origin [10] was used for scanning the entire rope length including a spliced length of 49 meters (1200 times of the diameter of the rope) as recommended by CSA standard CAN/CSA-Z98-M91 Passenger Ropeways (A National Standard of Canada). Resplicing was done first time after 5 months, then after 21 months (after 5150 operating hours), once during 2-6 years from initial rope installation. Recent resplicing has been carried out after 7 years 8 months of its installation. The distance between tail ends of the strands of the spliced length was observed to be within minimum suggested requirement of the Canadian Standard. The Wirerope Defectograph was calibrated by 80 sq.mm and 20 sq.mm rod for Hall effect channel for comparison of metallic cross-section. For calculation of relative loss in cross-sectional area, account was taken of the fact that steel cross-sectional area for stranded rope is about 55% of the full (nominal) cross-sectional area. Average rope speed during study was nearly 1.0 metre/second. The approximate length of the rope scanned during study has been 5.927 km. The results obtained in-situ in three consecutive studies on this haulage rope after its installation is tabulated below:

Table – 1 Flaws and relative loss percentage noticed over the haulage rope

Time of investigation	Number of Flaws	Relative loss %	Diameters observed (in mm)	Laylengths (in mm) observed
2 years 7 months	2	0.2	40.4, 40.9, 40.7, 40.9, 40.8	300 against off-tension laylength of 300/295 mm.
6 years 10 months	5	3.15	39.7, 39.7, 39.3, 39.9, 39.4, 40.2, 40.0, 39.7, 40.2, 40.0, 40.9, 40.0	303, 308, 312
8 years 8 months	6	4.0	40.0, 40.4, 39.6, 39.5, 39.8, 39.5, 39.9, 39.8, 39.7, 40.0 against the tensioned rope diameter of 40.4 mm measured after 7 years 8 months.	310, 310, 310 against reported laylength of 310 mm measured during recent resplicing i.e. after 7 years 8 months.

IV. RESULTS AND DISCUSSION

The first nondestructive evaluation on the rope has been carried out nearly 2 (two) years 7 (seven) months after its installation; not within one year. From the case study, following was observed:

(a) The length of splice is approx. 49 meters, i.e. 1200 times of rope diameter. Splicings in all the three investigations are compared in Fig. 3(a), (b) and (c).
(b) Reduction of diameter was 4.15% (max),
(c) The maximum and minimum diameters noticed during the study were 40.9 mm and 39.3 mm respectively,
(d) Total number of flaws are 6 (six) and 5 (five) during the third and second investigation respectively, a considerable one compared to 2 (two) found during first investigation [Fig. 4, 5 and 6],
(e) Lay lengths observed during second investigation were 303 mm, 308 mm and 312 mm respectively (Fig. 7) and during third investigation were 310 mm, 310 mm and 310 mm (Fig. 8) at different locations compared to initial lay length of 300 mm /295 mm. Thus, maximum 4% increase of lay length was observed from its initial value. The lay lengths observed ranged from 7.4 d to 7.6 d where d is the nominal diameter of the rope. The normal value of lay length lies between 6d to 8d.
(f) The maximum relative loss in metallic cross-sectional area compared to a healthy sector except splicing is 4.0% during third and 3.15% during second investigation compared to initial value of 0.2% observed during first investigation.

V. CONCLUSION

All wire ropes wear out eventually, gradually losing work capability throughout its useful life making periodic inspections, lubrication, and tensioning necessary [11]. It is important that the wire surface be sufficiently clean so that the broken wires are visible. The study depicts the present condition of ropes only. The measurements are intended to identify rope wear and other deterioration so that a wire 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. This nondestructive investigation on winding ropes does not include the aspect of *fatigue* that may develop in the rope in course of time [12].

Based on the observation, it is suggested to have close visual watch of the splicing portions of the rope that have been identified as localized flaws in the study. Rope should be kept clean and protected from corrosion. Since the third investigation on the haulage rope had revealed no abnormal deviation in qualitative and quantitative analysis, it was recommended for further continuance of this haulage rope in the installation. The reliability of electromagnetic inspection has made it a universally accepted method for the inspection of wire ropes in mines, for ski lifts, chair lifts, cable cars and many other applications.

ACKNOWLEDGMENT

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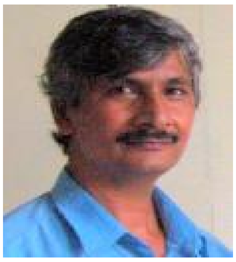

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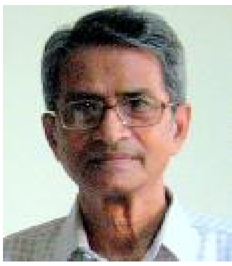

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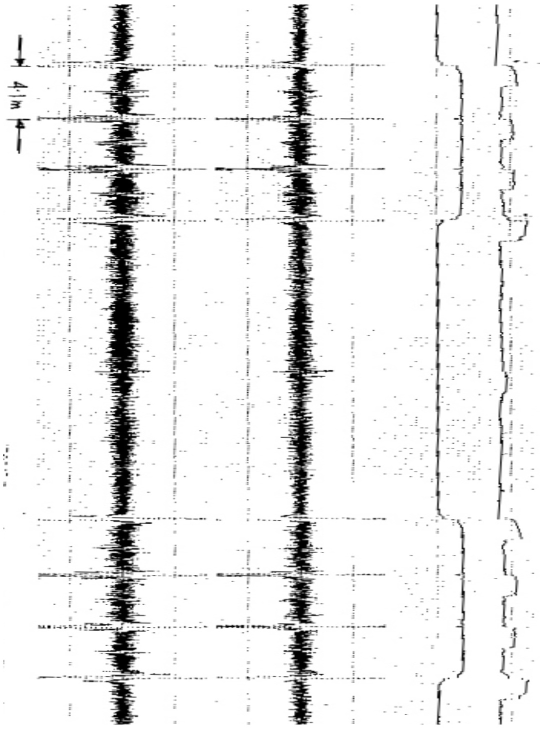

Fig. 3 (a). Splicing in the 1st investigation

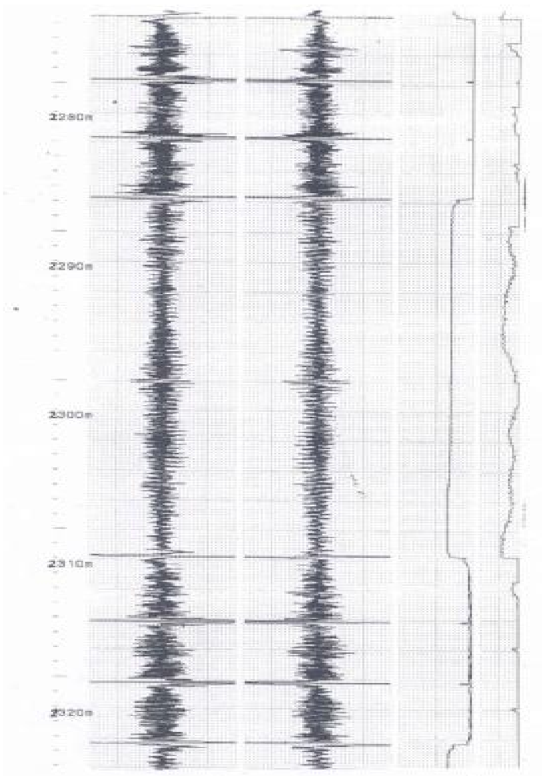

Fig. 3 (b). Splicing in the 2nd investigation

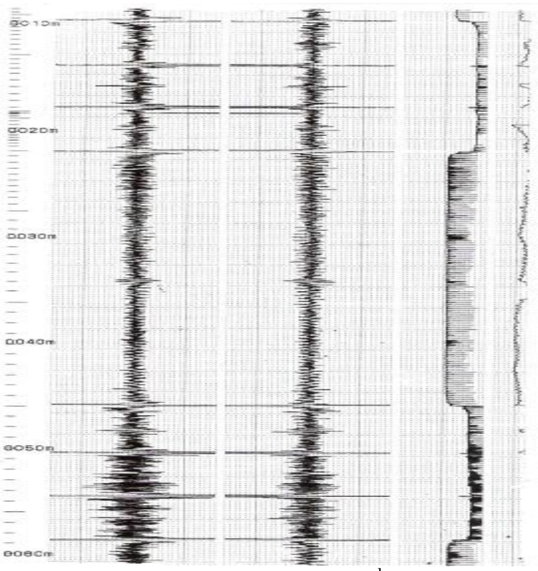

Fig. 3(c). Splicing in the 3rd investigation

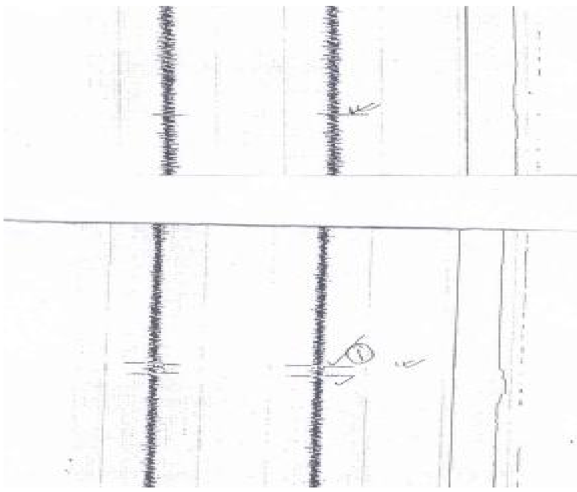

Fig. 4 Initiation of flaw and flaw during 1st investigation

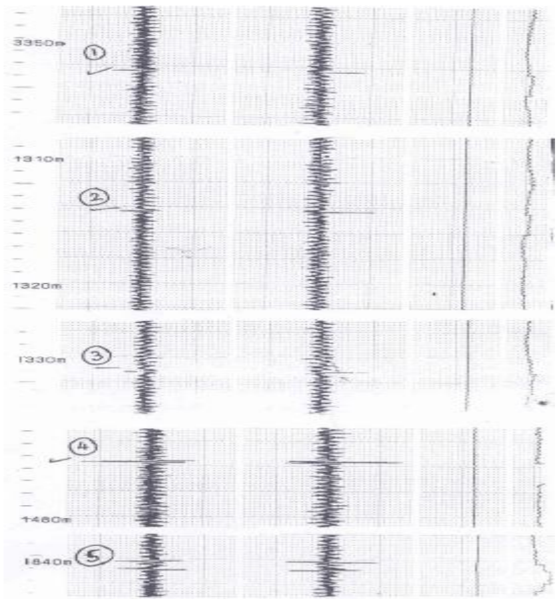

Fig. 5 Localised flaws and initiation of flaws during 2nd investigation

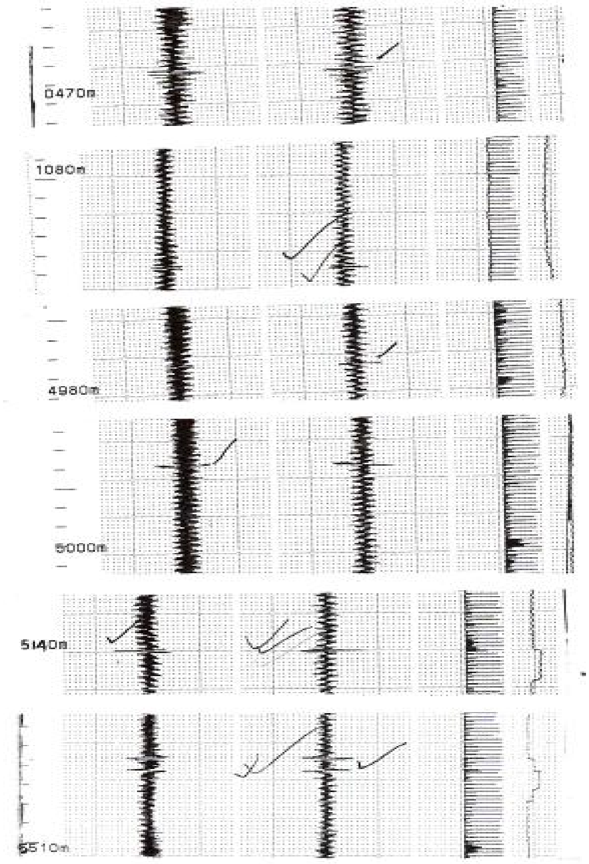

Fig. 6 Localised flaws and initiation of flaws during 3rd investigation

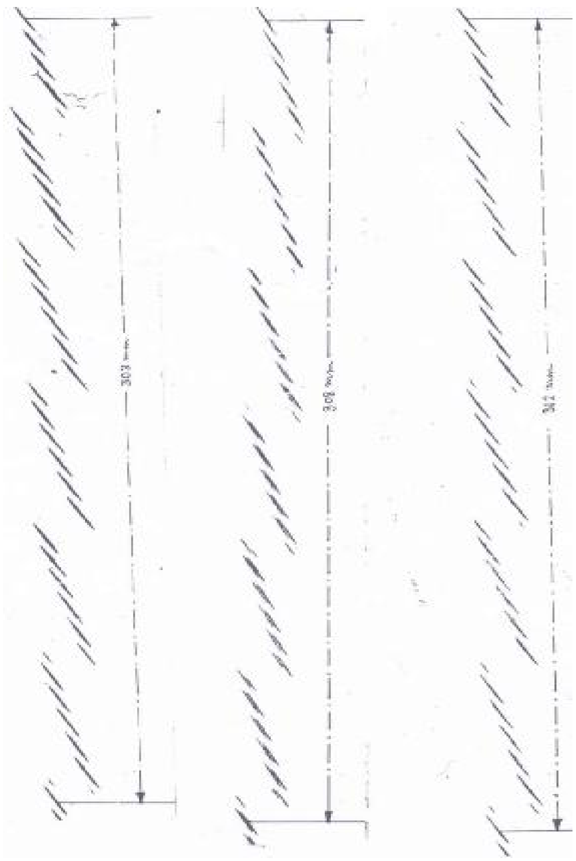

Fig. 7 Lay lengths observed during 2nd investigational study

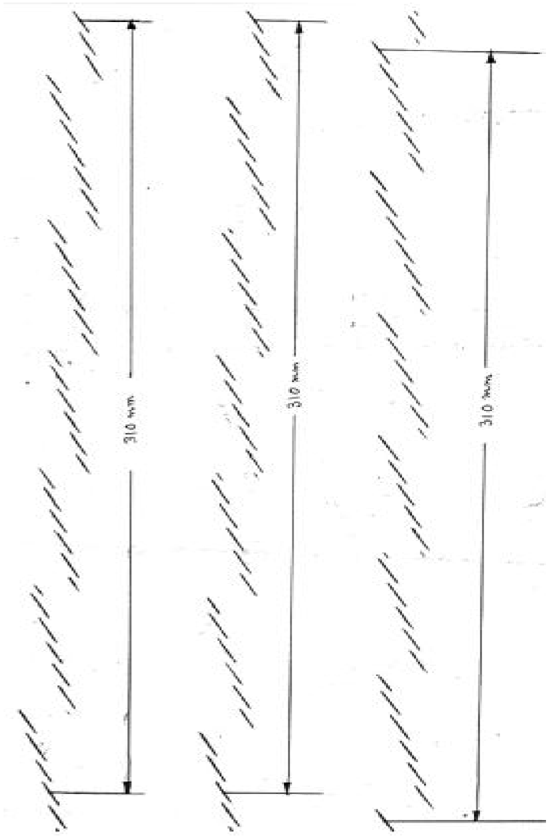

Fig. 8 Lay lengths observed during 3rd investigational study.