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NON- DESTRUCTIVE INVESTIGATION ON STEEL WINDING ROPES FOR MEN / MATERIAL HANDLING AND AERIAL ROPEWAY PASSENGER CABLE CAR INSTALLATIONS

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Abstract

Applications of Steel winding wire ropes are getting their importance day by day. Steel winding ropes which are heterogeneous in nature are to be inspected for their structural integrity to avoid untoward / unpredictable failures causing accidents due to different parameters by virtue of corrosion, abrasion wear and broken wires.

Non-Destructive inspection by magnetic method is the only means for rope evaluation towards qualitative and quantitative analysis of wire ropes which are required to be carried out at intervals and till date this technique of ndt has not been given due recognition / importance in India.

The author would like to bring to light this technique undertaken by C.M.R.I. on mine winder ropes (particularly on friction winder) for hauling men and material, cable belt system, conveyor ropes, aerial ropeway passenger cable car (mono cable- with fixed/automatic grips) haulage / carrying ropes and track ropes where drawl of a test specimen for conducting destructive test is ruled out and the importance of declaring this ndt specification as a mandatory since no other method of rope evaluation is possible other than ndt technique.

C.M.R.I. is engaged since last three decades in this endeavor by extending its facility by conducting such inspection to the mining and aerial ropeway installations.

Introduction:

Steel wire rope used for hauling men and material from underground mines as well hauling and track purposes in aerial rope way passenger cable car installation are basically of two different construction namely stranded construction and locked coil construction. Deterioration caused due to service condition in a rope are classified in to two categories namely localized flaws (LF) and distributed flaws or flaws due to loss in metallic area (LMA) Localized flaws are caused due to broken wires 1 nicking etc whereas distributed flaws are mainly due to corrosion, wear 1 abrasion, pitting of wires etc., The rope discard criteria adopted by different countries for mine winder ropes as well on haulage and track ropes for aerial rope way passenger cable car installation are briefed in different tables in this paper.

Ndt EQUIPMENT PRINCIPLE OF OPERATION:

There are three different types of instruments for evaluation of rope condition namely (a) electromagnetic instruments (b) direct current and permanent magnet method instruments and (c) Magnetic flux leakage instruments.

(a) Electromagnetic instruments

Works on the transformer principle with primary and secondary coil wound around a rope where the rope acts as a transformer core. The primary coil (which is the exciter) is energized with a low frequency a. c. in the range of 10 to 30 Hz. The secondary which is search coil measures the magnetic characteristics of the rope. Any significant change in the magnetic characteristics in the core i.e. the wire rope will cause a voltage change (in amplitude and phase) in the secondary coil.

This type of instruments operate at relatively low magnetic field strength and hence designed to detect changes in metallic cross sectional area and it is essential to completely demagnetize the rope before examination .

(b) Direct current and permanent magnet method instruments

This type of instrument supplies a constant flux which magnetizes a length of rope which passes through a magnetic head. The total axial magnetic flux in the rope can be measured either by Hall effect sensor,

an encircling coil or by any other appropriate device that can measure absolute magnetic field or variation in a steady magnetic field. This signal obtained through the sensor or encircling coil is electronically processed, and the output voltage is proportional to the volume of steel or the change in metallic cross sectional area within the region of influence of the magnetizing circuit. This type of instruments measures change in metallic area.

(c) Magnetic flux leakage instruments

A direct current or a permanent magnet instrument is used to supply a constant flux that magnetizes a length of rope which passes through the magnetic head. The magnetic flux leakage created by a discontinuity in the rope such as a broken wire can be measured with a differential sensor such as a hall effect sensor, sensor (Inductive) coil or by any appropriate device. This signal from the sensor is electronically processed and recorded.

The electronic integrated circuit integrates the sensing coil signals to directly determine the magnetic flux in the rope and hence the rope-cross sectional area. There fore LMA may be estimated quantitatively by measuring the total magnetic flux directly or by measuring the total magnetic flux directly in the rope with an accuracy to detect as small as 0.05% loss of cross sectional area. While all presently available can perform either LF inspection or LMA inspection, modern instruments are of the dual function type and can perform combined LF / LMA inspection.

Wire rope users now recognize that EM inspection is a powerful preventive maintenance tool. Those who test wire ropes should follow the stipulated guidelines to assure reliable results and the users of the rope should be familiar with the standards, understand the ndt procedure followed and the test results provided by the testing agency.

The phenomena of rope evaluation by conducting non - destructive tests by assessing the localized flaws viz. broken wires either individually or in groups, rope damage caused by lightning, squeezing, nicking etc. are local in nature and can not therefore be detected by measuring cross sectional area. The main application of cross sectional area measurement would appear to be the determination of loss of cross section of largely uniform material wear that is generally difficult to quantify.

DETERMINATION OF ABSOLUTE METALLIC AREA OF A ROPE

Certain conditions occur during the service life of a rope, which causes rope deterioration at different rates over different lengths. For example in an endless haulage rope deterioration may occur due to wear causing the best section to show a loss of metallic area. Corrosion may occur on a friction hoist balance rope, whereas both corrosion and wear may occur on a slope hoist rope in which the ends have been reversed to place the worn and corroded portion on the rope from the car end on to the drum. Under these conditions ndt may seriously under estimate the true loss of metallic area because of the reference point on the rope assumed to be at 100% is not true. Further, incorrect assumption of rope construction, determination of actual metallic area, (47 to 49% in case of stranded ropes and 83 to 85% in case of full locked coil ropes) metallic influence caused due to objects near the test head, influence of radio frequency electromagnetic signals inaccuracy in strip chart recording, under estimation of true LMA caused by instrument averaging as well due to metallic debris over the rope length correlating loss in metallic area by localized flaws and misinterpretation of test results are the common errors committed by unskilled personnel conducting NDT.

Finally, it is of utmost importance in conducting NDT of rope that the averaging length of an instrument is an important factor to understand and consider. Misapplication can cause a serious under estimation or over estimation of the LMA. One who NDT's ropes should analyze rope samples from retired ropes to acquire a good understanding of his NDT instruments and the strip chart indications which provides useful information for a preventive maintenance program.

ROPE DISCARD CRITERIA ADOPTED BY DIFFERENT COUNTRIES

Haulage / Carrying Ropes

O.I.T.A.F (International organization for Rope way Transport)
LF -8 Broken wires in 40 times the diameter of the rope
LMA -10% (max) reduction. In the stretched condition irrespective of the conditions the rope must be removed off the installation after 8 years.

Canadian Specification-CAN/CSA-Z98-M91 passengers rope ways Rope retirement criteria by Ndt.

Discard Criteria For Carrying And Haulage Of Ropes of Ropeways Adopted By Different Countries

Abbreviation of Countries:

D - Germany CH - Switzerland A - Austria I - Italy F - France
USA - United States of America NZ – New Zealand Hongk - Hongkong OITAF – International Organization for Ropeway Transport

Relative loss of cross section in % over a length of	D	CH	A	I	F	USA	NZ	HONGK	OITAF
500xd	25	-	25 [1)] / 37.5 [2)]		25	-	-	-	-
60xd	-	-	-	20	-	-	-	-	-
40xd	10	20/15 [1)3)]	12 [1)4)] 12/18 [2)4)]	-	10	-	-	-	-
30xd	-	20/15 [2)3)]	-	-	-	-	10/15 [4)]	10	10/15 [4)]
12xd	-	-	-	10	-	-	-	-	-
9xd	-	-	-	-	7.5	-	-	-	-
6.5xd	-	-	-	-	-	4/6/10 [5)]	6	-	-
6xd	5	-	6 [1)] / 9 [2)]	-	-	-	-	-	-
4xd	-	10/7.5 [1)3)]	-	-	-	-	-	-	-
3xd	-	10/7.5 [2)3)]	-	-	-	-	-	-	-

The Maximum number of Broken Wires in One Rope Lay

Rope Type	Maximum number of permissible broken wires	
	In one Strand	In all strands
6X7	2	4
6X19	4	6
6X37	6	10

Maximum permissible cross sectional area reduction by NDT (LMA)

Haulage Rope (All types)	25% in 500 x d length of the rope or 8% in 40 x d or 6 % in 6 x d
Track Ropes (Full Locked Coil)	10% in 200 x d or 5% in 30 x d

International Standard / British Specifications Regulations

Rope construction * S = Scale ** F = Filter	Maximum No. of Broken Wires		
	ISO 4309		BS 6570
	6 x d	10 x d	10 x d
6 X 7	2	3	2
6 X 19	5	6	5
6 X 19	3	4	5
6 X 19S* / 6 X 25 / 6 X 19 F**	5	6	7
8 X 19F**	6	8	10
6 X 36	7	9	10
6 X 37	10	13	11
6 X 41	9	11	12

Mine winding Haulage Ropes

(a) Code of Federal Regulations-Mineral resources-Recommends that atleast once in every 6 months non destructive test shall be conducted on the active length of rope. Retirement criteria under clause 57. 19024 stipulates that the maximum number of broken wires within a rope lay length excluding filler wire should not exceed 5% of the total number of wire or 15 % of the total number of wires within any strand. Loss of metallic area should not exceed 10 % of the actual metallic area.

(b) Regulations for mines and mining plants- Occupational Health and safety branch - Ontario regulation suggests rope replacement when broken wire exceeds 5% of the total in one lay length excluding filler wire as well a loss of 10% loss in cross section area is observed over the active rope length .

Mine Winding and Haulage Ropes

Bureau of Indian Standards specifications - Code of practice for the selection, installations and maintenance of the wire ropes (IS:3973/1984) recommends rope retirements when the rope approaches a loss in breaking strength to the tune of $1/10^{th}$ of the original strength due to localized/distributed flaws. Further, IS:5228/1969, IS:5229/1969 and IS:5230/1969 - Code of practice for the construction of continuous to and fro movement mono - cable ropeways with fixed grips intended for transportation of passengers, Code of practice for the construction of continuous to and fro movement mono-cable ropeways with automatic grips intended for transportation of passengers, Code of practice for the construction of continuous to and fro movement bi-cable ropeways intended for transportation of passengers, respectively although recommends that before the wire ropes are put into service, they shall be checked by suitable non - destructive means, but they do not incorporate the extent by which the rope is to be discarded due to localized / distributed flaws. Even the first revision Doc:HM6(0281) does not incorporate any changes.

Central Mining Research Institute since 1971 has extended its services to mining industry in evaluation and assessment of suitability of rope condition towards optimum and safe utilization of costly wire ropes. Its significant contribution in the mining sector has resulted economy as well inport substitution also at:

1. Drum type winder ropes at

a) Henry, Giffords and Golconda deep shaft winder ropes of M/s Bharat Go;d Mines Limited, Karnataka

b) M/s Hutti Gold Mines Company Limited Karnataka

2. Friction and Drum winder ropes at:
   a) M/s Hindustan Zinc Limited, Dariba and Zawar Mines Rajasthan
   b) M/s Hindustan Copper Limited, Khetri, (Rajasthan) and Mosaoni Mines, Ghatsila (Jharkhand)
   c) TISCO Jamadoba (2 Pit), Bhelatand (1&2 Pit), Jharkhand
   d) M/s Bharat Coking Coal Limited, Sudamdih, Moonidih K4000 and K6000 winders,Potki Balihari multirope winders
   e) M/s IISCO Chasnala (Jharkhand) friction winder ropes and
   f) M/s Uranium Corporation of India Limited, Jadugora and Narwa Pahar cage and skip winder ropes

   Besides the above the material handling cable belt conveyor system ropeways rope at M/s NALCO, Damonjodi (Orissa) and Lakwar Dam project concrete mixture transportation system ropeways (M/s Jayaprakash Industries Limited) at Himachal also was carried out by this Ndt investigation.

   Further to the above mining sector, the contribution of CMRI towards tourism industries also is worth mentioning here.Off late since 1993 this facility has been extended to different passenger cable car installation spread through out India like haulage ropes of :

   1. M/s Damodar Ropeways Construction Company, Appu Ghar amusement park mono cable installation with fixed grips, New Delhi and at Science City Kolkata besides Shri NaynaDeviji mono cable installation with automatic grips near Chandigarh
   2. ChandiDeviji and Mansa Deviji passenger cable car intallation with automatic grips of M/s Uhsa Breco at HariDwar and mono cable ropeway installation with fixed grips at Malampuzha (Kerala)
   3. M/s Sahara India Housing limited, Lona Wala monocable ropeway with fixed grips
   4. Gulmarg (Jammu Kashmir) monocable installation with automatic grips

   5. M/s Manokamna mono cable passenger cable car with automatic grips at Kurintal (Nepal).

Track and Haulage ropes of

6. Auli-Joshi Math (M/s GMVN) bi - cable passenger cable car installation (Uttaranchal)
7. Aerial Express (M/s KMVN) bi - cable passenger cable car installation at Nanital (Uttaranchal)
8. M/s Timber Trail (Asia Resorts Limited, Parwanoo (Himachal Pradesh) bi - cable car instatallation and

Conclusion:

Recent statistical analysis of over 8000 laboratory and field test records reveals that:

Roughly 10 % of all ropes showed over 15% strength loss as compared to the initial breaking strength, more than 2% of rope had lost over 30% of the initial breaking strength. In other wards while still in service, 10 % of all ropes were in and unacceptable and potentially hazardous conditions and 2% of the ropes were in an extremely dangerous condition.

Conversely, **more than 70% of all ropes in the sample were removed from service while still exhibiting near initial breaking strength. These findings raise some serious question as to the timeliness of rope removal, one-way or the other.** A program of regularly scheduled Ndt's typically at to 6 months intervals are of particular value for safe and extended rope usage. Presently dual function wire rope testers with improved computer technology for traditional measurement of loss of metallic area, local faults and new total change of metallic area are available in market. From the different discard criteria, it can be defined and understood unambiguously in dimension by number and reduction in cross section and the number of broken wire.

So far as the BIS standards are concerned, although non-destructive investigation in aerial ropeway haulage/carrying/track ropes and mining haulage ropes (especially in friction winders) is essential since there is no other means to evaluate / assess the rope condition while they are in service, the discard criteria is insignificant since the rope evaluation by assessing loss in breaking strength is a dangerously deceptive criterion

for continued service of a rope, which the wirerope community now recognizes to be unsuitable as a measure of the rope condition.

References :

Comparison of the discard criteria in the regulations of different countries –W. Beck, Universitat Stuttgart (D)

Procedure and results of electromagnetic testing of mine hoist ropes using the LMA -TESTTM instruments- DN.Poffenroth, U. S. Dept. of Labor

New methods of measuring the cross-section of ropes – A. Haller, EMPA (Swiss Fedeal Labortories for material testing and research Laboratories) Dupendorf

Electromagnetic testing- A reliable method for the inspection of wire ropes in service- H. R. Weischedel and R. P. Ramsey.

In-service inspection of wire ropes: State of the art- H. R. Weischedel.