THE STATUS OF NDT TECHNIQUES IN INDIAN COAL MINING INDUSTRIES

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Introduction: India with hard coal production of about 254 MT from about 550 nationalised mines in 1994-95 is the third largest coal producing country in the world after China & USA. The country with 16.4 percent population of the world has measure 6.8 percent share of proved world coal resources. Coalfield over an area of 4.37 million hectares out of the total land surface of 328.8 million hectares in India. However, the area covered by the past and present coal mining projects is only about 0.36 million hectares i.e 0.11% of the total area of our country. Coal industry in India is over 200 years old but the real growth in Indian coal industry took place since 1971. To achieve target of coal production the exact coordination of three M's are necessary i.e manpower, machinery and management. Out of these three machinery has the greatest role to play in achieving the target. It is the backbone of coal transportation through haulage transport and mine hoisting . Haulage are considered the second largest single cause of accident by studying the accident rate data (TABLE-II). Rope haulage still remains the primary means of transportation of men, minerals and supplies in the underground coal mines. The other rope transport system i.e. mine hoisting system transport men, minerals and the waste and employs many mechanical items from suspension gear to steel wire ropes and then head gear pulley shaft. In hostile environment of mining operation transportation system either by haulage or hoisting required to be reliable and safe. The accident rate data for mine hoisting was shown in TABLE-I.

All the above mentioned haulage, hoisting and winding components have sign of different material flaws like wear, fatigue crack etc. during operation. The flaws, which develop during manufacturing, are discontinuities, welding defects, lapping, flakes, lamination and service induced surface and sub-surface flaws. Any surface flaw can be a potential stress raiser, the severity being dependent on its location, size and shape. It is therefore imperative to examine the components carefully by non-destructive testing (NDT) techniques before incorporating the components into the service for maintaining the safety and reliability during service period. Thus it is required to be thoroughly visually inspected followed by magnetic particle crack detection test in search of any flaw which can not be detected by visual examination. In addition, there is an ultrasonic flaw detection test for any internal flaw developed during manufacturing of the components. For examination of steel wire rope electromagnetic inspection is done.

<u>Rope Haulage System</u>

In a study it reveals that 20% of the accident occurred due to mechanical failure like snapping of rope, failure of coupling, draw bar, clips and brakes, 19% due to uncontrolled movement, 17% unauthorised presence, 14% poor track condition and design, 10% set riding and 12% due to other unsafe practices.

The following causes of accident are most common:

Run-away of tubs due to failure of ropes, draw bars, coupling etc.
Crushing between tubs while coupling/uncoupling of tubs
Derailment of tubs due to defective track work or other causes
Absence of protective track fittings or defects in them
Riding an moving tubs
Due to whipping of ropes at curves, guide rollers etc.

Rope haulage still remains the primary means of transportation of man, minerals and supplies in the belowground coal mines. Haulage components e.g.; Drawbars, D-links, C-links etc. are the means to form a multiple unit of coal tubs for transportation which requires special attention to ensure safety in mines to avoid accident.

Failure occurs owing to one or more of the following reason:
The design of the drawbar had inherent weakness.
Manufacturing defect (Mainly transverse defects)
Substandard quality of material
The drawbar was maintained good shape
Considerably worn or damaged

Mine Hoisting System:

Mine hoisting comprises of hoisting of mining personnel and material in vertical and inclined shafts through cage. The increase in traveling distances between mine opening and coal face has necessitated an updating of manriding system to maintain and increase the time available for production at the coal face. Presently, cage hoisting system is used for man transport and for supplying materials needed for underground works and also for the transport of heavy loads. Cages may be classified in various ways depending on their functions, structure and suspension arrangement .Mine hoisting system should be such that it operates at maximum efficiency with optimum capital and maintenance cost. To avoid winding accident which often occur mine hoisting attachment should be perfectly reliable and qualitatively sound. Estimates shows that India wastes around Rs. 5400 million per year on account of rejection, rework and other consequential expenses in the manufacturing sector alone

Investigation have revealed that many accidents in mines can be attributed to fatigue defects tending towards failure arising from insufficient attention to handling and maintenance of winding installation components like Friction Wedge Type Rope Cappel (FWRC) , Safety hook, Distribution plate with shackles and Chains and other higher capacity cage suspension gear parts . Besides the fatigue defects , a number of imperfections may occur with the manufacturing processes which lead to failure of the components. The types of defects which can be determined by NDT methods include surface and sub-surface cracks, welding defects and internal flaws.

Non-destructive testing

Nondestructive testing(NDT) may be defined as test which can be performed on a material, components and assembly without damaging them and without affecting its ultimate serviceability. The prime objective of the NDT techniques is to ensure safety by detection of such cracks attributed to the manufacturing inefficiency or develop during mining operations. The scope of NDT in mining industry is wide and there are four techniques in particular which are being used to evaluate cage suspension gear , haulage items, head gear pulley shafts etc. are as follows:

Visual inspection
Magnetic particle crack detection
Fluorescent crack detection
Ultrasonic flaw detection

Visual Inspection

This method is conducted visually by naked eyes or with the help of magnifying glass for detecting any visible surface defects like material loss, scratches , indentation and wear due to fatigue or visible cracks developed due to poor manufacturing processes. For those surface and sub-surface(1.5 mm below the surface) defects which are invisible to naked eyes, Magnetic Particle Crack Detection is used . For those surfaces where it is difficult to reach Fibrescope or Boroscope are used. Visual inspection are needed for every mining components before going for any other NDT techniques and subsequently putting it into service.

Magnetic Particle Crack Detection

Magnetic particle crack detection is nondestructive method for detecting surface imperfections in ferromagnetic material. The mine hoisting components are of ferrous material and ferromagnetic in nature and thus this method is best suited for revealing the fine surface and subsurface flaws. Magnetic detection in ferromagnetic materials depends on the distortion of the magnetic field in a magnetised mass of metal by the defect or the difference in the magnetic properties between the defect and the main body . This distortion of difference is revealed by sprinkling the components with dry magnetic powder or spraying with a liquid containing magnetic particles of Magnetic Iron Oxide in suspension. The resulting concentration of particles indicating the position and nature of the defects. The components are magnetised by longitudinal and circular magnetisation . The current flow method(AC) is applied to such components as detaching hook, D-plate, socket ,pins etc. but is not applicable to chains,. For chains the induced magnetic flux method is adopted by suitable coil . Haulage items like coal tub's Draw bars, D-link, C-link etc. are also tested with this techniques. The haulage components are magnetised by circular magnetisation and longitudinal magnetisation by AC & DC . For Draw Bars the induced magnetic flux method is adopted by suitable coil. The longitudinal and transverse flaws could have been ascertained in AC and DC magnetisation respectively. Transverse flaw is not at all allowed to exist in the material.

Fluorescent Crack Detection

Fluorescent crack detection technique has an added advantage over magnetic particle crack detection that there is no directional sensitivity to be considered. In this method components are tested in a fluid containing fluorescent substance and penetrates into the surface defects which are revealed by a short wave radiation ultraviolet lamp. The ultraviolet light is produced by a high intensity mercury arc or mercury vapour discharge lamp.

Ultrasonic Flaw Detection

This technique is used to reveal the internal flaw up to the depth of more than 1 mm depth from the outer surface. The flaw detector is based on the principle that a beam of ultrasonic frequency transmitted into a solid is reflected by discontinuities such as cracks or cavities. The reflectogram is picked up by a receiver placed on the same face as the transmitter. A second echo from the far face of the solid will also be received after an interval of time . This pulse echo techniques allows the detection of minute defect in ferrous and non-ferrous metallic object. All cage suspension gears attachments like Friction Wedge Type Rope Cappel, Safety Hook, Distribution plate , cage shackles etc. & Haulage Rope Cappel and also Head Gear Pulley Shaft are evaluated with this technique.

Electromagnetic Inspection

Evaluation and assessment of structural integrity of steel wire ropes plays an important role in mining industry. In mine hoisting system wire ropes are subjected to different degradations by virtue of its service and environmental conditions. Premature failure of wire ropes results loss in personnel as well as heavy damage to the hoisting installation causing down time. Rope condition is evaluated by nondestructive technique after one month of this installation allowing a constructional stretch and this mother data is kept as a base for assessment of this condition on subsequent NDT investigations conducted on periodic interval.
The two types of flaws i.e. localised flaws due to broken wires and distributed flaws due to corrosion and corrosion pitting are evaluated by Permanent Magnet dual function wire rope tester. The permanent magnetic head which encircles wire rope supplies a constant flux which magnetises the length of rope as it passes through the head and this total axial magnetic flux in the rope as well as any variation in a steady magnetic field can be measured by the Hall Effect. Variation in these signals are processed electronically and the output voltage is proportional to the volume of steel /change in metallic area.
Further the constant flux supplied by the permanent magnet magnetizes the length of the rope as it passes through the test head and the magnetic flux leakage created by a discontinuity in the rope (broken wire) can be measured by the inductive sensor coils.
Thus , non-destructive examination of wire rope enables early detection of wear or corrosion and development of broken wires.

Conclusion: Non-destructive testing is the only suitable techniques to ensure safety of mine personnel during haulage transport and mine hoisting.
Optimisation of the cost of rejection, rework of the haulage and mine hoisting components due to sub-standard quality.
Accident could have been avoided by knowing the flaws and its severity in the haulage and mine hoisting components detected by NDT
Careful maintenance and inspection of all winding components must be followed rigorously.
The code of practice for ensuring safety may be made as follows
the type of steel to be used
heat treatment
permissible imperfection
permissible wear limits
service life
non-destructive testing techniques to be used
frequency of testing
procedure for the provision of replacement parts

References:
S.N.Padhi 'Mine Safety -Vision for the 21st Century' The IM & EJ,September 1998. PP-17-19
S.K.Kashyap et al; 'Coal transportation through mine hoisting - Safety consideration' CCI-99, New Delhi,PP-409-413
A.R Bingham et al ' Non-destructive testing in industry ,coal mining' Non-destructive Testing Feb,1972,PP-28-31

TABLE -I

MAJOR ACCIDENT IN INDIAN COAL MINES: CAUSE WISE SINCE 1901

Cause	No. of incidence	% of total incidence	Fatalities	% of total fatalities
Explosion	32	13.0	1181	38.1
Inrush of water	30	12.0	771	24.9
Roof fall	151	60.0	861	27.8
Mine fire	4	1.6	104	3.4
Suffocation of gas	4	1.6	21	0.7
Winding in shafts	22	8.8	116	3.7
Explosives	7	3.0	44	1.4
Total	250		3098	

Source: S.N.Padhi 'Mine Safety -Vision for the 21st Century' The IM & EJ,September 1998. PP-17-19

TABLE--II

TREND OF ACCIDENTS DUE TO HAULAGE IN BELOW GROUND COAL MINES

Year	Total accident due to all causes U/G	Fatal accidents due to haulage (% of total accident)	Total nos. of serious accidents in U/G due to all causes	Serious accidents due to haulage (% of total U/G accidents)	Total nos. of serious accidents in the U/G due to all causes (% of total U/G accident)
1985	120	22(8.3)	791	191(24.0)	68(6.8)
1986	113	21(18.6)	935	179(19.0)	81(8.71)
1987	110	21(19.1)	695	165(23.7)	78(11.2)
1988	100	17(17.0)	585	137(23.4)	64(10.91)
1989	110	22(20.0)	666	158(23.7)	70(10.51)
1990	91	20(21.9)	666	160(24.0)	79(11.8)
1991	80	24(30.0)	577	164(28.4)	58(10.0)
1992	107	20(18.7)	587	167(28.4)	64(10.9)
1993	101	26(25.7)	632	148(23.4)	92(14.5)
1994	93	24(25.8)	560	179(31.56)	64(11.4)
1995	91	11(12.1)	549	151(27.5)	78(14.2)

Source: T.K Mazumdar et al 1997.