International Research Journal of Mechanical Engineering Vol. 2 (8) pp. 211-216, August, 2014. Available online at www.Internationalscholarsjournals.org

Full Length Research Paper

Experimental Analysis on surface and sub surface imperfection through magnetic atom crack discovery for nonlinear dynamic model of some mining machinery

***Guru Shankar, Ram R. Raj and Mohan E. T**

Faculty of Mechanical Engineering, Department of Technical Education, University of Kota, Kota India.

Accepted 27 July, 2014

This paper reviews magnetic particle crack detection (MPCD) in terms of principle, advantages, disadvantages and limitations. Different mine gear components are evaluated through MPCD technique and results are analyzed in terms of their suitability by applying acceptance/rejection norms followed by the mining industry in India. MPCD is now a widely acceptable technique in the world and has simplified inspection processes, leading to significant cost reductions and quality control enhancement and confidence. It has great value in revealing surface flaws in magnetic materials such as mild and alloy steels, cast iron, etc. Not only will the technique reveal surface defects that are not visible to the naked eye, it also facilitates the detection of cracks that would, under normal circumstances, only be found by close and tedious examination of the surface. On the basis of this study, it can be concluded that MPCD evaluation must be conducted on manufactured equipment prior to use, so that failure of equipment in stipulated time could be prevented. It is also suggested that condition of vital components must be subjected to their condition monitoring at certain interval.

Key words: Magnetic particle crack detection, material defects, surface imperfection, non-destructive evaluation, quality assessment, mine gear components.

INTRODUCTION

Material defects are unwanted contaminants right from raw material to furnished products due to inadequate process adopted during metallurgical change manufacturing etc. Material defects can be appeared in different forms. As an example the some defects have to be mentioned here non metallic inclusions defects, manufacturers defects, high surface decarburization defects, bad microstructure defects, surface corrosion defects, mechanical damage defects, surface defect, Internal defects etc.

The represented examples don't have to lead to the failure of the material in every case. These are merely examined on the material surface and material insides as well as of structure anomalies, which differs from the standard. Defects play a crucial role in influencing the various materials properties, and exhibit complex structure on varying length scales - from electronic structure of the defect core (sub-nanometer and below) to elastic fields of the continuum (micrometer and beyond).

Defects in materials may be detected by various processes such as Magnetic particle inspection, X-ray radiography, Gamma radiography, Ultrasonic - testing, Electrical method, Damping test, Non-magnetic method of non-destructive testing, Optical holography method

*Corresponding author. E-mail: Shankar.g@yahoo.co.in

and Hardness test. This study is limited to surface/subsurface imperfection which is detected through magnetic particle crack detection technique each process is required visual inspection. So it is working to discuss about visual imperfection.

Visual testing is probably the most important of all magnetic particle crack detection tests. It can often provide valuable information about defects. The visual inspection however should not be confined only to the structure being investigated. It should also include neighboring structures, the surrounding environment and the climatic and services condition. This test report helps the component authority to allow their safe use in the installation. Due to time constraints it was decided to take up only magnetic particle crack detection testing of mine components. So this is an attempt to learn about the magnetic particle crack detection testing of materials in general, but mine gear components in particular.

OBJECTIVE OF THE STUDY

The objective of this study is to detect the surface and sub-surface imperfections by applying magnetic particles crack detection (MPCD) test without interfering in any way with the integrity of the materials. This study also ascertains the identification and quantification of surface imperfections followed by assessment of its suitability on basis of acceptance and rejection norms.

METHODOLOGY

First of samples to be tested are subjected to Proof load test which is three times of safe working load on horizontal/Vertical testing machine. After Proof load test of material, visual examination is done to verify any deformation occurred followed by Magnetic particle crack detection (MPCD) test is carried out to detect the surface or near surface defects in magnetic material made of iron. The principle of this technique is to generate flux in the component to be examined, with the flux lines running along the surface perpendicular to the surface imperfections. When the flux lines approach to a surface discontinuity they will stay in the air which leads the crack edges to behave as magnetic poles (North & South) (Sei and Goenka, 2001; Farley, 2002). These poles attract the minute magnetic particle of iron oxide supplied externally and the clear vision of imperfection exists. When defects are found in materials then filing or grinding on the surface of material where defects are found and again MPCD test is conducted if defects are found again then we accepted or rejected according to Indian standard.

Magnetic particle crack detection (MPCD)

This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferrite steel and iron. The principle is to generate magnetic flux in the article to be examined, with the flux lines running along the surface at right angles to the suspected defect. Where the flux lines approach a discontinuity they will stay out in to the air at the mouth of the crack. The crack edge becomes magnetic attractive poles north and south, (Betz, 1985; Alexander, 1989).

These have the power to attract finely divided particles of magnetic materials such as iron fillings. Usually these particles are of an oxide of iron in the size range 20 to 30 µ and are suspended in a liquid which provides mobility for particles on the surface of the test piece, assisting their migration to the crack edges. However, in some instances they can be applied in a dry powder form. The particles can be red or black oxide, or they can be coated with a substance, which fluoresces brilliantly under ultra – violet illumination (black light). The object is to present as great a contrast as possible between the crack indication and the material background. The technique not only detects those defects which are not normally visible to the unaided eye, but also renders easily visible those defects which would otherwise require close scrutiny of the surface.

There are many methods of generating magnetic flux in the test piece. Few important methods are:

i. The most common is the permanent magnet to the surface, but this method cannot be controlled accurately because of indifferent surface contact and deterioration in magnetic strength. Modern equipments generate the magnetic field electrically either directly or indirectly.

ii. In the direct method high amperage current is passed through the test piece and magnetic flux is generated at perpendicular to the current flow. The effect is to pass magnetic flux along the part to reveal transverse and circumferential defects.

Alternating current (AC)

It is commonly used to detect surface discontinuities. Using AC to detect subsurface discontinuities is limited due to what is known as the skin effect, where the current runs along the surface of the part. Because the current alternates in polarity at 50 to 60 cycles per second it does not penetrate much part of the surface of the tested object. This means the magnetic domains will only be aligned equal to the distance AC current penetration into the part. The Frequency of the Alternating Current decides how deep the penetration.

Direct current (DC, full wave DC)

It is used to detect sub surface discontinuities where AC can not penetrate deep enough to magnetize the part at the depth needed. The amount of magnetic penetration depends on the amount of current passed through the part. DC is also limited on very large cross sectional parts how effective it will magnetize the part.

Each methods of magnetizing has its pros and cons. AC is generally always best for discontinuities open to the surface, and some form of DC for subsurface.

For similar arrangement of test specimen alternating current is used to detect longitudinal defects and direct current is used to detect the transverse defects. But, if the position of the test specimen is changed by 90 degree (perpendicular to the previous position) alternating current will detect the longitudinal and the direct current will detect the transverse defect (as per current arrangement).

A magnetic field is established in a component made from ferromagnetic material. The magnetic lines of force travel through the material and exit and reenter the material at the poles. Defects such as crack or voids cannot support as much flux, and force some of the flux outside of the part (Figure 1). Magnetic particles distributed over the component will be attracted to areas of flux leakage and produce a visible indication.

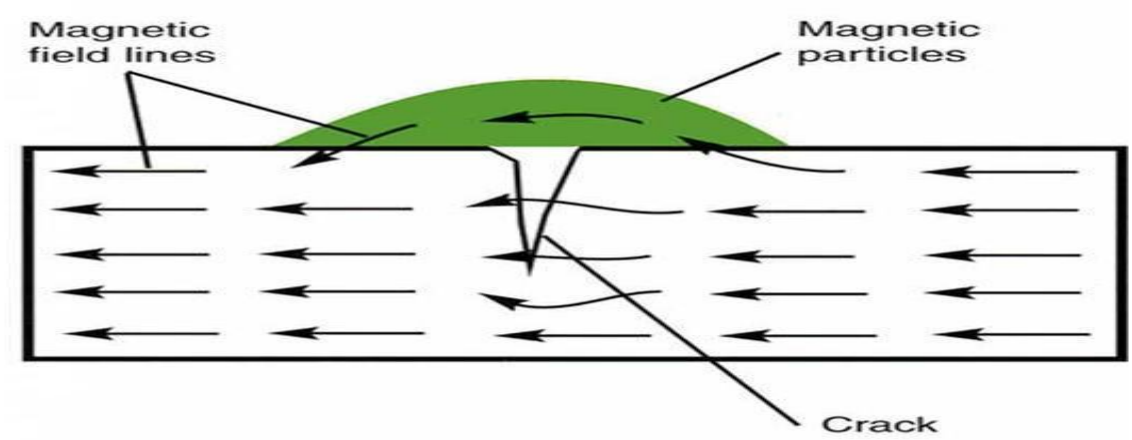


Figure 1. Interpretation of surface imperfection in Magnetic Particle Crack detection

Table 1. Indian standards for Acceptance/ Rejection of mine gear components.

IS : 3703:2004	Code of practice for magnetic particle flaw detection
IS : 6410:1991	Magnetic Flaw Detection links and Powers- specification
IS 7587 (Part 1): 2004	Cage suspension gear for winding in mines

Advantages include:

i. Simplicity of operation and application;
ii. Surface preparation criticality is less;
iii. Equipment costs are relative;
iv. Large surface area of complex parts can be inspected rapidly.

Disadvantages include:

i. Restricted to ferromagnetic materials;
ii. Restricted to surface or near surface defects;
iii. For large parts, large current is required;
iv. Required relatively smooth surface.

Typical situations where magnetic particle crack detection

Testing may be useful include:

i. Quality control of pre-cast units or construction *in situ;*
ii. Removing uncertainties about the acceptability of the material; supplied owing to apparent non-compliance with specification;
iii. Confirming or negating doubt concerning the workmanship involved in batching, mixing, placing, compacting or curing of materials;
iv. Monitoring of strength development in relation to formwork removal, cessation of curing, pre-stressing, load application or similar purpose;
v. Location and determination of the extent of cracks, voids, honeycombing and similar defects within a materials structure;
vi. Determining the materials uniformity, possibly preliminary to core cutting, load testing or other more expensive or disruptive tests;
vii. Determining the position, quantity or condition of reinforcement;
viii. Increasing the confidence level of a smaller number of destructive tests;
ix. Determining the extent of materials variability in order to help in the selection of sample locations representative of the quality to be assessed;
x. Confirming or locating suspected deterioration of materials resulting from such factors as overloading, fatigue, external or internal chemical attack or change, fire, explosion, environmental effects;
xi. Assessing the potential durability of the materials;
xii. Monitoring long term changes in materials properties;
xiii. Providing information for any proposed change of use of a structure for insurance or for change of ownership (McGonnagle, 1986; Carino, 1984).

Indian standards and Acceptance/Rejection norms

Table 1 presents the Indian standards and acceptance/rejection norms are used to assess the quality of mine gear components.

Input Data/ Structure/Questionnaire

The following data were generated to proceed in non-destructive test and examination as observe in Table 2.

Name and Number of sample tested:

i. Shackle
ii. Pin
iii. Safety hook
iv. Swivel
v. C-Type
vi. D-Plate

Nature of Problem: Magnetic particle crack detection

Table 2. Observation of magnetic particle crack detection.

S. No.	Name of components	Magnetic particle crack detection			Location	Remarks
		Longitudinal	Transverse	Complex		
i	D-Plate	Nil	Nil	Nil	Nil	Figure 2
ii	Shackle	35.7 and 48 mm	Nil	Nil	Eye and Body	Figure 3
iii	Pin	5 mm	Nil	Nil	Nil	Figure 4
iv	Safety Hook	Nil	Nil	12 mm	Near rivet	Outer plate, Figure 5
v	Swivel		15 mm	Nil	Body	Figure 6
vi	C-type	Nil	Nil	Nil	Nil	Figure 7

Table 3. Result of magnetic particle crack detection test of different mines component.

Specimen	Length of cracks (mm)	Nature of defects	Accepted or rejected	Permissible limit (mm)
Shackle	35.7 and 48	Longitudinal	Rejected	<32
Swivel	15	Transverse	Rejected	<10
Safety hook	12	Complex	Rejected	None
Pin	5	Longitudinal	Accepted	<32

Test performed: 1) visual examination; 2) magnetic particle crack detection

Equipment used: Magnifying glass, search light, Uni. magnetic particle crack detector.
Calibration status: O. K.
National/international Code No.: IS 3703:2004, IS 6410:1991, and IS 7587 (Part 1): 2004 [G],[H],[I]
Laboratory environment during testing: Normal Room Temperature

Analysis/solution/description

The test specimen is adjusted in the Universal magnetic particle crack detection or Portable magnetic particle crack detection tester. Let us supply alternating current through the test bench which causes the generation of magnetic field and then the magnetic flux at the probe ends longitudinally. When dielectric liquid solution (of kerosene oil and iron oxide particle) is made to flow over the specimen, therefore the cracks are clearly visible and can be measured with the help of measuring scale. To measure the transverse cracks either of the following steps are used:

i. Adjust the specimen as done for longitudinal cracks. Now, allow flow of direct current instead of alternating current. So, magnetic flux generated is perpendicular to the longitudinal axis; thus, transverse cracks are visible and can be measured.

ii. Continue to supply the alternating current to the universal/potable test bench and rotate the test specimen between two prods by 90° so that longitudinal cracks in step (i) become the transverse cracks in step (ii) and the transverse cracks in step (i) become the longitudinal cracks in step (ii). Hence, the transverse cracks can be detected and measured.

Magnetic particle crack detection (MPCD) was conducted on some mine gear components and observation are given in Table 2. Out of six components, two components are free from surface and imperfection of harmful character except four items mentioned in Table 3.

FINAL RESULTS

Final results of magnetic crack detection test are given in Table 3 on the basis of test result shown in Table 2. Shackle, Swivel and Safety Hook Outer plate are rejected as shown in Figures 3,4,5 and 6, because they are not within permissible limit of imperfection according to IS 7587 (Part 1): 2004 Figures 8 and 9.

Safety hook outer plate (Figures 5) contains multiple cracks of complex nature, so it is liable to be rejected as IS 7587 (Part 1): 2004 as shown in Figures 9. Pin Figures 4 contains longitudinal nature, under permissible, so it is liable to be accepted as IS 7587 (Part 1): 2004 Figures 10.

Conclusion

On the basis of this study, the following conclusions may be drawn:

i. Visual technique is useful to find out the condition of sample and helpful to get ready for future NDT operation.

ii. Magnetic particle crack detection can detect transverse as well as longitudinal cracks which can be identified and quantified.

iii. Some components like Distribution plate (Figure 2), C-type coupling (Figure 7) and pin are accepted due to no harmful character of surface imperfection.

Figure 2. Distribution plate.

Figure 3. Longitudinal defects in shackle.

Figure 4. Longitudinal crack in cage pin with nut.

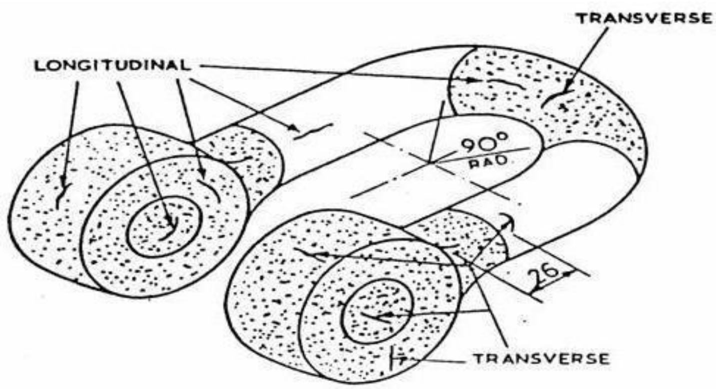
Figure 5. Complex type crack in rivet of outer plate of safety hook

Figure 6. Transverse defect in swivel.

iv. Some other components like –shackle, swivel, and safety hook outer plate (Figures 3, 4, 5 and 6) are rejected due to harmful character of surface imperfection.

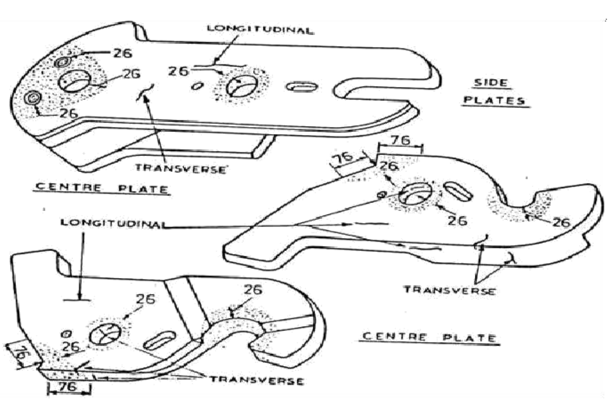
On the basis of this study, it can be concluded that MPCD evaluation must be conducted on manufactured equipment prior to use, so that failure of equipment in

Figure 7. C-type coupling.



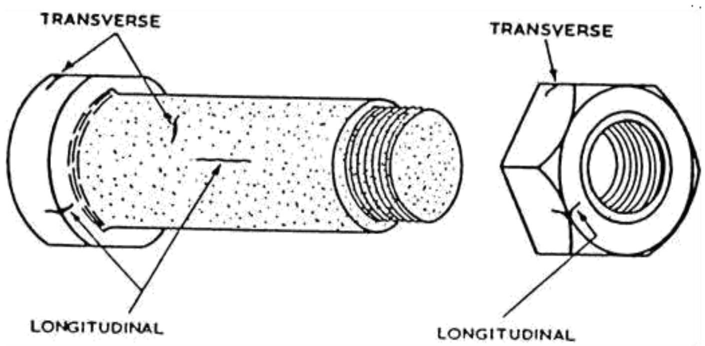
Part	Type of imperfection	Permissible imperfection
Shaded areas		
Shackle body	Transverse	None
	Longitudinal	None>10mm
Un-shaded areas		
Shackle body	Transverse	None
	Longitudinal	None>32

Figure 8. Shackle reprinted from IS 7587 (Part 1): 2004 [G]



Part	Type of imperfection	Permissible imperfection
Shaded areas		
Plate surfaces	Transverse	None
	Longitudinal	None>10 mm
Plate edge	Transverse	None
	Longitudinal	None>32 mm
Holes and slotes	Transverse	None
	Longitudinal	None>16 mm
Unshaded areas		
Plate surfaces and slotes	Transverse	None
	Longitudinal	None>32 mm
Plate edge	Transverse	None
	Longitudinal	None>64 mm

Figure 9. Safety hook reprinted from IS 7587 (Part 1): 2004 [G]



Part	Type of imperfection	Permissible imperfection
Shaded areas		
Pin: Barrel	Transverse	None
and thread	Longitudinal	None>32 mm
Un-shaded areas		
Pin head	Transverse	None>10 mm
and nut	Longitudinal	None>10 mm

Figure 10. Pin and Nut reprinted from IS 7587 (Part 1): 2004 [G].

stipulated time could be prevented. It is also suggested that condition of vital components must be subjected to their condition monitoring at certain interval.

REFERENCES

Betz CE (1985). Principles of Magnetic Particle Testing, American Society for Nondestructive Testing, P. 234, ISBN 9780318214856, retrieved from "http://en.wikipedia.org/wiki/Magnetic-Particle_inspection".

Alexander THT (1989). “Non-destructive Testing of Materials (Lew, HS, Ed.), ACI SP-112, p. 21.

Sei JP, Goenka (2001). Nanda Millar Co. “Prototype development of cage suspension Gear and Test Procedure”.

Farley JM (2002). NDT Vil-2, McGraw-Hill.

McGonnagle WJ (1986). International Advances in Non-destructive Testing 12, Gordon & Breach,New York, pp. 117-146.

CARINO NJ (1984). “Laboratory study of flaw detection in concrete by the pulse-echo method”, *In situ* Non-destructive Testing of Material (Malhotra, V.M., Ed.), ACI SP-82, American Concrete Institute 557.

IS 7587 Part 1 (2004). First Revision Indian Standard) Cage suspension gear for winding in mines.

IS 3703:2004 (Second Revision Indian Standard) Recommended practice for magnetic particle flaw detection.

IS 6410:1991 (First Revision Indian Standard) Magnetic flaw detection inks and powers- specification