A Detailed Study of Different Types of NDT Techniques in Industries under Different Machining Methods Used - A Review Paper

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Abstract—*Non-destructive Testing is a very vast field which helps the industries to check the material they are manufacturing without damaging them. Most of the industries take up NDT as the premier way to check the products, like Construction companies, Boiler industry, Automobile industry, Welding setups etc. In different industries different types of NDT techniques are used like Visual Testing, Magnetic Particle Testing (MPT), Ultrasonic Testing (UT) and Liquid Penetrating Testing (LPT) etc. Each technique has its significance and their results may vary, so we choose the best NDT technique for the product to be tested and in accordance with the budget. This paper is review papers on different types of NDT techniques which shows a trend between their working and let the scholars understand the know-how of latest in NDT.*

Keywords: - NDT, Non-destructive Testing, Review, Comparison, Visual Testing, MPT, LPT, UT

I. INTRODUCTION

NDT means Non- Destructive Testing, where any work-piece, product or material can be tested without harming its integrity. This means if we have manufactured any product then with the help of any mechanical operation like welding, forging, casting etc then the strength of that product can be tested without damaging that product. With the help of NDT we can even check the life of a product by inspecting its wear and tear and then calculate how long it can be used before getting fractured. NDT is only concerned with the detection and location of the flaw and after the inspection the defective portions are machined. The need to use NDT arrived when we could no longer damage our product for the sake of inspecting it e.g Jet Aircraft, Missiles, Nuclear Energy. Now-a-days NDT is finding its application in many fields, methods and techniques and it basically depends upon Material Type, Defect type, Defect Size and Defect Location. Thus the need and demand of NDT will continue to grow.

II. DIFFERENT TYPES OF NON DESTRUCTIVE TESTING METHODS

1. Visual Testing
2. Ultrasonic Testing
3. Liquid Penetrant Testing
4. Magnetic particle Testing

A. ***Visual Testing:*** In this type of testing the product is visually inspected by keeping it under high intensity light and then moving it at various angles to see the surface defects such as crater cracking, scratch, undercutting, slag inclusion, wear & tear, incomplete operation, bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish, large cracks and cavities, dents, inadequate dimensions and like. This method is usually done with naked eye aided or unaided.

B. Ultrasonic Testing: This method uses ultrasonic waves to detect any type of flaw within the material. The sound waves are of the frequency of 1MHz to 15 MHz and usually go up to 50 MHz. The sound waves of such high intensity penetrate inside the material and are used to detect to internal flaws and disabilities. Ultrasonic testing is mostly used on metallic structures because it gives high efficiency, though it can also be used on concrete and wooden elements but the efficiency reduces to a greater extent and the values obtained are not desirable. This testing is done with the help of a probe (transducer) which is attached to the diagnostic machine. A liquid solvent like oil, water etc is added between test product and the transducer to let the probe move smoothly over the surface of the product which in turn sends back the signals by reflection or attenuation to the same probe. More the speed of sound more will be the penetrating effect which in turn increases the detection strength and accessibility.

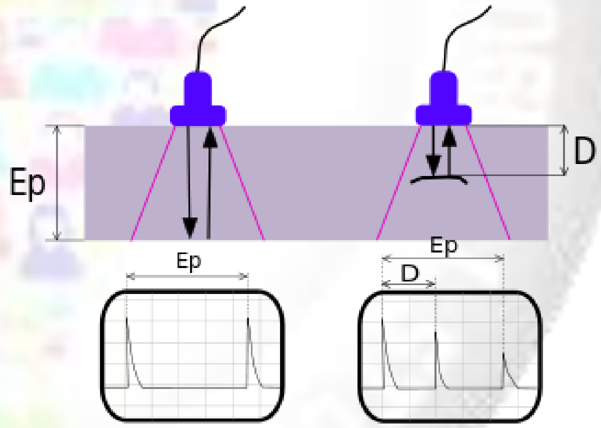

Fig. 1: An Illustration of Ultrasonic Flaw Detection.

C. Liquid Penetrant Testing: Liquid Penetrant Test also known as Dye Penetrant Inspection is an affordable type of NDT technique which gives better results than Visual Inspection to detect surface defects. In this technique a test product is selected and is coated with liquid dye solution. This dye solution may be visible or fluorescent. When this dye is applied to test product the entire surface gets immersed in the dye and this dye goes into the small holes and cracks due to capillary effect. After 5-10 minutes all the excessive dye is removed from the surface of test product and a developer is applied to the test product which acts like a blotter paper and brings out all Penetrant from the imperfections of the test product. The colour of dye and developer are contrasting in nature which helps us determine the imperfections easily. In case of fluorescent dyes, a fluorescent lamp is used to make the penetrant look brighter and help in distinguishing the imperfections on the surface of test product.

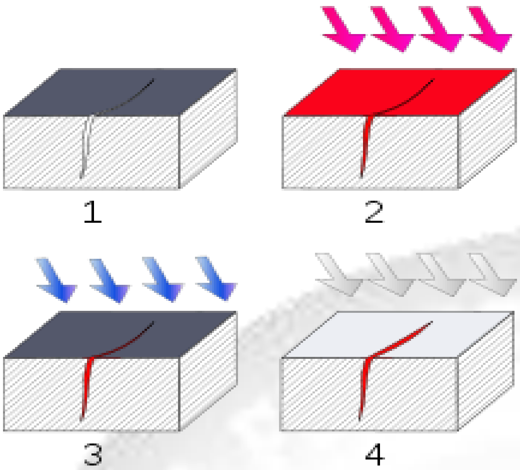

Fig.2: An Illustration of liquid penetration testing.

D. ***Magnetic Particle Inspection:*** This method is used to find our surface and near surface defect in ferromagnetic particles such as Iron, Cobalt, Nickel and their alloys etc. This technique uses magnetic field to detect the imperfections in the test product. This magnetic field may be produced by either direct or indirect magnetization. In direct magnetization electric current is passed through the test product while in indirect magnetization outer magnetic field is induced and then induced upon the test product. This technique works on the principle that the magnetic lines of forces will become distorted as soon as there comes any discontinuity in the test product. But these magnetic lines of forces are not visible to naked eye, so iron flux in the powder form is spread along the test product. If there is any deformity in the product then the flux will accumulate at the leakage point and will indicate that there is any type of defect in the test product. After detection the cause of that distortion is detected and machined. This method can use AC, DC or half DC current to magnetize the test product. The iron powder is crushed to a size of 0.5 to 10mircometers with wetting element (oil, water).

Fig.3:An Illustration of the Equipments used in Magnetic Particle Inspection

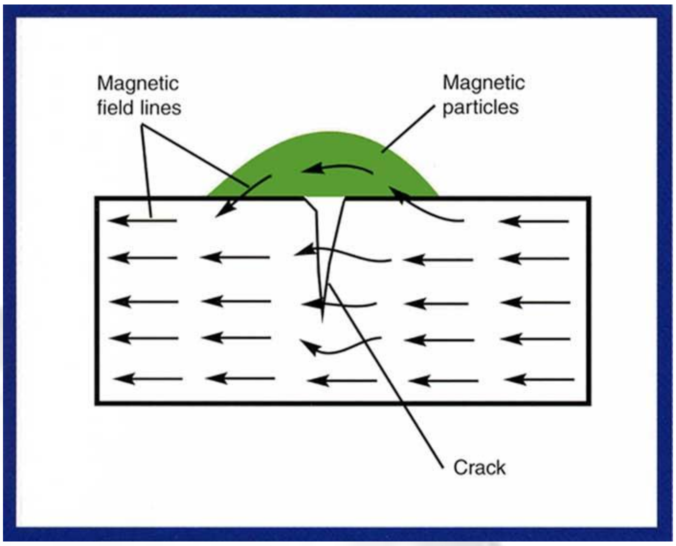

Fig.4: An Illustration of the Principle of Magnetic Particle Inspection

III. OBJECTIVES

- To evaluate defects on the surface and subsurface of materials.
- To reduce cost of the product.
- To avoid downtime of machines and wastage of materials.
- Predicting the material behaviour
- To attain high reliability.
- To detect the flaws and defects at early stages of manufacturing.
- To measure the thickness of the product.
- To evaluate the properties of material and its components.
- To provide batter quality products.
- To gain customer satisfaction.

IV. LITERATURE SURVEY

Luis S. Rosado et al. focused upon micro size superficial defects in metallic joints. The innovative system was composed by a new type of eddy currents probe, electronic devices for signal generation, conditioning and conversion, automated mechanized scanning and analysis software. The key original aspect of this system was the new type of eddy currents probe. The new probe provided enhanced lift-off immunity and improved sensitivity for micro sized imperfections. The probe concept was studied using a Finite Element Method (FEM) tool and experimental verified using a standard defect.

The testing results on some friction stir welding (FSW) specimens clearly showed that the system was able to detect superficial defects less than 60μm deep, which significantly increased the actual state of the art in NDT reliability for micro imperfections detection. This system can be applied to a broad range of manufacturing, maintenance and engineering companies [1].

Bo Li et al. focused on the relationship between primary friction stir welding process parameters and varied types of weld-defect discovered in aluminium 2219-T6 friction stir butt-welds of thick plates. Besides a series of optical metallographic examinations for friction stir butt welds, multiple non-destructive testing methods including X-ray detection, ultrasonic C-scan testing, ultrasonic phased array inspection and fluorescent penetrating fluid inspection were successfully used aiming to examine the shapes and existence locations of different weld-defects. Also the precipitated Al_2Cu phase coarsening particles were found around a 'kissing-bond' defect within the weld stirred nugget zone by means of scanning electron microscope and energy dispersive X-ray analysis. On the basis of volume conservation law in material plastic deformation, a simple empirical criterion for estimating the existence of inner material-loss defects was proposed. Defect-free butt joints were obtained after process optimization of friction stir welding for aluminium 2219-T6 plates in 17–20 mm thickness. Process experiments proved that besides of tool rotation speed and travel speed, more other appropriate process parameter variables played important roles at the formation of high-quality friction stir welds, such as tool-shoulder target depth, spindle tilt angle, and fixture clamping conditions on the work-pieces. Furthermore, the nonlinear correlation between weld tensile strengths and weld crack-like root-flaws of different lengths was briefly investigated [2].

M. Thornton et al. evaluated an ultrasonic C-scan technique for non-destructive testing (NDT) of resistance spot welding of aluminium. It was established through fundamental trials that removal of surface indentation from the welding electrode is necessary in order to obtain credible non-destructive assessments of aluminium spot weld size and shape. The non-destructive test results showed good correlation with peeled samples and metallographic cross sections. The technique also provided further fundamental understanding of aluminium resistance spot welding (RSW) process; especially with respect to the presence of an outer fused ring. The fundamental aspect of this study was underpinned using the NDT technique for a real assembly; challenging the technique with access issues, different material combinations, multiple joint stacks and independent measurements. The non-destructive test analyses obtained correlated well with actual tear down results and offered further encouragement that the C-scan technique is viable as a production tool if a suitably flattened surface can be provided [3].

B. Ghaffari et al. discussed non-destructive evaluation of spot welds, with emphasis on ultrasonic inspection of resistance spot welds in mild steel. Detection of stick welds and of small nuggets surrounded by a zinc corona is the principal challenges faced by resistance spot-weld inspection. The post-process single-element ultrasonic method is the most common inspection technique currently employed in manufacturing environments. Recent interest has centred on imaging techniques, which offer spatially resolved information and increased sensitivity, and on in-process inspection, which allows examination of the events that occur during the course of the welding process. These techniques are described and their strengths and weaknesses are discussed [4].

Luis S. Rosado et al. studied the geometrical parameters of an eddy currents planar probe intended for non-destructive testing. Finite element modelling simulations were used to evaluate the effect of each geometrical parameter on the probe response amplitude and spatial discrimination while testing an arbitrary defect. A representative set of probes was produced and used to experimentally validate the simulation study. The results show that modifications of the studied parameters can substantially improve the probe performance targeting specific testing requirements. Additional probes were produced using parameters combination optimized for two different testing situations. It also showed that the modification of the defects properties does not substantially modify the relative effectiveness of the additional probes produced [5].

Mohammed Cherfaoui presented in this article that all the stages of implementation of a process that allowed initially to make an accurate diagnosis of the condition of a sphere of storage and to evaluate its lifetime, and then in a second time, ensured the operations back into compliance to ensure a reactivation of the structure. The process was fully insured by the CETIM and involved a hydraulic test with acoustic emission monitoring, additional Non Destructive testing (NDT) (TOFD, Ultrasonic, Magnetic), Checks by the method of metallographic replicas and/or levies, a study of life estimated by calculations based on NDT and metallurgical studies, a procedure recommending repair by welding of critical defects, the supervision during repairs and the testing after repairs [6].

Bernard Kamsu-Foguem included general methods and procedures for industrial maintenance and about principles of maintenance methods. Particularly, Non-Destructive Testing (NDT) methods were important for the detection of aeronautical defects and they were used for various kinds of material and in different environments. Conventional non-destructive evaluation inspections were done at periodic maintenance checks. Usually, the list of tools used in the maintenance program was simply located in the introduction of manuals, without any precision to their characteristics, except for a short description of the manufacturer and tasks in which they were employed. Improving the identification concepts of the maintenance tools was needed to manage the set of equipments and establish a system of equivalence, a consistent maintenance conceptualization was necessary, flexible enough to fit all current equipment, and also all those likely to be added/used in the future. The contribution was related to the formal specification of the system of functional equivalences that can facilitate the maintenance activities with means to determine whether a tool can be substituted for another by observing their key parameters in the identified characteristics. Reasoning mechanisms of conceptual graphs constitute the baseline elements to measure the fit or unfit between an equipment model and a maintenance activity model. Graph operations were used for processing answers to a query and this graph-based approach to the search method gave the logical view of information retrieval. The methodology described knowledge formalization and capitalization of experienced NDT practitioners. As a result, it enabled the selection of a NDT technique and outlined its capabilities with acceptable alternatives [7].

Bo Hu et al. studied non-destructive testing method for thin-plate aluminium alloys based on the geomagnetic field. A high-precision magnetic sensor was used to measure slight changes in the magnetic field strength. The relative permeability of aluminium alloys was proven to be greater than that of aluminium through the magnetization of aluminium alloy materials. Therefore it was known that aluminium and its alloys are paramagnetic materials. The aim of this study was to analyze the effect of magnetic field on defects and to determine the test mechanism based on the differences in relative permeability. A thin-plate aluminium alloy 2024, with a thickness of less than 2 mm, was used as a specimen. An artificial groove defect was set in the specimen. The result shows that the signal from the magnetic field was obvious and unusual at the location of the artificial defect. A metallographic test verified that other abnormities observed from the signal were consistent with the natural defects of the specimen. The magnetic method was found to be accurate, and a clear test mechanism was observed [8].

N.V. Dezhkunov et al. showed that Methyl chloroform is an important part of the special Penetrant process, but also a ‘severe ozone depletor’. It was used for advanced and special purposes which were scheduled for elimination in 2002 under the Montreal Protocol. For the replacement of methyl chloroform, the first potentially ozone-friendly chemical was HCFC-123. The rise capability factor was important for the applications of liquid Penetrant tests, but it seemed that methyl chloroform was still more suitable than HCFC-123 especially for application to shallow discontinuities [9].

P. Prokhorenko et al. described theoretically the Penetrant extraction by a powdery developer in Penetrant testing. Formulas for calculation of the minimal widths of defects detected by the Penetrant testing method, and of the time necessary for impregnation of a developer layer with the prescribed width were derived. The influence of the developer characteristics and the initial Penetrant column length inside a defect upon the plane crack detection has been considered [10].

D.K. Hsu discussed the defects in aerospace composite structures and the ultrasonic techniques used for their non-destructive detection and characterization. The defects discussed include manufacturing defects such as porosity, errors in ply layup or stacking sequence, ply waviness, and service-induced delamination, disbond, crushed core, and microcracks. Ultrasonic inspection of both solid laminates and honeycomb sandwiches was discussed. The techniques addressed included novel processing of C-scan images in water-coupled ultrasonic testing, application of air-coupled ultrasound, and electromagnetically generated shear waves to exploit their strong interaction with fiber direction. This chapter discussed laboratory systems, stationary systems used in manufacturing environment, and portable inspection systems for field applications [11].

M.P. Paulraj et al. discussed about the detection of damages present in the steel plates using non-destructive vibration testing. A simple experimental model was developed to hold the steel plate complying with the simply supported boundary condition. Vibration patterns from the steel structure were captured based on the impact testing using a simple protocol. The vibration signals in normal condition of the steel plate were recorded. The damages of size 512nm to 1852nm were simulated manually on the steel plate using drill bits. The vibration signals in the fault condition of the steel plate were collected. The captured vibration signals were pre-processed and time domain based feature extraction algorithms were developed to extract features from the vibration signals. The conditions of the steel plate namely healthy and faulty were associated with the extracted features to establish input output mapping. A feed-forward neural network was modelled to classify the condition. The neural network parameters were adjusted to train the network. The performance of the network was calculated using Falhman criterion [12].

W. Polanschütz investigated the influences of mechanical stresses on magnetic properties. A qualitative and quantitative description of the reversible and irreversible components of the magnetostrictive effect in iron and carbon steels was presented. Applications of the effect in a new method for analysis of stress waves in mechanically stressed ferromagnetic metals, and also in an alternative strategy for enhancement of the signal-to-noise ratio of eddy current testing of tubes, wires and rods in mechanized lines were described, and a non-destructive method for evaluation of the martensite content in the structure of wire rod [13].

Abdelkrim Chelghoum presented an approach for nondestructive testing using a Laser Doppler Micrometer (LDV). The LDV is an optical instrument using laser technology to measure velocity field of a generic point located on a vibrating structural element. From the recorded velocity data, local and global frequencies as well as the corresponding modes shapes of a moving structure were evaluated and therefore monitoring of its mass and stiffness was easily carried out. Any change in the frequency value affected both mass and stiffness of the structure and therefore its global integrity. A real nondestructive test was carried out on bridge's piles and LNG tank located in the Districts of Coors and Raze (Algeria). The validation of the obtained frequencies was done using results from numerical procedures such as finite element approach which clearly showed the accuracy LDV's methodology as far as lateral movements was concerned. The velocity data, frequency and defection of any part of the structure can easily be extracted to check material integrity [14].

Anders Boström discussed the benefits of theoretical modelling of ultrasonic non-destructive testing and gave some examples from a recently developed model. This included level plots of the field radiated by a piezoelectric probe and also some examples of signal responses from testing for cracks [15].

S. Roccella et al. discussed the application of non-destructive testing (NDT) by ultrasonic technique for the control of the joining interfaces of the ITER divertor vertical target plasma facing units. The defect detection capability had to be proved for both metal to metal and metal to carbon/carbon fibre composite (CFC) joints because these two types of joints had to be realized for the manufacturing of the high heat flux units. The UT results from the investigation performed during the manufacturing, but also after the thermal fatigue testing (up to 20 MW/m^2) of six mock-ups manufactured using the Hot Radial Pressure technology (HRP) in ENEA labs were presented and compared with the evidences from the final destructive examination. Regarding the Cu/CFC joint, the effectiveness of the ultrasonic test had been deeply studied due to the high acoustic attenuation of CFC to ultrasonic waves. To investigate the possibility to use the ultrasonic technique for this type of joint, an 'ad hoc' flat Cu/CFC joint sample, that reproduces the actual annular joint interfaces, was manufactured. This flat sample had the advantage of being easily tested by probes with different geometry and frequency. UT results were compared with X-ray and eddy current testing of the same sample [16].

G. Vértesy et al. characterized cold-rolled austenitic stainless-steel samples non-destructively by means of magnetic adaptive testing (MAT). The flat samples were magnetized by an attached yoke, and sensitive, reliable descriptors were obtained from the proper evaluation, based on the measurements of series of magnetic minor hysteresis loops, without magnetic saturation of the samples. The results were compared with the results of previous measurements performed by a direct study of minor loops. Significant increase of sensitivity was found on application of MAT [17].

V. SUMMARY OF LITERATURE SURVEY

Sr. No.	Author Name(YEAR)	Investigated Problem Type
1	Luis S. Rosado, Telmo G. Santos(2010)	Micro size superficial defects in metallic joints
2	Bo Li, Yifu Shen(2011)	The shapes and existence locations of different weld-defects
3	M. Thornton, L. Han(2012)	Ultrasonic C-scan technique for non-destructive testing (NDT) of resistance spot welding of aluminium
4	B. Ghaffari, G. Mozurkewich(2010)	Detection of stick welds and of small nuggets surrounded by a zinc corona
5	Luis S. Rosado, João C. Gonzalez(2013)	Geometrical parameters of an eddy currents planar probe intended for non-destructive testing
6	Mohammed Cherfaoui(2012)	Diagnosis of the condition of a sphere of storage and its lifetime
7	Bernard Kamsu-Foguem(2012)	Detection of aeronautical defects
8	Bo Hu, Runqiao Yu (2012)	Thin-plate aluminium alloys based on the geomagnetic field
9	N.V. DEZHKUNOV, P.P. PROKHORENKO (1989)	Methyl chloroform is an important part of the special Penetrant process
10	P. Prokhorenko, N. Migoun(1988)	Penetrant extraction by a powdery developer in Penetrant testing
11	D.K. Hsu(2013)	Defects in aerospace composite structures and the ultrasonic techniques
12	M.P. Paulraj, Sazali Yaacob(2013)	Detection of damages present in the steel plates using nondestructive vibration testing
13	W. Polanschütz(1986)	The influences of mechanical stresses on magnetic properties
14	Abdelkrim Chelghoum(2012)	Approach for nondestructive testing using a Laser Doppler Vibrometer (LDV)
15	Anders Boström(1994)	Benefits of theoretical modelling of ultrasonic non-destructive testing
16	S. Roccella, G. Burrasca(2011)	Application of non-destructive testing (NDT) by ultrasonic technique for the control of the joining interfaces of the ITER divertor vertical target plasma facing units
17	G. Vértesy, I. Tomáš(2007)	Cold-rolled austenitic stainless-steel samples non-destructively by means of magnetic adaptive testing (MAT)

VI. DISCUSSION

- To influence the mechanical stresses induced in magnetic properties of materials.
- NDT is an effective way to detect any type of defect in a product without damaging its integrity.
- Magnetic Particle Testing is most widely used technique to check internal cracks in any of the ferromagnetic material and it gives better results than any of the other technique.
- To detect deep internal cracks, Ultrasonic Testing is the best method among the other techniques and it is widely used to detect cracks developed in boilers, steam turbines etc.
- In case of automobiles we can add up two or more NDT techniques to get the desired results because under load its parts goes under various types of distortions which can be checked by using different techniques.
- With the help of ultrasonic testing, huge pipelines and gas reservoirs can be easily checked and maintained, it also helps in detecting their age.
- Cold rolled austenitic sheets can be easily checked by using magnetic adaptive testing.
- Ultrasonic testing technique is used to join interfaces of the ITER divertor vertical target plasma facing units
- To detect the superficial defects which are less than 60 µm deep in friction stir welding.
- Eddy currents induced are one of the most important and effective technique to check surface defects, sub-surface defects of all the electrically conductive materials.
- Liquid penetration method is used to detect surface defects in welded joints most effectively.

VII. Conclusions

Based on the literature review it is found out that there are various types of NDT techniques which can be used in detecting defects in different products. Some techniques have advantages over other techniques. The cost, time consumed and efficiency of every NDT technique varies and we can check almost every metal, material and composites by using NDT. Going through Literature review we get to know that the NDT technique is widely used in automobile industries, aerospace, heavy industries, railways and like.

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