

Recent Trends in Industrial and other Engineering Applications of Non Destructive Testing: A Review

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Abstract

The field of NDT is a very broad, interdisciplinary field that plays a critical role in inspecting that structural component and systems perform their function in a reliable fashion. Certain standards has been also implemented to assure the reliability of the NDT tests and prevent certain errors due to either the fault in the equipment used, the miss application of the methods or the skill and the knowledge of the inspectors. Successful NDT tests allow locating and characterizing material conditions and flaws that might otherwise cause planes to crash, reactors to fail, trains to derail, pipelines to burst, and variety of less visible, but equally troubling events. However, these techniques generally require considerable operator skill and interpreting test results accurately may be difficult because the results can be subjective. This paper presents the reviews of different works in the area of NDT and tries to find out latest developments and trends available in industries and other fields in order to minimize the total equipment cost, minimize damages and maximize the safety of machines, structures and materials

Index terms— non destructive testing, objectives, literature review, summary of literature review and conclusion.

1 Introduction

on-Destructive Testing (NDT) is defined by the American Society for Non-destructive Testing (ASNT) as: "The determination of the physical condition of an object without affecting that object's ability to fulfil its intended function. Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed)." The application of physical principles for detecting in homogeneities in materials without impairing the usefulness of the materials has brought into being a technique known as "non-destructive testing".

The term NDT is often considered to be concerned only with the detection and location of flaws. Actually, the methods and techniques used in NDT measure physical properties or non-uniformity in physical properties of materials as well. Variations or non uniformities in physical properties may or may not affect the usefulness of a material, depending upon the particular application under consideration. Non destructive testing is the testing of materials, for surface or internal flaws or metallurgical condition, without interfering in any way with the integrity of the material or its suitability for service. The technique can be applied on a sampling basis for individual investigation or may be used for 100% checking of material in a production quality control system.

2 II.

3 Non Destructive Testing Methods

The common NDT methods are: Visual inspection is particularly effective detecting macroscopic flaws, such as poor welds. Many welding flaws are macroscopic: crater cracking, undercutting, slag inclusion, incomplete

5 E) RADIOGRAPHY TESTING

42 penetration welds, and the like. Likewise, VI is also suitable for detecting flaws in composite structures and
43 piping of all types. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper
44 surface finish, large cracks, cavities, dents, inadequate size, wrong parts, lack of code approval stamps and similar
45 proofs of testing.

46 4 b) Ultrasonic Testing

47 This technique is used for the detection of internal and surface (particularly distant surface) defects in sound
48 conducting materials. The principle is in some respects similar to echo sounding. A short pulse of ultrasound is
49 generated by means of an electric charge applied to a piezoelectric crystal, which vibrates for a of the crystal.
50 In flaw detection this frequency is usually in the range of 1 MHz to 6 MHz. Vibrations or sound waves at this
51 frequency have the ability to travel a considerable distance in homogeneous elastic material, such as many metals
52 with little attenuation. For example the velocity in steel is 5900 metres per second, and in water 1400 metres
53 per second. Ultrasonic testing employs an extremely diverse set of methods based upon the generation and
54 detection of mechanical vibrations or waves within test objects. The test objects are not restricted to metals, or
55 even to solids. The standard method of presenting information in ultrasonic testing is by means of a cathode
56 ray tube, in which horizontal movement of the spot from left to right represents time elapsed. The rate at
57 which the spot moves is such that it gives the appearance of a horizontal line on the screen. The system is
58 synchronised electronically so that at the instant the probe receives its electrical pulse the spot begins to traverse
59 the screen. An upward deflection (peak) of the line on the left hand side of the screen is an indication of this
60 occurrence. Electromagnetic Testing (ET), as a form of NDT, is the process of inducing electric currents or
61 magnetic fields or both inside a test object and observing the electromagnetic response. If the test is set up
62 properly, a defect inside the test object creates a measurable response. The main applications of the eddy current
63 technique are for the detection of surface or subsurface flaws, conductivity measurement and coating thickness
64 measurement. Eddy currents can be produced in any electrically conducting material that is subjected to an
65 alternating magnetic field (typically 10Hz to 10MHz). The alternating magnetic field is normally generated by
66 passing an alternating current through a coil. The coil can have many shapes and can between 10 and 500 turns
67 of wire. The magnitude of the eddy currents generated in the product is dependent on conductivity, permeability
68 and the set up geometry. Any change in the material or geometry can be detected by the excitation coil as a
69 change in the coil impedance. The simplest coil comprises a ferrite rod with several turns of wire wound at one
70 end and which is positioned close to the surface of the product to be tested. When a crack, for example, occurs in
71 the product surface the eddy currents must travel farther around the crack and this is detected by the impedance
72 change. Infrared Thermography is the science of measuring and mapping surface temperatures. Infrared and
73 thermal testing methods are characterized by the use of thermal measurements of a test object as it undergoes
74 a response to a stimulus. Thermal imaging cameras are the most common sensing method. Passive imaging of
75 machinery or electronics may be used to detect hot spots indicative of problems. Imaging of test objects after
76 the application of energy can be used to monitor the flow of heat in the object, which is a function of material
77 properties as well as boundaries. Flash thermography techniques have been very successful in imaging disbands
78 and delaminations in composite parts. Another significant recent advancement is the use of mechanical energy
79 to stimulate localized heating at sub-surface discontinuities, such as cracks in metals, opening up a new field of
80 application for the IR method. Infrared thermography, a nondestructive, remote sensing technique, has proved to
81 be an effective, convenient, and economical method of testing concrete. It can detect internal voids, delaminations,
82 and cracks in concrete structures such as bridge decks, highway pavements, garage floors, parking lot pavements,
83 and building walls. An infrared thermographic scanning system can measure and view temperature patterns
84 based upon temperature differences as small as a few hundredths of a degree Celsius. Infrared thermographic
85 testing may be performed during day or night, depending on environmental conditions and the desired results.
86 All objects emit electromagnetic radiation of a wavelength dependent on the object's temperature. The frequency
87 of the radiation is inversely proportional to the temperature. In infrared thermography, the radiation is detected
88 and measured with infrared imagers (radiometers). The imagers contain an infrared detector that converts the
89 emitting radiation into electrical signals that are displayed on a colour or black & white computer display monitor.

90 5 e) Radiography Testing

91 Radiography has an advantage over some of the other processes in that the radiography provides a permanent
92 reference for the internal soundness of the object that is radiographed. The x-ray emitted from a source has
93 an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting tube. If a void
94 present in the object being radiographed, more x rays will pass in that area and the film under the part in turn
95 will have more exposure than in the non-void areas. The sensitivity of x-rays is nominally 2% of the materials
96 thickness. Thus for a piece of steel with a 25mm thickness, the smallest void that could be detected would
97 be 0.5mm in dimension. For this reason, parts are often radiographed in different planes. A thin crack does
98 not show up unless the x-rays ran parallel to the plane the crack. Gamma radiography is identical to x-ray
99 radiography in function. The difference is the source of the penetrating electromagnetic radiation which is a
100 radioactive material such m Co 60. However this method is less popular because of the hazards of handling
101 radioactive materials. This technique is suitable for the detection of internal defects in ferrous and non ferrous

102 metals and other materials. X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes,
103 are penetrating radiation which is differentially absorbed by the material through which it passes; the greater
104 the thickness, the greater the absorption. . The technique is based on the ability of a liquid to be drawn into
105 a "clean" surface breaking flaw by capillary action. This method is an inexpensive and convenient technique
106 for surface defect inspection. Materials that are commonly inspected using LPI include the following; metals
107 (aluminium, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, plastics. The penetrant may
108 be applied to all non-ferrous materials and ferrous materials; although for ferrous components magnetic-particle
109 inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and
110 welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on
111 in-service components. LPI is based upon capillary action, where low surface tension fluid penetrates into clean
112 and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying,
113 or brushing. After adequate penetration time has been allowed, the excess penetrant is removed and a developer
114 is applied. The developer helps to draw penetrant out of the flaw so that an invisible indication becomes visible
115 to the inspector. Inspection is performed under ultraviolet or white light, depending on the type of dye used
116 fluorescent or nonfluorescent (visible). ? Section of material with a surface-breaking crack that is not visible to
117 the naked eye. ? Penetrant is applied to the surface.
118 ? Excess penetrant is removed.
119 ? Developer is applied, rendering the crack visible.

120 **6 g) Magnetic Particle Inspection**

121 This method uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components.
122 The only requirement from an inspect ability standpoint is that the component being inspected must be made
123 of a ferromagnetic material such iron, nickel, cobalt, or some of their alloys, since these materials are materials
124 that can be magnetized to a level that will allow the inspection to be effective. In its simplest application, an
125 electromagnet yoke is placed on the surface of the part to be examined, a keroseneiron filling suspension is poured
126 on the surface and the electromagnet is energized. If there is a discontinuity such as a crack or a flaw on the
127 surface of the part, magnetic flux will be broken and a new south and north pole will form at each edge of the
128 discontinuity. Then just like if iron particles are scattered on a cracked magnet, the particles will be attracted
129 to and cluster at the pole ends of the magnet, the iron particles will also be attracted at the edges of the crack
130 behaving poles of the magnet. This cluster of particles is much easier to see than the actual crack and this is the
131 basis for magnetic particle inspection. For the best sensitivity, the lines of magnetic force should be perpendicular
132 to the defect. This method is suitable for the detection of surface and near surface discontinuities in magnetic
133 material, mainly ferrite steel and iron.

134 **7 i. Acoustic Emission**

135 Acoustic emission (AE) is the sound waves produced when a material undergoes stress (internal change), as a
136 result of an external force. AE is a phenomenon occurring in for instance mechanical loading generating sources
137 of elastic waves. This occurrence is the result of a small surface displacement of a material produced due to
138 stress waves generated when the energy in a material, or on its surface is released rapidly. The wave generated
139 by the source is of practical interest in methods used to stimulate and capture AE in a controlled fashion, for
140 study and/or use in inspection, quality control, system feedback, process monitoring and others.

141 **8 ii. Acoustic Impact Technique**

142 This technique consists of tapping the surface of an object and listening to and analyzing the signals to detect
143 discontinuities and flaws. The principle is basically the same as when one taps walls, desktops or countertops
144 in various locations with a finger or a hammer and listens to the sound emitted. Vitrified grinding wheels are
145 tested in a similar manner to detect cracks in the wheel that may not be visible to the naked eye. This technique
146 is easy to perform and can be instrumented and automated. However, the results depend on the geometry and
147 mass of the part so a reference standard is necessary for identifying flaws.

148 **9 i) Magnetic Resonance Imaging**

149 Magnetic resonance imaging (MRI), nuclear magnetic resonance imaging (NMRI), or magnetic resonance
150 tomography (MRT) is a medical imaging technique used in radiology to visualize internal structures of the
151 body in detail. MRI makes use of the property of nuclear magnetic resonance (NMR) to image nuclei of atoms
152 inside the body. MRI can create more detailed images of the human body than are possible with X-rays.

153 An MRI scanner is a device in which the patient lies within a large, powerful magnet where the magnetic field
154 is used to align the magnetization of some atomic nuclei in the body, and radio frequency magnetic fields are
155 applied to systematically alter the alignment of this magnetization. This causes the nuclei to produce a rotating
156 magnetic field detectable by the scanner and this information is recorded to construct an image of the scanned
157 area of the body. Magnetic field gradients cause nuclei at different locations to process at different speeds, which
158 allows spatial information to be recovered using Fourier analysis of the measured signal. By using gradients in
159 different directions, 2D images or 3D volumes can be obtained in any arbitrary orientation. j) Near-Infrared

160 Spectroscopy Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of
161 the electromagnetic spectrum (from about 800 nm to 2500 nm). Typical applications include pharmaceutical,
162 medical diagnostics (including blood sugar and pulse oximetry), food and agrochemical quality control, and
163 combustion research, as well as research in functional neuroimaging, sports medicine & science, elite sports
164 training, ergonomics, rehabilitation, neonatal research, brain computer interface, urology (bladder contraction)
165 and neurology (neurovascular coupling).

166 Near-infrared spectroscopy is based on molecular overtone and combination vibrations. Such transitions are
167 forbidden by the selection rules of quantum mechanics. As a result, the molar absorptivity in the near IR region
168 is typically quite small. One advantage is that NIR can typically penetrate much farther into a sample than mid
169 infrared radiation. Near infrared spectroscopy is, therefore, not a particularly sensitive technique, but it can be
170 very useful in probing bulk material with little or no sample preparation.

171 10 k) Optical Microscope

172 The microscope has a digital camera, and is attached to a computer. The optical microscope, often referred to as
173 the "light microscope", is a type of microscope which uses visible light and a system of lenses to magnify images
174 of small samples. Optical microscopes are the oldest design of microscope and were possibly designed in their
175 present compound form in the 17th century. Basic optical microscopes can be very simple, although there are
176 many complex designs which aim to improve resolution and sample contrast. Historically optical microscopes
177 were easy to develop and are popular because they use visible light so that samples may be directly observed
178 by eye. The image from an optical microscope can be captured by normal light-sensitive cameras to generate
179 a micrograph. Originally images were captured by photographic film but modern developments in CMOS and
180 chargecoupled device (CCD) cameras allow the capture of digital images. Purely digital microscopes are now
181 available which use a CCD camera to examine a sample, showing the resulting image directly on a computer
182 screen without the need for eyepieces.

183 11 III.

184 12 Objectives

- 185 ? Providing better quality of products.
- 186 ? Reducing costs and increasing production.
- 187 ? Detection of unwanted failures in the very beginning phase. ? Providing the ability to inspect the equipments
188 in operational state. ? Reaching to higher levels of reliability.
- 189 ? Gaining consumer satisfaction.
- 190 ? Avoiding or reducing downtime and wastage of material. ? Thickness measurements.
- 191 ? Evaluation of surface characteristics.
- 192 ? Determining areas with high stress concentration.
- 193 ? Prediction of material behaviour.
- 194 ? To evaluate the properties of a material, component or system without causing damage. ? Internal
195 characteristics of solid structures can be examined without permanently affecting the structure.
- 196 IV.

197 13 Literature Survey

198 D. Bates et al [1] compares the use of different thermal non-destructive testing techniques to rapidly inspect
199 carbon fibre composite aircraft components. Samples were prepared to simulate inclusions and barely visible
200 impact damage in carbon fibre reinforced plastic laminate which represent faults in the manufacturing process
201 and in-service environment respectively. The limits of material fault detection were then compared for transient
202 and lock-in thermography and the results were verified with underwater ultrasonic c-scans.

203 Infrared thermography (thermal imaging) is an important and powerful technique for consideration when
204 investigating any structural situation where a ready source of surface heating (or cooling) is available. The
205 methods used are totally non-destructive and noninvasive, and can be highly cost-effective. D.J. Titman 2Global
206 Journal of Researches in Engineering (D D D D) J [2]

207 explores a wide range of applications, particularly relating to structural investigation situations. Some guidance
208 is given on optimum timing, conditions and viewing locations for the various situations described as well as
209 limitations of the technique.

210 P Cawley [3] states that The NDT market is dominated by the 'big five' techniques: radiography, ultrasonic,
211 eddy current, magnetic particle and penetrant testing. There is therefore a continuing drive to increase the speed
212 of inspection, to reduce the preparation required and, if possible, to inspect without the need to shut down
213 operation.

214 Jacek Jarmulak et al [4] present how the casebased reasoning methodology (where interpretation of new data
215 is based on previous data-interpretation cases) can be used to tackle the problem of NDT data interpretation.
216 The article presents the characteristics of CBR, which make it an interesting alternative to statistical classifiers
217 and to expert systems.

218 Non destructive testing is an important method of insuring quality of the composites. Comparing with other
219 non destructive testing methods, the ultrasonic inspection can be considered an effective method of checking the
220 common defects and damages in composites, and its development of studying and application is introduced by
221 Li Zhijun [5].

222 G. S. Park et al [6] describes the design method of a magnetic system to maximize the magnetic flux leakage
223 (MFL) in a non-destructive testing (NDT) system. The defect signals in a MFL type NDT system mainly depend
224 on the change of the magnetic leakage flux in the region of a defect.

225 The basis of the wave propagation and the principles of the hyperbolic triangulation are presented by P.
226 Tschelignig [7]. The state-of-the-art AE inspection system is explained with examples drawn from the TUV
227 Vienna's 32-channel equipment and software. The AE tests performed at TUV Vienna and the results gained
228 are discussed under the headings of integrity analysis and leakage tests.

229 Non-destructive testing provides the ability to differentiate different structures of materials or to measure
230 internal and induced stresses, thus providing data for the calculation of reliability and potential lifetime [8].
231 Here, a closer monitoring of fast processes like crack propagation, especially under an impact load, may provide
232 a better understanding of materials behaviour.

233 In Pulse Echo Ultrasonic testing piezoelectric transducers generate ultrasonic pulses, which are transmitted
234 into the specimen to check for cracks and other defects [9]. Flaws in the specimen will reflect the signals back
235 to be detected by the transducers. The amplitude and size of reflected pulses indicate the size and location of
236 the flaw. Ultrasonics is limited in its capability to characterise near surface defects because of the interference
237 between transmitted and received pulses in this area.

238 A new non-destructive testing (NDT) method for defect detection in concrete structures is presented by K.
239 Mori et al [10]. The method is based on the dynamic response of flawed concrete structures subjected to impact
240 loading. Conversely to similar NDT techniques, such as the impact-echo method, the present method uses non-
241 contacting devices for both impact generation (a shock tube producing shock waves) and response monitoring
242 (laser vibrometers measuring concrete surface velocity). According to the experimental and numerical results,
243 it appears that the present method enables an effective detection of defects, particularly in the range of shallow
244 defects.

245 The use of infrared thermography in the architectural restoration field is examined by Giovanni M.
246 Carlomagno et al [11]. Three samples, made of a support of marble, brick, or tuff, covered with a layer of
247 plaster with inclusions to simulate detachments or cracks in frescoes, are considered. Different techniques: pulse
248 thermography, lateral heating thermography, lockin or modulated thermography and pulse phase thermography
249 are employed to detect the flaws artificially created.

250 M.R Clark et al [12] shows that even with the low ambient temperatures experienced in Europe it is possible
251 to use infrared thermography to identify correctly known areas of delamination in a concrete bridge structure
252 and also to investigate the internal structure of a masonry bridge. M.D. Beard et al [13] are aimed at the
253 development of a portable non-destructive testing instrument for evaluating the condition of rock bolts. In
254 applications such as coal mine roof reinforcement, the opportunities for rock bolt inspection are currently limited
255 to destructive techniques such as the pull-out test.

256 Spectral Analysis of surface waves (SASW) in concrete structures consists of the generation, measurement and
257 processing of dispersive surface waves [14]. In SASW test, the surface of the media under consideration is subject
258 to an impact using, for example, a 12-mm steel ball, to generate surface wave energy at various frequencies. Two
259 vertical accelerometer receivers detect the energy transmitted through the testing media.

260 The optimum elements of the suitably defined matrices of the magnetic variables, based on the measurement
261 of families of minor hysteresis loops, are more sensitive than any of the traditional parameters obtained from
262 the saturation-to-saturation loop [15]. In order to get the optimum elements, the samples do not have to be
263 measured up to their saturation value, but to a pre-determined lower magnetization value only.

264 The J wheels and gauge corners was the main activity of the NDT division. Firstly the inspection of the wheels
265 rim and disk should be carried out without dismantling the wheels and using ultrasonic techniques [16]. On the
266 other hand, the inspection of the railroad track surface at a train speed of about 70 km/h should be guaranteed
267 using eddy current techniques.

268 Thermal non-destructive testing (NDT) is commonly used for assessing aircraft composites. In this work,
269 certain applications of transient thermal NDT relating to the assessment of aircraft composites are presented by
270 N.P. Avdelid et al [17]. Real-time monitoring of all features was obtained using pulsed thermography. However, in
271 the composite repairs cases thermal modelling and pulsed-phase thermography were also used with the intention
272 of providing supplementary results.

273 Pulsed eddy current techniques, which are believed to be potentially rich of information, are also sensitive to
274 the effect. Gui Yun Tian et al [18] gives an approach using normalisation and two reference signals to reduce
275 the lift-off problem with pulsed eddy current techniques is proposed. The technique can also be applied for
276 measurement of metal thickness beneath non-conductive coatings, microstructure, strain/stress measurement,
277 where the output is sensitive to the lift-off effect.

278 C. Hakan Gur et al. [19] investigate the effect of quenching and tempering on sound velocity of steels, and to
279 contribute to the non destructive control and optimisation of the quenching/tempering systems. Microstructures
280 of the samples were characterised by metallographic examinations and hardness measurements. The reference

281 values were obtained for as-quenched and tempered structures by measuring sound velocities for both longitudinal
282 and transversal waves.

283 Impulse-thermography is well suited for the detection of voids and honeycombing in concrete up to concrete
284 covers of 10 cm and more [20]. For quantitative analysis, a computer program for numerical simulation of the
285 heating up and cooling down processes was developed based on Finite Differences. With this program parameter
286 studies have been performed for investigating the influence of environmental conditions, material parameters and
287 geometry on the thermal behaviour.

288 Yi-mei Mao et al [21] gives a detection technique for locating and determining the extent of defects and cracks
289 in oil pipelines based on Hilbert-Huang time-frequency analysis is proposed. The ultrasonic signals reflected from
290 defect-free pipelines and from pipelines with defects were processed using Hilbert-Huang transform, a recently
291 developed signal processing technique based on direct extraction of the energy associated with the intrinsic time
292 scales in the signal.

293 A non-destructive method is described by Gary S. Schajer et al [22] to estimate fiber (grain) direction,
294 moisture density, and dry density of an orthotropic material such as wood, from measurements of the complex
295 attenuation of microwaves transmitted through the material. The complex attenuation in an orthotropic material
296 has a tensor character, similar to other tensor quantities such as stress and strain.

297 Allen G. Davis et al [23] describes the use of non-destructive testing to examine the efficiency of tunnel lining
298 grouting programmes, with particular emphasis on results obtained by the impulse response and impulse radar
299 methods.

300 K. Kosmas et al [24] presents a laboratory developed Hall sensor for non-destructive testing of ferromagnetic
301 surfaces, based on magnetic anomaly detection phenomena. The principle of operation is based on the detection
302 of the magnetic flux leakage in the dimensional boundaries of a gap.

303 Bruce W. et al [25] bring together the most relevant published work on arrays for non-destructive evaluation
304 applications, comment on the state-of the art and discuss future directions. There is also a significant body of
305 published literature referring to use of arrays in the medical and sonar fields and the most relevant papers from
306 these related areas are also reviewed.

307 Impulse-thermography is an active method for quantitative investigations of the near surface region of various
308 structures [26]. It has recently been applied and optimised to applications in civil engineering. By using either
309 an internal or external heat source, parts of the structure under investigation are heated up and the transient
310 heat flux is observed by recording the temperature change at the surface as a function of time.

311 Carosena Meola et al [27] study was focused on the aid provided by lock-in thermography for nondestructive
312 evaluation of aerospace materials and structures. The experimental analysis was performed by testing
313 several specimens, which were made of different materials employed in the fabrication of aircraft (composites,
314 hybrid composites, sandwiches, metals) and which included the most commonly encountered kinds of damage
315 (delamination, impact damage, fatigue failure).

316 Christoph Kohl et al [28] present the results of measurements carried out in the laboratory at BAM and on-
317 site at several bridges using reconstructed and fused radar and ultrasonic echo data sets. In this context different
318 scanning systems, developed for the on-site application of NDT-methods (e.g. reinforced concrete bridges) are
319 introduced.

320 The diagnosis based on the propagation of guided ultrasonic waves along the pipes offers an attractive solution
321 for the fault identification and classification. Francesca Cau et al [29] J simulate the guided wave propagation
322 in the pipes. In particular, the finite element method has been used to model different kinds of pipes and faults,
323 and to obtain several returning echoes containing the faults information.

324 In the first project material degradation due to thermal aging is investigated, in the second project neutron
325 exposed specimens from national surveillance programmes of nuclear power plant (NPP) pressure vessels were
326 characterised in the hot cell of the research reactor in Patten [30]. Fatigue specimens especially prepared in LCF
327 tests were measured by electromagnetic and micro-magnetic non-destructive testing and evaluation techniques.

328 The steel cord rubber belt is one of the most important parts of a conveyor. The durability of the belt
329 depends mainly on the steel cord durability. When a conveyor belt is in use the ropes of the cord can be broken
330 or corroded [31]. Rope splice damage is also possible. A scanner with set of eddy current probes installed at
331 the belt under the test surface is significantly lighter than a magnetic one and can work in the gap up to 10-20
332 mm between the probes and the belt. D. Bracun et al [32] presents a laser-based method for three-dimensional
333 (3D) measurements of the shape of an electrode indentation. The method is based on the illumination of the
334 indentation with structured light and the detection of the image of the illuminated indentation by means of a
335 digital camera. Image processing algorithms are employed to determine the 3D shape of the indentation.

336 Janez Marko Slabe et al [33] treats the results obtained in simultaneous measurements of Acoustic Emission
337 (AE) with PZT AE sensors and of deformations with resistance measuring rosettes carried out during and
338 immediately after laser cutting-out of a deep-drawn sheet product, i.e., mudguard. It was found that the main
339 source of AE during laser cutting was the cutting gas jet.

340 In ultrasonic non-destructive testing it is very difficult to detect flaws in materials with coarse-grain structure.
341 The ultrasonic signals measured on these materials contain echoes which are very similar to fault echoes. These
342 echoes arise from grains which are contained in the material. For the detection of flaws various methods for
343 suppressing echoes from grains have to be used. Vaclav Matz et al [34] used the method for filtering ultrasonic

344 signals based on discrete wavelet transform. For the classification of ultrasonic signals in A-scan we used a pattern
345 recognition method called support vector machines. In this study we classify signals with fault echoes, echo from
346 weld and back-wall echo. Ultrasonic signals were measured on materials used for constructing aeroplane engines.

347 Defects need to be banned and dimensional measurement of complex geometries with high resolution is
348 required. In addition, throughput is high and production cycles may last only a few seconds. These objectives call
349 for non-destructive testing that keeps step with the production cycle [35]. Production and quality measurement
350 techniques therefore play an important role in providing customers with more economical and reliable products.
351 We briefly compare various NDT techniques and demonstrate the feasibility of X-ray tomography as a technique
352 suitable for the dimensional measurement of complex structures with sub- μ m resolution.

353 Dye Penetrant Inspection (DPI) and Magnetic Particles Inspection (MPI) are two of the most commonly
354 used NDT techniques in industry. Both techniques do rely heavily on human judgment and visual capability to
355 identify any faults or defects on the specimen at the end of the process. Despite the fact that human plays an
356 important role on the reliability of the NDT test results, very little research work has been carried out to study
357 the ergonomics and human factors in using these NDT methods. Several human factors which could affect the
358 reliability of the tests are discussed and some recommendations are also provided to improve the tests [36].

359 The designed software can be used to calculate mechanical and physical properties of an unknown sample if
360 the chemical composition and hardness value of that sample is available, where the effect of every element in
361 the unknown sample on its mechanical and physical properties can be deduced from the comparison between
362 the data of the same element in the standard samples [37]. In this work, tensile strength, elongation, and
363 microscopic structure of 15 standard steel samples of low and medium carbon steel were determined by using
364 destructive testing methods. Non-destructive testing (NDT) was carried out using ultrasonic pulse velocity
365 (UPV) and impact rebound hammer (IRH) techniques to establish a correlation with the compressive strengths
366 of compression tests. The resulting correlation curve for each test is obtained by changing the level of compaction,
367 water/cement ratio and concrete age of specimens. The resulting calibration curves for strength estimation were
368 compared with others from previous published literature [38].

369 Satellite nozzles are manufactured from C/SiC, using the Liquid Polymer Infiltration (LPI) process. In this
370 article the applicability of different non-destructive analysis methods for the characterisation of C/SiC components
371 will be discussed [39]. Synchrotron radiation using tomography on small samples with a resolution of 1.4 μ m, i.e.
372 the fibre scale, was used to characterise three dimensionally fibre orientation and integrity, matrix homogeneity
373 and dimensions and distributions of micro pores.

374 E. Bayraktar et al [40] gives a comparative study on the new developments in non-destructive controls of
375 the composite materials and applications in the manufacturing engineering and also reviews essentially the
376 performance and advantages of X-rays computed tomography (XR-CT) medical scanner about its usage at
377 multiple scales (macro, micro, meso and nano), the method and also the terminology.

378 Rodrigo Benenson et al [41] address the problem of autonomous navigation of a car-like robot evolving in
379 an urban environment. Such an environment exhibits a heterogeneous geometry and is cluttered with moving
380 obstacles.

381 An approach for the analysis of gamma ray incoherent scattering on free and binding electrons is presented
382 for Non destructive Testing (NDT) [42]. The method is based on computational simulation and backscattering
383 gamma ray measurements for carbon steel walls. The results of thickness measurements for steel walls are
384 described by the theory of the energy transfer model.

385 Lattice defects and microstructure in homogeneities like vacancies, dissolved atoms dislocations and precipita-
386 tions are normally not discussed as defects but they are influence parameters which mainly predict the macroscopic
387 properties, the physical properties as well as the mechanical ones [43]. In order to keep these properties constant in
388 materials production more and more material characterization by NDT is integrated in the production processes.

389 The current dynamic process in computing, microelectronics, smart sensors and automation provide NDT
390 system engineers with challenging opportunities for improved NDT solutions. Peter Bieder et al [44] focus on
391 the quantification of inspection results with respect to flaw type, flaw location and flaw size, at high inspection
392 speeds.

393 U.C. Hasar et al [45] shows microwave reflection and transmission properties measured from various sides of
394 hardened mortar and concrete specimens with different water to cement ratios. These properties are important
395 in predicting/measuring accurate electrical properties of cement-based materials which can eventually be utilized
396 in structural health monitoring, public safety, and propagation-related research.

397 Pulsed thermography, an infrared nondestructive evaluation (NDE) technique, is proposed by M. Genest et al
398 [46] for the detection of disbond and monitoring of disbond growth in bonded graphite repairs. Correlated results
399 with ultrasonic pulse echo cscan inspections and destructive testing show good disbond detection capability with
400 accuracy similar to that of ultrasonic inspection.

401 Zoltán Orbán et al [47] present methods of inspection and testing for masonry arch railway bridges. An
402 overview of a selection of available non-destructive, minor-destructive and monitoring methods is given and their
403 efficacy for the assessment of masonry arch bridges is discussed. S. Chaki et al [48] deals with a guided ultrasonic
404 wave procedure for monitoring the stress levels in seven-wire steel strands (15.7 mm in diameter). The mechanical
405 and geometrical characteristics of the prestressed strands were taken into account for optimizing the measurement
406 configuration and then the choice of the guided ultrasonic mode at a suitable frequency.

407 A.A. Shah et al [49] present findings on nonlinear ultrasonic testing of concrete. The study was focused on
408 testing cubic concrete specimens. It consisted of the non-destructive evaluation of concrete cubes using nonlinear
409 ultrasonic technique with different frequency transducers. The transducer used at the wave-transmitting end had
410 a broadband frequency of 100 kHz.

411 Ahmed Haddad et al [50] examine the applicability of eddy current techniques in-process for monitoring of
412 powder density particle size and the time necessary to structure variation. An eddy current based monitoring
413 system developed to measure metal powder density is expanded for monitoring metal powder diameter in metal
414 compounds.

415 The assessment of creep damage in steels employed in the power generation industry is usually carried out
416 by means of replica metallography, but the several shortcomings of this method have prompted a search for
417 alternative or complementary non-destructive techniques, ranging from ultrasonic to electromagnetic methods,
418 hardness measurements and nuclear techniques. A critical review [51] of the main results obtained to date in the
419 secondary and tertiary stages of creep is presented in this paper, and the advantages and disadvantages of each
420 method are discussed.

421 Pulsed eddy current (PEC) testing is a new emerging and effective electromagnetic non-destructive testing
422 (NDT) technique. The main purpose [52] of this study is to identify surface defects and sub-surface defects using
423 features-based rectangular pulsed eddy current sensor. The further study of PEC rectangular sensor proposed in
424 author's previous work has been made to classify the different types of defects in specimen. In different directions
425 of sensor scanning, peak waves of pick-up coil are studied.

426 Maryam Sargolzhahi et al [53] deal with the application of various test methods for monitoring the progression
427 of alkali-silica reaction (ASR) in laboratory concrete mixtures. The effectiveness of each method is reported.
428 Mechanical properties were assessed with conventional destructive test and with non-destructive tests (ultrasonic
429 pulse velocity, dynamic modulus of elasticity and nonlinear acoustics). Petrographic examination was performed
430 to confirm damage associated with ASR.

431 The purpose of this study is non-destructive determination of residual stresses in J [54]. A MBN-stress
432 calibration set-up and a residual stress measurement system with scanning ability were developed. To control the
433 accuracy and the effectiveness of the developed system and procedure, various MBN measurements were carried
434 out. The MBN results were verified by the hole-drilling method. Microstructural investigation and hardness
435 measurements were also conducted.

436 J. HO?A et al [55] presents a survey of state-of-the-art non-destructive diagnostic techniques of testing building
437 structures and examples of their applications. Much attention is devoted to acoustic techniques since they have
438 been greatly developed in recent years and there is a clear trend towards acquiring information on a tested
439 element or structure from acoustic signals processed by proper software using complex data analysis algorithms.

440 Highly automated processes ensure high quality on a constant level, if it is connected with a high degree of
441 (automated) monitoring and control. Meanwhile, continuous process and quality monitoring by non-destructive
442 testing (NDT) [56] is an accepted procedure to early diagnosis of irregular process conditions, followed by an
443 NDT-based feedback control and optimization. Consequently, the development of process integrated NDT is an
444 important scientific task.

445 Yong-Kai Zhu et al [57] provides a review of the main optical NDT technologies, including fibre optics,
446 electronic speckle, infrared thermography, endoscopic and terahertz technology. Among them, fibre optics features
447 easy integration and embedding, electronic speckle focuses on whole-field high precision detection, infrared
448 thermography has unique advantages for tests of combined materials, endoscopic technology provides images
449 of the internal surface of the object directly, and terahertz technology opens a new direction of internal NDT
450 because of its excellent penetration capability to most of non-metallic materials.

451 Surface defects in metals are not necessarily confined to orientations normal to the sample surface; however,
452 much of the previous work investigating the interaction of ultrasonic surface waves with surfacebreaking defects
453 has assumed cracks inclined at 90° to the surface. B. Dutton et al [58] explores the interaction of Rayleigh
454 waves with cracks which have a wide range of angles and depths relative to the surface, using a non-contact laser
455 generation and detection system. Additional insight is acquired using 3D model generated using finite element
456 method software.

457 Javier Garcia Martin et al [59] gives an overview of the fundamentals and main variables of eddy current testing.
458 It also describes the state-of-the-art sensors and modern techniques such as multi-frequency and pulsed systems.
459 Recent advances in complex models towards solving crack-sensor interaction, developments in instrumentation
460 due to advances in electronic devices, and the evolution of data processing suggest that eddy current testing
461 systems will be increasingly used in the future.

462 Cast irons look like 'composites' made of a steel matrix and graphite filler. The standard description of matrix
463 and graphite structure properties, e.g., after EN 945 is not satisfactory. Physical description of its structure can
464 be better carried out using rigidity and hardness of matrix [60]. The expression of this description in a plane
465 using bi-dimensional vector of tension strength or yield strength offers new useful relations to manufacturing
466 metallurgy.

467 Vijay R. Rathod et al [61] proposed research experimentation has been established in Central Foundry Forge
468 Plant (CFFP) of Bharat Heavy Electrical Ltd. India (BHEL). The proposed image segmentation techniques are
469 introduced to detect and assess the weld flaws from the weldments and calculate the features such as length,

470 width, area, perimeter, major axis length, minor axis length, orientation and resolution. Software has fully
471 written in Mat lab.

472 A novel ultrasonic non-destructive technique (NDT) based on application of a transmission tomography of
473 guided ultrasonic waves is proposed for floor inspection of large storage tanks and detection of non-uniformities,
474 such as corrosion [62]. The technique needs access only to the outer edge of the tank floor and does not require
475 emptying the tank. Estimation of the attenuation of different wave modes propagating in steel plates and
476 determination of the losses in the lap welds showed that most suitable is S0 Lamb wave mode which possesses
477 smallest losses and consequently enables investigation of tank floors up to average diameter 20-30 m.

478 Antonio J. Salazar et al [64] reports the influence of surface roughness on the characterisation, through the
479 use of ultrasonic signals, of AISI-SAE 4340 steel samples. The samples were prepared with varying surface
480 roughnesses, applied through mechanical methods and measured using a Mitutoyo Surfest-211. A normal
481 incidence direct contact pulse-echo method was applied, using transducers of 5, 7.5 and 10 MHz, all with a
482 0.375 inch diameter.

483 Sharad Shrivastava et al [65] deals with the existing research gap in medical field by the application of non-
484 destructive testing technique. They give a general idea about the various non-destructive testing techniques
485 used in biomedical field. It also covers the disadvantages of various techniques and how these disadvantages
486 can be taken care by Acoustic emission and Acousto-ultrasonic technique Christian Garnier et al [66] evaluate
487 the efficiency of these NDT methods in the detection of in site defects resulting from Barely Visible Impact
488 Damages (BVID) or in-service damages to complex surfaces such as wings or rods. The size and position of all
489 the defects were determined by GVI (General Visual Inspection). The evaluation of the three NDT techniques
490 NDT techniques that provide surface and internal information of the blade are necessary. I. ??menabar et al
491 [67] inspect the detection capabilities and performance of ultrasonic, shearography, thermography and X-ray CT
492 techniques for the inspection of wind turbine blades with delamination defects have been analyzed.

493 F. Van den Abeele et al [68] gives the philosophy of risk based inspection is introduced and recent advances
494 in non destructive testing (in particular ultrasonic and electromagnetic techniques) are reviewed. Then, the use
495 of fracture mechanics based damage models is demonstrated to predict fatigue failure for offshore structures.

496 The capability of the new approach of AE acquisition in discriminating between different loading and damage
497 states is shown and discussed by T.H. Loutas et al [69]. Interesting findings on the effect of the oil temperature
498 upon AE recordings only speculated theoretically so far are also presented. Both methods yielded interesting
499 results and showed an ability to distinguish between healthy and defected gears.

500 Bo Li et al [70] study focused on the relationship between primary friction stir welding process parameters and
501 varied types of weld-defect discovered in aluminium 2219-T6 friction stir butt-welds of thick plates, meanwhile,
502 the weld-defect forming mechanisms were investigated. Besides a series of optical metallographic examinations
503 for friction stir butt welds, multiple non-destructive testing methods including X-ray detection, ultrasonic C-scan
504 testing, ultrasonic phased array inspection and fluorescent penetrating fluid inspection were successfully used
505 aiming to examine the shapes and existence locations of different weld-defects.

506 A. Lopes Ribeiro et al [71] show that a simple algorithm used to model the eddy current inspection of an
507 aluminium plate can be used to preview the acquired voltage signals. Thus, the algorithm is suitable to work
508 as a forward problem solver to determine the expected measurement signal obtained with a uniform excitation
509 field probe including a giant magneto resistor sensor. The algorithm is based on a conformal transformation and
510 is able to preview the shape of the electrical current lines when a metallic plate with a superficial straight crack
511 is subject to a sinusoidal excitation field with constant amplitude and orientation in a bounded zone around the
512 sensor element.

513 Umesh Singh et al [72] reviews magnetic particle crack detection (MPCD) in terms of principle, advantages,
514 disadvantages and limitations. Different mine gear components are evaluated through MPCD technique and
515 results are analyzed in terms of their suitability by applying acceptance/rejection norms followed by the mining
516 industry in India. MPCD is now a widely acceptable technique in the world and has simplified inspection
517 processes, leading to significant cost reductions and quality control enhancement and confidence.

518 Rodrigo Velázquez Castillo et al [73] analyze the relevance of Non Destructive Technique (NDT) thermal
519 infrared imaging (TIRI) as a way of reference to the heritage conservation. The assessment of thermography
520 testing was done in order to evaluate the correspondence concerning the physical and chemical characterization
521 and compatibility among original and restored plastered mortars and stuccos, considering the correlation between
522 thermal emissivity values and other well-known materials characterization methods such as Fourier Transform
523 Infrared (FTIR), X-ray diffraction (XRD).

524 Bo Hu et al [74] propose a non-destructive testing method for thin-plate aluminium alloys based on the
525 geomagnetic field. A high-precision magnetic sensor was used to measure slight changes in the magnetic field
526 strength. The relative permeability of aluminium alloys was proven to be greater than that of aluminium through
527 the magnetization of aluminium alloy materials. Therefore, aluminium and its alloys are paramagnetic materials.
528 The aims of the current study are to analyze the effect of magnetic field on defects and to determine the test
529 mechanism based on the differences in relative permeability.

530 The inspection of voids in external PT tendons is important and necessary in order to protect strands before
531 corrosion occurs. Based on literature review [75], several Non Destructive Testing (NDT) methods are compared

532 for effectiveness of identifying voids in external PT tendons, and the Impact Echo (IE), ultrasonic, and sounding
533 inspection methods are then selected and assessed using small-scale and mock-up specimens.

534 A variety of NDT tests were targeted at different parts of the bridge elements, and have been conducted as
535 part of a major investigation into the bridges [76]. The NDT tests performed included; Magnetic Flux Leakage
536 Tests and Radiographic Tests at hanger sockets and Dye Penetrant Testing / Magnetic Particle Testing of the
537 welding, non destructive testing on the concrete parts in anchorage rooms comprised of Schmidt Hammer Tests
538 and Carbonation Depth Tests of concrete.

539 I. Afara et al [76] evaluates the viability of near infrared (NIR) spectroscopy, an EM method for rapid non-
540 destructive evaluation of articular cartilage. Intact, visually normal cartilage-on-bone plugs from 2-3yr old bovine
541 patellae were exposed to NIR light from a diffuse reflectance fibre-optic probe and tested mechanically to obtain
542 their thickness, stress, and stiffness.

543 A recently developed frequency-modulated thermal wave imaging (FMTWI) has been applied for subsurface
544 defect detection of jute fibre-reinforced 2 J polypropylene (PP) matrix composite [77]. Composites are subject
545 to manufacturing and in-service defects like voids, delamination, cracks and so on. Active thermography like
546 lock-in thermography (LT) and pulsed thermography (PT) has been widely used for nondestructive testing of
547 composites and laminates.

548 V.

549 14 Summary of Literature Survey

550 The summery researches done by experts in the area of NDT have been presented in Table1 which Carries the
551 Author name, year and investigated problem types.

552 15 Discussion

553 ? The ultrasonic inspection can be considered an effective method of checking the common defects and damages
554 in composites. ? AET as a NDT tool will make an important contribution to increased security for pressure
555 vessels and better protection against environmental pollution. ? Pulse thermography is easy and fast to use
556 for information about the state of the art treasures, but data may be affected by non-uniform heating and local
557 variation of thermal emission. ? NDT is essential in the inspection of alteration, repair and new construction
558 in construction industry and Spectral analysis of surface waves (SASW) in concrete structures is widely used. ?
559 In the composite repairs cases thermal modelling and pulsed-phase thermography were also used, whilst in the
560 case of through skin imaging thermal modelling was also used in order to demonstrate the importance of thermal
561 contact resistance between two surfaces (skin and strut).

562 16 Conclusions

563 Based on the literature review, it is concluded that the various non destructive techniques have many advantages,
564 but also some disadvantages. Many NDT techniques have the ability to detect and characterize defects in
565 structures made entirely of composite materials. Based on the literature review, it was found that most of
566 the NDT techniques are primarily being used in the aerospace industry, manufacturing industries and have the
567 potential to be used for evaluating civil infrastructures. More research needs to be performed on these techniques
568 to make them applicable for field use for civil infrastructure. ^{1 2 3}

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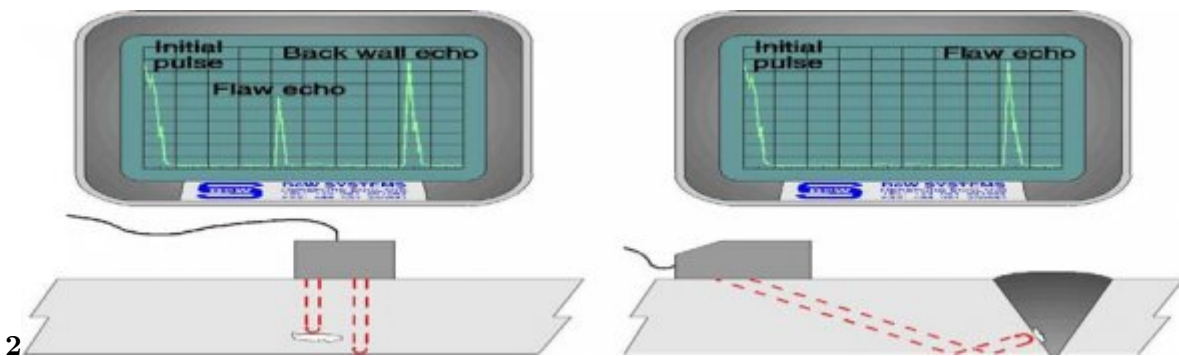
²© 2013 Global Journals Inc. (US) Volume XIII Issue III Version I

³© 2013 Global Journals Inc. (US) of non-destructive testing techniques suitable for delamination inspection
in wind turbine blades; Composites Part B: Engineering, Volume 42, Issue 5, July 2011, Pages 1298-1305.



1

Figure 1: Figure 1 :



2

Figure 2: AFigure 2 :

Schematic diagram of ultrasonic detection of slag in steel section using a normal probe.

3

Schematic diagram of the use of an angle probe to detect defects not directly under the probe. Such as in weld inspection.

Figure 3: Figure 3 :

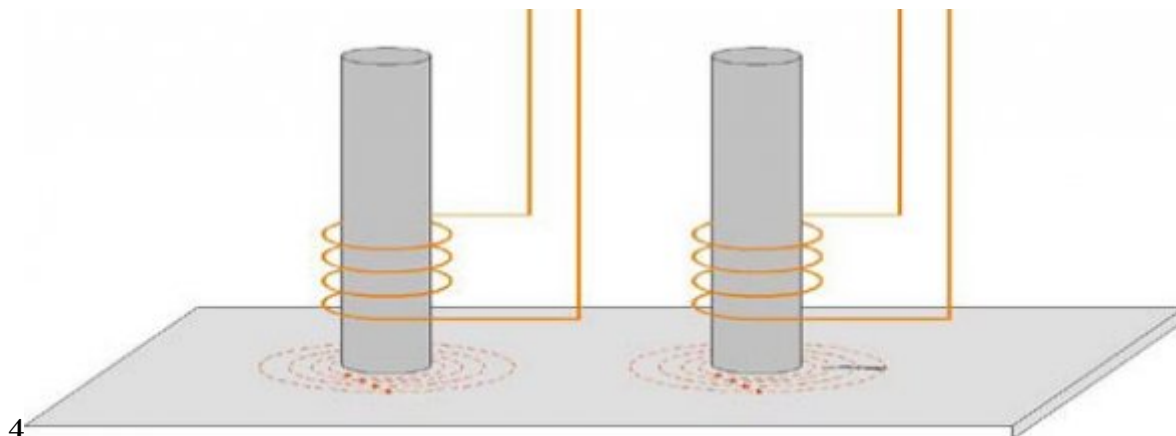


Figure 4: Figure 4 :

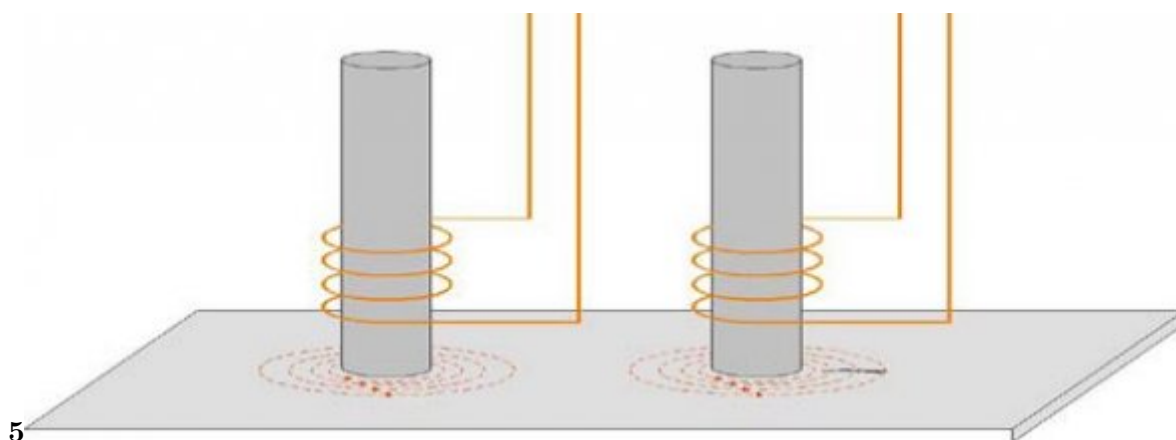


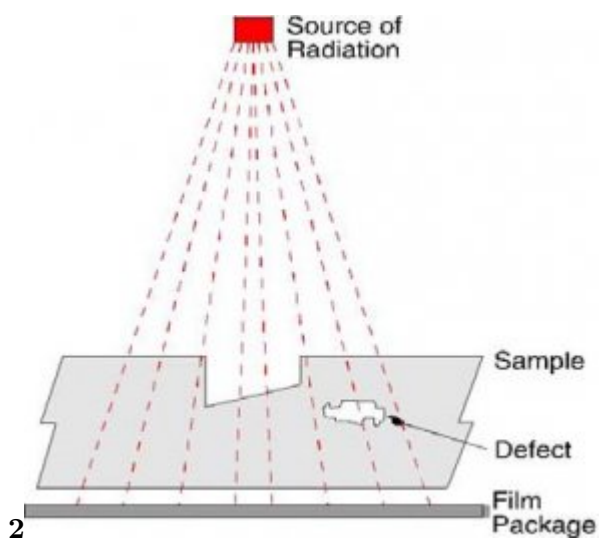
Figure 5: Figure 5 :



Processed Film

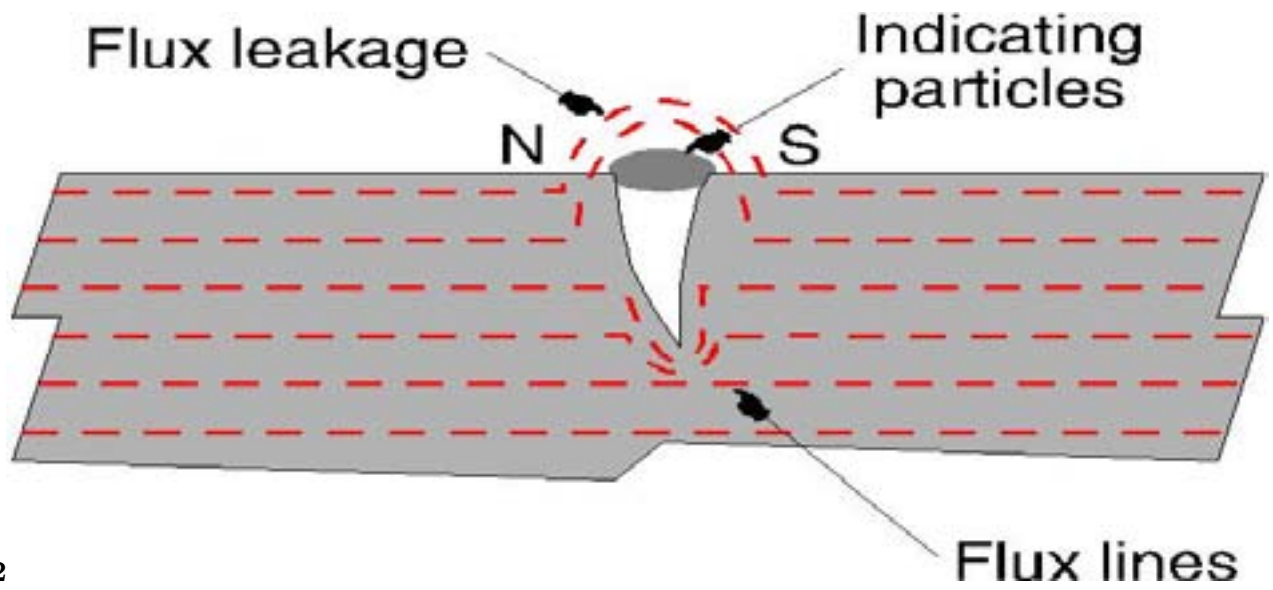
The resultant radiograph shows the subject as seen from the source.

Figure 6:



Schematic illustration of a typical exposure arrangement for radiography. The source of radiation can be either an X-ray tube or a radioactive isotope.

Figure 7: 2 Global



2

Figure 8: 2 Global

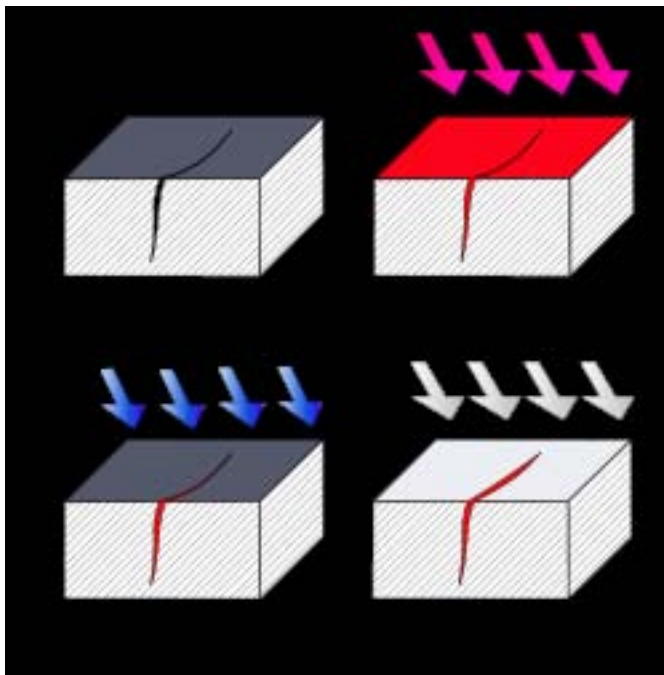


Figure 9:

1

Sr. no.	Author Name (Year)	Investigated Problem Type
2		

Figure 10: Table 1 :

VII.
D D D D)
Global Journal of Researches in Engineering (

[Note: J?]

Figure 11:

569 V. Sukhorukov (2006) Steel cord conveyor belt NDT D. ??racun et al (2006) Indentation shape parameters
570 as indicators of spot weld quality Janez Marko Slabe et al ??2006) Measurement of acoustic emission and
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