Outline

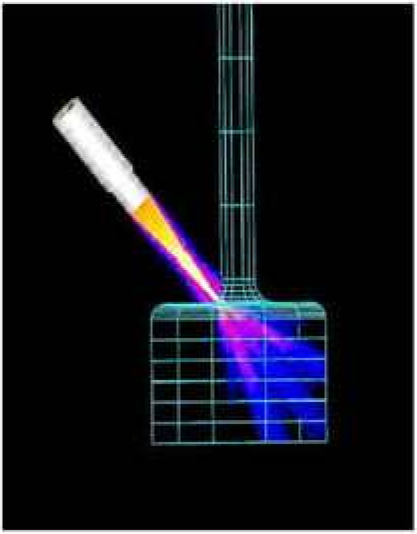
- Introduction to NDT
- Selected Applications
- Overview of Six most common NDT methods
- Process of each NDT Method
- Advantages and limitations of NDT methods
- Conclusion

Definition of NDT

The use of noninvasive(undisturbed) techniques to determine the integrity of a material, component or structure

or

quantitatively measure some characteristic of an object.



i.e. Inspect or measure without doing harm.

Methods of NDT

Thermography

Visual

Microwave

Magnetic Particle

Tap Testing

Acoustic Microscopy

X-ray

Acoustic Emission

Magnetic Measurements

Liquid Penetrant

Ultrasonic

Replication

Laser Interferometry

Eddy Current

Flux Leakage

What are Some Uses of NDE Methods?

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination

When are NDE Methods Used?

There are NDE application at almost any stage in the production or life cycle of a component

- To assist in product development
- To screen or sort incoming materials
- To monitor, improve or control manufacturing processes
- To verify proper processing such as heat treating
- To verify proper assembly
- To inspect for in-service damage

Importance of NDT

1. NDT increases the safety and reliability of the product during operation.
2. It decreases the cost of the product by reducing scrap and conserving materials, labor and energy.
3. It enhances the reputation of the manufacturer as a producer of quality goods. All of the above factors boost the sales of the product which bring more economical benefits for the manufacturer.
4. NDT is also used widely for routine or periodic determination of quality of the plants and structures during service.
5. This not only increases the safety of operation but also eliminates any forced shut down of the plants.

Scope of NDT

- Non-destructive testing is a descriptive term used for the examination of materials and components in such a way that allows materials to be examined without changing or destroying their usefulness. NDT or NDE can be used to find, size and locate surface and subsurface flaws and defects.

- NDT plays a crucial role in everyday life and is necessary to assure safety and reliability. Typical examples are found in aircraft, spacecraft (shuttle), motor vehicles, pipelines, bridges, trains, power stations, refineries, buildings and oil platforms which are all inspected using NDT.

Scope of NDT Cont..

- NDT is a Quality Assurance management tool which can give impressive results when used correctly. It requires an understanding of the various methods available, their capabilities and limitations, knowledge of the relevant standards and specifications for performing the tests

NDT is used typically for the following reasons:

Accident prevention and to reduce costs

To improve product reliability

To determine acceptance to a given requirement

To give information on repair criteria.

Scope of NDT

NDT methods are very useful in several fields:

- In automotive-engine parts, frame and other accessories.
- Aviation field space and air frame.
- In power plant- propeller, engines, gas turbines, heat exchangers etc.
- In surface flaws, cracks, gagging, dimensions etc..
- In construction of bridges, structures.
- Manufacturing of machine parts, casting, forging
- Submarines, naval ships
- Medical applications(X-rays and gamma rays)
- In railways.

ADVANTAGES OF NDT

- The equipments are easy to handle
- Defects can be detected without damaging the components
- Methods are quick and accurate
- Components can be sorted out on the basis of electrical, magnetic or chemical properties
- Test results and other information can be conveniently recorded on paper films, cassettes and floppies

Comparison Between Destructive and Non Destructive Testing

	Destructive Testing	Non Destructive testing
Purpose	It is carried to find properties and behaviour of specimen under different load	It is used to find properties of material and to find out defects.
Specimen	Specimen is damaged during test	Specimen is not damaged during test
Defects	Defects cannot be found using Destructive testing	Defects are found using NDT
Cost	More Costly	Less Costly
Example	Bending Test, Tensile Testing, Compression Testing, Impact testing e.t.c.	Ultrasonic testing, Liquid die penetrant method, eddy current testing.

DIFFERENCE BETWEEN DESTRUCTIVE AND NON DESTRUCTIVE TEST

NON DESTRUCTIVE TEST	DESTRUCTIVE TEST
Used for finding out defects of materials	Used for finding out the properties of the material
Load is not applied on the material	Load is applied on the material
No load applications, so no chance for material damage	Due to load application, material gets damaged
No requirement of special equipments	Special equipments are required
Non expensive	Expensive
Less skill	Skill is required
e.g: dye penetrate test, ultrasonic, radiography, etc	e.g: tensile test, compression test, hardness test, etc

Commonly used NDT techniques

Technique	Capabilities	Limitations
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, no subsurface flaws.
Microscopy	Small surface flaws	Not applicable to larger structures; no subsurface flaws.
Radiography	Subsurface flaws	Smallest defect detectable is 2% of the thickness; radiation protection. No subsurface flaws not for porous materials
Dye penetrate	Surface flaws	No subsurface flaws not for porous materials

Technique	Capabilities	Limitations
Ultrasonic	Subsurface flaws	Material must be good conductor of sound.
Magnetic Particle	Surface / near surface and layer flaws	Limited subsurface capability, only for ferromagnetic materials.
Eddy Current	Surface and near surface flaws	Difficult to interpret in some applications; only for metals.
Acoustic emission	Can analyze entire structure	Difficult to interpret, expensive equipments.

Six Most Common NDT Methods

1. **Visual Testing (VT)**
2. **Dye Penetrant Testing (DPT)**
3. **Magnetic Particle Testing (MPT)**
4. **Ultrasonic Testing (UT)**
5. **Eddy Current Testing (ECT)**
6. **Radiography Testing (RT)**

Visual Testing

Visual testing is the most basic and common inspection method involves in using of human eyes to look for defects. But now it is done by the use special tools such as video scopes, magnifying glasses, mirrors, or borescopes to gain access and more closely inspect the subject area.

Visual Testing Equipments:

•Mirrors (especially small, angled mirrors),
•Magnifying glasses,
•Microscopes (optical and electron),
•Borescopes and fiber optic borescopes,
•Closed circuit television (CCTV) systems,
•Videoscope.

Visual Inspection

Most basic and common inspection method.

Tools include fiberscopes, borescopes, magnifying glasses and mirrors.

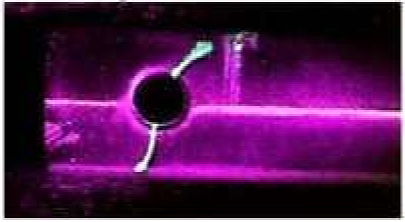
Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

Liquid Penetrant Inspection

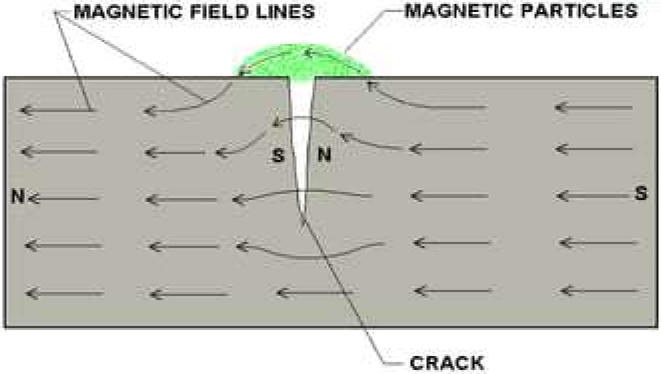
- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.



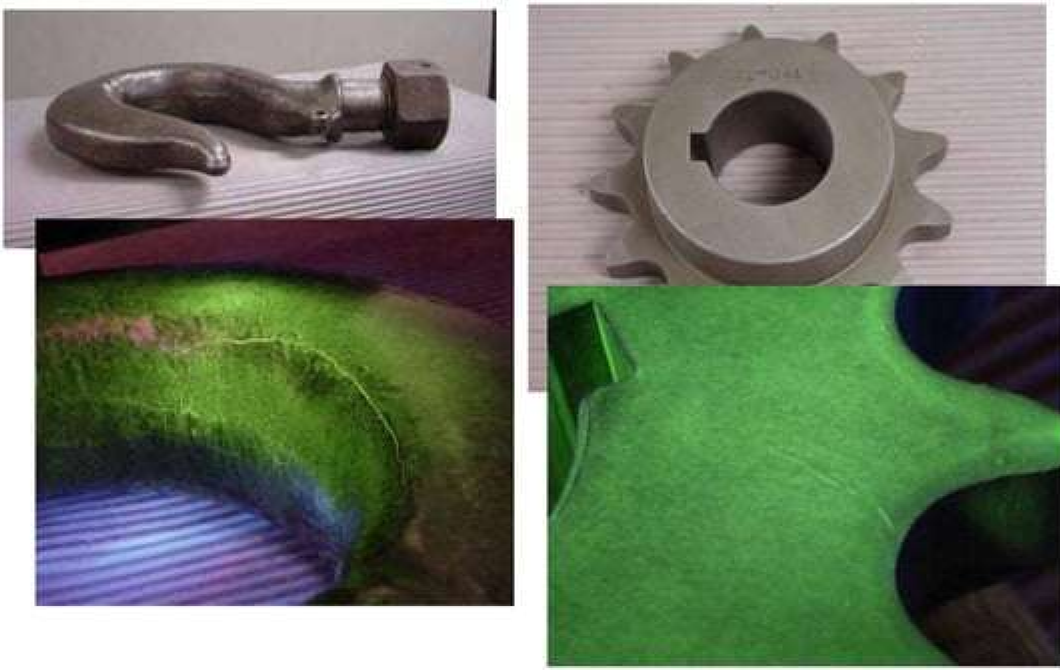



Magnetic Particle Inspection

The part is magnetized. Finely milled iron particles coated with a dye pigment are then applied to the specimen. These particles are attracted to magnetic flux leakage fields and will cluster to form an indication directly over the discontinuity. This indication can be visually detected under proper lighting conditions.

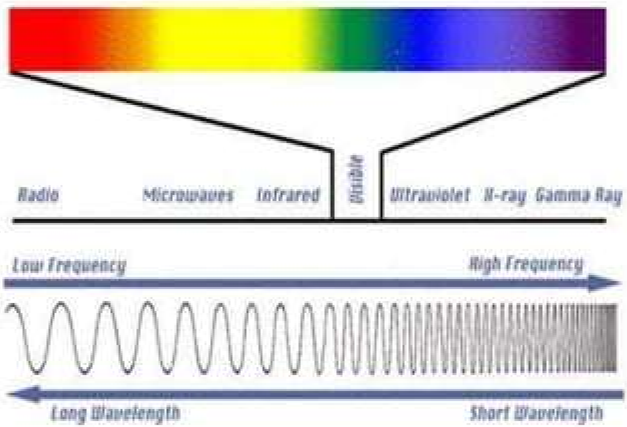


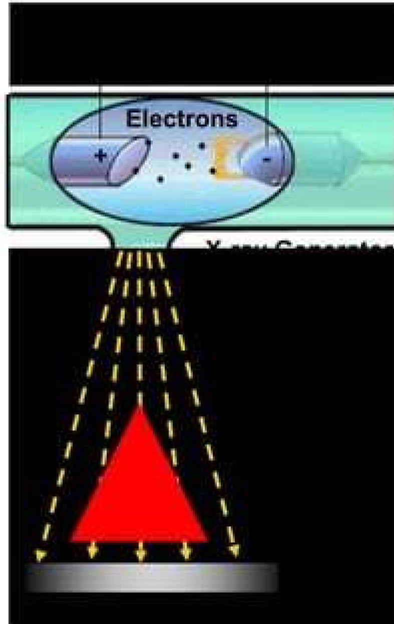
Magnetic Particle Crack Indications



Radiography

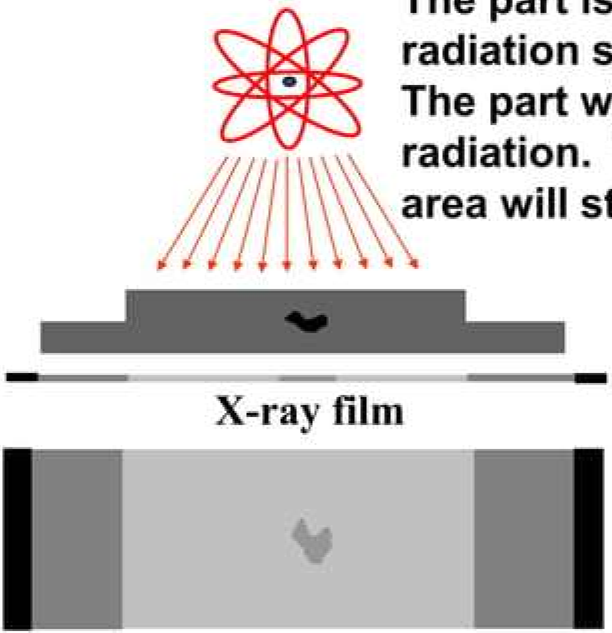
The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.





Film Radiography

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.



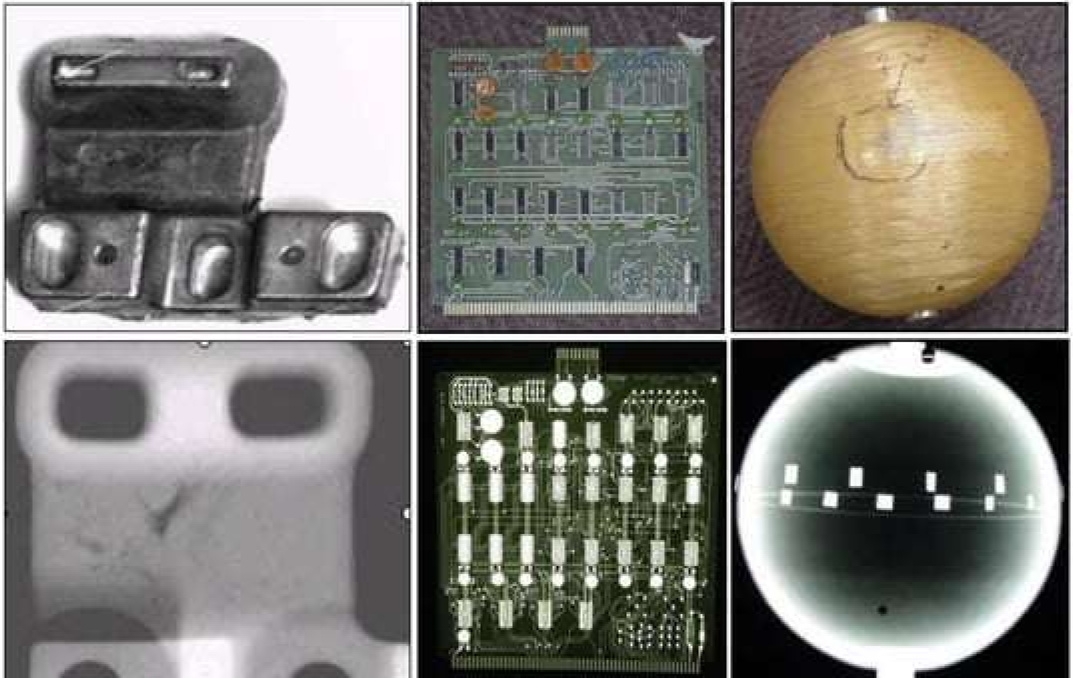
Top view of developed film

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

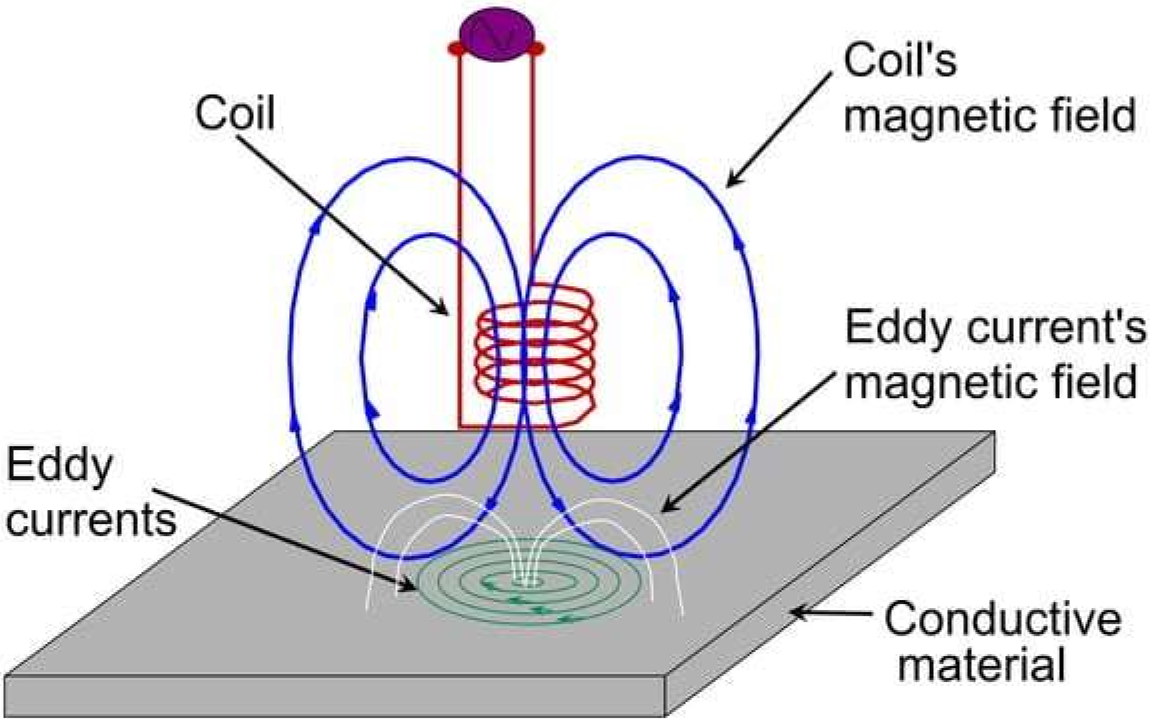
= less exposure

= more exposure

Radiographic Images



Eddy Current Testing



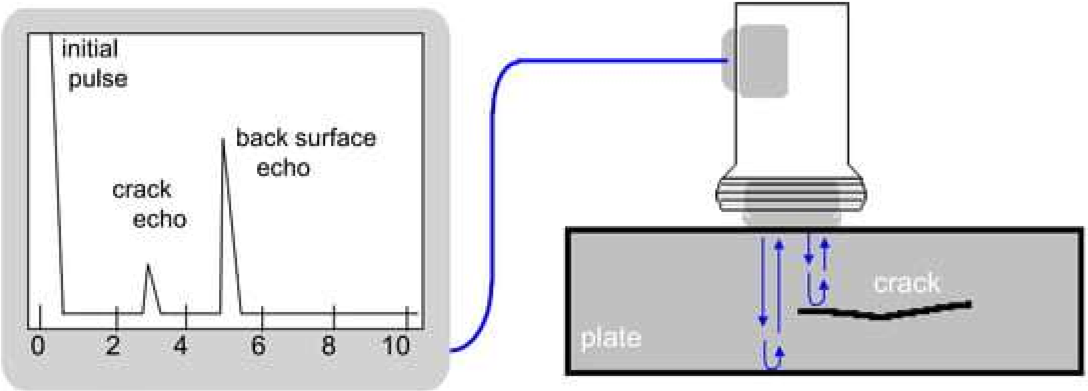
Eddy Current Testing

Eddy current testing is particularly well suited for detecting surface cracks but can also be used to make electrical conductivity and coating thickness measurements. Here a small surface probe is scanned over the part surface in an attempt to detect a crack

Ultrasonic Inspection (Pulse-Echo)

High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.



Oscilloscope, or flaw detector screen

Ultrasonic Imaging

High resolution images can be produced by plotting signal strength or time-of-flight using a computer-controlled scanning system.

Gray scale image produced using the sound reflected from the front surface of the coin

Gray scale image produced using the sound reflected from the back surface of the coin (inspected from "heads" side)

Advantages of NDT

1. Analysis of parts can be done without breaking it.
2. Cost saving procedure.
3. Improves the quality of production.
4. Save times in production evaluation.
5. Evaluation can be done at manufacturing stage or in service stage.
6. Portable mode of inspection.
7. Surface defects and inside defects can be easily evaluated.

Applications

1. Flaw detection & evaluation
2. Leak detection
3. Location Determination
4. Dimensional measurement
5. Structure and Microstructure characterization
6. Estimation of Mechanical and Physical Properties
7. Stress (strain) and Dynamic response.

Common Application of NDT

- Inspection of Raw Products
- Inspection Following Secondary Processing
- In-Services Damage Inspection

Inspection of Raw Products

- Forgings,
- Castings,
- Extrusions,
- etc.

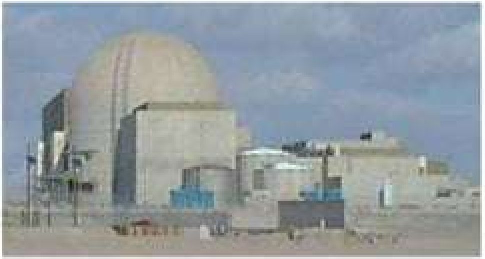
Inspection Following Secondary Processing

- Machining
- Welding
- Grinding
- Heat treating
- Plating
- etc.

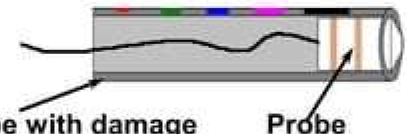
Inspection For In-Service Damage

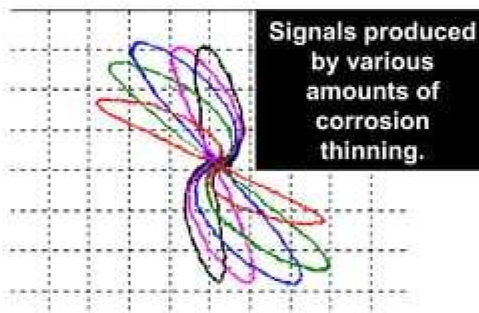
- Cracking
- Corrosion
- Erosion/Wear
- Heat Damage
- etc.

Power Plant Inspection



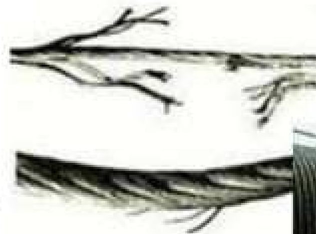
Periodically, power plants are shutdown for inspection. Inspectors feed eddy current probes into heat exchanger tubes to check for corrosion damage.





Wire Rope Inspection

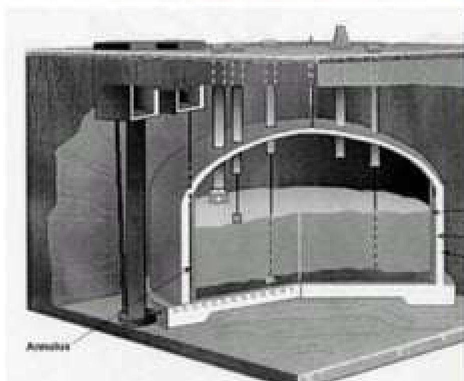
Electromagnetic devices and visual inspections are used to find broken wires and other damage to the wire rope that is used in chairlifts, cranes and other lifting devices.



Storage Tank Inspection

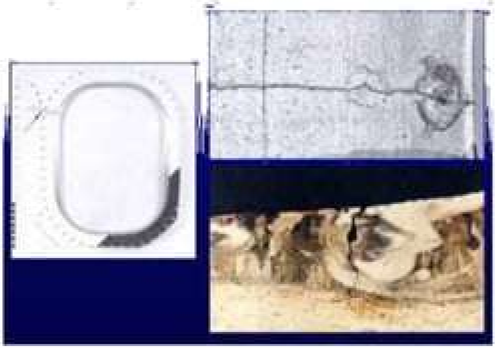
Robotic crawlers use ultrasound to inspect the walls of large above ground tanks for signs of thinning due to corrosion.

Cameras on long articulating arms are used to inspect underground storage tanks for damage.



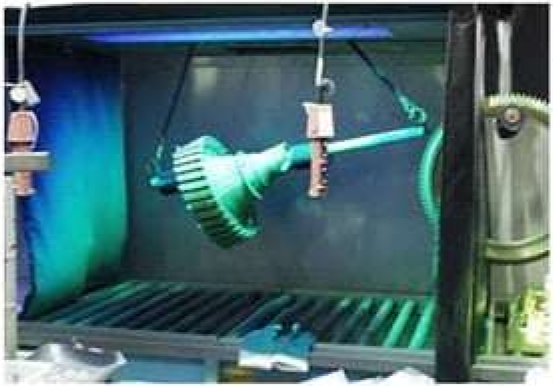
Aircraft Inspection

- Nondestructive testing is used extensively during the manufacturing of aircraft.
- NDT is also used to find cracks and corrosion damage during operation of the aircraft.
- A fatigue crack that started at the site of a lightning strike is shown below.



Jet Engine Inspection

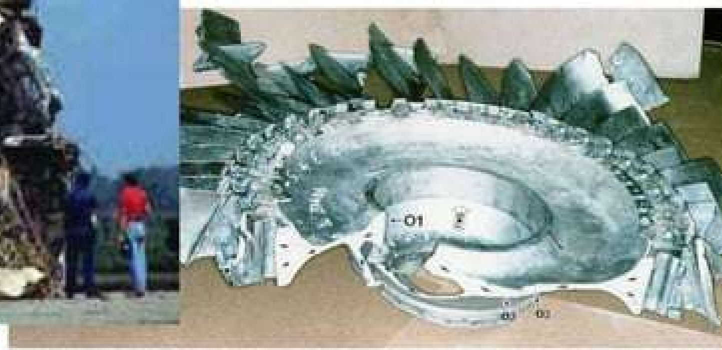
- Aircraft engines are overhauled after being in service for a period of time.
- They are completely disassembled, cleaned, inspected and then reassembled.
- Fluorescent penetrant inspection is used to check many of the parts for cracking.



Crash of United Flight 232

Sioux City, Iowa, July 19, 1989

A defect that went undetected in an engine disk was responsible for the crash of United Flight 232.



Pressure Vessel Inspection

The failure of a pressure vessel can result in the rapid release of a large amount of energy. To protect against this dangerous event, the tanks are inspected using radiography and ultrasonic testing.

Rail Inspection

Special cars are used to inspect thousands of miles of rail to find cracks that could lead to a derailment.

Bridge Inspection

- The US has 578,000 highway bridges.
- Corrosion, cracking and other damage can all affect a bridge's performance.
- The collapse of the Silver Bridge in 1967 resulted in loss of 47 lives.
- Bridges get a visual inspection about every 2 years.
- Some bridges are fitted with acoustic emission sensors that "listen" for sounds of cracks growing.

Pipeline Inspection

NDT is used to inspect pipelines to prevent leaks that could damage the environment. Visual inspection, radiography and electromagnetic testing are some of the NDT methods used.


Photo Courtesy of Inuktun

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Special Measurements

Boeing employees in Philadelphia were given the privilege of evaluating the Liberty Bell for damage using NDT techniques. Eddy current methods were used to measure the electrical conductivity of the Bell's bronze casing at various points to evaluate its uniformity.

TERMINOLOGY

The standard US terminology for Nondestructive testing is defined in standard (**American Society for Testing and Materials)** ASTM E-1316. Some definitions may be different in European standard EN 1330.

INDICATION

The response or evidence from an examination, such as a blip (a temporary change or a small spot of light) on the screen of an instrument. **Indications are classified as *true* or *false*.**

False indications are those caused by factors not related to the principles of the testing method or by improper implementation of the method, like film damage in radiography, electrical interference in ultrasonic testing etc.

True indications are further classified as *relevant* and *non relevant*.

Relevant indications are those caused by flaws.

Non relevant indications are those caused by known features of the tested object, like gaps, threads, case hardening etc.

Conti…

INTERPRETATION (an explanation)

Determining if an indication is of a type to be investigated. **For example**, in electromagnetic testing, indications from metal loss are considered flaws because they should usually be investigated, but indications due to variations in the material properties may be harmless and no relevant.

FLAW

A type of discontinuity that must be investigated to see if it is rejectable. For example, porosity in a weld or metal loss.

EVALUATION

Determining if a flaw is rejectable. For example, is porosity in a weld larger than acceptable by code?

DEFECT

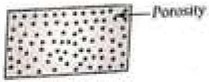
A flaw that is rejectable – i.e. does not meet acceptance criteria. Defects are generally removed or repaired.

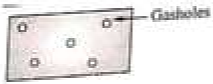
Flaws and Defects

- A defect is reported when discontinuity indications are judged unacceptable to specification criteria, other indications that do not affect the performance of the part in its intended service, should be referred to as discontinuities.
- A defect can occur at almost at any time in the history of piece of metal.
  - If it is introduced at the production stage, it is termed as inherent defect.
  - If caused during further processing, fabrication or finishing, It is called as processing defect.
  - If defect can arise during the use of the end product due either no environment or load perhaps both, these are known as service defect.

Inherent Discontinuities

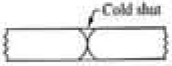
- **SCAR-** It is a shallow blow which is generally found on the flat surface after casting.
- **POROSITY-** It is arises due to reduction in solubility of gases during solidification.
- **GAS HOLES-** It is a result from entrapped gases of spherical shapes.
- **DROP-** It is a irregular shape projection on cone..
- **DROSS-** are light weight impurities appearing on the top surface of casted product.
- **DIRT-** It is a projection on the surface of casting when some embedded sand particles are removed.
- **BUCKLE-** is a long, fairly shallow, broad, v-shaped depression on casted surface.

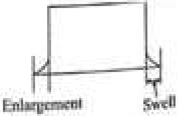


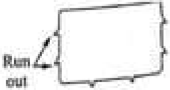


Conti...

- **WASH-** is a low projection near the gate on drag surface of casted product.
- **MISRUN-** is incomplete filling of molten fluid on the mould cavity.
- **COLD SHUT-** is a type of misrun, occurs at the centre of the casting having gates at its two sides.
- **SCAB-** It is a high projection which occurs when a portion of mould face lifts and metal flows underneath in a thin layer.
- **RAT TAIL-** these are streaks on large flat surfaces.
- **SWELL-** occurs due to enlargement of the mould cavity after pouring.
- **RUN OUT-** occurs when molten metal leaks out from the mould cavity.
- **HOT TEAR-** is a form of rapture produced by tensile stresses on the casting when it is near the solidus temperature.

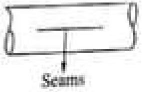






Fabrication & Processing Discontinuities

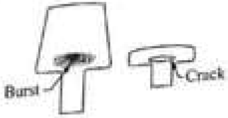
- **SEAMS-** these are surface discontinuities and appears as longitudinal scratches or folds in the material.



- **STRINGERS-** these are non metallic inclusions in slab or billets that are thinned and lengthened in the direction of rolling.

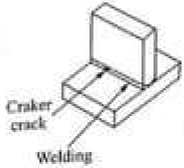
- **LAPS-** are the discontinuous irregular contours caused by the folding of metal in a thin plate on the surface at forged product.

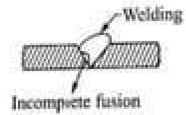
- **FORGING BURSTS OR CRACKS-** It occurs when a material is forged at a temperature at which it cant withstand at high internal stresses.

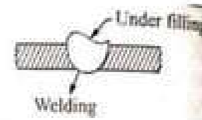


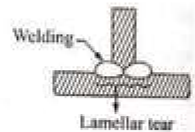
WELDING DEFECTS

- **CRATER CRACKS:-** when a welding arc is broken, a crater will form if adequate molten metal is available to fill the arc cavity.
- **SLAG INCLUSION:-** occurs when compound such as oxides, fluxes and electrode coating material that are trapped in the weld zone.
- **INCOMPLETE FUSION:-** when the depth of welded joints is insufficient.
- **UNDER FILLING:-** occurs when joints are not filled properly.
- **UNDER CUTTING:-** occurs due to melting away of the base metal.
- **LAMELLAR TEARS:-** occurs due to shrinkage of the restrained members in the structure during cooling.
- **DISTORTION and WRAPPING:-** occurs due to differential thermal expansion and contraction of different regions of the welded assembly.



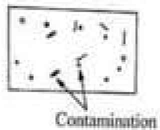


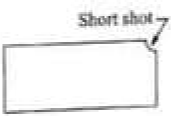




Miscellaneous Defects

- **BLUSH-** causes due to shear stress between molecules during injection and may be due to small gate or fast injection speed.
- **BURN-** is a discoloration usually black, brown or dark, yellow/brown depending upon the severity. Feels rough and crunchy.
- **COLD FLOW-** is a wavy or streaked appearance on part surface. Looks like a fingerprints and small waves on the surface of water.
- **CONTAMINATION-** foreign particles embedded in the part.
- **DELAMINATION-** is a surface of metal surface layer giving a flaking or onion skin effect.
- **JETTING-** is a squiggly line in part pointing to gate. Look like a worm in the part. Occurred due to incorrect gate placement or size.
- **SHORT SHOT-** It is a missing corners or features having a smooth rounded appearance.





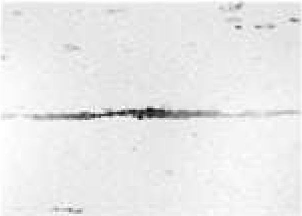


FIGURE 2.1 [illegible]

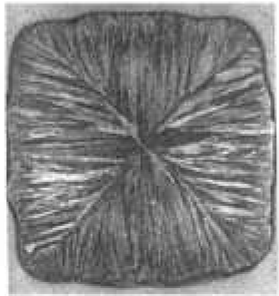


FIGURE 2.2 [illegible]

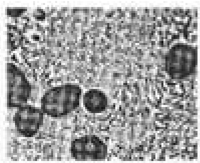


FIGURE 2.3 [illegible]

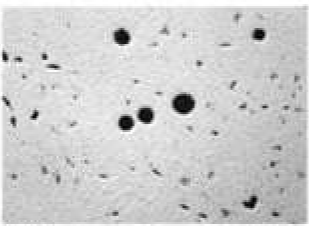


FIGURE 2.4 [illegible]

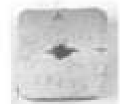
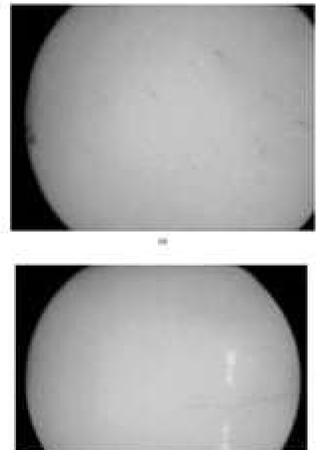


FIGURE 2.5 [illegible]



(a)

(b)

FIGURE 2.6 [illegible]

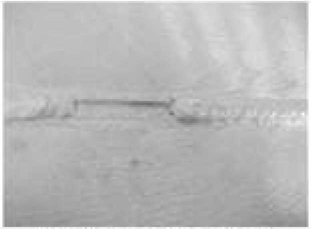


FIGURE 2.8 Lack of penetration in welds. (Courtesy of C. Hellier.)

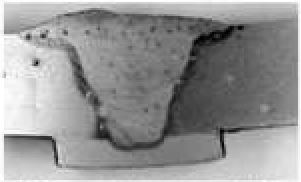


FIGURE 2.9 Cross section of a weld showing heat affected zone as a dark band adjacent to the weld. (Courtesy of R. H. Pond, Jr.)

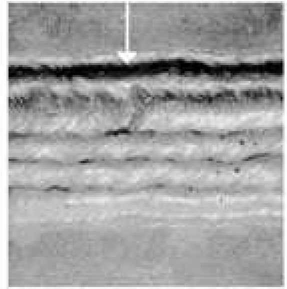


FIGURE 2.10 Undercut at the edges of weld beads in a multiple pass weld. (Courtesy of C. [illegible]

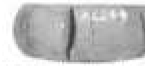


FIGURE 2.11 Multiple forging bursts in a steel blank. (Courtesy of C. Hellier.)

FIGURE 2.12 Corrosion pit that penetrated a pipe wall (2×). (Courtesy of R. H. Pond, Jr.)

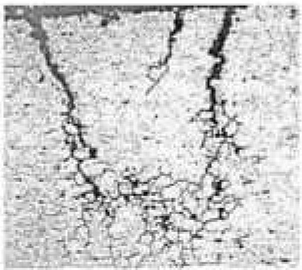


FIGURE 2.13 Stress corrosion cracking in nickel alloy (200×). (Courtesy of R. H. Pond, Jr.)

FIGURE 2.14 Beach marks in a drill rod fractured by fatigue. (Courtesy of R. H. Pond, Jr.)

FIGURE 2.15 [illegible] (Courtesy of [illegible] R. H. Pond, Jr.)

FIGURE 2.16 "Rock candy" fracture surface of a grade 8 bolt cracked by hydrogen embrittlement. (Courtesy of R. B. Pond, Jr.)

FIGURE 2.17 Brittle fracture surface of fastener. Bright flecks are planar cleavage facets of ferrite in the steel. (Courtesy of R. B. Pond, Jr.)

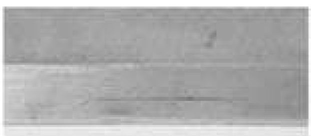


FIGURE 2.18 Lamination in plate edge.

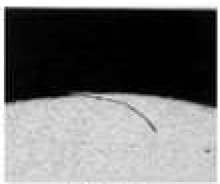


FIGURE 2.19 Forging lap.

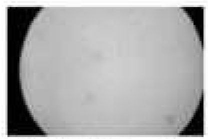


FIGURE 2.20 Sand and slag inclusions in a casting.

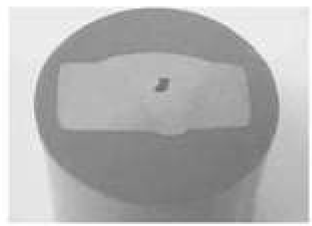


FIGURE 2.21 Slag inclusion in weld cross section.

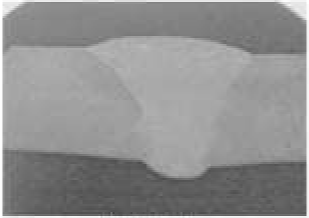


FIGURE 2.22 Lack of fusion.

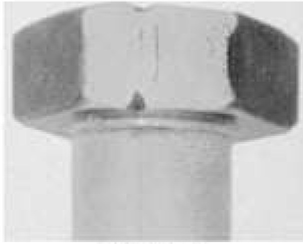


FIGURE 2.23 Seam in bolt.

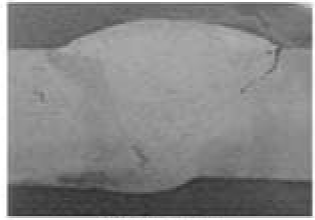


FIGURE 2.24 Toe crack in weld.

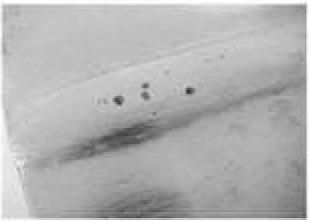


FIGURE 2.25 Surface porosity in weld.

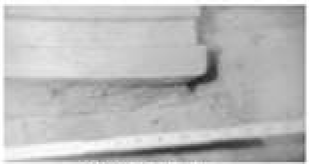


FIGURE 2.26 Crack between two welds.

FIGURE 2.27 Burst in bar.

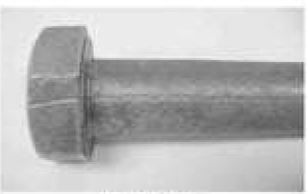


FIGURE 2.28 Crack in bolt.

FIGURE 2.29 Lack of penetration in aluminum weld.