ANK 315 AIRCRAFT MAINTENANCE

INTRODUCTION TO DIAGNOSTICS NDT, SHM

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EUROPEJSKI FUNDUSZ SPOŁECZNY

NON-DESTRUCTIVE TESTING

The need of **non-destructive testing (NDT) application in aviation** demands much of the equipment and technique makers qualification what is connected with a great variety of shape and complexity of testing units

Thereby, it is usually necessary to test the areas of stress concentration: holes for fasteners, panels edge, fillet transitions etc. In operation it is often essential to carry out NDT without removing the layer of paint-and-lacquer coating or sealant what excludes the usage of penetrant and ultrasonic techniques. In many cases there is no two-way access what makes it impossible to apply X-ray NDT technique

Moreover, it is often necessary to perform NDT in field conditions and airfield conditions

During field service of aircrafts an operator with the equipment should be located directly on the wing or stepladder

Basic Technology Requirements Range

- Detection capability
- Temperature loading
- Chemical loading
- Mechanical loading

Reliability > 30 years (applies to the four items above)

- Manufacturing aspect
- System integration aspect
- Maintainability
- Reparability
- Self-diagnostic capability

- Non Destructive Testing NDT NDE NDI
- continuous damage monitoring
- Structural Health Monitoring (SHM)
- Health and Usage Monitoring System (HUMS)
- Engine Monitoring System (EMS)

NON-DESTRUCTIVE TESTING

NDT TECHNIQUES

OBSERVE AND DIRECTLY DEFECT DAMAGE

VISUAL/OPTICAL,
ULTRASONICS,
SHEROGRAPHY,
THERMOGRAPHY,
etc.

STRUCTURAL HEALTH MONITORING

DETECT AND MONITOR USING INDIRECT MEASUREMENTS

VIBRATION/MODAL ANALYSIS,
ACUSTO-ULTRASONICS,
FIBER BRAGGS GRITINGS
etc.

9 NDT TECHNICS ARE USED IN AVIATION

- Visual, Optical
- Liquid Penetrant
- Magnetic
- Eddy Current
- Radiography (X-ray/ gama ray)
- Sonic/Resonance
- Ultrasonic
- Infrared Thermography
- Sherography

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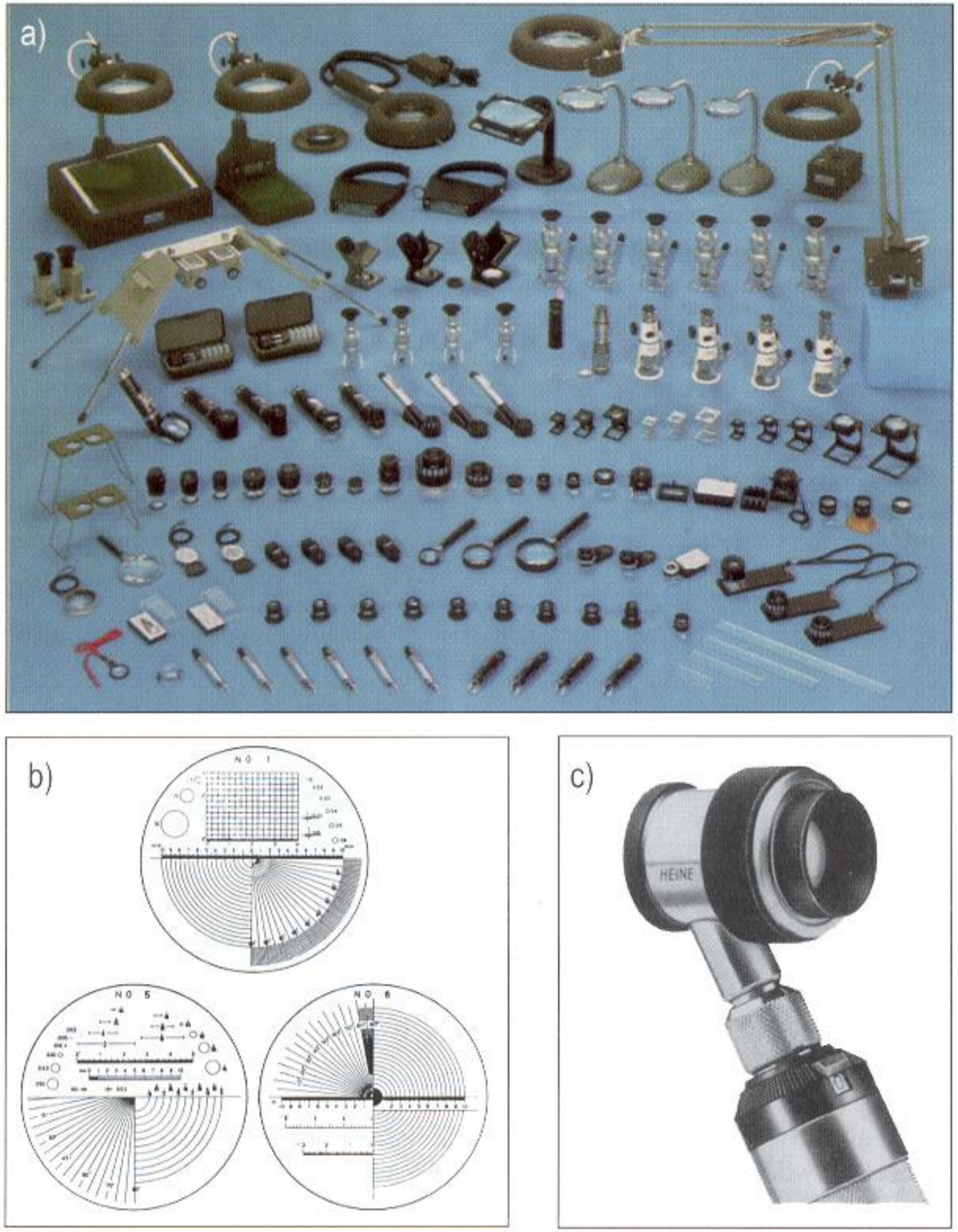
- Spectography

VISUAL INSPECTION

- ALL HUMAN SENCES INVOLVED
- HIGHLY DEPENDENT ON CAPABILITIES
  OF OBSERVER, WHO IS TRAINED TO FIND
  AND ASSESS CHANGES IDENTIFING DAMAGES

- THERE ARE TWO GROUPS:
  - 1ST IS DIRECT VISUAL INSPECTION USE BOROSCOPES, FIBEROSCOPES WITH REAL-TIME VIDEO FOR DIRECT OBSERVATION
  - 2ND IS INDIRECT VISUAL INSPECTION BASED ON EXAMINATION OF PHOTOGRAPHS, RADIOGRAPHS OR VIDEOTAPES



Drobne wyposażenie do badań wizualnych: a) lupy, mikroskopy piórowe (u dołu) i mikroskopy pomiarowe (w środku), b) skale do lup i mikroskopów do badań wizualnych, c) lupa z oświetlaczem i skalą, firmy Heine. Za zgodą firmy Heine


Image capture with the Portable Video
Monitor at the touch of a button!


apm
AIRCRAFT POWER MAINTENANCE N.V.
JAA approved organisation
JAR-145 Bel 16
AIRPORT 49
B-8560 WEVELGEM
BELGIUM

VISUAL INSPECTION

- VISUAL AIDS SUCH AS LIGHT SOURCES, MAGNIFICATION DEVICES AND SENCORS FOR REMOTE VIEWING EMPLOYED
    - UP TO 80% OF CRACKS ARE FOUND BY VISUAL MEANS
        - INEXPENCIVE, HIGHLY PORTABLE, IMMEDIATE RESULTS, MINIMAL TRAINING
            - APPROPRIATE FOR ONLY SURFACE DEFECTS, DAMAGES
                - HUMAN FACTOR

VISUAL INSPECTION

+ INEXTENSIVE, HIGHLY PORTABLE, IMMEDIATE RESULTS, MINIMAL TRANING

- ONLY SURFACE DEFECTS, CLEANING REQUIRED, VISUAL ACCESS REQUIRED, HUMAN FACTOR

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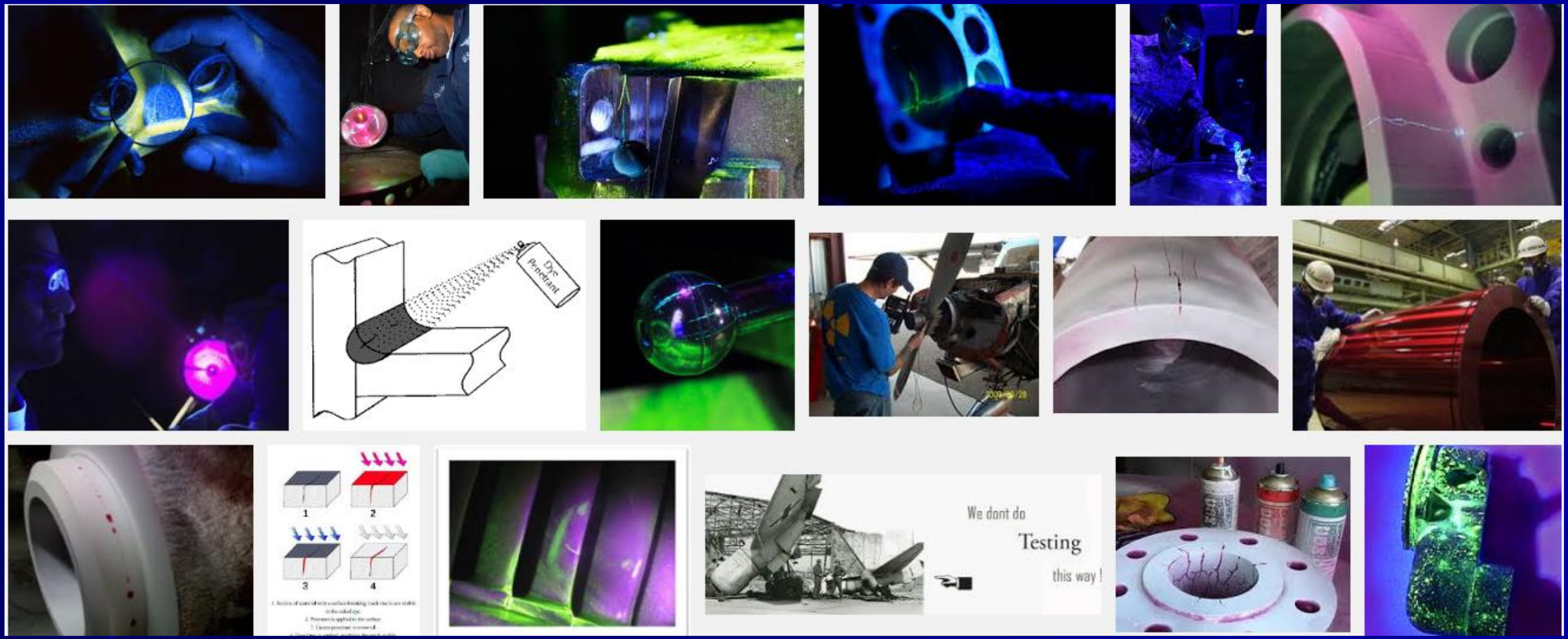
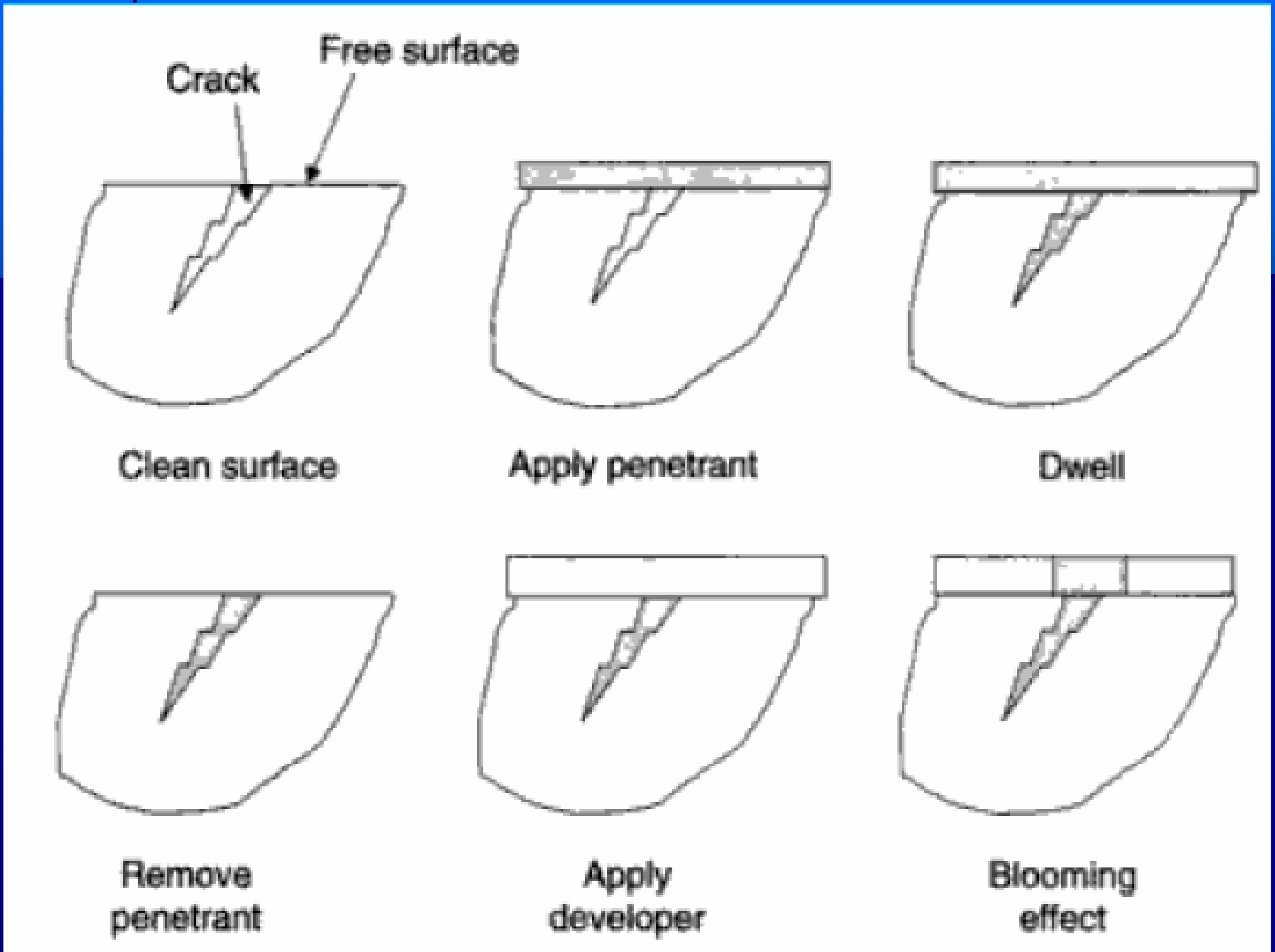
LIQUID PENETRANT INSPECTION

- RELATIVELY SIMPLE BUT EFFECTIVE TECHNIQUE FOR LOCATING SURFACE CRACKS
- APPLICABLE TO MANY MATERIALS

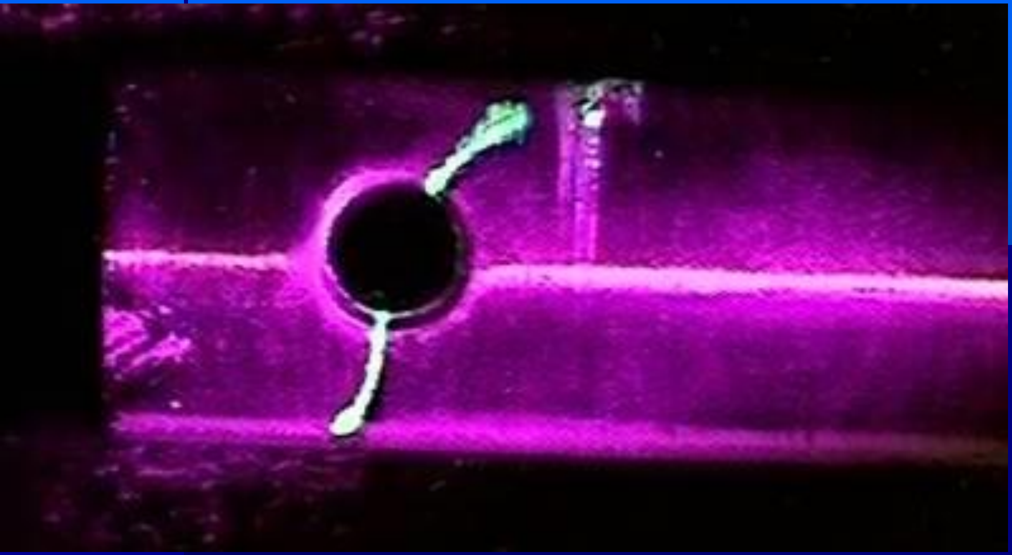




- INVOLVES FLOODING SURFACE OF TEST OBJECT WITH LOW-VISCOSITY FLUID. FLUID SOAKS INTO CREVICES VIA CAPILLARY ACTION

- PENETRANT IS CLEANED AND DEVELOPER IS APPLIED TO DRAW OUT PENETRANT REMANING BETWEEN CRACK FACES
- DEVELOPER PROVIDES CONTRASTING BACKGROUND AND BLOOMING EFFECT TO ENHANCE CRACK VISIBILITY

Liquid penetrant inspection



PENETRANTS CAN BE FLUORESCENT
AND VIEWED UNDER SUITABLE e.g. ULTRAVIOLET LIGHT

LIQUID PENETRANT INSPECTION

\+

PORTABLE AND WELL SUITED FOR FIELDWORK. INEXPENCIVE AND REQUIRES MINIMAL SKILLS. SENSITIVE TO SMALL DISCONTINUITIES. CAN BE APPLIED TO NONPOROUS MATERIALS. FLAW ORIENTATION DOES NOT USUALLY POSE A PROBLEM

\-

ONLY SURFACE ANOMALIES. MUST HAVE ACCESS TO SURFACE. STRESSES AT SURFACE CAN CAUSE UNCERTAINLITY. SIGNIFICANT SURFACE PREPARATION REQUIRED. FAIRLY SLOW DUE TO PREPARATION, DWELL AND CLEAN UP

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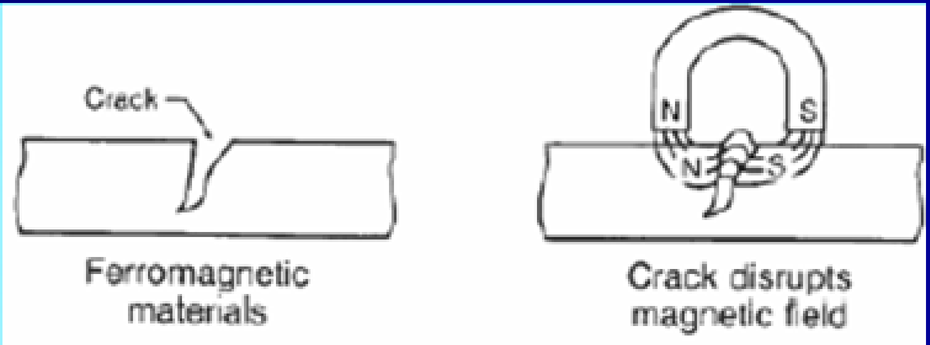
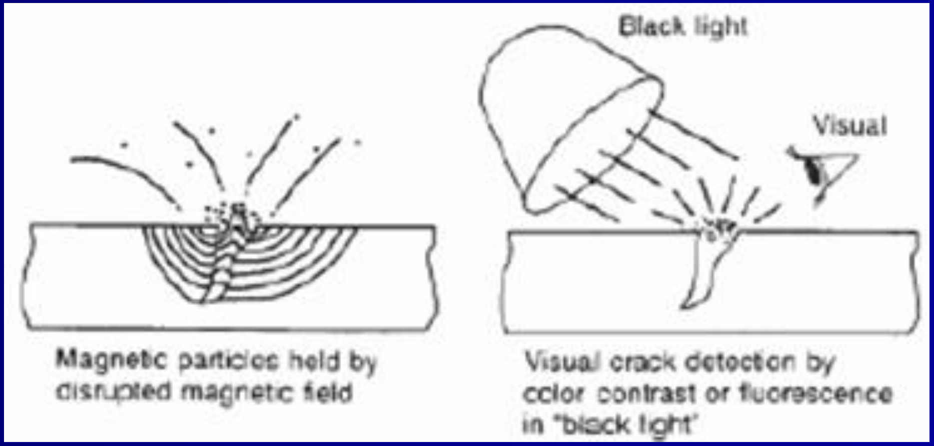
Magnetic Particle Inspection

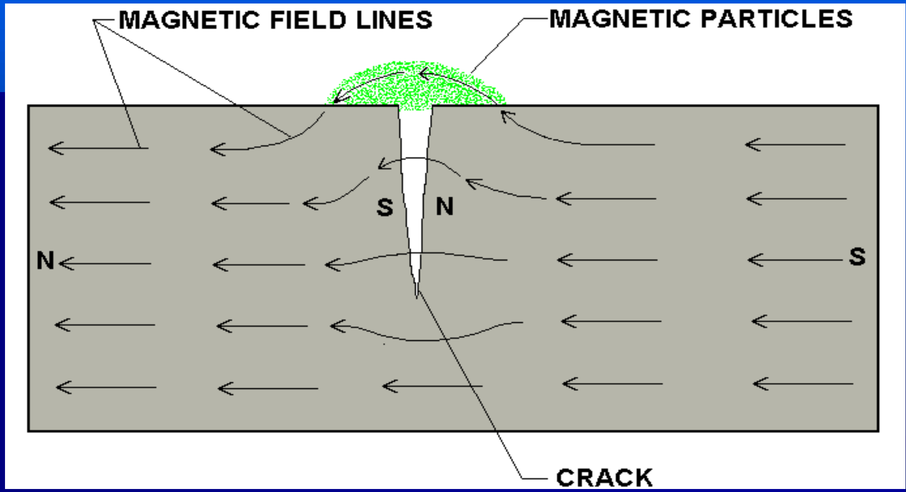
FERROMAGNETIC TEST PIECE IS MAGNETISED. MAGNETIC FLUX LEAKAGE FIELDS ARE DETECTED THROUGH THE ADDITIONAL OF SMALL PARTICLES WHICH MIGRATE TO THE FLUX LEAKAGE



CAN DETECT SURFACE AND NEAR SURFACE FLAWS



Magnetic Particle Inspection



Magnetic Particle Inspection

+ COMPLEX SHAPES READILY TESTED. FAIRLY PORTABLE AND RELATIVELY INEXPENSIVE. SENSITIVE TO SMALL SURFACE(OR NEAR-SURFACE) DFECTS. REQUIRES MODERATE SKILL LEVEL. RELATIVELY QUIK RESULTS

- LIMITED TO FERROMAGNETIC MATERIALS. SURFACES MUST BE ACCESIBLE. LARGE ELECTRIC CURRENT CAN BE REQUIRED. MAY NEED TO MAGNETIZE OBJECT. LIMITED TO SURFACE AND NEAR SURFACE DEFECTS. SURFACE FINISHES MAY NEED TO BE REMOVED. FLAW DETECTION SENSITIVE TO MAGNETIC FIELD ORIENTATION

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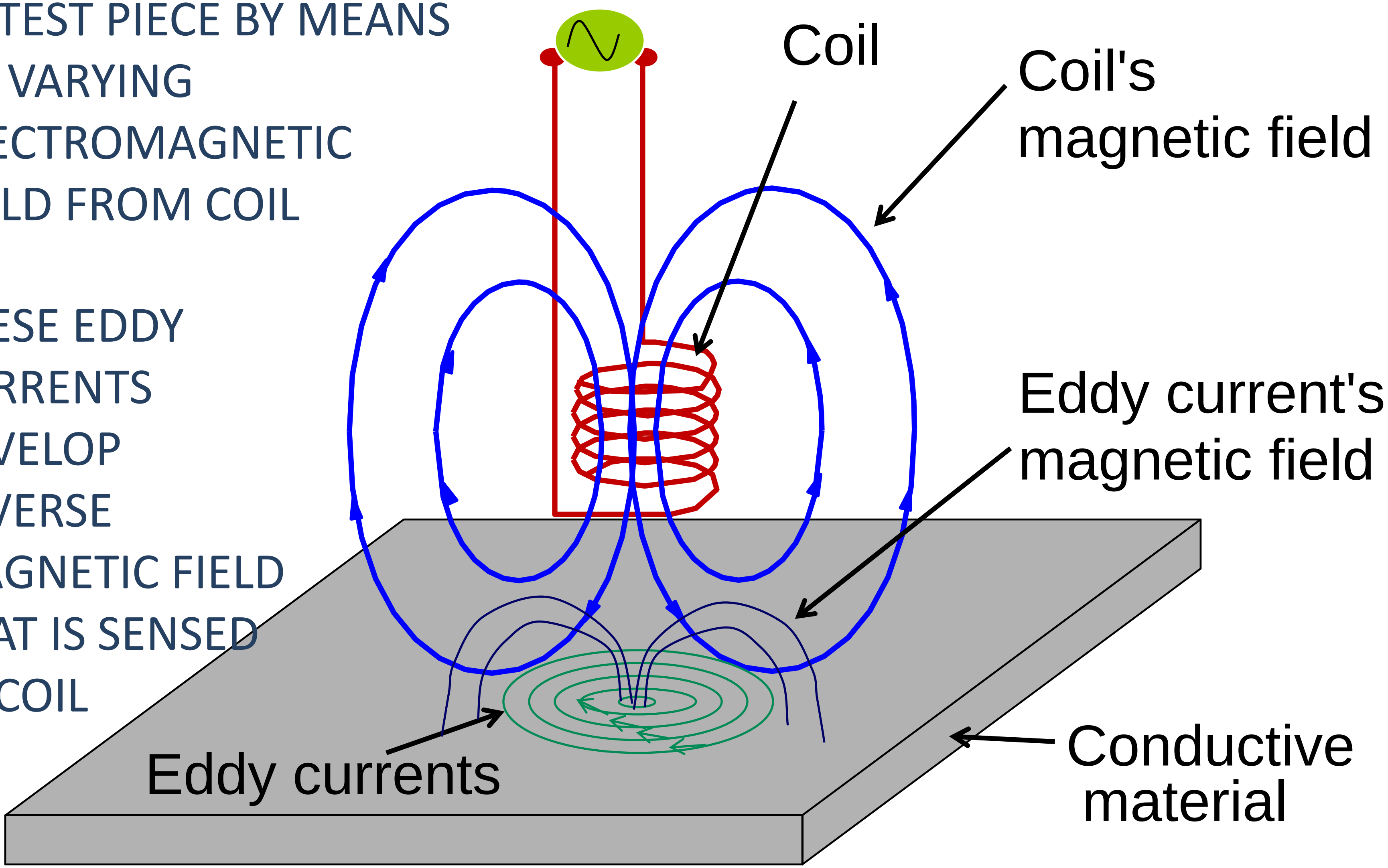
Eddy Current Inspection

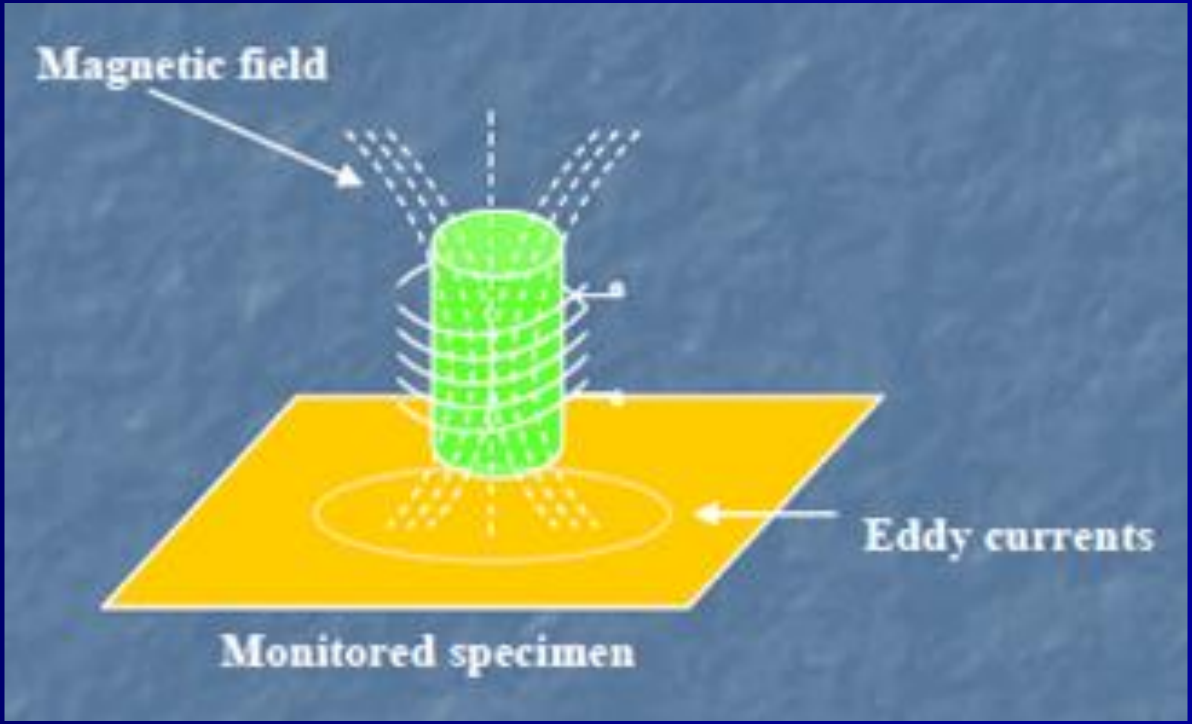
EDDY CURRENT TESTING GENERATES SMALL ELECTRICAL CURRENTS IN TEST PIECE BY MEANS OF VARYING ELECTROMAGNETIC FIELD FROM COIL

THESE EDDY CURRENTS DEVELOP REVERSE MAGNETIC FIELD THAT IS SENSED BY COIL



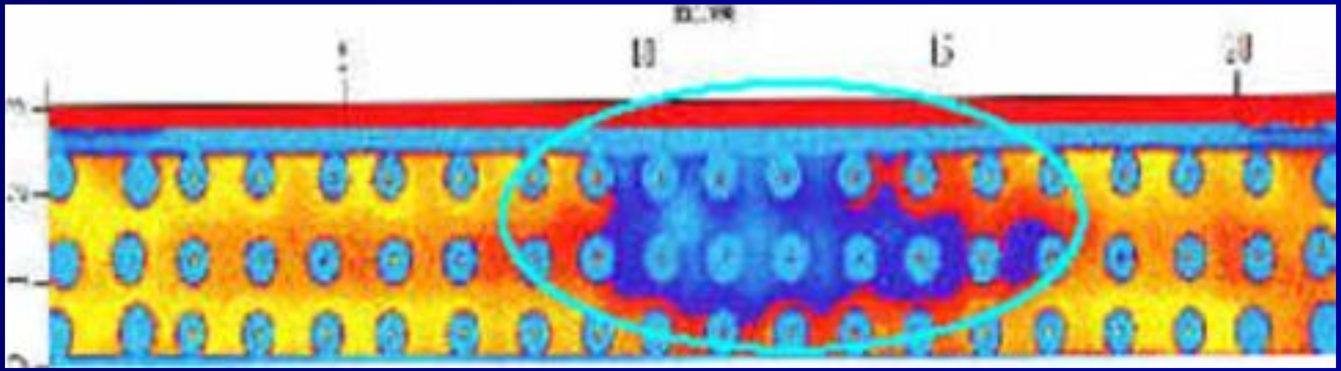
Eddy Current Inspection

ANYTHING THAT AFFECTS EDDY CURRENTS (E.G. CRACKS, POROSITY, INCLUSIONS) WILL MODIFY SECONDARY MAGNETIC FIELD AND BE SENSED BY IMPEDANCE CHANGE IN COIL



Eddy Current Inspection

- Edddy current inspection is a surface method and can only detect defectts up to a depth of around 6 mm
- The method requires calibration(artificial defects such as saw cuts, holes etc.)



Eddy Current Inspection

Three probe types:

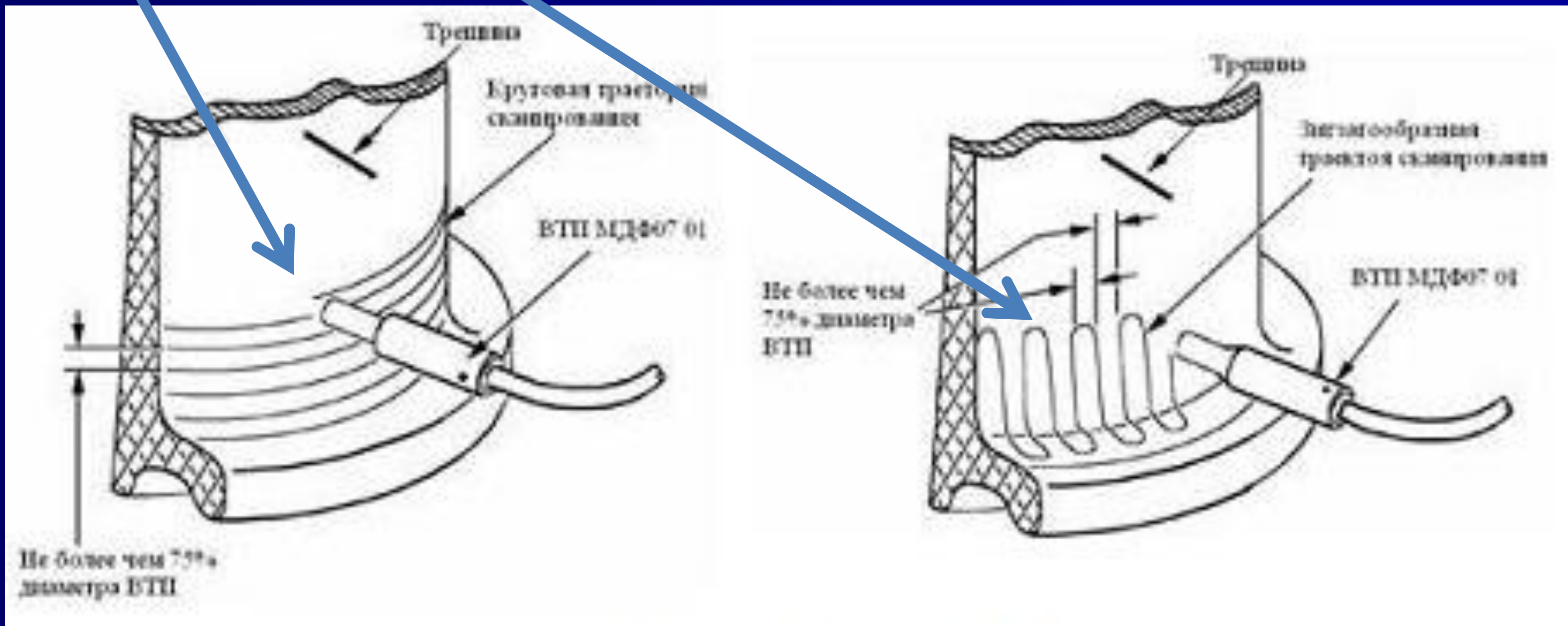
- ❑ Surface probes for testing plates
- ❑ Encircling probes for bars and rods
- ❑ Bobbin probes for inspection of tubes

Eddy Current Inspection

Practicing of local corrosion damages detection technique

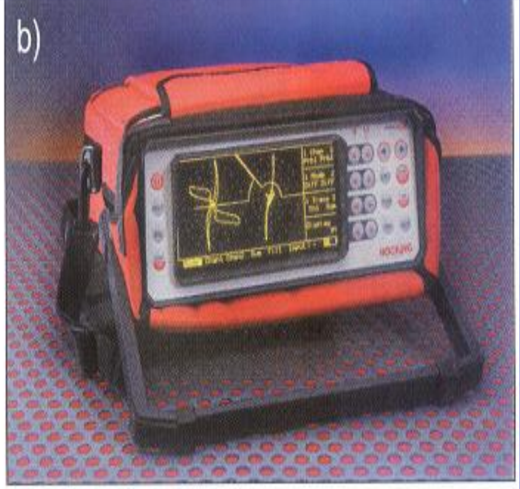
Eddy Current Inspection

Two scanning types are applied: circular and zigzag

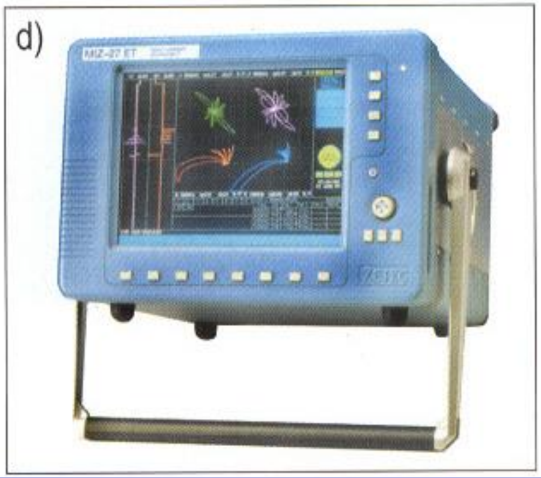


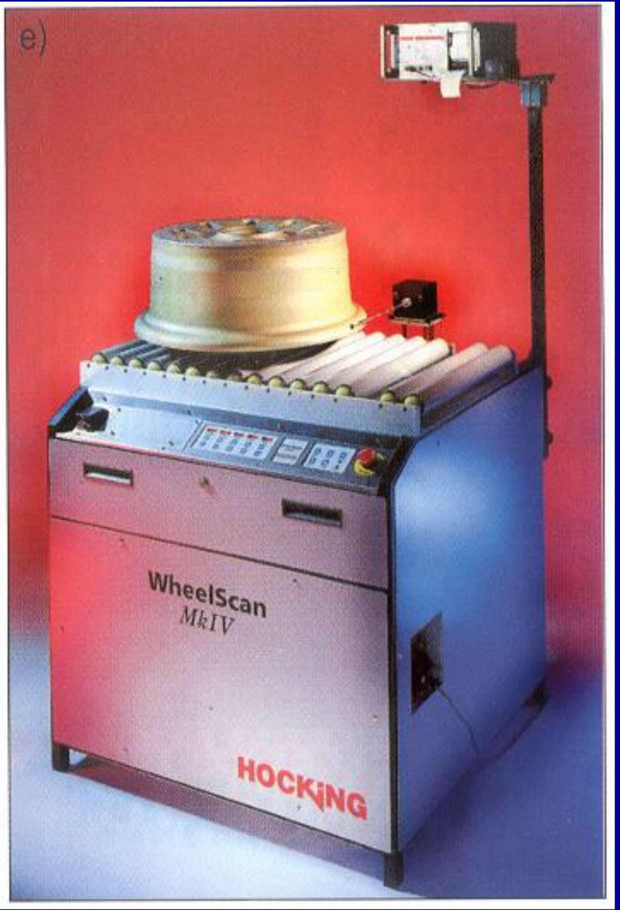
Scanning schemes during wheels inspection


a)
HELP


b)
HOCKING


c)
FREQUENCY 6.0 kHz
OK


d)
MIZ-27 ET


e)
WheelScan
MkIV
HOCKING

Eddy Current Inspection

- \+ SENSITIVE TO SEVERAL STRUCTURAL AND METALLURGICAL VARIABLES LEADING TO MANY APPLICATIONS. MODERATELY FAST TECHNIQUE GIVING INSTANTANEOUS INDICATION. PORTABLE. CAN DETECT SMALL SURFACE OR NEAR-SURFACE ANOMALIES. MINIMAL PART PREPARATION
- \- TEST OBJECT MUST BE ELECTRICAL CONDUCTOR. SURFACE MUST BE ACCESSIBLE TO PROBE. LIMITED DEPTH OF PENETRATION. SKILL AND TRAINING REQUIRED TO INTERPRET RESULTS. CAN BE TIME CONSUMING FOR LARGE INSPECTION AREAS

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- Ultrasonic
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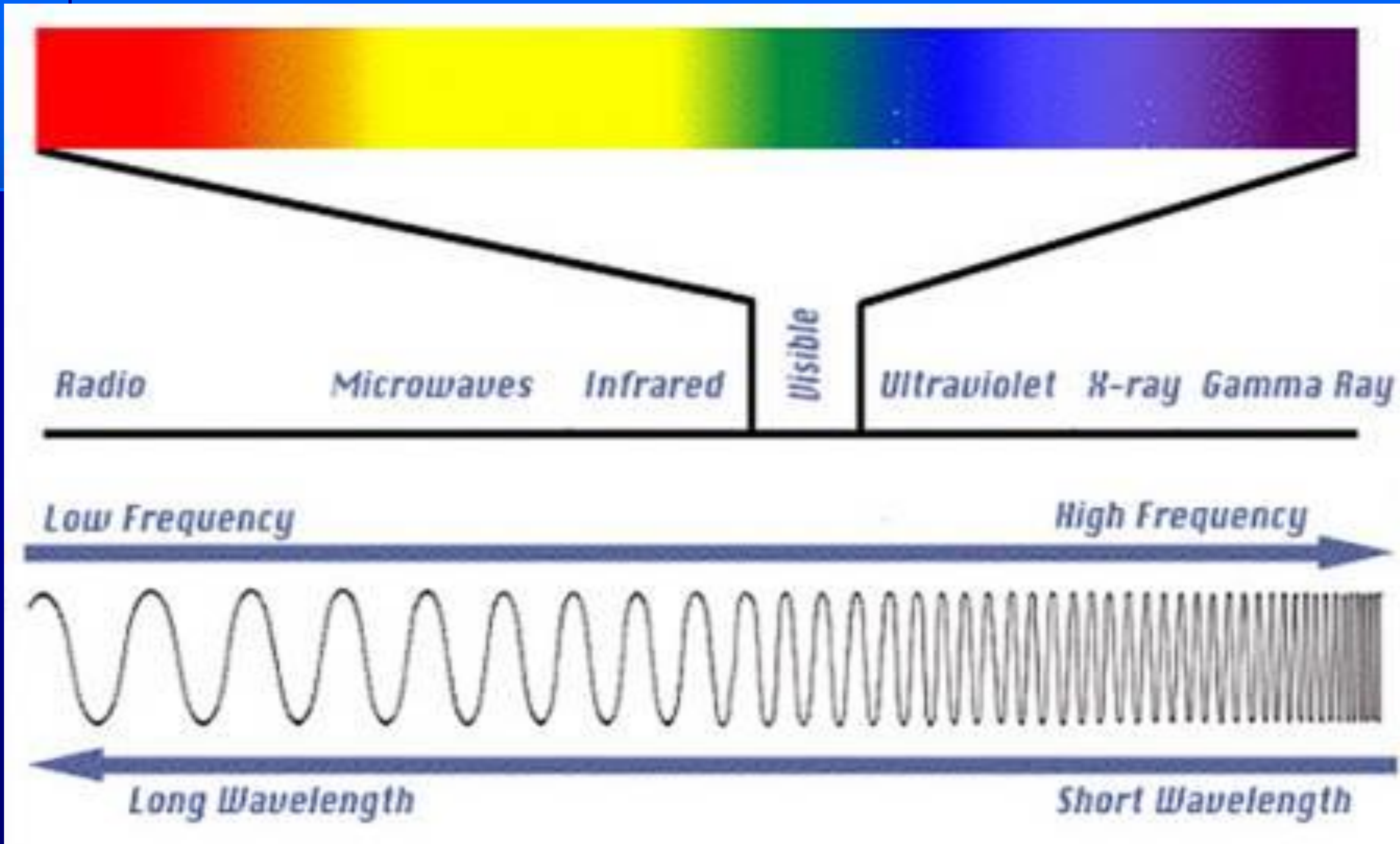
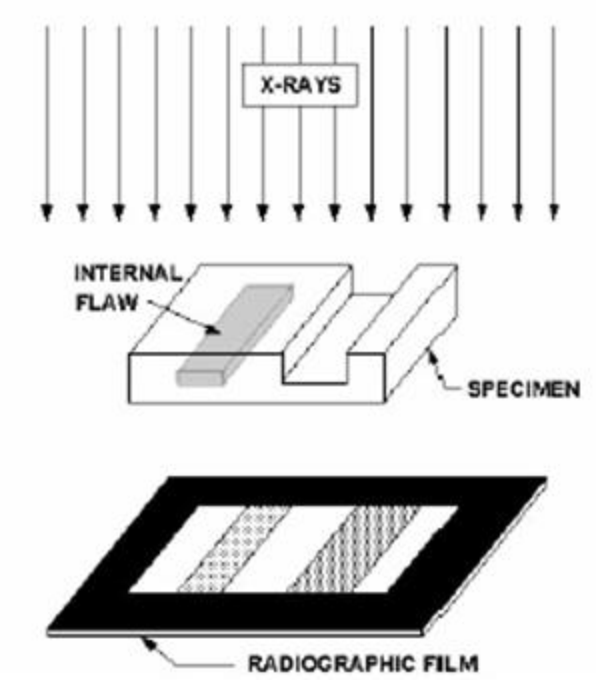
- Sherography


Radio
Microwaves
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
Low Frequency
High Frequency
Long Wavelength
Short Wavelength

RADIOGRAPHIC INSPECTION



- RADIOGRAPHY IS ONE OF THE OLDEST NDT METHODS FOR LOCATING INTERNAL AND EXTERNAL ANOMALIES
- EXPLOITS CHARACTERISTIC OF MANY MATERIALSTO DIFFERENTIALLY ABSORB AND PASS HIGH-ENERGY RADIATION
- SOURCE OF RADIATION MAY BE X-RAYS, GAMMA RAYS OR NEUTRONS
- VARIATIONS IN ABSORPTION WHICH RESULT FROM CHANGES IN MATERIAL DENSITY OR THICKNESS ARE RECORDED USING EITHER FILM OR REAL-TIME DETECTORS

RADIOGRAPHIC INSPECTION

APPLICATIONS INCLUDE:

CHECKING FOR POROSITY IN CASTINGS OR WELD DEFECTS

DETERMINING INTERNAL GEOMETRY

DETECTING CRACKS IF PROPERLY ORIENTED

LOCATING AND MEASURING CORROSION THINNING

ROBOSCAN 2M AERIA

Radiographic Inspection

+ CAN DETECT INTERNAL AND EXTERNAL DEFECTS. APPLICABLE TO WIDE VARIETY OF SOLID MATERIALS AND COMPLEX SHAPES. PERMAMENT RECORD OBTAINED. MINIMAL PART PREPARATION. REAL-TIME VIEWING POSSIBLE. 3D IMAGING POSSIBLE

- SIGNIFICANT SAFETY ISSUES. TWO-SIDES ACCESS TO TEST PIECE GENERALLY REQUIRED. DIRECTION VERY SENSITIVE TO FLAW ORIENTATION. HIGH DEGREE OF SKILL AND EXPERIENCE. RELATIVELY EXPENSIVE. USUALLY SOME DELAY IN OBTAINING RESULTS

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Acoustic Emission

- Acoustic Emission (AE) has been defined as *"a transient elastic stress wave generated by the rapid release of energy from a localized source within a material"* – 1995 Annual Book of American Society of Testing and Materials Standards, Nondestructive Testing.
- Most non-destructive evaluation applications involve loading test object, sensing AE and correlating it with source of damage.

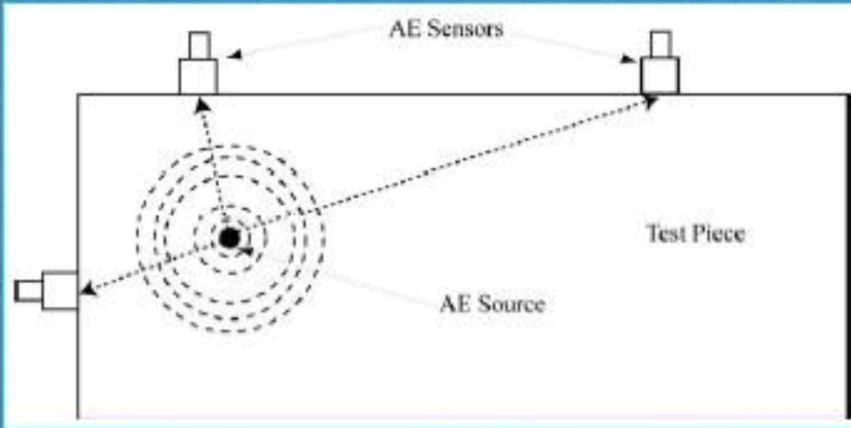
Acoustic Emission

- Modern utilisation of AE began in 1950s and has success with “noisy” materials such as composites and concrete.
- Many sources of AE including crack formation and growth and corrosion activity.
- Sources of AE in composite materials include fibre breakage and delamination.

Acoustic Emission

- AE involves "listening" for sound generated by growing damage in the test piece.

- Location of AE damage can be determined by triangulation techniques based on time for signal to reach sensors – damage size cannot be found by AE.



Acoustic Emission

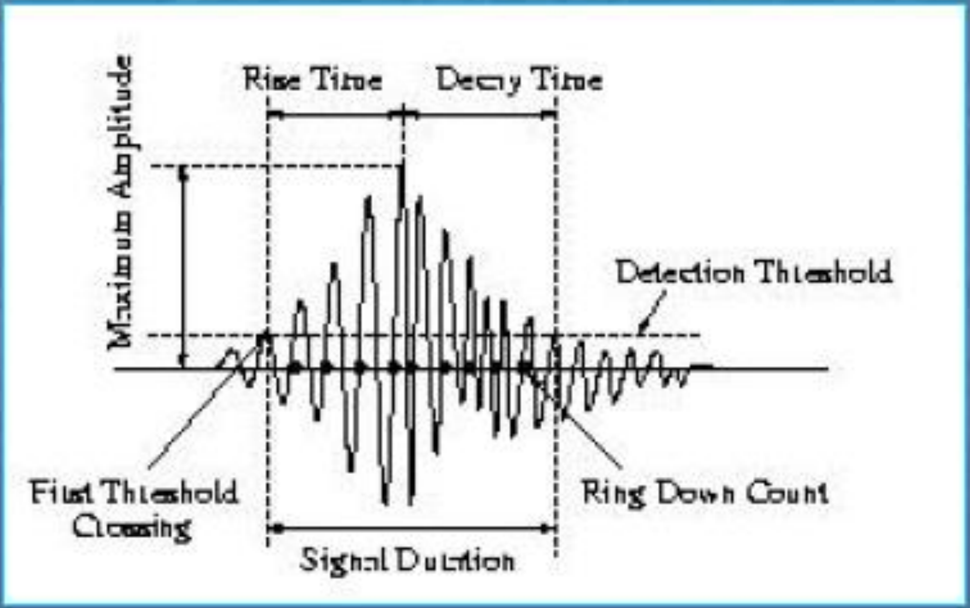
- Each loading event emits unique burst of sound so AE inspections not directly repeatable.
- Although AEs generated by material and not external source, stimulus is required to trigger original AEs – can be mechanical, thermal or magnetic induced stress.
- Although AE signals cover wide range of frequencies and energy levels, they consist of two basic types:

Acoustic Emission

- Although AE signals cover wide range of frequencies (typically 20kHz – 1200kHz) and energy levels, they consist of two basic types:
  - Burst Emissions – correspond to particular emission event such as development of cracks in metals.
  - Continuous Emissions – give sustained signal associated with rapidly occurring events such as motion of dislocations.
- Both types of emissions may propagate by combinations of standard ultrasonic modes.

Acoustic Emission

- Early AE applications gave inconsistent or misleading results due to inadequate standards.
- Problem addressed in recent years with generally accepted AE parameters:



Acoustic Emission

- Acoustic Emission are ultrasonic waves and are measured using similar methods:
  - Piezoelectric transducers – most common – sensitive and reliable and suitable for wide range of frequencies.
  - Accelerometers – limited frequency range (100kHz maximum).
  - Optical/laser transducers – employ laser interferometry – wide frequency response and ability to integrate signals over large area.

Acoustic Emission

+ AE signals locate source of growing damage in loaded structure. Monitoring equipment relatively simple and expensive. Signals can be monitored online or recorded and analysed later. Can detect discontinuities below surface. Wide-area coverage possible.

- Applied stress or chemical activity required for emissions to occur – stabilised damage not detect. Not all damage emits AE. Not applicable to all materials. Crack sizes not readily determined. Method not directly repeatable. Multiple sound paths can complicate signal identification.

Sonic/Resonance

- Resonance test method
- Pitch/catch swept test method
- Pitch/catch impulse test method
- MIA(Mechanical Impedance Analysis) test method
- Eddy sonic harmonic test method
- Tap test

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Ultrasonic Inspection

- Ultrasonic inspections measure travel of high-frequency sound waves introduced into test object at various surface locations.
- Propagation of these electronically controlled sound pulses through test object is detected at specific points where acoustic energy is converted back to electrical signal.
- Interpretation of reflection and refraction of sound waves at boundaries leads to information regarding discontinuities in test object.

Ultrasonic Inspection

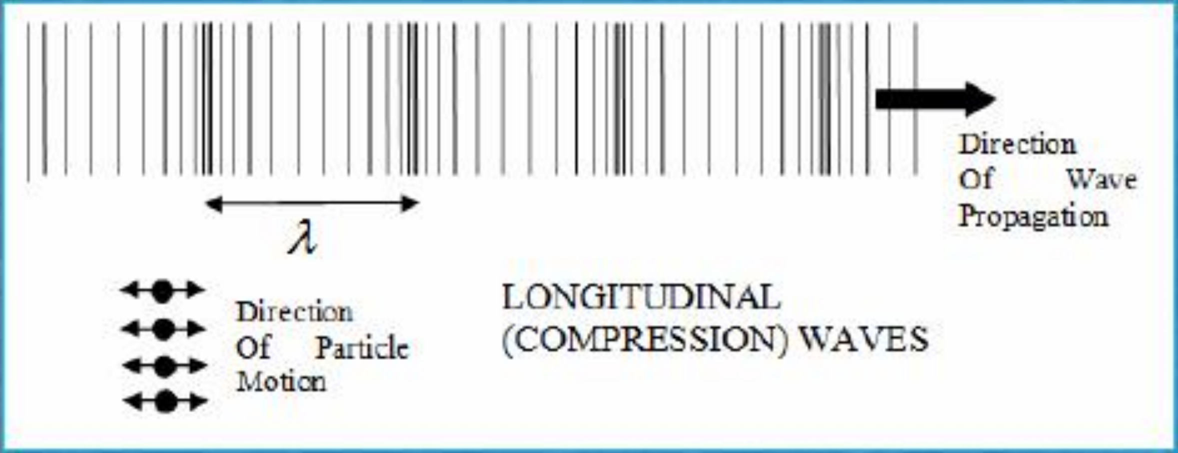
- Since sound waves travel in many materials, ultrasonic inspection is one of most widely used NDT tool for internal and surface flaws.
- Typical ultrasonic frequencies range between 200kHz and 25MHz and do not, in general, represent significant health hazards.
- Several types of sound waves can propagate in solids.
- Velocity depends on density and elastic properties of parent material. $V = f\lambda$
- They may be reflected, focussed and refracted.

Ultrasonic Inspection

- Longitudinal (compression) and shear (transverse) are two main modes of ultrasonic propagation.
- Longitudinal is most commonly used waveform for NDT and occur when ultrasonic beam enters nearly perpendicular to test object surface.
- Easily generated and detected.

Ultrasonic Inspection

- Longitudinal waves propagate so that particle vibrations are parallel to direction of wave travel.



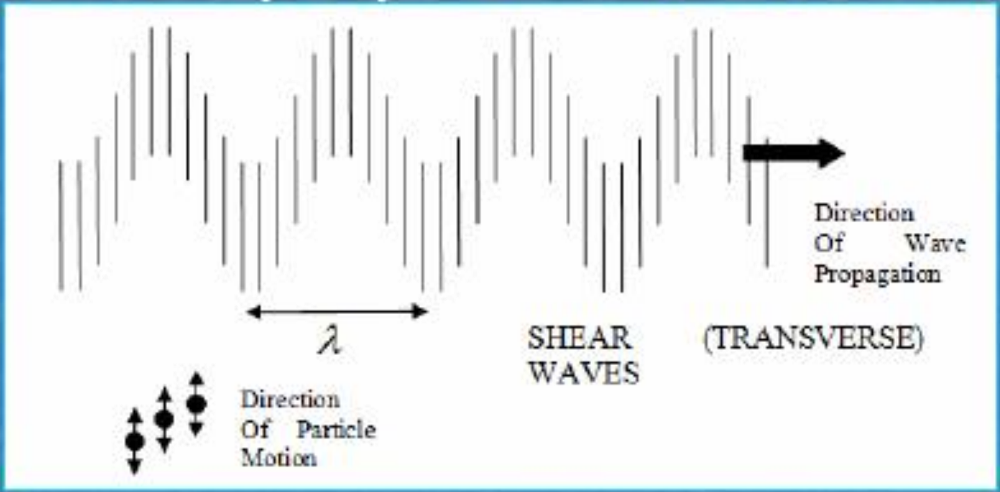
- Compression wave speed in large body is given by:

$$V_c = \left(\frac{E(1-\upsilon)}{\rho(1+\upsilon)(1-2\upsilon)} \right)^{\frac{1}{2}}$$

where E is elastic modulus, υ is Poisson's ratio and ρ is density of material.

Ultrasonic Inspection

- Shear (transverse) waves propagate so that particle motion is perpendicular to wave motion.



- Shear waves are formed when sound enters object surface at moderate angle. Speed given by:

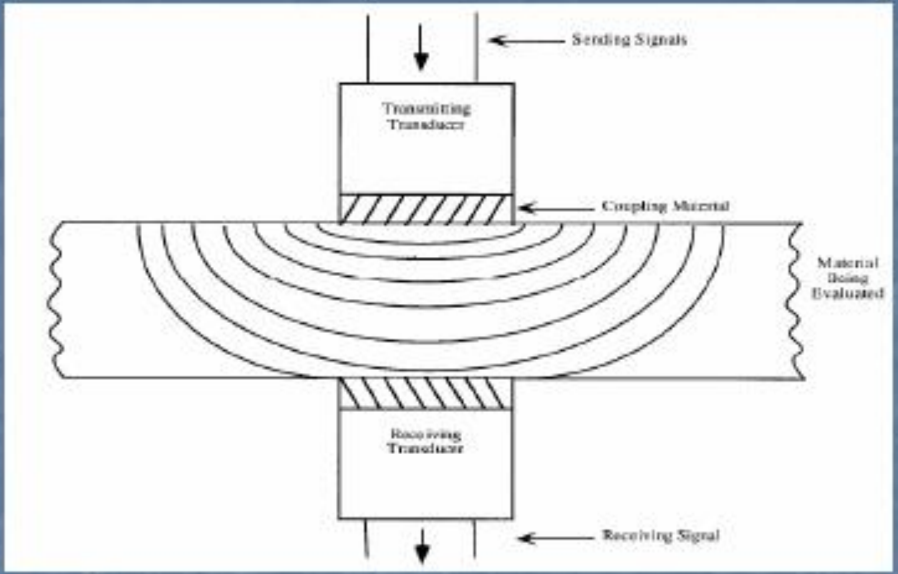
$$V_s = \left(\frac{E}{2\rho(1+\upsilon)} \right)^{\frac{1}{2}}$$

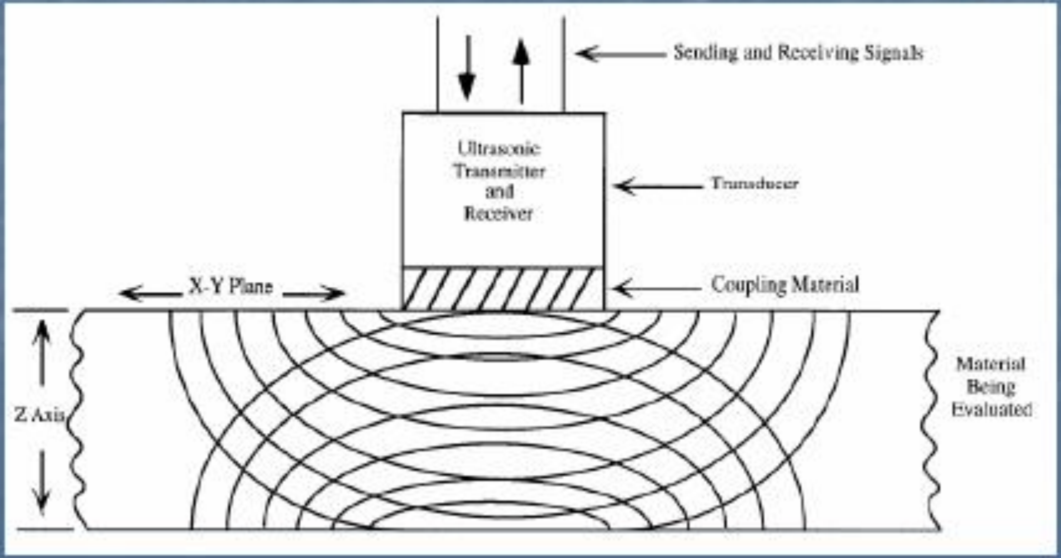
Ultrasonic Inspection

- Ultrasonic waves usually generated by piezoelectric transducers coupled to test object.
- Sound waves generated when electrical signal is transformed to mechanical vibrations. Receiver converts the vibration back into electrical signals.
- Two modes of transmitting and receiving signals are used.

Ultrasonic Inspection

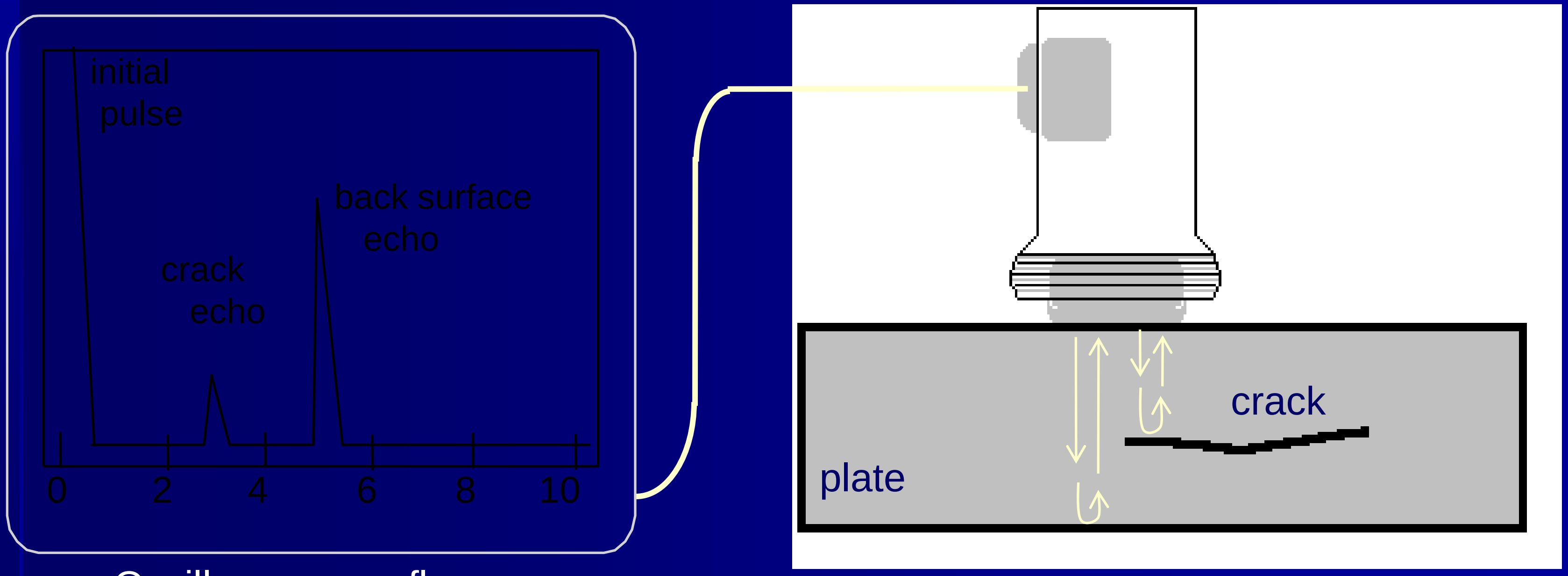
- Pitch-catch (through transmission) testing.





- Pulse Echo testing.

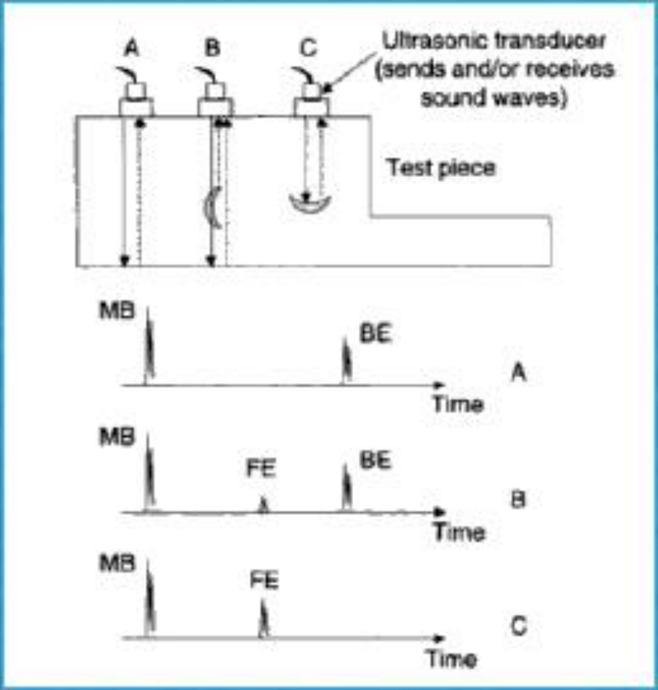
Ultrasonic Inspection (Pulse-Echo)

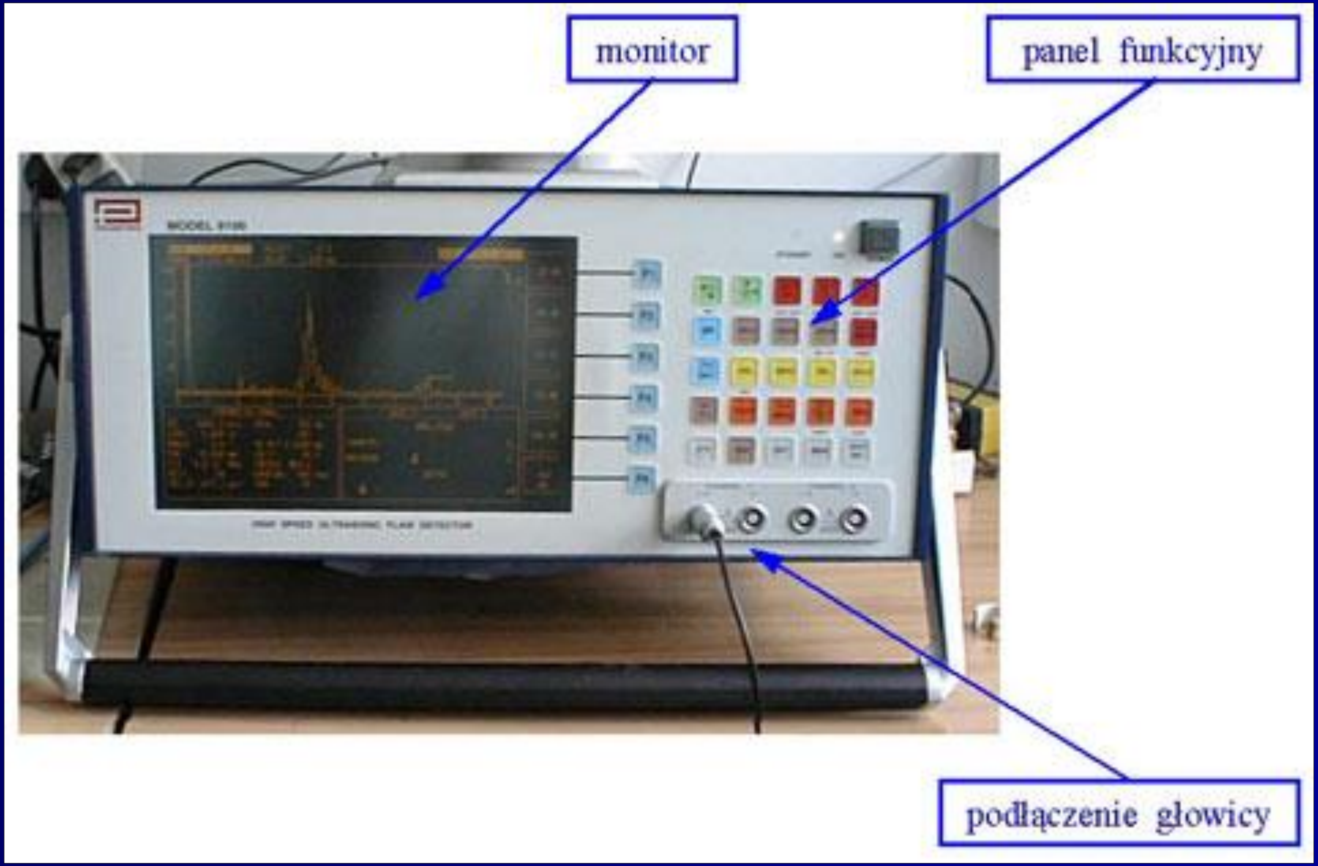


Oscilloscope, or flaw detector screen

Ultrasonic Inspection

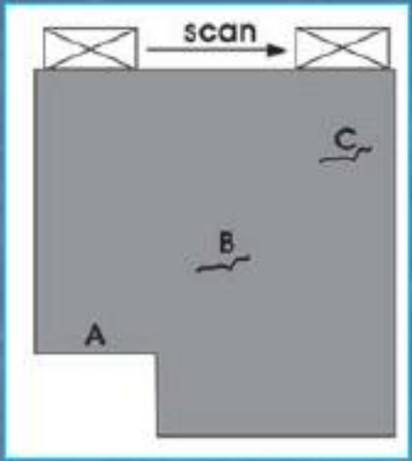
- Ultrasonic signals may be displayed in several formats (or scans) to aid interpretation.
- A-scan is most common form of display.
- Unfaulted object – Main Bang (MB) and Back Echo (BE).
- Faulted object – flaw location indicated by time of Flaw Echo (FE).
- Sensitive to flaw orientation.

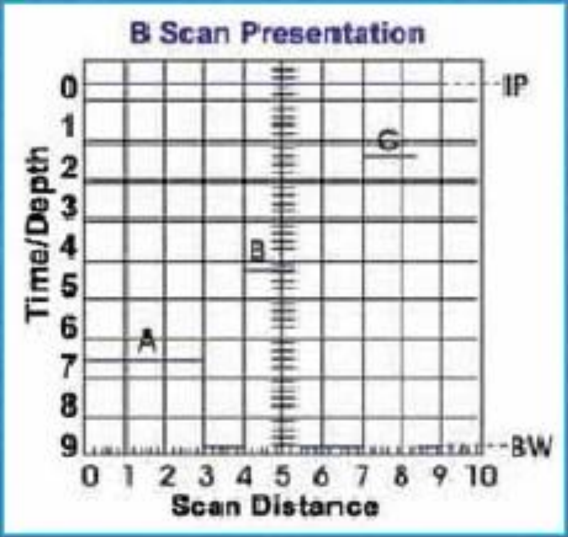



monitor
panel funkcyjny
podłączenie głowicy

Ultrasonic Inspection

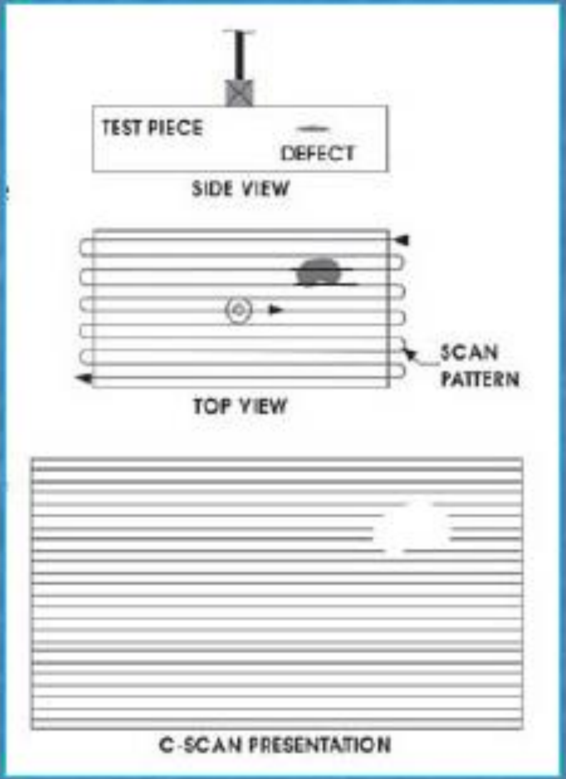
- B-scan presents a profile (cross-sectional) view of test specimen.
- Time-of-flight displayed on vertical axis and linear transducer position on horizontal axis.
- Line A shows reduced thickness and lines B and C indicate flaws B and C indicating depth and length. IP is initial pulse and BW is backwall reflection.

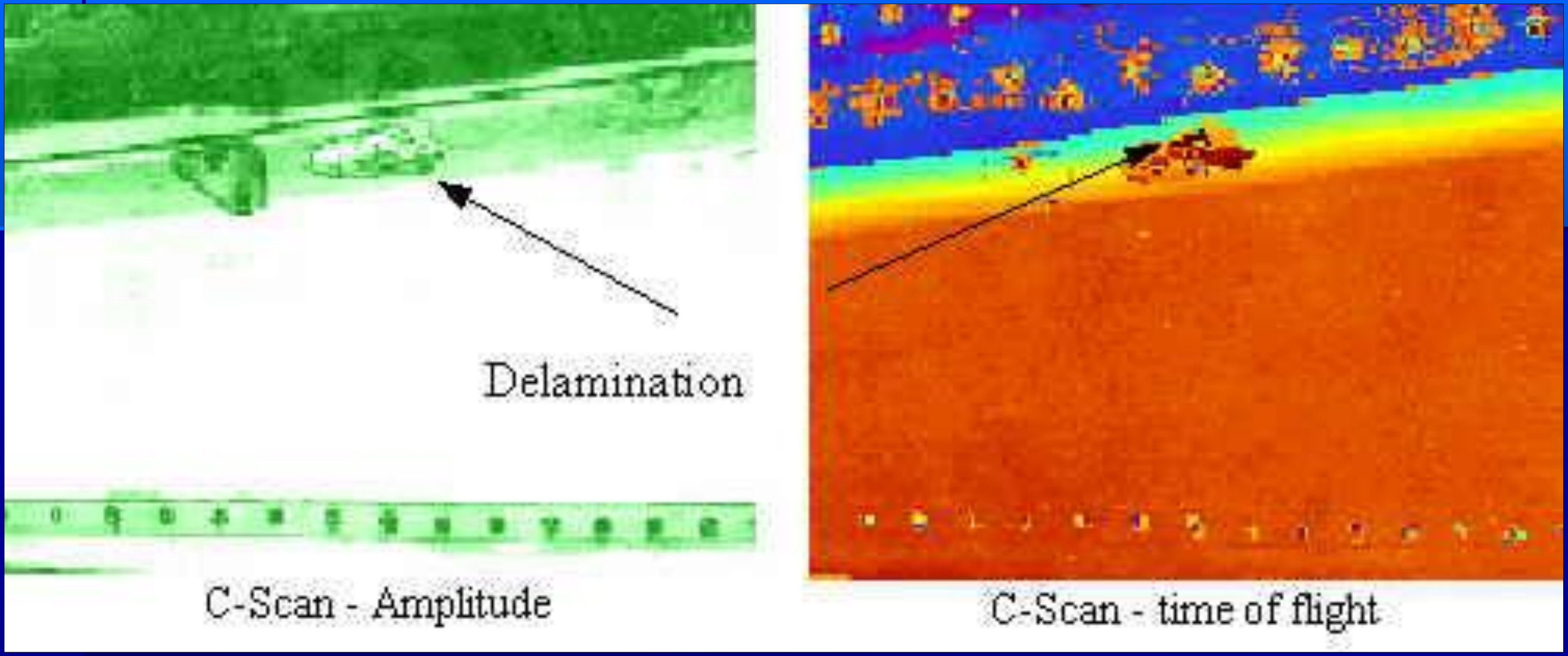




Ultrasonic Inspection

- C-scan provides a plan-type view of location and size of test specimen features.
- Produced with automated data acquisition system, such as computer controlled immersion scanning system.
- Relative time-of-flight displayed as shade of grey or colour indicating location and size of flaw.





2-D + colour

Ultrasonic Inspection

+ Both surface and subsurface anomalies may be detected in relatively large objects. Wide range of metallic and non-metallic materials and thicknesses may be inspected. Information may be obtained regarding flaw size, orientation and location. Portable. Variety of presentation formats. Sensitive to small defects. Little part preparation.

- At least one surface must be accessible. Rough surfaces cause problems – couplant required. Highly sensitive to beam and defect orientation. High degree of skill required to interpret. Can be impractical to inspect complex shapes.

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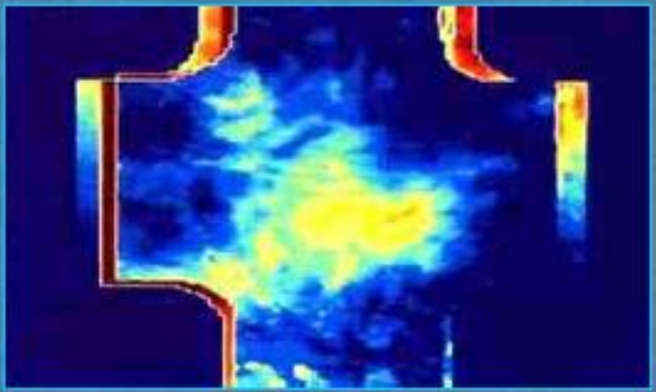
Thermography and Shearography

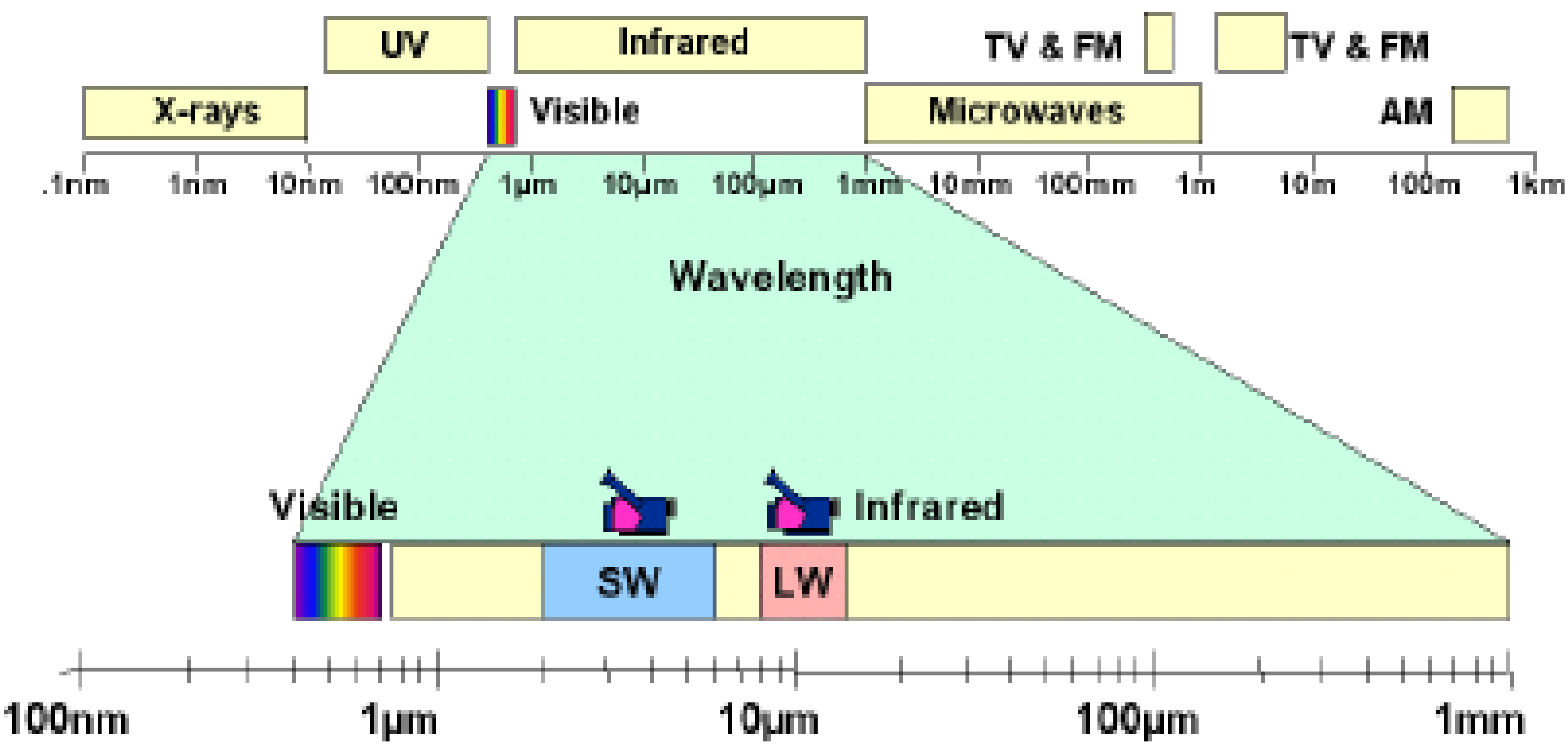
- Thermography works on the principle that some anomalies alter the heat flow in the material causing localised temperature differences.

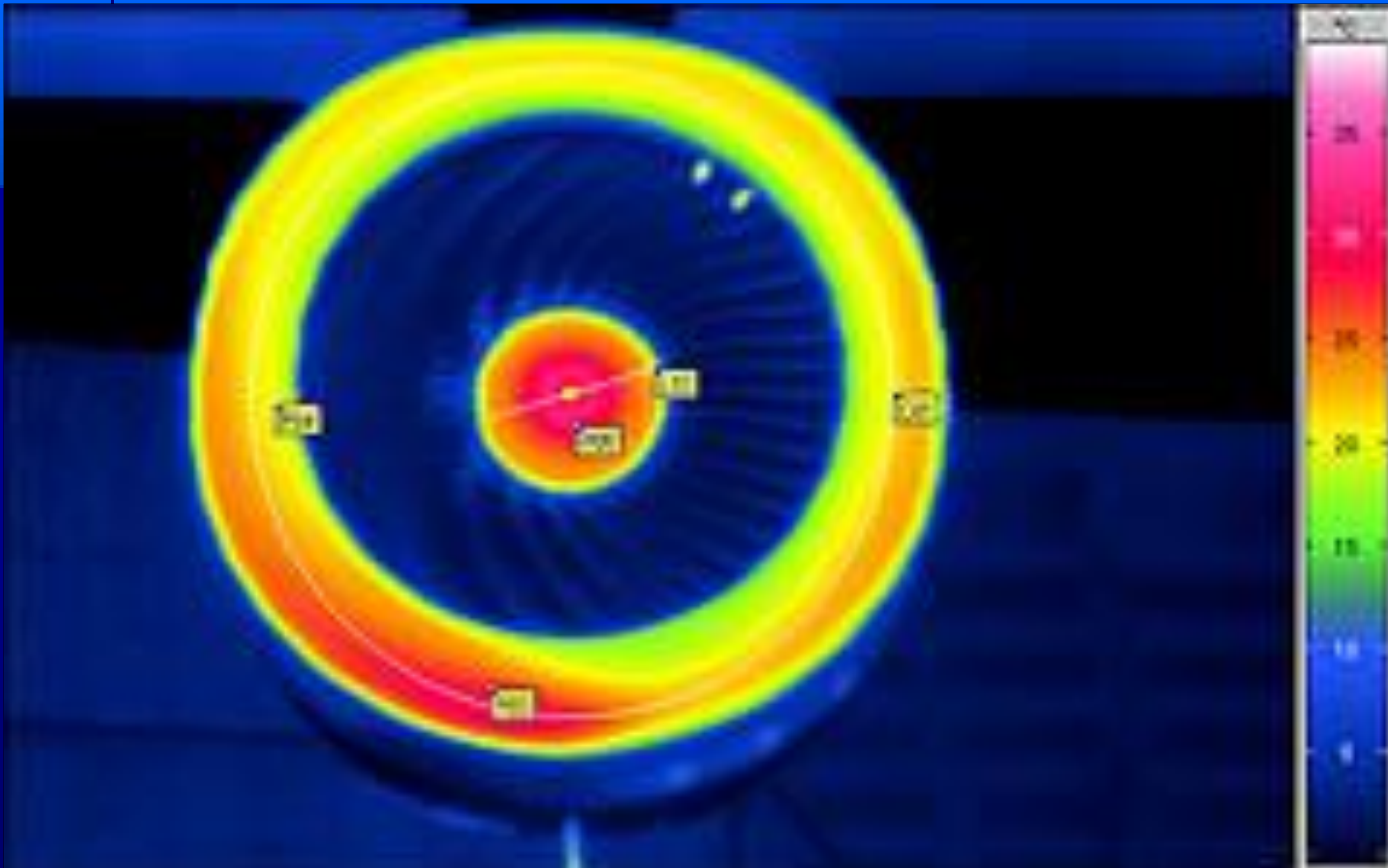
- Shearography detect stress concentrations around flaws using image-shearing camera which takes images of part in undeformed and deformed states. Test piece illuminated by expanding laser beam.

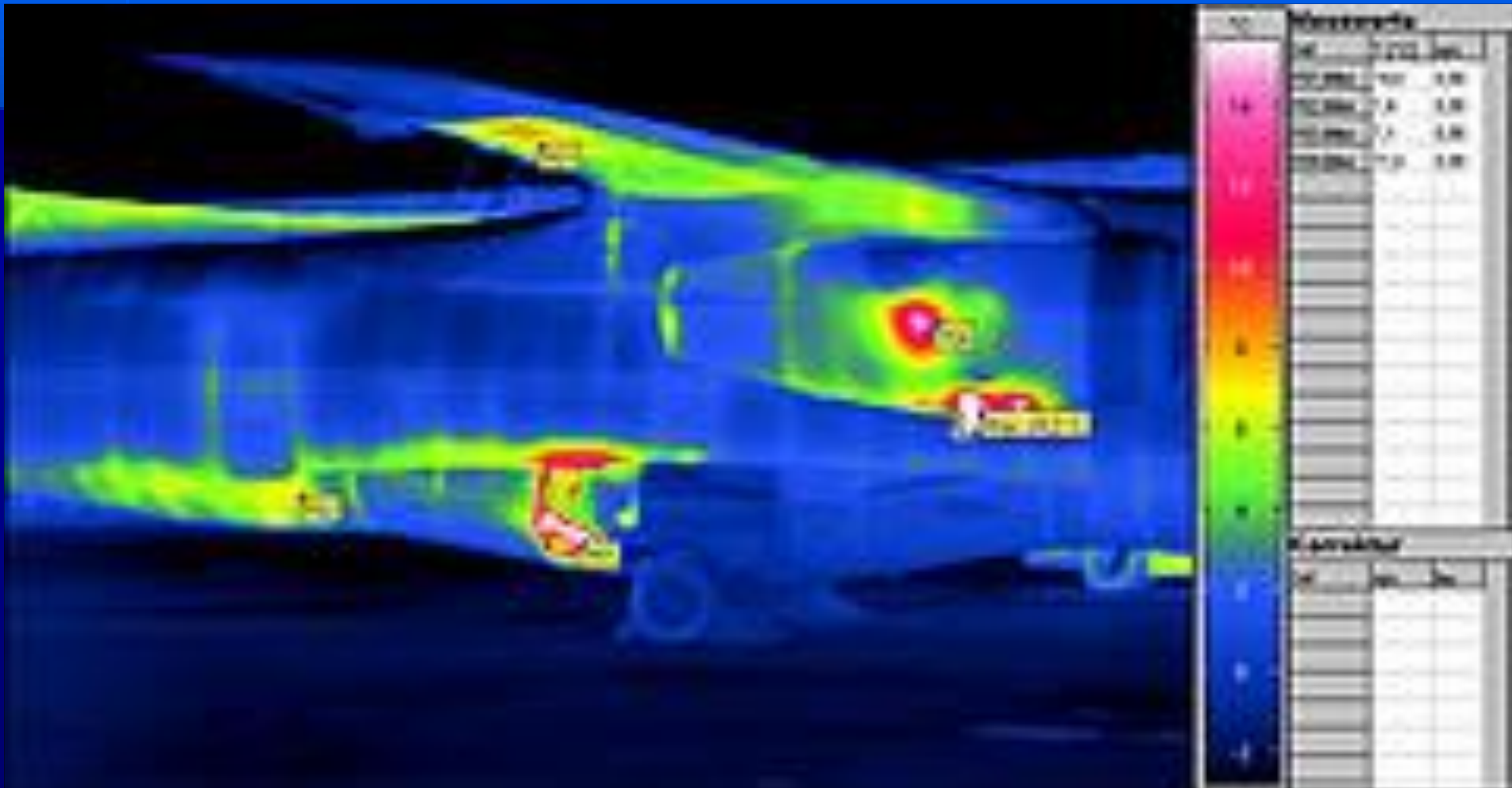


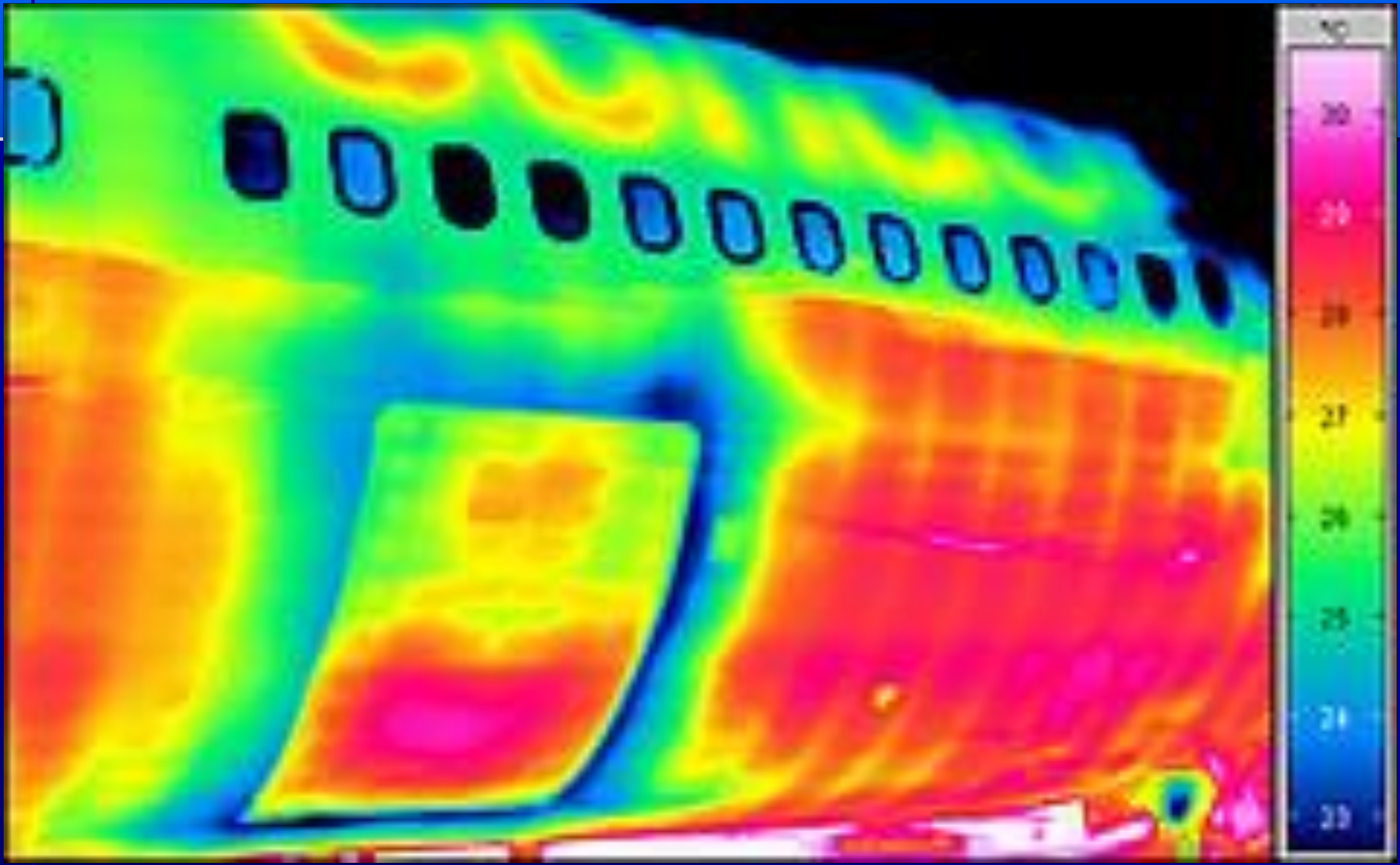
THERMOGRAPHY

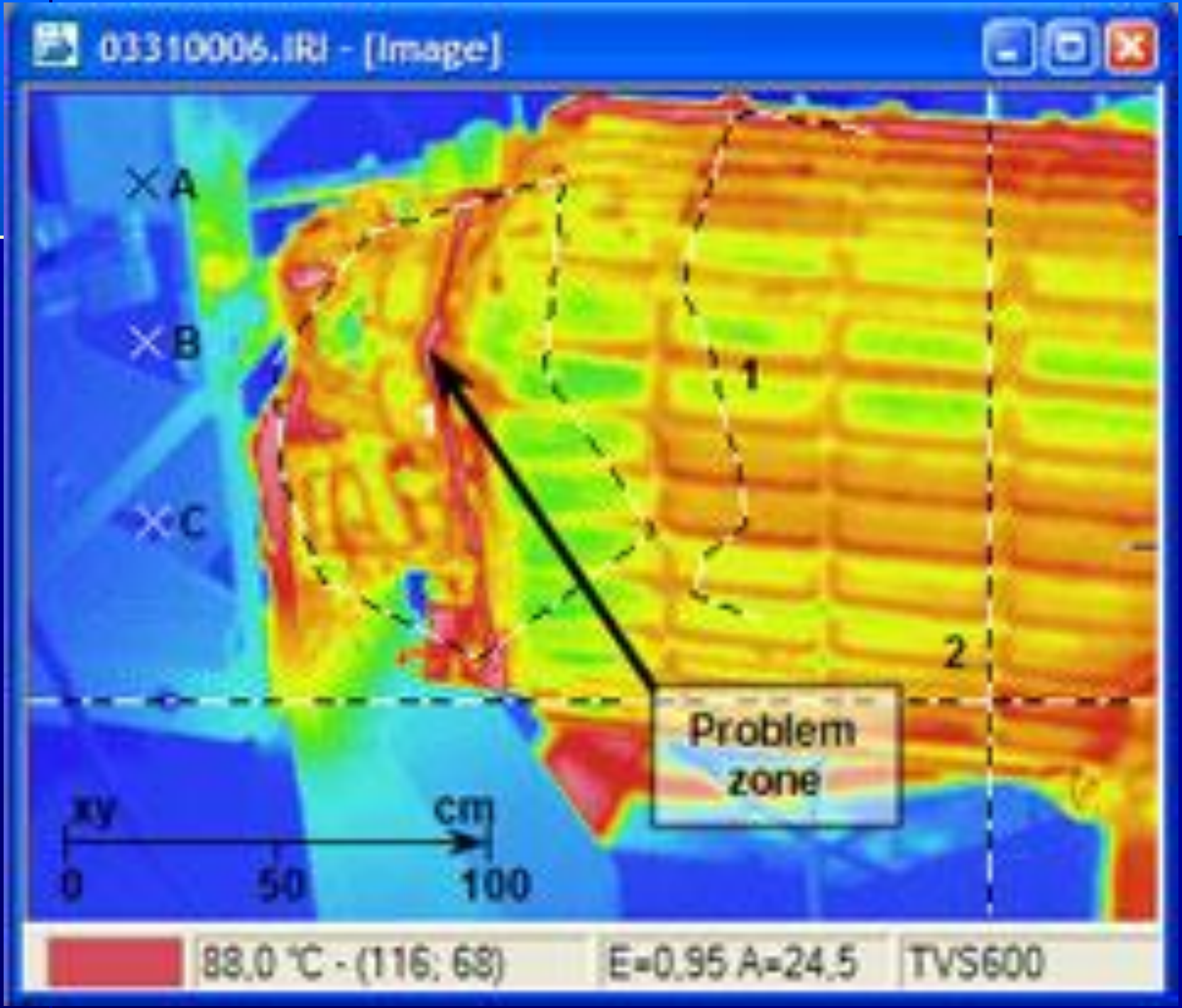
Infrared thermography (IRT), **thermal imaging**, and **thermal video** are examples of infrared imaging science. Thermographic cameras detect **thermograms**. Since infrared radiation is emitted by all objects above absolute zero according to the black body radiation law thermography makes it possible to see one's environment with or without visible illumination.





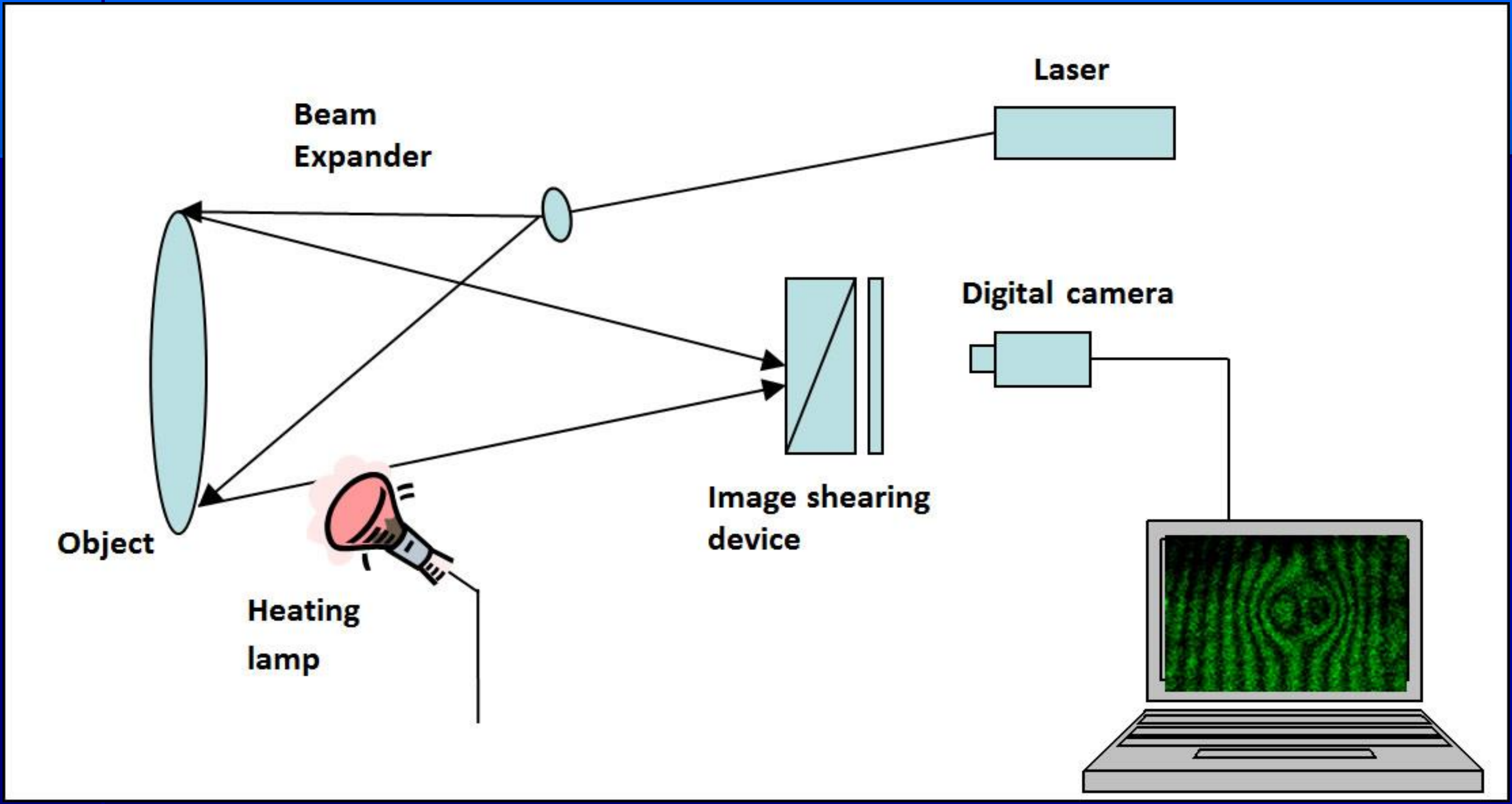




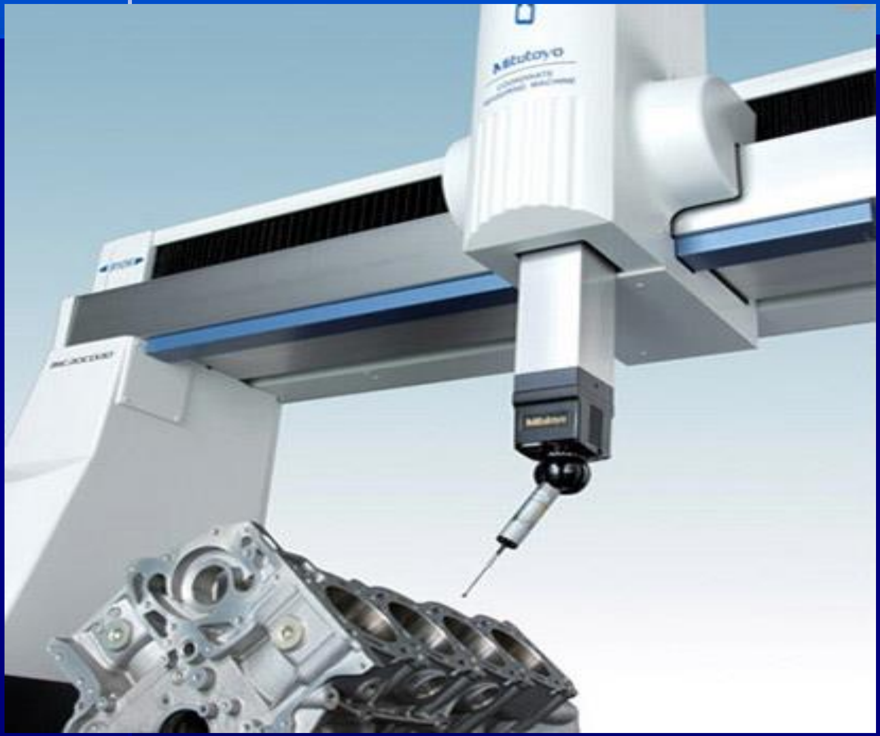


03310006.IRI - [Image]
A
B
C
1
2
Problem zone
xy
cm
0
50
100
88,0 °C - (116; 68)
E=0,95 A=24,5
TVS600

SHEAROGRAPHY



MEASUREMENTS OF DIMENSIONS



http://www.mitutoyo.co.uk/media/wysiwyg/landingpages/cmm.jpg

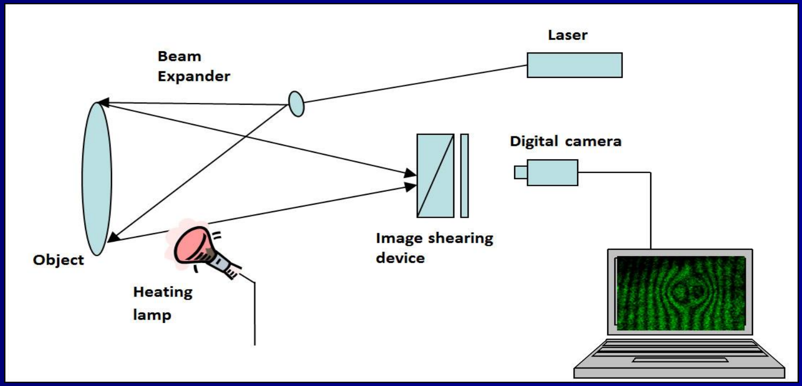
http://img.directindustry.com/images_di/photo-g/optical-sensor-for-coordinate-measuring-machine-cmm-5693-2649407.jpg

- DIRECT METHODS
- OPTIC MEASURES

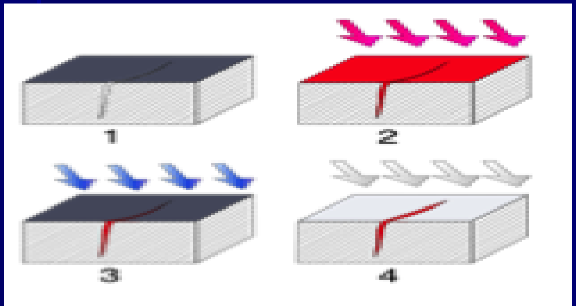
SUMARY: SURFACE METHODS

OPTIC/VISUAL

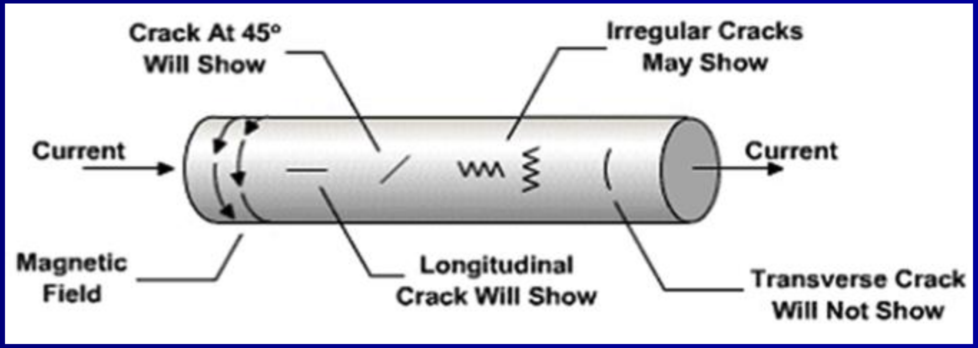
SHEAROGRAPHY



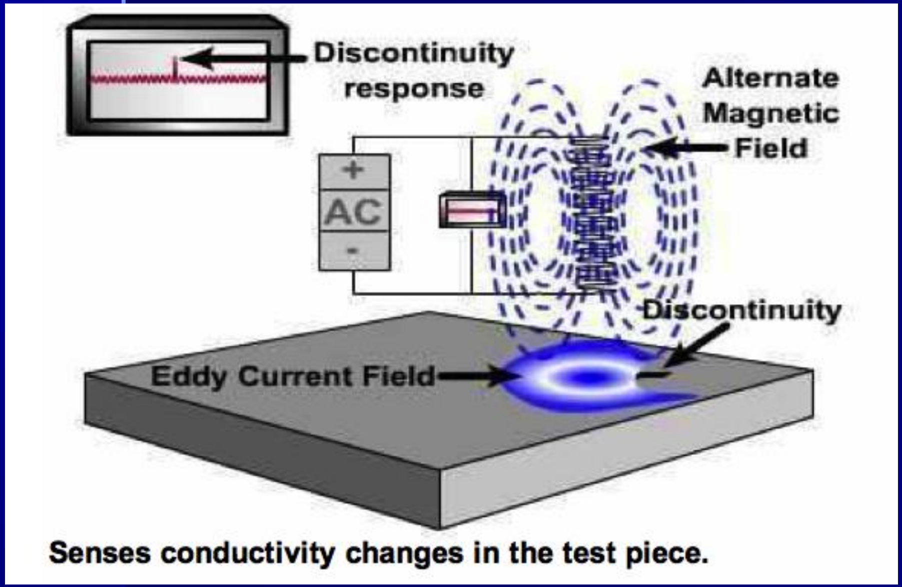
LIQUID PENETRANT



MAGNETIC



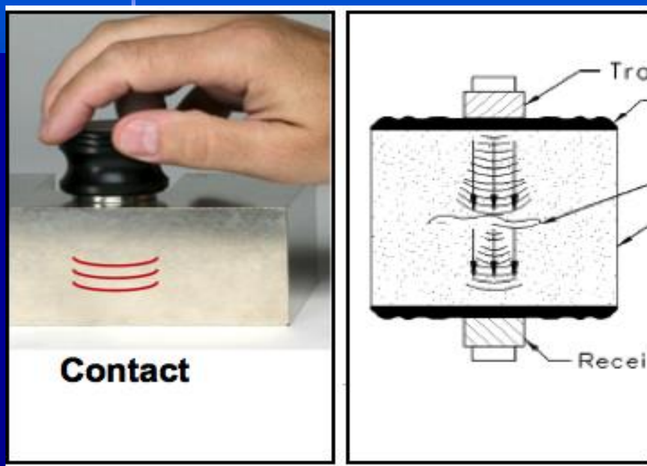
SUMMARY: UNDERSURFACE METHODS

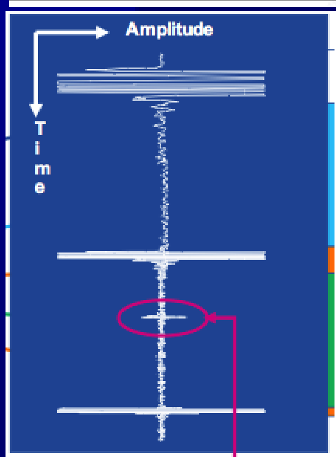


EDDY CURRENT

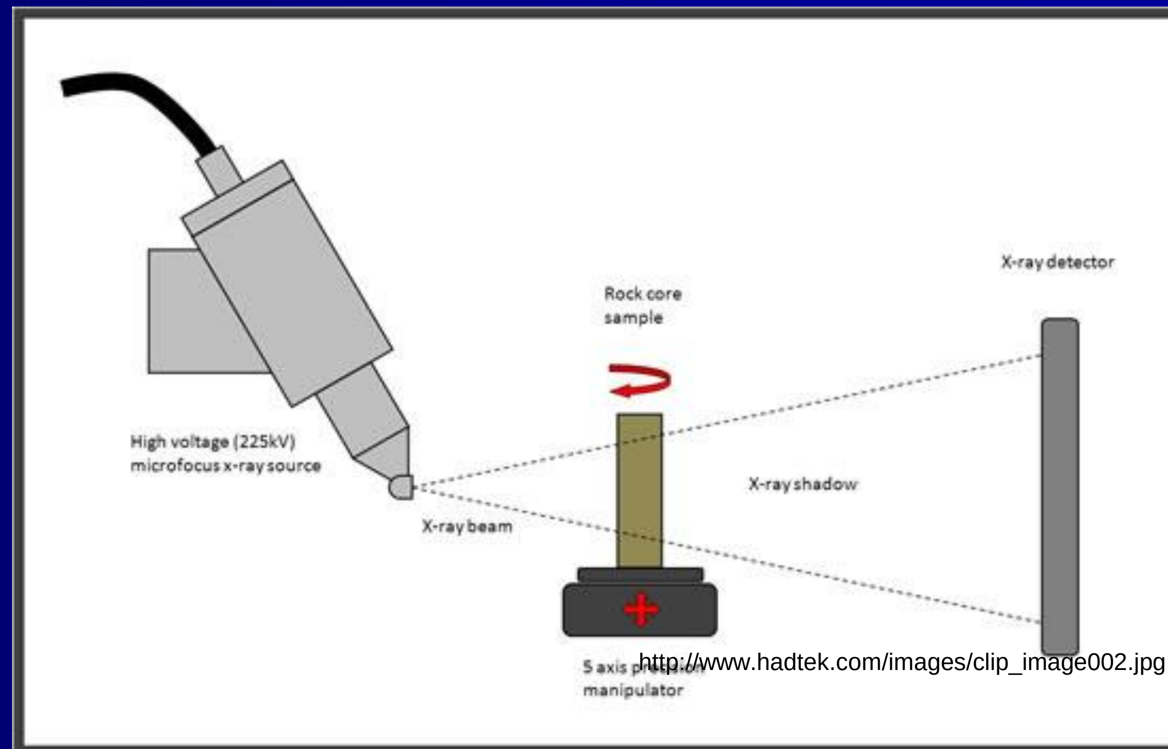
rysynki pochodzą z udostępnionych slajdów z przedmiotu „Materiały lotnicze"

VOLUME INTERIOR METHODS





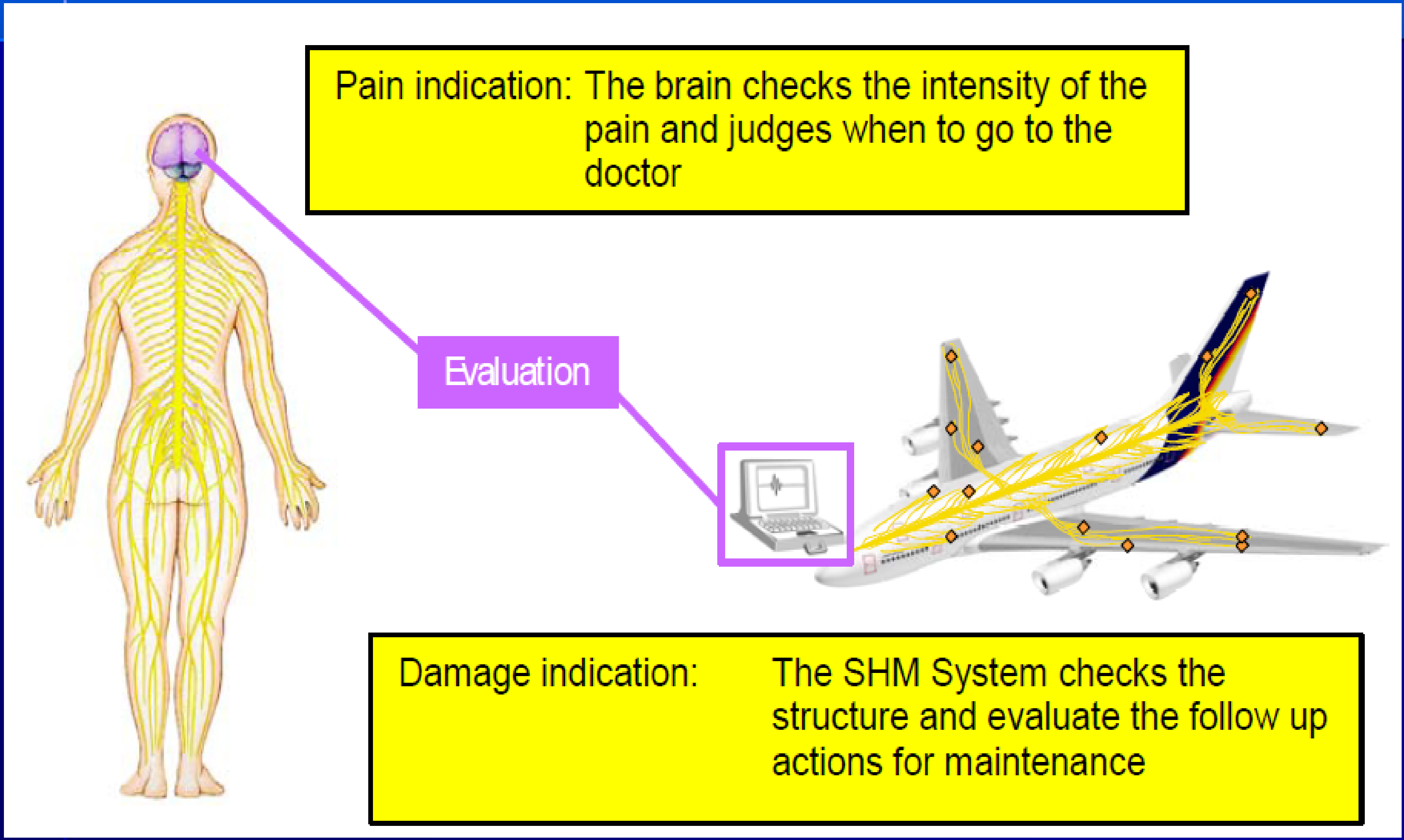
ULTRASONIC



RADIOGRAPHY

SHM – Structural Health Monitoring

SHM

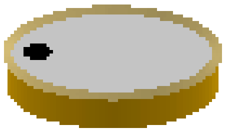


Pain indication: The brain checks the intensity of the pain and judges when to go to the doctor
Evaluation
Damage indication: The SHM System checks the structure and evaluate the follow up actions for maintenance

- In which way could **Nanotechnology** help Airbus to support **SHM Application Scenarios**?
  - sensor material
  - sensor design
  - multi-functional materials
  - multi-functional coatings
  - signal transfer
  - ...

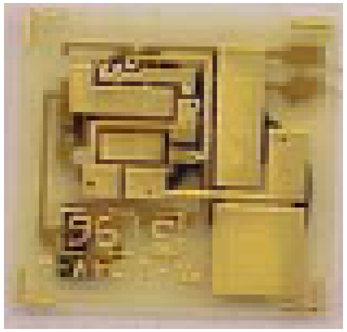
AIRBUS

SENSORS

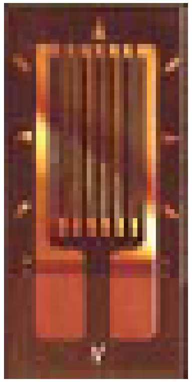


Piezoelectric

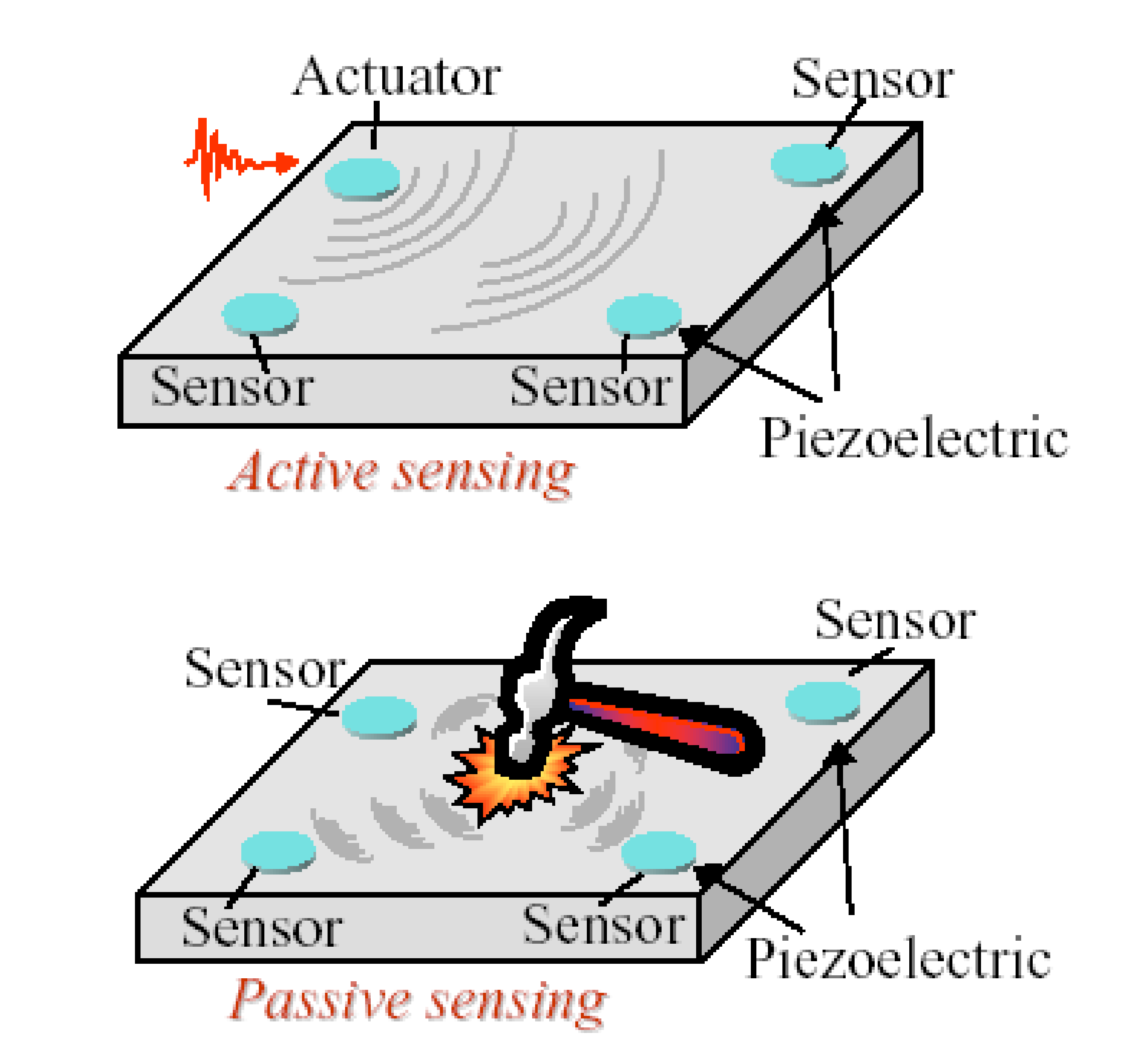
Fiber-optic



MEMS



Strain-gages



Actuator
Sensor
Sensor
Sensor
Piezoelectric
Active sensing
Sensor
Sensor
Sensor
Sensor
Piezoelectric
Passive sensing

http://www.acellent.com; Acellent Technologies, Inc.,

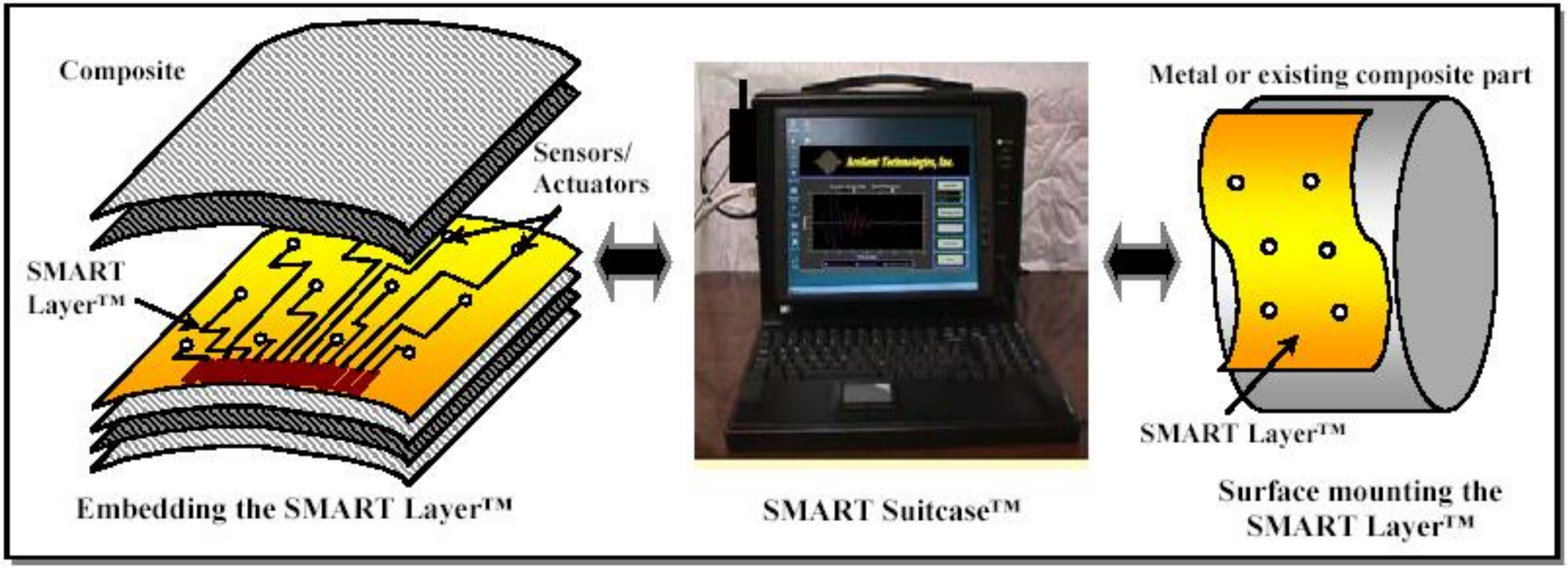
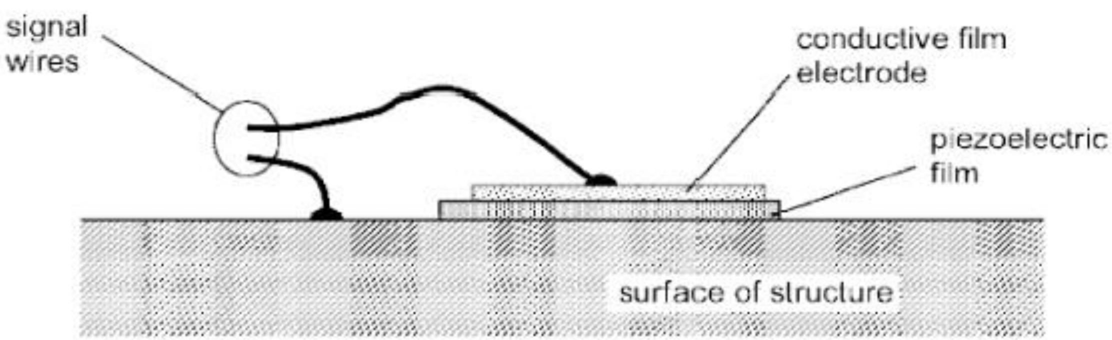


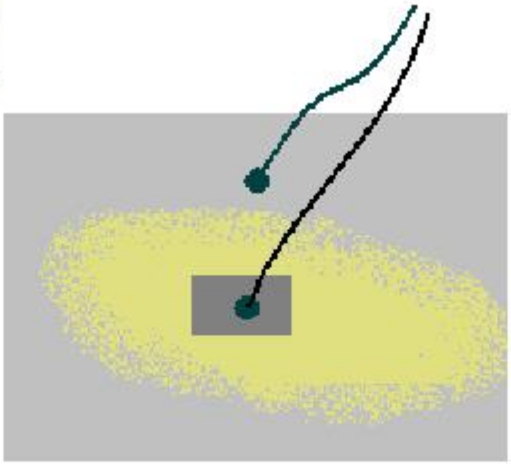
Figure 1: Acellent's SMART Layers™ and SMART Suitcase™.

SMART™ stands for **S**tanford **M**ulti-**A**ctuator-**R**eceiver **T**ransduction.

Piezo-electric Paint

- Nano Powder of lead-zirconate-titanate (PZT)
- Conversion of mechanical to electrical energy
- Aircraft Surface as a large ultrasound transducer for detection of
  - Impact
  - Vibration
  - Defects





Piezo Foils

- Nano Powder of lead-zirconate-titanate (PZT)
- Flexible and thin sensors / actuators
- Small contact wires
- Integration of many sensors
- Multi-sensor systems
  - Multi- layer / element sensors / actuators
- High sensitivity
- Broad frequency range (0,001 Hz to several GHz)

Metal Structure Application Scenarios

Detection of…

- Cracks (localisation, size)
- Crack growth (localisation, size)
- Accidental damage (localisation, intensity)
- Corrosion (localisation, severeness)
- Loads/Strain (localisation, intensity)

REDUKCJA MASY DLA ELEMENTÓW KOMPOZYTOWYCH

Ważne jest pozyskanie informacji w przypadku struktur kompozytowych o fizycznych własnościach, uszkodzeniach, uderzeniach i rozkładach naprężeń i odkształceń podczas użytkowania SP. Informacje służą do poprawy elementów konstrukcyjnych bądź systemu eksploatacji SP

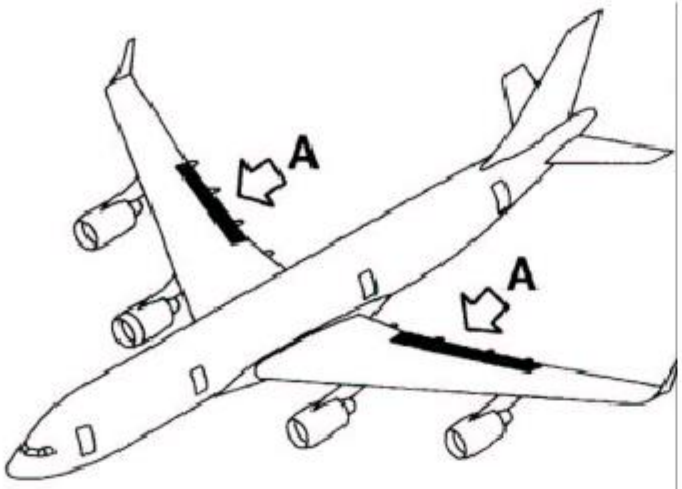
Dla kompozytów powinno być objętych działaniem SHM 8

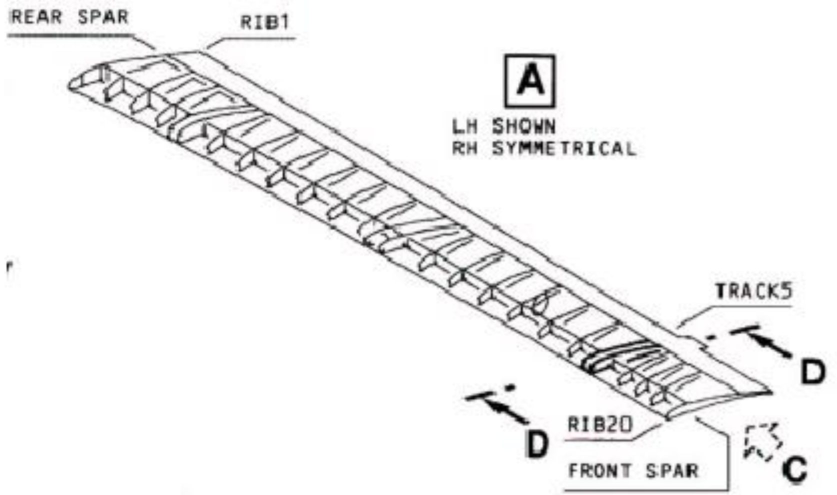
1. Impact damage
2. Stringer /skin interface failure
3. Debonding of CFRP co-bonded parts
4. Core / skin sheet debonding in sandwich structures
5. Delamination of CFRP-skin layers
6. Damage of honeycomb structure
7. Detection of missing rivet heads in CFRP structures
8. Detection of loads, stress/ strain distribution in CFRP structures.

Composite Structure Application Scenarios

Detection of…

- Impact (localisation, intensity)
- Delaminations (localisation, size)
- Debondings (localisation, size)
- Water ingress (localisation, intensity)
- Loads/Strain (localisation, intensity)





AIRBUS

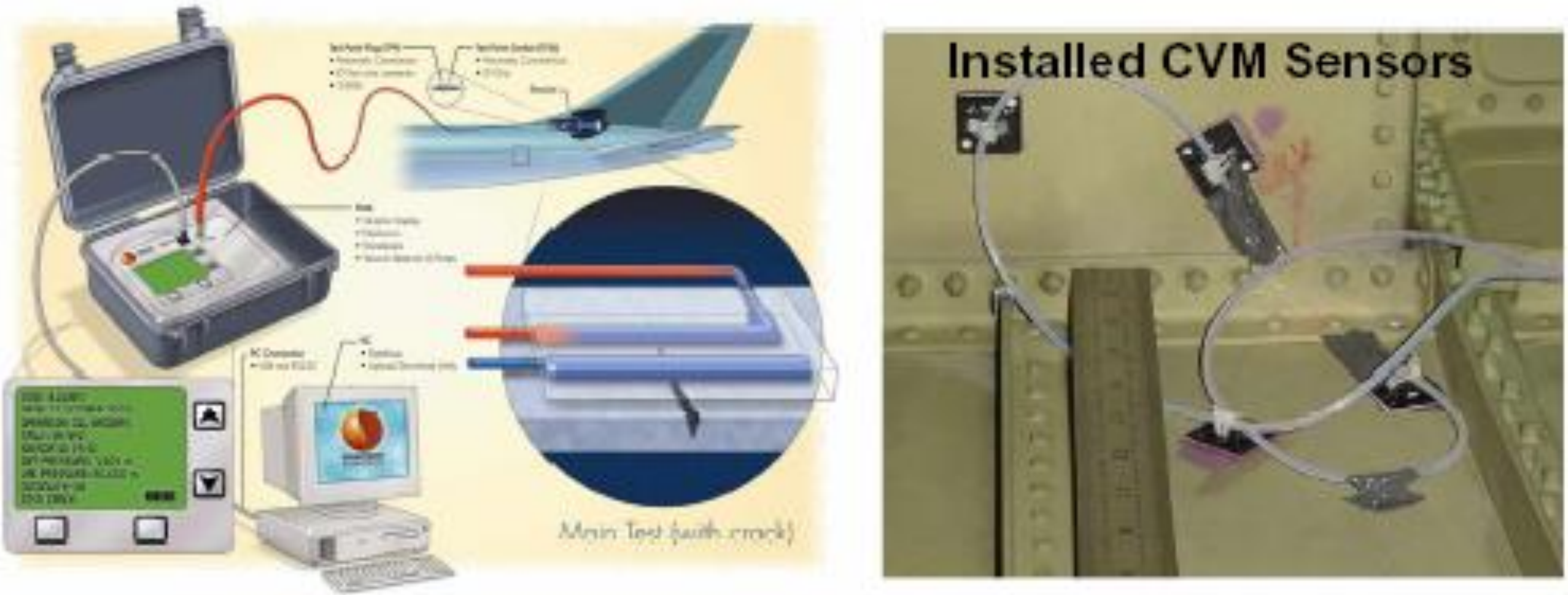
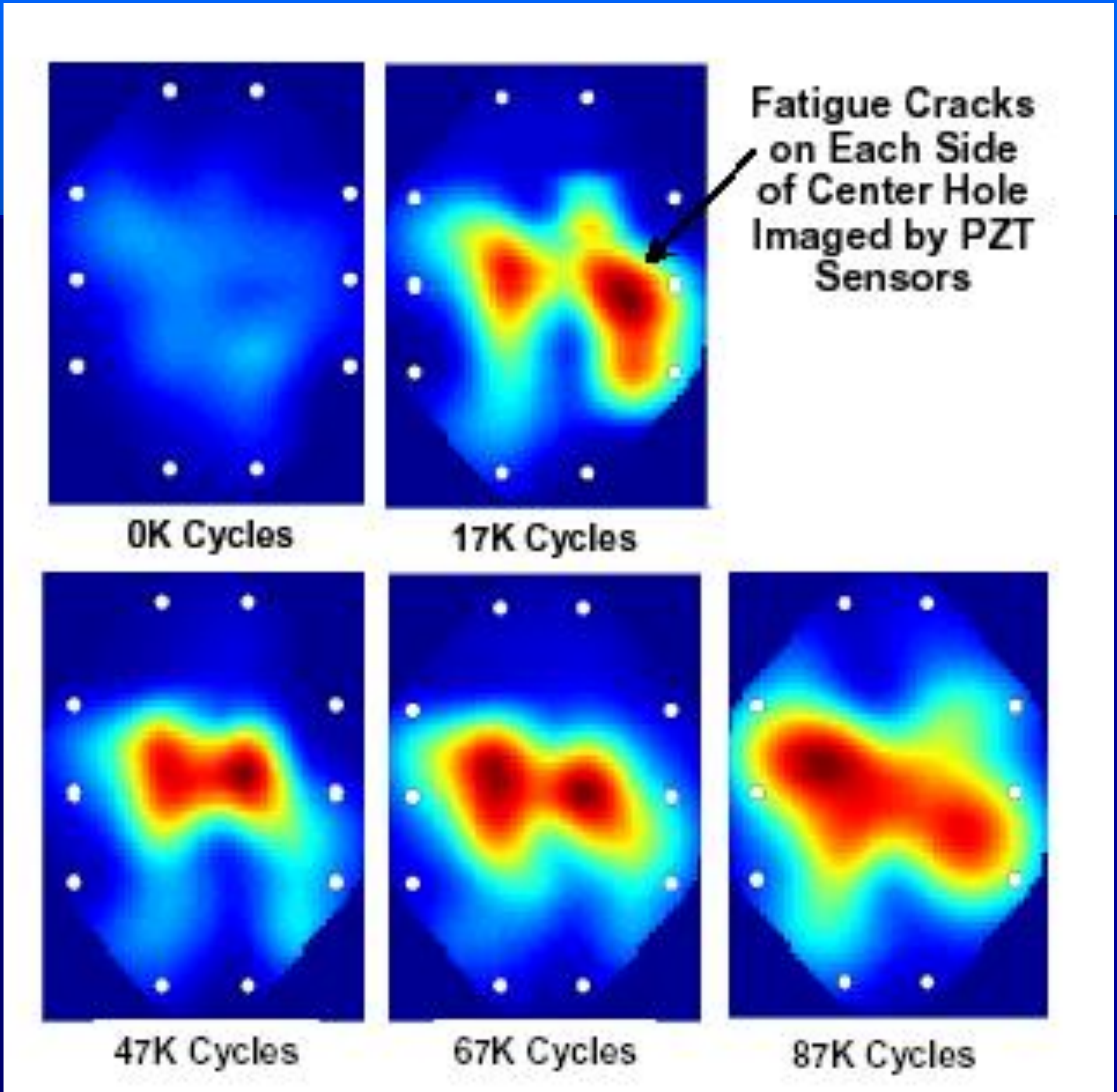


Figure 4: Crack Detection Via CVM System and Aircraft Test Installations of Sensors

Piezoelectric Transducers (PZT)



MONITORING OF A COMPOSITE REPAIR PATCH