VEDANT College of Engineering & Technology

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Department of Mechanical Engineering

I MID TERM TEST

SEM 6th **SUBJECT:** NON DESTRUCTIVE EVALUATION AND TESTING **Code: 6ME6.1A**

TIME: 1Hr Max.Marks=20

Note: (i) Answer Two Questions.
(ii) Figures to the right indicate maximum marks.

Q.1 (a) Define Penetrants and give their classification. (5)

(b) Define Developers and give their classification. (5)

OR

Q.1 (a) Explain the types of defects in composite materials. (5)

(b) Explain defect detection method for composite materials? (5)

Q.2 (a) Explain radiography process? (5)

(b) Describe scattered radiation (5)

OR

Q.2 Explain the terms
(a) Image quality indicator
(b) System performance check (5*2=10)

<u>**Solution**</u>

Answer 1(a) Penetrants

Penetrants are carefully formulated to produce the level of sensitivity desired by the inspector. The penetrant must possess a number of important characteristics:

- spread easily over the surface of the material being inspected to provide complete and even coverage.
- be drawn into surface breaking defects by capillary action.
- remain in the defect but remove easily from the surface of the part.
- remain fluid so it can be drawn back to the surface of the part through the drying and developing steps.
- be highly visible or fluoresce brightly to produce easy to see indications.
- not be harmful to the material being tested or the inspector.

Penetrant materials are not designed to perform the same. Penetrant manufactures have developed different formulations to address a variety of inspection applications. Some applications call for the detection of the smallest defects possible while in other applications, the rejectable defect size may be larger. The penetrants that are used to detect the smallest defects will also produce the largest amount of irrelevant indications.

Standard specifications classify penetrant materials according to their physical characteristics and their performance.

☐ Penetrant materials come in two basic types:

Type 1 - Fluorescent Penetrants: they contain a dye or several dyes that fluoresce when exposed to ultraviolet radiation.

Type 2 - Visible Penetrants: they contain a red dye that provides high contrast against the white developer background.

Fluorescent penetrant systems are more sensitive than visible penetrant systems because the eye is drawn to the glow of the fluorescing indication. However, visible penetrants do not require a darkened area and an ultraviolet light in order to make an inspection.

☐ Penetrants are then classified by the method used to remove the excess penetrant from the part. The four methods are:

Method A - Water Washable: penetrants can be removed from the part by rinsing with water alone. These penetrants contain an emulsifying agent (detergent) that makes it possible to wash the penetrant from the part surface with water alone. Water washable penetrants are sometimes referred to as self-emulsifying systems.

Method B - Post-Emulsifiable, Lipophilic: the penetrant is oil soluble and interacts with the oil-based emulsifier to make removal possible.

Method C - Solvent Removable: they require the use of a solvent to remove the penetrant from the part.

Method D - Post-Emulsifiable, Hydrophilic: they use an emulsifier that is a water soluble detergent which lifts the excess penetrant from the surface of the part with a water wash.

☐ Penetrants are then classified based on the strength or detectability of the indication that is produced for a number of very small and tight fatigue cracks. The five sensitivity levels are:

Level ½ - Ultra Low Sensitivity

Level 1 - Low Sensitivity

Level 2 - Medium Sensitivity

Level 3 - High Sensitivity

Level 4 - Ultra-High Sensitivity

The procedure for classifying penetrants into one of the five sensitivity levels uses specimens with small surface fatigue cracks. The brightness of the indication produced is measured using a photometer.

Answer 1(b) **Developers**

The role of the developer is to pull the trapped penetrant material out of defects and spread it out on the surface of the part so it can be seen by an inspector. Developers used with visible penetrants create a white background so there is a greater degree of contrast between the indication and the surrounding background. On the other hand, developers used with fluorescent penetrants both reflect and refract the incident ultraviolet light, allowing more of it to interact with the penetrant, causing more efficient fluorescence.

According to standards, developers are classified based on the method that the developer is applied (*as a dry powder, or dissolved or suspended in a liquid carrier*). The six standard forms of developers are:

Form a - Dry Powder

Form b - Water Soluble

Form c - Water Suspendable

Form d - Nonaqueous Type 1: Fluorescent (Solvent Based)

Form e - Nonaqueous Type 2: Visible Dye (Solvent Based)

Form f - Special Applications

Dry Powder

Dry powder developers are generally considered to be the least sensitive but they are inexpensive to use and easy to apply. Dry developers are white, fluffy powders that can be applied to a thoroughly dry surface in a number of ways; by dipping parts in a container of developer, by using a puffer to dust parts with the developer, or placing parts in a dust cabinet where the developer is blown around. Since the powder only sticks to areas of indications since they are wet, powder developers are seldom used for visible inspections.

Water Soluble

As the name implies, water soluble developers consist of a group of chemicals that are dissolved in water and form a developer layer when the water is evaporated away. The best method for applying water soluble developers is by spraying it on the part. The part can be wet or dry. Dipping, pouring, or brushing the solution on to the surface is sometimes used but these methods are less desirable. Drying is achieved by placing the wet, but well drained part, in a recirculating warm air dryer with a temperature of 21°C. Properly developed parts will have an even, light white coating over the entire surface.

Water Suspendable

Water suspendable developers consist of insoluble developer particles suspended in water. Water suspendable developers require frequent stirring or agitation to keep the particles from settling out of suspension. Water suspendable developers are applied to parts in the same manner as water soluble developers then the parts are dried using warm air.

Nonaqueous

Nonaqueous developers suspend the developer in a volatile solvent and are typically applied with a spray gun. Nonaqueous developers are commonly distributed in aerosol spray cans for portability. The solvent tends to pull penetrant from the indications by solvent action. Since the solvent is highly volatile, forced drying is not required.

Special Applications

Plastic or lacquer developers are special developers that are primarily used when a permanent record of the inspection is required.

OR

Answer *1(a)* Defects in Composites

Defects can inadvertently be produced in composite materials, either during the manufacturing process or in the course of the normal service life of the component. The manufacturing process has the potential for causing a wide range of defects, the most common of which is “porosity,” the presence of small voids in the matrix. Porosity can be caused by incorrect, or non-optimal, cure parameters such as duration, temperature, pressure, or vacuum bleeding of resin. Porosity levels can be critical, as they will affect mechanical performance parameters, such as inter-laminar shear stress. Preparation of the resin-impregnated fiber layers (pre-preg), prior to curing, can be by hand or machine. In either case there is the potential for the inclusion of foreign bodies ranging from backing film to just greasy marks from fingers. More recent low-cost manufacturing techniques, involving the infusion of resin into pre-formed dry fibers in moulds, have introduced other potential defects such as fiber misalignment, or waviness, both in the plane of the material and out-of-plane. Stitching of fiber tows (bunches of fibers), to hold them in place and prevent misalignment during cure, can itself introduce numerous regularly-spaced sites for void formation. Sandwich structures with honeycomb or foam cores can suffer from poor bonding of the skin to the core. Disbonds can occur at the skin-to-adhesive interface or at the adhesiveto-core interface. In service damage is most often caused by impacts. In monolithic composites this results in matrix cracking and delaminations of the ply layers. In some cases the surface is punctured, but often this is not the case, despite the internal delamination damage being extensive. Such damage is termed “barely-visible impact damage” (BVID). Sandwich structures can suffer from the same matrix cracking and delaminations in the skins when impacted, but other types of failure can also occur. For example, disbonding can be caused at the skin-to-adhesive interface. Fillet-bond failure is where the honeycomb-to-adhesive bond is weakened. Core crushing occurs where the impact energy is absorbed by the core, which distorts and folds, often being returned to its original shape but with greatly reduced compressive strength.

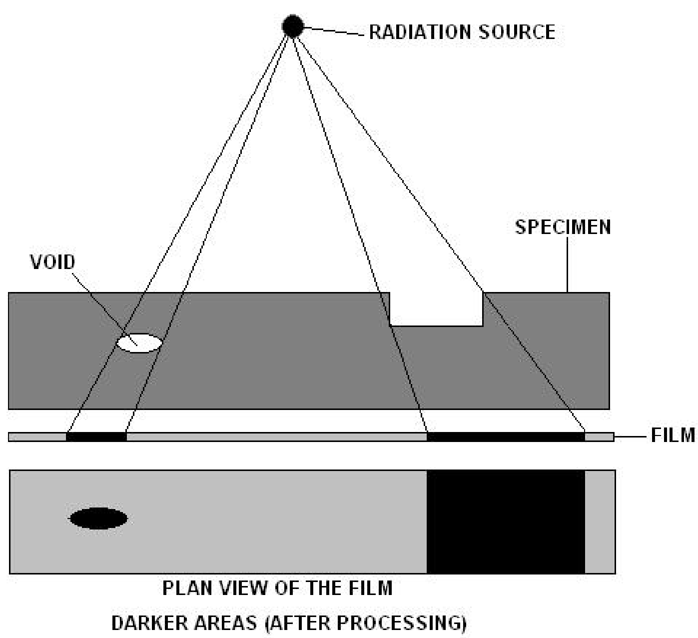
Significance of Defects in Composites It is clear that in many ways, a composite can differ from the ideal either during manufacture or in service. The extent to which any of these deviations from ideal should be considered as a defect is a function of the intended use of the material and the significance of the deviation on the required performance. All defect types are known to adversely affect performance in some way. However, the type and size of defect that needs to be found can only be set for each application based on the results of mechanical destructive tests and a detailed knowledge of how such defects grow, if at all, in the expected service environment. This process sets the acceptance criteria for manufacturing and in-service defects. It is beyond the scope of this article to discuss the significance of defects in detail but it should be stressed that defect significance must be assessed before meaningful acceptance and rejection criteria can be established. In order to discuss the use of NDE for composites it will be necessary to assume that some of the defects mentioned will reach a significant size and must therefore be found. This will be done by taking the conclusions that are emerging from defect significance studies for long fiber CFC materials for aerospace applications. This will serve as a general guide since this is one of the most demanding applications due to the necessity of reducing weight as much as possible. These assumptions may not, however, be applicable to another application or composite type.

Answer *1(b)* For a defect detection method to be reliable, its response on a defective structure must be significantly different to that on a sound structure. By far the most commonly used non-destructive test for composite structures is ultrasonic inspection, often producing a two-dimensional "C-scan" map of the structure. In composite structures, defects are most often in the form of either disbonds or delaminations in the plane of the material, or porosity. The reason for favoring ultrasound inspection is that it is very sensitive to these types of defect commonly found in composites. It is also one of the few methods available for detecting porosity and it can detect most of the other defects at the same time. Low-frequency vibration methods are utilized for in-service inspection of sandwich structures with honeycomb cores where ultrasound is not sensitive to all the types of defect. They are particularly useful as a rapid search tool to detect trouble spots but have difficulty when identifying the type or extent of defects. For glass-fiber reinforced pressure vessels acoustic emission is in common use for monitoring pressure tests to detect damage. X-ray imaging has some uses for damage characterization where the damage is surface-breaking and a contrast medium can be injected.

The two most commonly used detection methods

(a) Ultrasound
(b) Low-frequency vibration

Answer 2(a) Radiography is a method of non-destructive testing where many types of manufactured components can be examined to verify the internal structure and integrity of the specimen. Industrial Radiography can be performed utilizing either X-rays or gamma rays. Both are forms of electromagnetic radiation. The difference between various forms of electromagnetic energy is related to the wavelength. X and gamma rays have the shortest wavelength and this property leads to the ability to penetrate, travel through, and exit various materials such as carbon steel and other metals



This method of weld testing makes use of X-rays, produced by an X-ray tube, or gamma rays, produced by a radioactive isotope. The basic principle of radiographic inspection of welds is the same as that for medical radiography. Penetrating radiation is passed through a solid object, in this case a weld rather that part of the human body, onto a photographic film, resulting in an image of the object's internal structure being deposited on the film. The amount of energy absorbed by the object depends on its thickness and density. Energy not absorbed by the object will cause exposure of the radiographic film. These areas will be dark when the film is developed. Areas of the film exposed to less energy remain lighter. Therefore, areas of the object where the thickness has been changed by discontinuities, such as porosity or cracks, will appear as dark outlines on the film. Inclusions of low density, such as slag, will appear as dark areas on the film while inclusions of high density, such as tungsten, will appear as light areas. All discontinuities are detected by viewing shape and variation in density of the processed film.

Radiographic testing can provide a permanent film record of weld quality that is relatively easy to interpret by trained personnel. This testing method is usually suited to having access to both sides of the welded joint (with the exception of double wall signal image techniques used on some pipe work). Although this is a slow and expensive method of nondestructive testing, it is a positive method for detecting porosity, inclusions, cracks, and voids in the interior of welds. It is essential that qualified personnel conduct radiographic interpretation since false interpretation of radiographs can be expensive and interfere seriously with productivity. There are obvious safety considerations when conducting radiographic testing. X-ray and gamma radiation is invisible to the naked eye and can have serious health and safety implications. Only suitably trained and qualified personnel should practice this type of testing..

Answer 2(b) Scatter radiation

Most people are concerned about their own health and safety when they get an X-Ray. In truth, unless you receive frequent X-rays, the individuals who are at most risk for cumulative radiation damage are the radiology technicians who spend the bulk of their working day surrounded by radioactive waves and particles. While technicians typically retire behind a radiation-proof wall or barrier, they must still take very careful precautions in terms of protective clothing, shielding and their daily work habits. They are protecting themselves from a particular form of radiation, called “scatter” or “secondary” radiation.

Scatter Radiation Occurs in Three Ways

By definition, “Scatter radiation occurs when radiation deflects off an object, causing x-rays to be scattered. It is important to keep in mind that scatter radiation has the ability to travel in all different directions,” (courtesy of unversalmedicalinc.com).

In the case of X-rays, the most common source of scatter radiation for most humans, the “object” in question is the patient. Even those the X-Rays are specifically focused on a single target, the x-rays will still scatter and those scattered rays can continue to scatter around the room based on various design features.

• Scatter radiation. The bulk of this type of radiation derives from the X-rays bouncing off the patient’s body.

• Back scatter. This type of scatter radiation is created from behind the film and directed back towards the X-ray tube. To prevent backscatter, the industry has adopted the standard procedure of adding a 0.005″ lead screen in front and a 0.010″ screen behind the film for added protection. Additionally, a letter “B” is placed

on the back of the cassette to indicate an abundance of backscatter. If the B is visible in the resulting image, backscatter is occurring, the strength of the “B”’s visibility indicating the level of backscatter taking place.
• Side scatter. Side scatter is caused by objects in the immediate areas, such as walls, floors and tables. To mitigate side scatter, you may have noticed that X-ray rooms are typically void of other objects and the table is located in the center of the space. This isolates the X-rays as much as possible so they are less prone to side scatter.

Precautions For Avoiding Scatter Radiation

There are several types of precautions that medical facilities and other workplaces prone to scatter radiation take to ensure the health of their employees.

1. Design the room and space accordingly. The designers must be educated about the risks and dangers of radiation and scatter radiation so that rooms are designed accordingly. For example, room designs and furnishings should encourage minimum exposure to scatter radiation, and placing the radiation tech behind a protective wall or curtain, at an angle that makes them the least prone to absorbing scattered radiation.
2. Provide proper protective clothing. In most cases, a lead apron is all that is required to keep personnel safe. However, more extensive protective clothing may be required depending on the situation and the length and duration of the employees’ radiation exposure.
3. Take proper precautions. Employees who work with radiation should be continuously educated and trained regarding the dangers of radiation exposure and the precautions that make the most sense for their workplace and environment. For example, radiologists should minimize the X-ray beam to cover the area of interest, diminishing the potential for scatter; they should also stand at least 6-feet away and at a 90-degree angle to the patient.

While it’s easy to grow accustomed to health and safety risks in the workplace, it’s imperative that those exposed to scatter radiation do not take those risks lightly. A little protective clothing and a change in routine can go a long ways towards preserving your long-term health.

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OR

Answer 2(a) **Image quality indicators are** used in RTR for the same reasons they are in film radiography to measure the performance of technique and equipment. (As with film radiography, contrast changes (seeing small thickness changes) and definition in film radiography or spatial resolution in RTR is being able to see small anomalies.) Image quality indicators (IQI) such as plaque type and wire type pentameters can be used, but the orientation to the X-ray beam is critical. IQIs original use was to indicate quality with a still image, not with a moving image as with RTR.

A line pair gauge is a device used in many radioscopic inspections. This device indicates how many line pairs can be discerned in a width of one millimeter (.03937 inches). The resolving capability of an RTR system often is referred to as a certain number of LP, meaning LP/mm. Typical ranges are 2-5 LP/mm for conventional RTR systems and up to 20 LP/mm for microfocus RTR systems. Ten LP/mm indicates a space of .003937 inches (1 mm divided by 10). The line pair gauge is made of lead or gold and situated on a plastic base providing a good contrast. The lines at one end of the gauge are spaced widely and converge at the opposite end. When the separation of the lines no longer is visible, the perpendicular line closest to it is noted. Starting at the end of the gauge with the wide spaces, perpendicular lines are counted until no separation can be seen, and this number of lines is noted as well. With the gauge being used for this example, there are 18 perpendicular lines on one side and 18 corresponding numbers on the top opposite side. Matching the number with its line indicates the LP/mm. For instance, if the separation of lines cannot be seen beyond the mark between that labeled 3 and that labeled 4, this is 3 ½ LP/mm. If the limit of separation of the lines is one mark below the last mark where they converge or the 17th mark, this corresponds to 18 LP/mm because the 17th number down the scale is 18. In some instances, a part with an actual defect can be used as a check to see if the equipment is performing at a minimum level.

Figure . Photograph of line pair gauge made by Victoreen.

Another device made by Victoreen appears in Figure below. This is a wire mesh LP gauge which is used to verify the resolution achievable by the system. This gauge reads in LP/in and can be placed directly on the image intensifier.

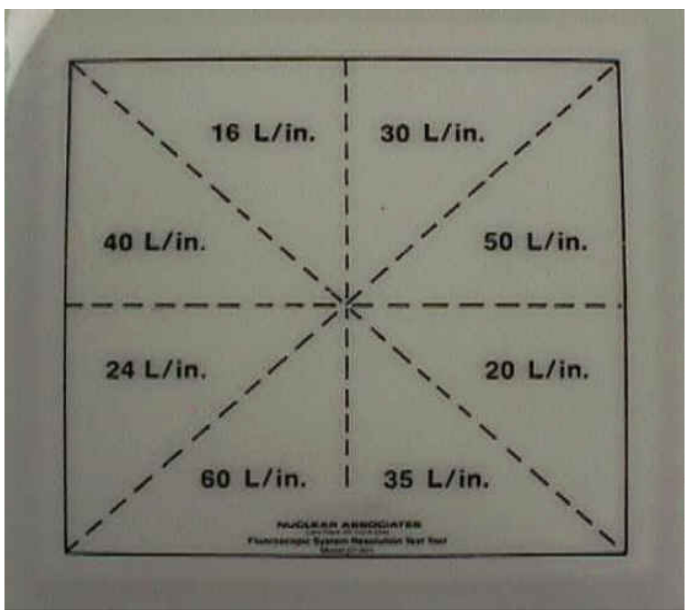
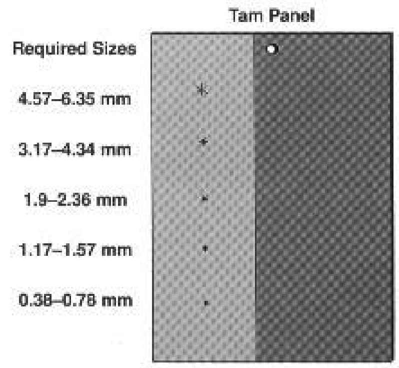


Figure . Photograph of line pair gauge made by Victoreen.

In summary, several different image quality indicators can be used, the most common being the LP gauge for spatial resolution and the step wedge for contrast sensitivity. Calibration blocks or actual test pieces with known discontinuities also are used. Some test procedures require a check of the image before and after each inspection shift.

Answer 2(b) A system performance check is typically required daily, at the reactivation of a system after maintenance or repairs, or any time the system is suspected of being out of control. System performance checks involve processing a test specimen with known defects to determine if the process will reveal discontinuities of the size required. The specimen must be processed following the same procedure used to process production parts. The ideal specimen is a production item that has natural defects of the minimum acceptable size. As with penetrant inspections in general, results are directly dependent on the skill of the operator and, therefore, each operator should process a test specimen.



There are some universal test specimens that can be used if a reference part is not available. The most commonly used test specimen is the *TAM* or *PSM* panel which is used for fluorescent penetrant systems. These panels are usually made of stainless steel that has been chrome plated on one half and surfaced finished on the other half to produce the desired roughness. The chrome plated section is impacted from the back side to produce a starburst set of cracks in the chrome. There are five impacted areas with a range of different crack sizes corresponding to the five levels of sensitivity.

Care of system performance check specimens is critical. Specimens should be handled carefully to avoid damage. They should be cleaned thoroughly between uses and storage in a solvent is generally recommended. Before processing a specimen, it should be inspected under UV light to make sure that it is clean and not already producing an indication.