APPLICABILITY OF NDT METHODS TO VARIOUS TYPES OF FLAW

Flaw	Material	Appearance and cause of flow	Penetrant	Magnetic	Ultrasonic	Eddy Current	X-ray
Burst	F and NF wrought	Processing. Surface or internal. Straight or irregular cavities, large to very tight. Caused by to low a working temperature during forging, rolling or extruding.	NO	Yes if s.b.	R	Confined rod wire 6 mm.	NO
Cold Shut	F and NF castings	Inherent. Surface or subsurface. Smooth indentations on surface similar to forging laps. Caused by two streams of molten metal not fusing together due to formation of oxide films, dross, or partial solidification, Splashing and interrupted pouring are also culprits.	R	R	No	No	Yes
Fillet crack	F and NF wrought	Service. Surface. Occurs at head/shank radius of bolts or where large changes in diameter occur. Caused by service loading, leading to fatigue cracking, or overloading.	Yes	Yes	Yes	No	No
Grinding cracks (see note)	F and NF wrought	Processing. Surface. Very shallow and sharp at the root. Similar to heat treatment cracks, and may occur in groups. Generally at right angles to grinding direction. Normally occurs in hardened surfaces, or high-strength steel, and titanium. Caused by incorrect grinding technique resulting in localized overheating, leading to microstructural phase changes and dimensional changes and hence cracking.	R	R	No	Possible	No
Heat-affected zone cracks	F and NF weldments	Processing. Surface. Deep and very tight cracks parallel to weld, in the heat-affected zone. Due to hot cracking; see chapter 3 ‘Welding’.	Yes	Yes	Specialized	Possible	No
Heat treatment	F and NF wrought castings	Processing. Surface. Usually deep and forked with random patter. Caused by sharp changes in section, scores, nicks, etc. leading to thermal gradients on heating or cooling which set up high localized stresses, sufficient to cause rupture of the metal. Keyways, sharp corner radii, undercuts, etc. are very often the primary cause of this type of cracking.	Yes	Yes	No	No	No

APPLICABILITY OF NDT METHODS TO VARIOUS TYPES OF FLAW

Flaw	Material	Appearance and cause of flow	Penetrant	Magnetic	Ultrasonic	Eddy Current	X-ray
Surface shrinkage cracks	F and NF wrought	Processing. Surface. On the face of the weld, fusion zone and base metal. Range from very small, tight to shallow open or deep. Generally the result of incorrect heat application during welding, resulting in localized hot spots, thermal gradients and cracking. Restriction of movement (contraction or expansion) during heating or cooling during welding or heat treatment may also cause this form of cracking.	R	Yes	No	Confined to tune and pipe	No
Cracks in threads	F and NF wrought	Processing. Surface. Surface in root of threads. If threads are rolled, cracking may be due to incorrect thread-rolling technique. In service cracks may arise due to service loading leading to either tensile failure or fatigue cracking.	Yes	Yes	No	No	No
Cracks in tubes	F and NF wrought	Inherent, internal and external, may be surface or subsurface. Generally parallel to longitudinal direction of tube. Caused during tube-making operations by over-reduction (working), foreign material entrapment, lack of lubricant, faulty hollows.	Possible for external flaws.		Yes	Yes	No
Cracks in tubes	F and NF wrought	Processing. Surface. Due to service conditions; over-pressurization, fatigue, expansion and contraction, etc. Cracks may be longitudinal or transverse too tube.	Generally indicated in service by leakage from tube or pipe.				
Cracks in tubes	F and NF wrought	Processing. Surface. Generally transverse, but may be longitudinal. Due to tube-manipulation techniques, e.g. bending, beading, swaging, etc., not taking into account material material characteristics.	Yes Yes No Pressure testing may be more applicable.			NO	
Hydrogen flake	F and NF wrought	Processing. Internal. May be exposed on fracture surface as silver-grey flakes. Very thin and parallel to grain. Caused by decreased solubility of hydrogen in metal on cooling from forging temperature, resulting in internal fissure. Usually found in heavy forgings.	No	No	R	No	No

APPLICABILITY OF NDT METHODS TO VARIOUS TYPES OF FLAW

Flaw	Material	Appearance and cause of flow	Penetrant	Magnetic	Ultrasonic	Eddy Current	X-ray
Hydrogen embitterment	F wrought	Processing. Generally found in high-strength steels with a tensile strength in excess of 1500 MPa. Cracks are unlikely to be found, as cracking occurs only on loading and even then failure is likely to be instantaneous.	Yes	Yes	Yes	Yes	No
Stress Corrosion cracking	F and NF wrought	Inherent characteristic of material, particularly high-strength steels and aluminum alloys containing zinc. Surface, but cases of subsurface cracks are known. Cracks may be shallow, deep, randomly orientated. Stresses may be due to service loadings or residual stresses from processing. Corrosive environment does not necessarily have to be highly aggressive.	Yes	Yes	Yes	Yes	NO
Inclusions	F and NF weldments	Processing. Surface and subsurface. Any shape, grouped or randomly distributed. Caused by oxides, sulphides, slag or other non-metallic foreign material entrapped in weld metal or between base metal and weld metal.	No	Yes if s.b	R	Confined to thin-walled tube	R
Inclusions	F and NF wrought	Inherent. Internal, may appear on surface following machining. Generally long and straight following grain direction of the material, these are likely to be slag or oxides. Non-plastic inclusions tend to be fragmented, and may be associated with small cavities. Occur in the original billet and ingot.	No	Yes if s.b	R	Confined to thin-walled tube	No
Inclusions	F and NF castings	Inherent. Internal. May be surface. Due to slag, dross, mould pickup, oxide etc. Due to lack of control during melting and pouring stages. Also poor mould preparation.	No	No	No	No	Yes
Lack of penetration	F and NF weldments	Processing. Internal and surface. Generally irregular and fine occurring at root and parallel to weld run. Caused by root face of weld not reaching fusion temperature before deposition of metal. Too large a welding rod and too fast a traverse speed can cause this. Welding technique faulty.	Yes, if weld root accessible	Yes	Specific applications	Confirmed to thin-walled tube.	R
Laminations (banding)	F and NF wrought	Inherent. Surface and internal. Flat and thing aligned parallel to surface of metal. May be due to pipe, blisters, seams, oxides and segregates etc, which elongate into thin layers on working the metal.	Yes	Yes	R	No	No

APPLICABILITY OF NDT METHODS TO VARIOUS TYPES OF FLAW

Flaw	Material	Appearance and cause of flow	Penetrant	Magnetic	Ultrasonic	Eddy Current	X-ray
Laps and seams	F and NF wrought	Processing. Surface. Appear as wavy lines, sometimes quite deep and very tight. Also found in rolled threads. Occurs during rolling, forging and stamping due to faulty or over-filled dies caused material to be folded back on itself and flattened into surface of metal.	Yes	Yes	Yes	Confined to tube and pipe	No
Micro-shrinkage	F and NF castings	Inherent/processing. Internal. Small filamentary voids at grain boundaries, appearing as porosity in cross-section. Shrinkage occurs while metal is in a plastic or semi-plastic state, and if molten metal cannot flow into these areas as the casting cools, a void will result. Caused by withdrawal of low melting point constituents from grain boundaries.	Yes if s.b	No	No	No	R
Gas porosity	F and NF weldments	Processing. Surface or subsurface. Rounded or elongated, pear-shaped with or with out sharp discontinuity at the point. Scattered or uniformly distributed. May be concentrated at toe of weld. Caused by gas entrapment in molten metal during welding due to moisture in base metal, flux, or filler, or incorrect weld preparation.	Yes if s.b	R	R	Confined to tube and pipe	R
Oxide porosity	F and NF aluminum	Inherent/processing. Internal. Thin fissures in metal parallel to grain flow. Originates from porosity in the ingot, which if oxidized prevents fusion of the porosity during subsequent rolling, forging or extruding.	No	R	R	No	No
Hot tears	F and NF castings	Inherent. Surface or internal. Ragged lines of variable width, and branching cracks. Occurs singularly or in groups. Caused by non-uniform cooling, resulting in high localized stresses which cause rupture of the metal while it is still in a semi-molten state. Generally occurs adjacent thin-thick sections.	Yes if s.b	No	No	No	R

Key: F = ferrous, NF = non-ferrous, R = Recommended, s.b = surface breaking
Yes = generally applicable, No = not recommended due to better methods being available, or not suitable, Possible = may require a specialized approach for that part.

Note: Incorrect grinding techniques while producing localized micro structural changes may not necessarily result in cracking. Surface etching following grinding can indicate localizes areas of grinding abuse. It is recommended that ground parts are inspected by both acid etching and NDT methods.

APPLICABILITY OF NDT METHODS TO VARIOUS TYPES OF FLAW

Expected minimum flaw sizes detectable with the various NDT methods.

NDT method	Expected minimum flaw size*
Magnetic	1mm surface length 0.015 mm float bottomed hole† 1mm surface length 2% of the material thickness (i.e. min flaw size increases with thickness) 1 mm surface length
Penetrant Dye	
Ultrasonics	
Eddy currents	
Radiography	

* The flaw sizes are based on equipment that is in reasonable condition and is operated by competent operators. Inexperienced operators may not be able to detect this minimum size of flaw, whereas very experienced operators may locate similar flaws. The standard of the materials surface finish and the material itself will also influence the minimum flaw sizes that can be detected.

†In ultrasonics it is usual to express flaw sizes as being equivalent to the signal response that would be obtained from a flat-bottomed hole (FBH) of known diameter.