SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
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AEROSPACE RECOMMENDED PRACTICE

SAE ARP4784

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PERFORMANCE AND EVALUATION CRITERIA, SURFACE DEFECTS, REQUIREMENTS FOR

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) provides the requirements for surface defects, performance and evaluation criteria for various defects and discontinuities encountered in aerospace couplings, tube fittings and hose assembly components. The discontinuities fall into three basic categories: inherent discontinuities, which are present in the raw material stock; primary processing discontinuities, which are caused by processes which work the metal down by either hot or cold deformation into semifinished products; and secondary processing discontinuities, which are associated with finishing operations which occur after rolling. This document is intended to be used in conjunction with existing callouts on government and industry standards. Recommendations of allowable discontinuities are only guidelines, and any government/industry requirements will prevail over this document.

1.1 Purpose:

When the engineering application requires control of surface discontinuities, this ARP shall be specified on the specification, engineering drawing or original purchase order. A typical drawing callout would be: "Surface defects per ARP4784, Grade B." If the grade designation is not specified, Grade C is the default.

1.2 Field of Application:

When the engineering application requires control of surface discontinuities closer than those specified in this ARP, those limits shall be clearly specified on the specification, engineering drawing or original purchase order.

2. REFERENCES:

2.1 Related Publications:

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS3071 Acceptance Criteria - Magnetic Particle, Fluorescent Penetrant

2.1.2 Military Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-F-5509 Fitting, Flared Tube, Fluid Connection
MIL-STD-1907 Inspection, Liquid Penetrant and Magnetic Particle, Soundness Requirements for Materials, Parts and Weldments
MIL-STD-1949 Inspection, Magnetic Particle
MIL-STD-6866 Inspection, Liquid Penetrant

2.1.3 Air Force Technical Orders: Available from San Antonio ALC/MMEDT, Kelly AFB, Texas 78241-5000.

T.O.33B-1-1 Nondestructive Methods

2.1.4 American Society for Metals Publications: Available from American Society for Metals, Metals Park, OH 44074.

Metals Handbook, 10th Edition: (Volume 11, Nondestructive Inspection)
(Volume 17, Nondestructive Evaluation)

Anderson, Robert Clark, Inspection of Metals, Volume I, Copyright 1983 by American Society for Metals

2.2 Definitions:

2.2.1 General: The following terms are used throughout this document.

CRITICAL SIZE: The established flaw size deemed to be detrimental to the serviceability of the product criteria.

DEFECT: A discontinuity which interferes with the usefulness of a part; a fault in any material or part detrimental to its serviceability. Note that all cracks, seams, laps, etc. are not necessarily defects as they may not affect serviceability of the part in which they exist.

DISCONTINUITY: Interruption in the normal physical structure or surface configuration of a part material. Considered to be a defect only when its nature, degree, frequency and location is detrimental to the quality, appearance, or performance of the part in which it occurs.

SHALLOW DISCONTINUITY: A discontinuity open to the surface of a solid object which possesses little depth in proportion to the width of this opening. A scratch or nick may be a "shallow discontinuity" in this sense.

2.2.1 (Continued):

FAULT: Any physical condition that causes failure or unacceptable reduction in performance.

FLANGE: Projecting rim of a mechanical part.

ROUGHNESS: Relatively finely spaced surface irregularities, the height, width and direction of which establish the predominant surface pattern.

ROUGHNESS HEIGHT RATING: Quantitative expression of the roughness of a surface; arithmetical average, normally expressed in microinches, of the absolute values of surface height deviation from the mean surface height.

2.2.2 Definitions of Defects: Unless otherwise stated, the following generally constitute true defects and are not allowed regardless of size, number and location.

BURR: Metal piece outside geometrical surface defined by the drawing. May be short or long in relation to thickness. Occurs on edges and corners.

COLD SHUT: Surface discontinuity resulting when lumps of softened metal come together inside a mold but fail to fuse. A portion of the part is partially separated from the main body of metal by the failure of two streams of metal to unite.

FIN: Protrusion formed by incorrect reduction during hot working.

HOT TEAR: Fracture, usually on the surface of the part, formed in a metal during solidification because of hindered contraction.

FLAKES: Short, discontinuous propagating cracks in ferrous metals caused by localized transformation stresses and decreased solubility of hydrogen during cooling after hot working. In a fractured surface, flakes appear as bright silvery areas; on an etched surface they appear as short, discontinuous cracks. Also called "shatter cracks" and "snowflakes".

LAMINATIONS: May appear as inclusion stringers between rolled surfaces or material such as rectangles or plates; but in some instances, actual separations may occur.

QUENCH CRACKS: Propagating cracks which usually traverse an irregular and erratic course on the surface. May occur during heat treatment due to excessively high thermal and transformation stresses.

PIPE: Discontinuity in the center of a rolled bar, caused by internal cavities in the ingot formed during solidification. If the shrink cavity is not cut away or cropped before rolling or forging, it may become elongated or stretched in the rolling operations and show up as voids called "pipe" in the finished product.

2.2.2 (Continued):

PIT: Individual hole chemically produced. Irregular in shape. May contain active chemical that will continue etching to enlarge it.

SCAB: A defect resulting from splashing or splattering of liquid metal, which solidifies and becomes oxidized. Most are reabsorbed into the molten metal, but some remain as scabs of oxidized metal adhering to the surface. A scab consists of a flat volume of metal joined to a casting through a small area. It is usually set in a depression, a flat side being separated from the metal by a thin layer of sand.

SLIVER: Loose or torn pieces of metal rolled into the surface.

STRINGER: Solid nonmetallic impurity in the parent metal, often the result of an inclusion that has been stretched during a rolling process.

UNDERFILL: Shortage of metal such that the true shape is not completely filled; results from incomplete working of a section during reduction.

2.2.3 Definitions of Inherent Discontinuities: The following terms define discontinuities that are present in the raw material stock.

BLISTER: Raised spot on or near surface of metal, resulting from gas expansion in a subsurface zone during thermal treatment.

BLOW HOLES: Gas bubbles which are trapped as the metal freezes during solidification. Smaller ones often appear near the surface; larger ones appear deeper in the metal. Many become welded shut during secondary processing operations, but those which have become oxidized, usually those near the surface, do not and may appear as seams (see definition). The deeper ones which do not weld shut may appear as laminations (see definition).

INCLUSION: Particles of impurities, usually oxides, sulfides, silicates, and such, which are retained in the metal during solidification or which are formed by subsequent reaction of the solid metal. Appear as round or sharp-edged, elongated particles which may appear internally or on the surface of various products. Sharp-edged inclusions are considered defects and are not acceptable.

PIN HOLES: Very small holes, sometimes found as a type of porosity because of microshrinkage or gas evolution during solidification of molten metal.

2.2.4 Definitions of Primary Processing Discontinuities: The following terms define discontinuities caused as the metal is worked into semifinished products.

BURST: Surface fissures or ruptures caused by metal movement during rolling or forging . Open break in the metal. Often large and very seldom healed during subsequent working. Bursts can also be caused by processing at improper temperatures.

2.2.4 (Continued):

FORGING CRACKS: Rupture of the metal that develops during the forging operation due to overstressing the metal by forging at too low a temperature.

FOLD: A doubling over of metal, which may occur during forging. May occur at or near the intersection of diameter changes, and are especially prevalent with noncircular necks, shoulders and heads.

LAP: A surface discontinuity, appearing as a fold or tangential seam, which occurs when a protrusion of hot metal is folded over and rolled into the surface. Presence of oxide on the internal surface of the lap prevents the metal in the crevice from joining, and creates a discontinuity with a sharp root.

SEAM: Surface discontinuity caused by a void or crack in rolled material parallel to the axis of the material which, although closed, is not welded. Caused by cracks or hot tears in the billet from which the bar is rolled. Surface opening or closed surface crack resulting from a discontinuity obtained during casting or rolling; also extraneous material, , not homogeneous with base metal.

VOID: A shallow pocket or hollow on the surface, due to nonfilling of metal during forging or upsetting.

2.2.5 Definitions of Secondary Processing Discontinuities: The following terms define discontinuities associated with finishing operations.

CHATTER: In machining or grinding:

a. A vibration of the tool, wheel or workpiece, producing a wavy surface on the work.

b. The finish produced by such vibration.

CRACK: A discontinuity characterized by a sharp dip with a high ratio of length and width to opening displacement, caused by excessive stresses developed during fabrication or service. Machining Cracks (also called machining tear): Generally short, jagged surface discontinuities at right angles to the direction of machining, caused by too heavy a cut, a dull tool, chatter, or dragging the tool over the metal when not cutting cleanly.

GOUGES/NICKS: Elongated grooves or cavities.

SCRATCH: A shallow mark or injury produced by abrasion. Sharp bottomed or curved bottomed indentation at least two or more times longer than its width, caused by harder opposing tool or object dragging across surface in random or controlled path.

TOOL MARKS: Grooves of shallow depth produced by the movement of manufacturing tools over the surface of the part.

3. ACCEPTANCE CRITERIA:

3.1 Grade A:

Grade A applies to the most critical parts, such as hydraulic fittings, or to the most critical zone within a part, such as bearing surface. Grade A acceptance criteria for the above discontinuities is specified in the following paragraphs.

3.1.1 Blisters, Blowholes, and Pinholes:

a. On machined surfaces: For Grade A, these discontinuities are considered defects and must be removed prior to acceptance of the part.

b. On unmachined surfaces: Less than 10 per linear inch or 10 within a .50 in circle, separated by at least .020 in, and with a maximum dimension of .020 in any direction.

3.1.2 Bursts: For Grade A, bursts are considered defects and are not acceptable.

3.1.3 Chatter: Permissible as long as they fall within the specified surface roughness limitations.

3.1.4 Cracks: Must be at least .5 inch apart linearly and .25 in a parallel direction, with a maximum length of .125 and depth per Table 1.

3.1.5 Folds, Seams, and Laps:

a. On Machined Surfaces: For Grade A, these discontinuities are considered defects and must be removed prior to acceptance of the part.

b. On Unmachined Surfaces: Cannot be greater than .5 in length (see Table 1 for depth), and must be at least .5 in apart linearly and .25 in a parallel direction. Folds, seams, and laps are not acceptable in internal corners at or below bearing surface, or at the intersection of flange periphery and bearing surface.

3.1.6 Gouges/Nicks: Permissible if they are not easily detectable with a fingernail and the maximum depth does not exceed the limits in Table 1. No more than three within any 1 in^2 area.

3.1.7 Inclusion, Rounded: Maximum two per specified area, with a maximum diameter of .031 and depth per Table 1. Inclusions are not acceptable if they extend into a fillet, hole, or over an edge. Sharp-edged inclusions are not acceptable and are considered a defect.

3.1.8 Scratches: Maximum depth .001 in axial or helical, .005 in for all others. Minimum wall thickness specified for the part must be maintained.

3.1.9 Tool Marks: Acceptable as long as minimum specified surface rough requirements are met.

3.1.10 Voids: Maximum depth of .010 in. No more than three per any 1 in^2 area. Minimum wall thickness specified for the part must be maintained.

3.2 Grade B:

Grade B applies to critical areas where slight imperfections may be permitted, and units subject to high but well-distributed stresses. Grade B acceptance criteria for the above discontinuities is specified in the following paragraphs.

3.2.1 Blisters, Blowholes, and Pinholes:

a. On machined surfaces: Less than 10 per linear inch or 10 within a .50 in circle, separated by at least .020 in, and with a maximum dimension of .020 in any direction.

b. On unmachined surfaces: No limits if discontinuities are less than one half the maximum size of .020 in in any direction and are well dispersed. Otherwise, the acceptance criteria for machined surfaces shall apply.

3.2.2 Bursts: Width shall not exceed .010 in and maximum depth shall be per Table 1.

3.2.3 Chatter: Acceptable as long as the specified surface roughness requirements are met.

3.2.4 Cracks: Must be at least .5 in apart linearly and .25 in a parallel direction, with a maximum length of .125 in and maximum depth per Table 1.

3.2.5 Folds, Seams, and Laps:

a. On machined surface: For Grade B, these discontinuities are considered defects and must be removed prior to acceptance of the part.

b. On unmachined surface: Cannot be greater than 1 in in length, with maximum depth per Table 1. Must be at least .5 in apart linearly and .25 in a parallel direction. Folds, seams, and laps are not acceptable in internal corners at or below bearing surface, or at the intersection of flange periphery and bearing surface.

3.2.6 Gouges/Nicks: Permissible if they are not easily detectable with a fingernail and the maximum depth does not exceed the limits in Table 1.

3.2.7 Inclusion, Rounded: Maximum diameter of .047 in, and no closer together than three times the maximum size. Sharp-edged inclusions are not acceptable and are considered a defect.

3.2.8 Scratches: Maximum depth .001 in axial or helical, .005 in for all others. No more than three in any 1 in^2 area. Minimum wall thickness specified for the part must be maintained.