# Section 3
## *Damage Size Characterizations*

The damage tolerance approach to structural integrity assumes that cracks are present in all critical locations and demonstrates that these cracks will not grow undetected to a critical length during a period of service usage. Since the rate of crack growth depends on the crack length, the structural service lives or periods between inspections are greatly influenced by the crack lengths assumed at the beginning of a usage period. From the safety viewpoint, these initial crack lengths must be longer than any equivalent damage that could be present in the structure after passing quality inspections. From a practical viewpoint, however, the degree of conservatism introduced by assuming long cracks must be limited to reach realistic usage lives or periods of operation without inspections. This trade-off results in great emphasis being placed on quantifying the damage sizes that may be present in the structure at the beginning of an operational period.

The distribution of crack lengths in any given structure can be considered to consist of the composite of the several distributions shown in Figure 3.0.1. The material as received from the vendor will contain very small flaws or defects such as inclusions, cracks, porosity and surface pits, scratches, and machine marks. These inherent material flaws are considerably below the detection capability of the non-destructive inspection (NDI) and should be sufficiently small to not grow appreciably in service. These small flaws form the basis of the continuing damage crack size assumption and are characterized by a single crack length, $a_i$, which is assumed to be an upper bound on the distribution.

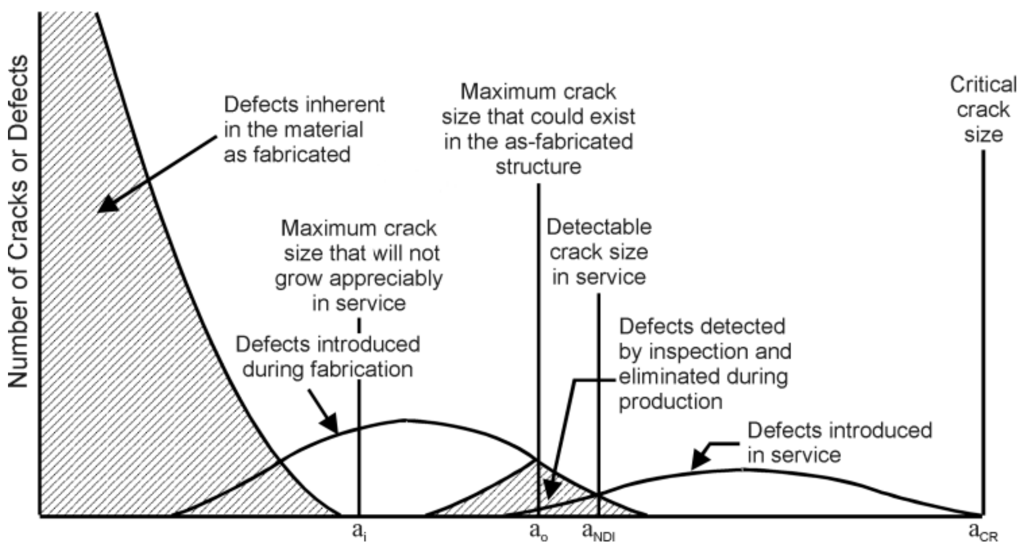


**Figure 3.0.1.** The Effect of Defects Distribution in Structural Integrity Planning [Walker, et al., 1979]

A distribution of larger defects can exist as a result of the fabrication process or as large inherent flaws. The production quality control process is designed to detect and eliminate as many of these cracks as possible but those which are not detected will propagate due to fatigue mechanisms during service. The largest crack size that could remain undetected in the newly fabricated structure after the final inspection is designated as $a_o$. This crack length provides the starting point for crack growth projections which demonstrate adequate service life or the necessity for an in-service inspection.

Cracks smaller than $a_o$ will propagate in service operations and others, due to fatigue crack initiation, corrosion, and foreign object damage, will be initiated. If any of these cracks can propagate to critical size, $a_{cr}$, before the end of the service life, they must be detected and repaired at scheduled maintenance intervals. The largest crack size that can remain undetected after an inspection is designated as $a_{NDI}$ and becomes the initial crack size for the next usage period. Figure 3.0.2 is a schematic of the projected crack growth of the critical crack lengths and illustrates the resetting of the potential crack to $a_{NDI}$ after the inspection. In this figure, the inspection was scheduled at one-half the usage time required for an initial crack ($a_o$ or $a_{NDI}$) to grow to critical.

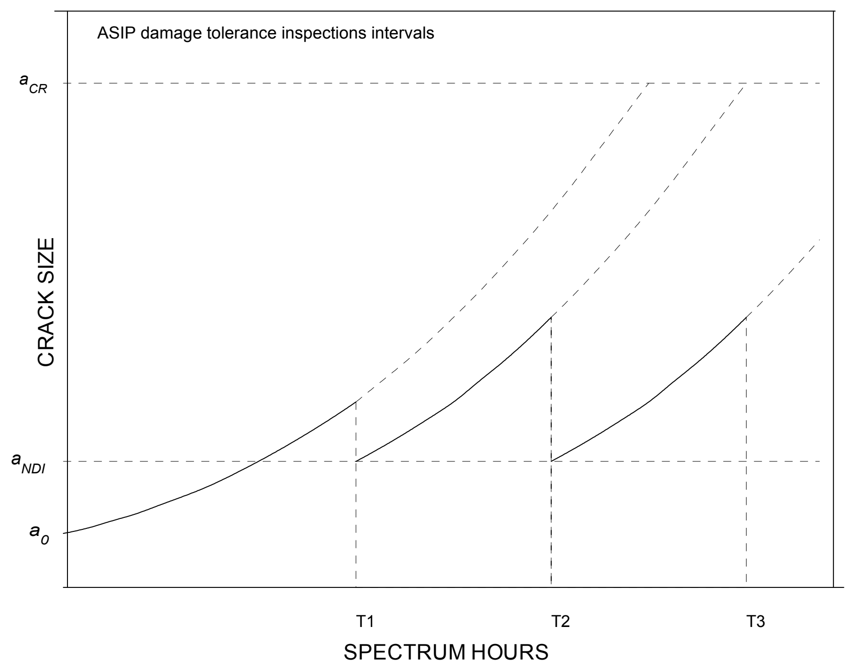


**Figure 3.0.2.** Crack Growth-Life Curve after Second Inspection

JSSG-2006 specifies the type and size of cracks that must be assumed during design. These are summarized in Section 1.3.4. The assumed crack sizes depend on:

1) the design concept (slow crack growth or fail safe);
2) inspectability level (inspectable or non-inspectable) with and without component removal; and
3) continuing damage after initial primary damage.

In the current version of the Specification Guide, smaller initial crack sizes ($a_o$) may be assumed for slow crack growth structures based on the contractors demonstrated capability to eliminate all cracks greater than the smaller value. This demonstration may be based on an NDI system or on a proof test. These qualification processes are shown schematically in Figure 3.0.3(a) and 3.0.3(b).

The continuing damage crack size assumption can also be reduced if the contractor can demonstrate an improved manufacturing quality. One method for such a demonstration is based on the determination of the distribution of equivalent initial flaws as shown schematically in Figure 3.0.3(c).

Since NDI, proof testing, and the equivalent initial quality method can be applied under the current airplane damage tolerance requirements and may receive greater emphasis in future specifications, they are reviewed in the following subsections. Section 3.1 describes the major NDI methods currently in use and discusses statistically based demonstrations program for measuring NDI capability. Sections 3.2 and 3.3 describe and give examples of the proof test and equivalent initial quality methods, respectively.

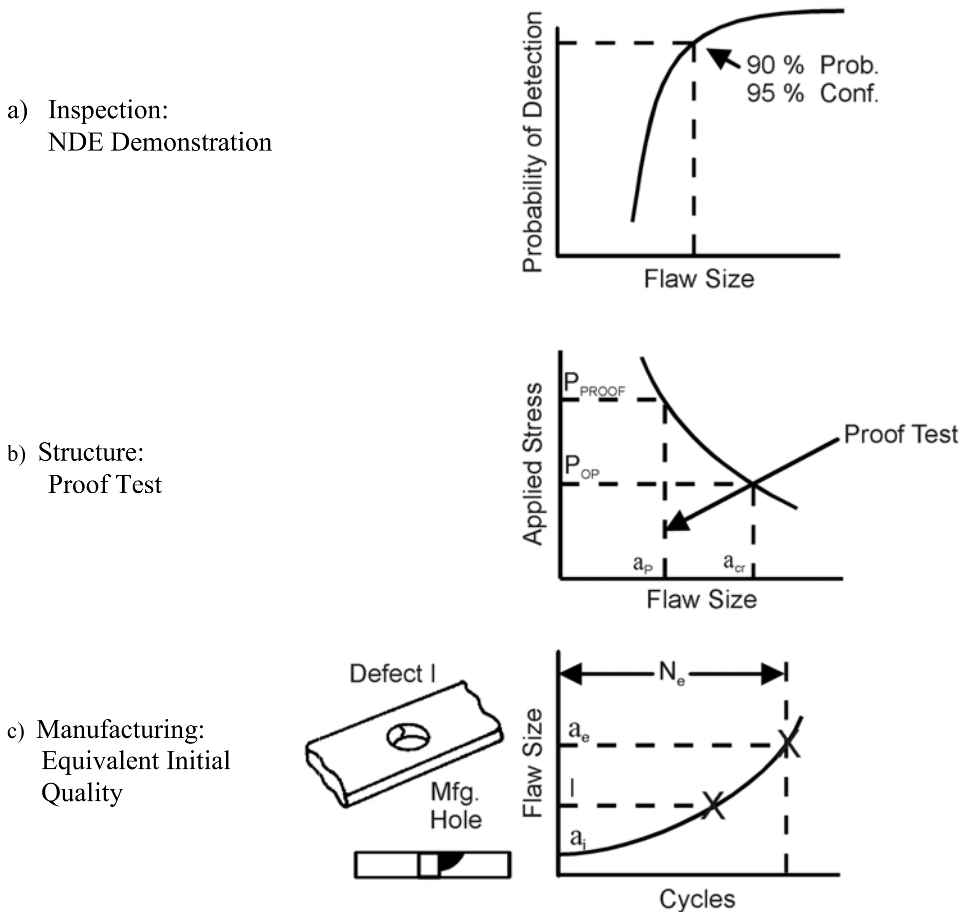


**Figure 3.0.3.** Various Qualification Processes