7.3 Quality Control Testing

The quality control tests provide data that (a) support the initial quality design assessments and non-destructive inspection (NDI) requirements, or (b) ensure the uniformity of the production product. Because many of these tests will be conducted during the production run they are fairly simple tests. Requirements for these tests are defined after the preliminary sizing and the identification of fracture critical parts. Quality control data covered by this category of tests include equivalent initial quality (EIQ) data, continuing assessment of the non-destructive evaluation (NDE) capability, and component prolongation tests for fracture toughness and crack growth resistance.

One sure method for minimizing damage tolerant problems due to the presence of the manufacturing induced rogue flaw is to take ample precautions on the production line to minimize the probability that such defects could be present in safety-of-flight structures. The manufacturer, during design, will typically suggest methods for ensuring strict production line control of material preparation, fabrication and joining techniques. The manufacturer's control can be periodically checked using the same type of testing and analysis approaches that were utilized in design to justify the choices of materials and defect sizes for the airframe's damage tolerant analysis.

Throughout the procurement cycle of several recent weapon systems, fracture toughness was controlled to specified design minimum levels for airframe safety-of-flight type structure. The particular fracture toughness property used for quality control was the plane-strain fracture toughness – K_{Ic}, (see Section 7.2). Since some manufacturing processes are such that they alter the microstructure of some materials (and thus the fracture resistance), it was believed necessary to monitor the behavior of material subjected to the gamut of processes that precede final assembly. In fact, the B-1A material quality control program was designed so that the fracture toughness was sampled for each fracture critical part after each major manufacturing process; such a sampling program provided an immediate indication if any process was detrimental to the fracture toughness.

In almost all the past cases where fracture toughness was controlled, ASTM E399 was employed to obtain a valid plane-strain fracture toughness (K_{Ic}) value. As a result of the difference in cost between a K_{Ic} test and other much simpler mechanical tests such as the tensile test, engineers have been giving attention to the development of tests that are both simple and representative of the fracture toughness property of interest. The double-edge notched specimen and the round edge-notched specimen are two notched geometries that have been examined. Both notched geometries are prepared with sharp root radii, i.e. radius < 0.002 inch, but do not contain fatigue precracks. A Chevron Notch Test for K_{IV} (ASTM E1304) can also be used as a K_{Ic} indicator.

For quality control purposes, the manufacturer might prepare a series of round-edge notched specimens and K_{Ic} specimens with the same microstructure (from the same lot of material) and determine the relationship between, for example, notched tensile strength and fracture toughness. The series of tests would be repeated for different microstructure (different lots of material) until every possible combination of microstructure was covered. The manufacturer would then formulate a global relationship between notched tensile strength and fracture toughness of this material. Using standard statistical techniques, the manufacturer could then establish the required level of notch tensile strength that should be measured during production in order to achieve the minimum allowable level of fracture toughness.

While the crack growth property is actually of greater concern than the fracture toughness property, controlling the level of subcritical crack growth resistance via a quality control test has not been attempted for any large weapon system due to the expense and complexity of the crack growth rate test. The Air Force funded one study to explore the possible development of an inexpensive crack growth test but the results of this program were mixed [Creager & Sommers, 1977]. With the advent of automated fatigue crack growth rate test methods, future quality control programs could incorporate a test for controlling the subcritical crack growth resistance of fracture critical parts.