10.3 Structural Configuration Analysis

The fracture control program must consider all of the design details incorporated into the structural configurations as possible critical items. It is as a part of this function that the critical parts list is developed and each part analyzed for its fracture propagation characteristics. The method to be used to inspect the critical parts must also be established. This will set the initial flaw size that is used in the analysis. Any testing which must be done to establish the damage tolerance of a part is also done during this phase of the development.

10.3.1 Critical Parts List

The development of the fracture critical parts list begins with the first design studies. This list is then maintained throughout the life of the aircraft. It identifies those parts that would cause loss of the aircraft or endanger personnel and cargo if they failed as a result of flaw propagation. The logic pattern and analysis necessary to identify critical parts is outlined in Figure 10.3.1 [Ehert, 1979].

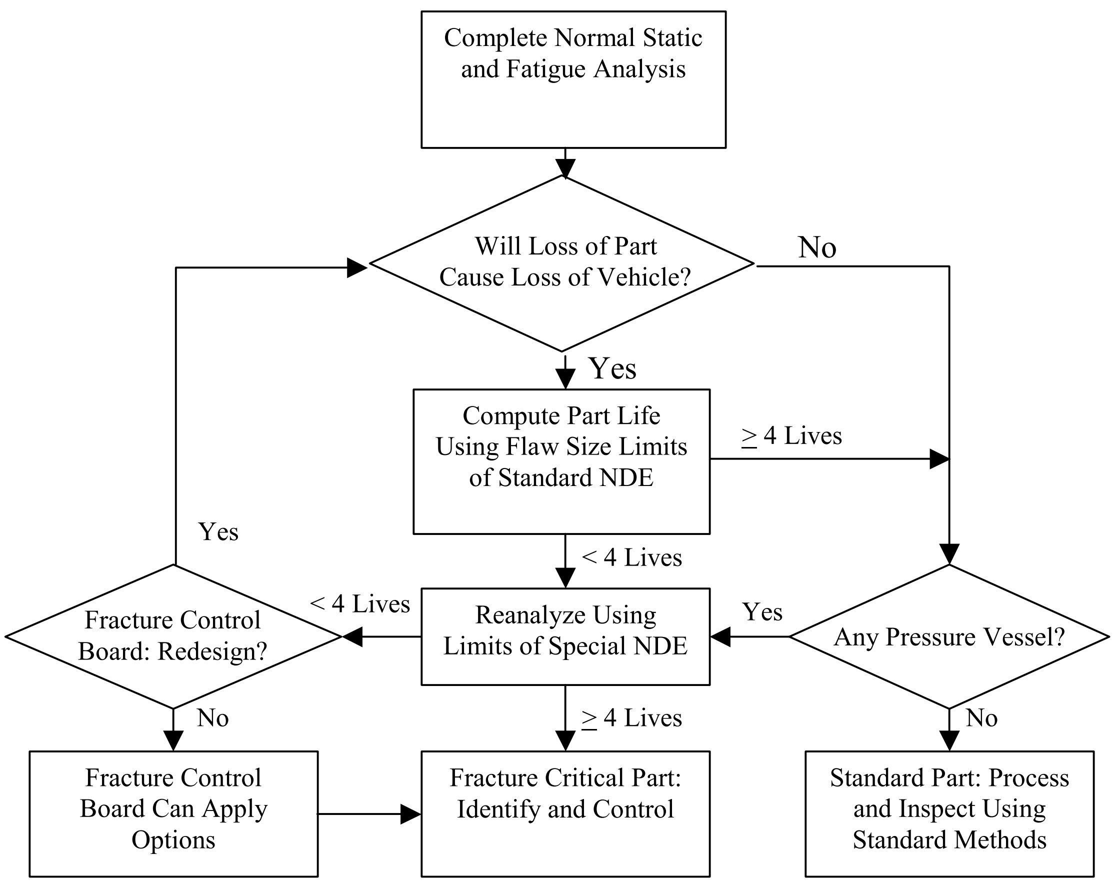

Figure 10.3.1. Illustration of Selection Logic for Fracture Critical Parts [Ehert, 1979]

Initially, the static analysis is used to identify the highly stressed areas of safety of flight items. A crack growth analysis using the best estimate of an initial flaw at the time of the analysis and the design load spectrum is run until either the required life has been exceeded without a predicted failure or until a failure is predicted in the part. Failure is usually related to a critical crack size and the required residual strength load. This analysis is usually conducted as a part of the design trade studies used to select materials, select stress loads and to size the part. The factors affecting the selection of design stress levels are illustrated in Figure 10.3.2 [Walker, et al., 1979].

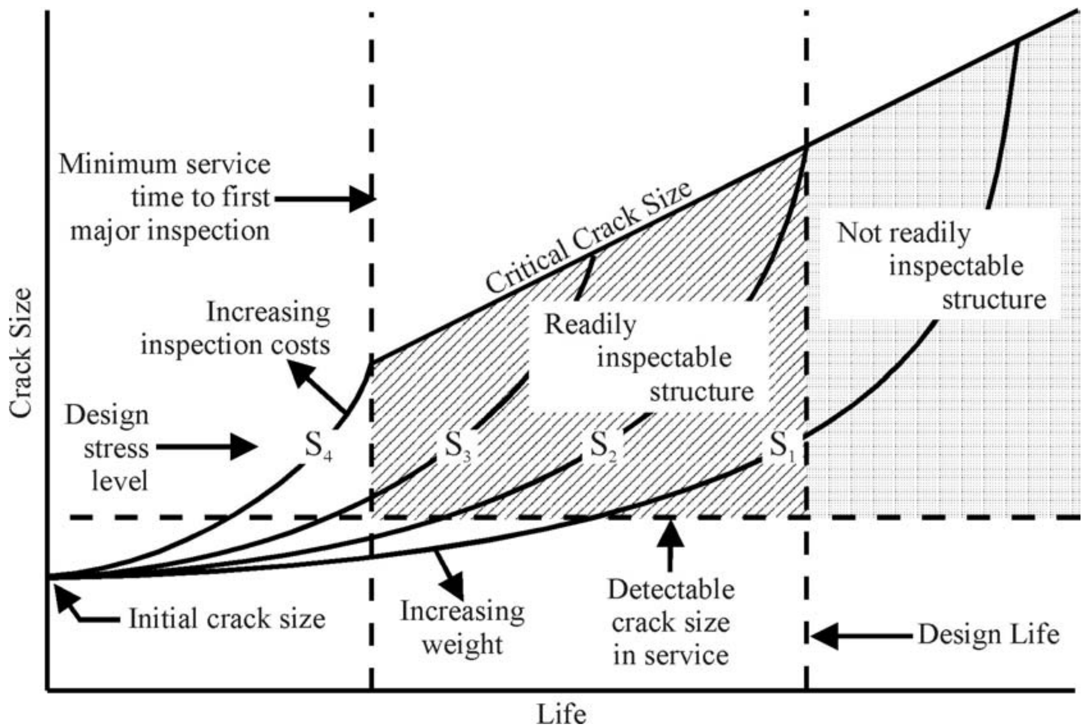

Figure 10.3.2. Selecting Design Stress Level to Meet Residual Strength Crack Growth and Inspectability Requirements [Walker, et al., 1979]

Redesign is done as necessary until the required life is attained. Figure 10.3.2 shows a decision point at four lifetimes. Actual life requirements will vary depending on the part; however, the logic is similar for all parts. The accurate determination of the component stress field for identification of critical areas is important. The best results can be achieved with fine grid finite element models.

Each part finally identified as a fracture critical part is then added to the list and identified for controlled handling during the manufacturing process. Establishment of this procedure early results in little disruption of standard procedures and makes the handling of fracture critical parts an integral part of the design and manufacturing process.

When the design load spectrum is developed to its final form, which should also be relatively early in the design process, the initial analysis of the most critical items should be repeated to determine if there are any changes in results. Any differences must be evaluated and redesign accomplished as indicated.

The selection of the manufacturing processes for the critical part should be made with care. Such things as surface finish, edge finish, location of parting planes, location of identification marks, and amount of metal removal per part must be considered during the design. Considerations of these and other items are presented in publications such as Lunde [1976], Goranson, et al. [1981], and Watson [1979]. It is not considered appropriate to present a large number of details in this handbook, but a catalogue of acceptable and unacceptable design and machining details should be developed by the manufacturer as a guide to design and fabrication.

10.3.2 Inspection Method Development

The initial assumed flaw used in all crack growth computations is determined either by a specified minimum flaw based on standard inspection techniques or by a special minimum flaw which can be substantiated by special inspection techniques. Table 10.3.1 from Ehert [1979] lists an example of what may be expected from several inspection methods. These will vary with specific equipment.

During the development of the critical parts list, it is necessary to consider how each part will be inspected for flaws. This must be considered not only during the manufacturing process but also during the periodic inspections to be performed during the aircraft life. The results of the fracture analysis can be significantly affected by the inspection method and the selection of initial flaw sizes.

As improved inspection methods are incorporated into production use, it is to be expected that improved design will result. The trade-off between inspection costs and performance may also be considered.

Table 10.3.1. Examples Of NDE Capabilities [Ehert, 1979]

Inspection Method	Flaw Type	Standard NDE	Special NDE
Penetrant or magnetic particle	Surface flaw (Depth x length)	0.19 x 0.38 cm (0.075 x 0.150 in.) or equivalent area	0.083 x 0.127 cm (0.025 x 0.050 in.) or equivalent area
Ultrasonics	Embedded flaw (diameter)	0.254 cm (0.100 in.)	0.12 cm (0.047 in.)
Radiographic	Surface or embedded (depth x length)	0.7t x 1.4t Min length = 0.38 cm (0.150 in.)	0.6t x 1.2t Min length = 0.127 cm (0.050 in.)

t = thickness

10.3.3 Demonstration Test Development

The use of tests to demonstrate the existence of damage tolerant design is necessary when design details depart from past acceptable usage and when various environments are present for which data is not available. It is suggested that such testing begin early and start with element and small component tests. This testing should also use the flight-by-flight design load spectrum being used for analysis.

As the design progresses, large component tests of critical areas should be conducted. As much as possible, the anticipated environments should be a part of the test. As mentioned earlier, the influence of environment can be quite extensive on crack growth behavior.