10.2 Material Selection

The selection of materials for damage tolerant design is one of the most important functions. Materials must be evaluated and selected on both their static strength and their toughness and flaw growth characteristics. The properties used for these comparisons are:

- Yield strength, F_{ty}
- Ultimate strength, F_{tu}
- Fracture toughness, K_c or K_{IC}
- Stress corrosion factor, K_{Iscc}
- Crack growth rate, da/dN vs. ΔK

Figure 10.2.1 shows how some of these properties can be compared. In addition, typical crack growth characteristics for each material are analyzed.

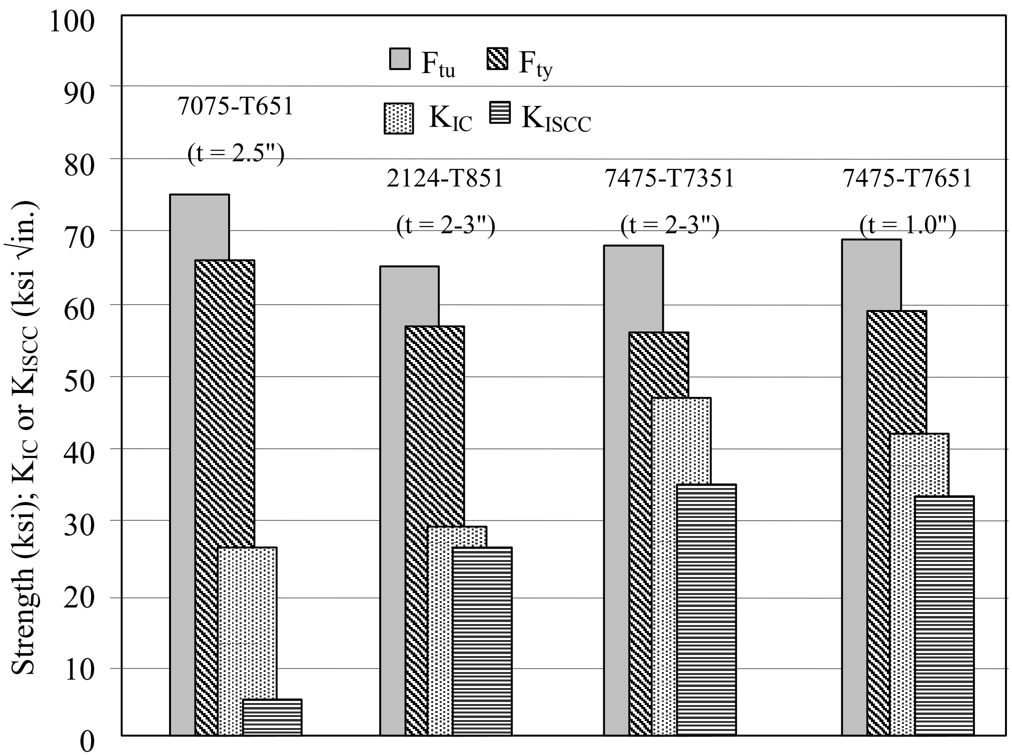

Figure 10.2.1. A Method of Presenting Comparative Material Data

10.2.1 Crack Growth Resistance and Fracture Toughness

The material properties used for the selection criteria must be obtained for conditions that correspond to those expected in the structural usage environment. Crack growth resistance as expressed in the *da/dN* data should be obtained from tests conducted using thickness similar to the anticipated structure applications and in similar environments. Some alloys are quite susceptible to corrosive media such as may be experienced in aircraft fuel bays or during operation near salt water. Effects of these variables are shown in Figure 10.2.2 [Circle & Conley, 1980].

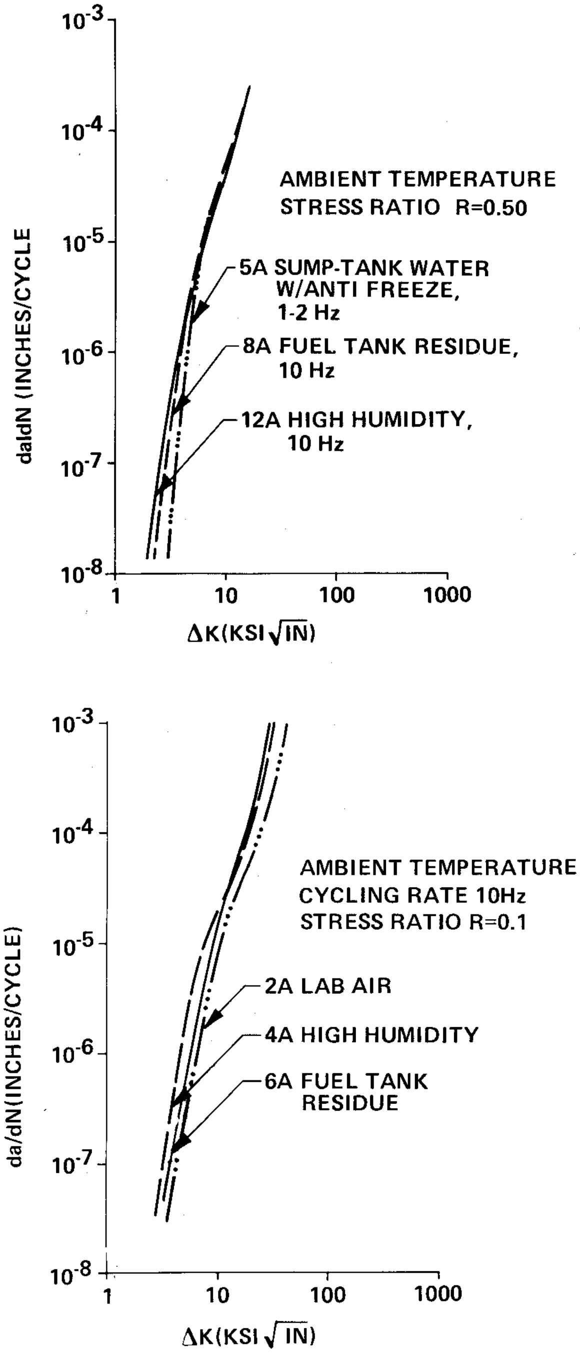

Figure 10.2.2. Illustration of Effects of Environment on Crack Growth Rates [Circle & Conley, 1980]

For ease of application in the design process, the crack propagation data is usually described by an empirical relationship, such as the Forman equation, given as:

$$\frac{da}{dN} = \frac{C(\Delta K)^n}{(1-R)K_c - \Delta K}$$

where

K_c - fracture toughness

ΔK - stress-intensity factor range

C, n - constants dependent on material, obtained from curve fitting techniques

It may be necessary to model the data in several parts over the ΔK range of interest in order to achieve adequate representation.

Ekvall, et al. [1982] presents a method for evaluation of weight savings due to the usage of advanced materials. The utilization of materials having improved damage tolerance characteristics as evidenced by a higher allowable stress value was shown to effect a weight savings from 1-3 percent for an improvement in allowable stress of 10-25 percent.

Simenz and Guess [1980] discusses material properties and characteristics of some new materials based on obtaining high strength with good durability and damage tolerance properties. This is mentioned to make the reader aware of current efforts to improve structural materials. Goals stated in this report are to increase the static strength, decrease the crack growth, and increase the temperature capability of aluminum alloy.

10.2.2 Material Property Control

Along with the selection of various materials for use on the structure, it is essential that a control system be established. Ehert [1979] describes such a system as including the areas of source selection, usage, evaluation, documentation, and tracking of all materials. The establishment of material control specifications is necessary to achieve the desired end result. It is suggested that a rating system be established for each material based on the expected usage. Ehert [1979] suggests a five-level system (A, B, C, U, X) which may be defined as:

- A - Acceptable for Usage
- B - Acceptable with Specific Controls
- C - Acceptable with Demonstration Evaluation
- U - Not Evaluated for a Given Usage
- X - Not Acceptable

The development of a material selection list includes all properties that are required for each material usage. A pre-release material approval is suggested as a screening device. This would be by a material review board that would pass on all selected materials.

After the approval of all selected materials, the next step is to assure that only approved materials are actually used and that they meet the requirements. An accountability procedure must be implemented. As a minimum, this system must do the following:

1. Identify the part
2. List all material data required

3. List all supplemental data related to part;
    a.) Test Data
    b.) Change Notices
    c.) Deviations
    d.) Process Specifications
    e.) Inspection Reports
    f.) Rework Required

This system should be easily accessible and usable throughout the design, manufacturing, and usage phases of the aircraft life cycle. It would provide the information necessary to solve any future problems and will be the basis for the next design. This system is directed toward fracture critical parts, but it is evident that such material control is necessary for all parts. If such is the case, then fracture critical parts can be easily identified and tracked as part of the total aircraft design and development.

As a part of this system, it is necessary to establish a material quality control program. Sample testing of all material which is identified for fracture critical parts should include verification of crack growth rate and toughness properties. Special handling instructions for this material to preserve initial quality should be implemented. Non-destructive testing techniques must be developed and incorporated into the manufacturing process to insure that manufacturing quality is maintained.

While such systems of material control are easily established by a prime contractor, it is also necessary to extend them to subcontractors and parts vendors who furnish fracture critical parts. All procurement specifications for such parts must include the same requirements for incorporation and maintenance of quality as practiced by the prime. Figure 10.2.3 from Ehert [1979] illustrates how such vendor interfaces can be achieved.

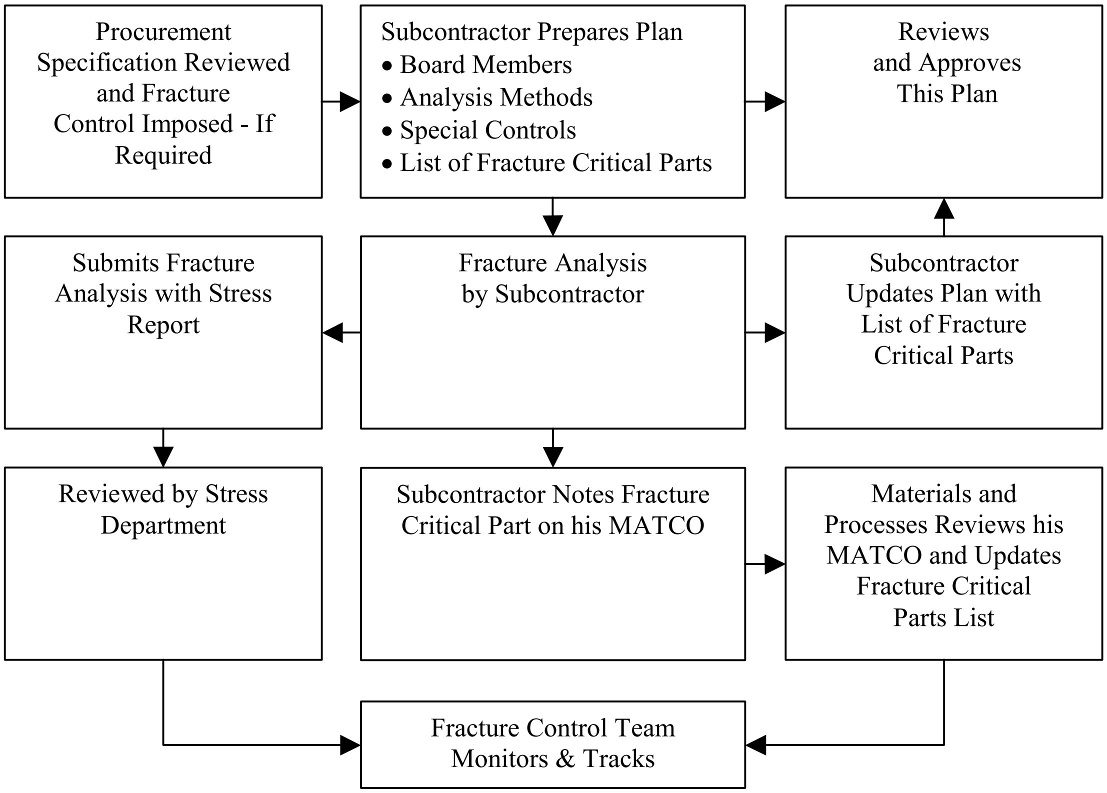

Figure 10.2.3. Fracture Control System for Subcontractors [Ehert, 1979]