7. Strength and Failure Theories

7.1. Introduction

In the past sections we have focused upon the functional requirements of beam, plate and shell structural elements as subjected to particular loading environments. The material presented in this section now addresses the broader based objective of having acquired a knowledge of the load analysis methodology, how can one now apply this knowledge to design a structural system to ensure a potentially safe design.

This objective, for composite structures design, is captured in the closed loop stress design profile shown below in Figure 7.1. It should be noted that as with any structural design, a key feature in the design is the selection of an appropriate failure criterion and the inherent iterative nature of the design process proper. In addition, for the case of monolithic materials such as metals it is sufficient to use one observable metric such as the ultimate tensile, compressive, or shear stress to describe failure. For composites, however, the structural engineer is faced with the dilemma of selecting a suitable failure criterion based upon a number of observable stress metrics.

Thus one of the most difficult and challenging subjects to which one is exposed to in the mechanics of advanced composite materials involves finding a suitable failure criterion for these systems. This is compounded by our still limited grasp of understanding and predicting adequately the failure of all classes of monolithic materials to which we seek recourse for

![Figure 7.1.](image-url)
guidance in establishing descriptive failure criterion for composites. To a large degree the development of such criteria must be associated with philosophical notions of what the concept of failure is about. For example, in most instances failure is perceived to be separation of structural components or material parts of components. This of course need not be the case since the function of the material and/or component may be the design driver and thus, for example, excessive wear in an axle joint may produce a kinematic motion no longer representative of a key design feature. In addition, any micromechanical or substructural failure features associated with early on failure initiation such as flaws and voids, surface imperfections, and built-in residual stresses are generally neglected in these design type approaches to failure. These mechanisms would serve as design drivers for initiating damage and/or degradation in the composite. Thus, failure identification can best be classified along a spectrum of disciplines and in the particular case of composites further subjugated to different levels of definition of failure dependent upon the level of material characterization. To this end, Figure 7.2 appears useful for focusing attention on the different levels of failure characterization and discipline linkage necessary for identity with