CRASHWORTHINESS OF COMPOSITE AIRFRAME STRUCTURES – MATERIAL DYNAMIC PROPERTIES

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The crashworthiness of an airframe structure is measured in terms of its ability to maintain a survivable volume for the occupants and alleviate the loads transmitted to the occupants during potentially survivable accident scenarios per FAR §25.561 and §25.562. The occupant loads are minimized by dissipating the kinetic energy using an energy absorption device, while the structural integrity is maintained by accounting for the dynamic loads during the sizing of structural elements. The performance of an airframe under crash loads is dictated primarily by its geometry, structural arrangements, materials and energy absorption devices used to dissipate the energy, and the interaction of these variables. The energy dissipation in metallic airframes is primarily due to plastic deformation while in composite airframes is due to synergistic sequence of failure mechanisms. The limited number of dynamic and drop tests performed on fully composite fuselage structures have indicated differences in the crush patterns/failure modes, stiffness and other structural properties, compared with the traditional metallic fuselage structures. The test results are useful in the appraisal of the structural performance under crash loading, but do not reveal the various mechanisms that do and do not contribute to the overall performance of the structure. Further, the performances of individual components may be influenced by the overall structural assembly. To investigate the effectiveness of various components, numerical modeling would be more appropriate and less expensive. However, the predictions of the numerical models are dependent on the geometric definition of the structure, the material models, failure criteria, etc. The description of material behavior under dynamic loading is a key aspect of the numerical modeling of the crash scenarios.

In the present investigation a building block approach illustrated in figure (1) has been embraced to study the rate effects on the behavior of composite airframe structures. To begin with, the rate effects (i.e., strain rate effects), will be characterized at the fundamental ply level, since for most numerical analysis, the material properties are specified at this level. The material testing at this level includes the characterization along the primary ply directions and off-axis specimen testing. The off-axis specimen tests are intended to simulate a combined stress state in the plies and not to characterize material property. This combined stress state will be used for benchmarking material models in the future. The next level of testing will include cases where *strain* and *strain rate* gradients exist, e.g., open-hole tension, which will serve as benchmark data for the material failure models. Moving up the building blocks, small components and assembly of components will be characterized under dynamic loading, culminating in characterization of scaled aircraft structures, which would be the most expensive. The understanding of rate effects at the ply level will help identify the contributions of geometric effects and material rate sensitivity to the observed rate effects in structural components and their assemblies subjected to dynamic loading.

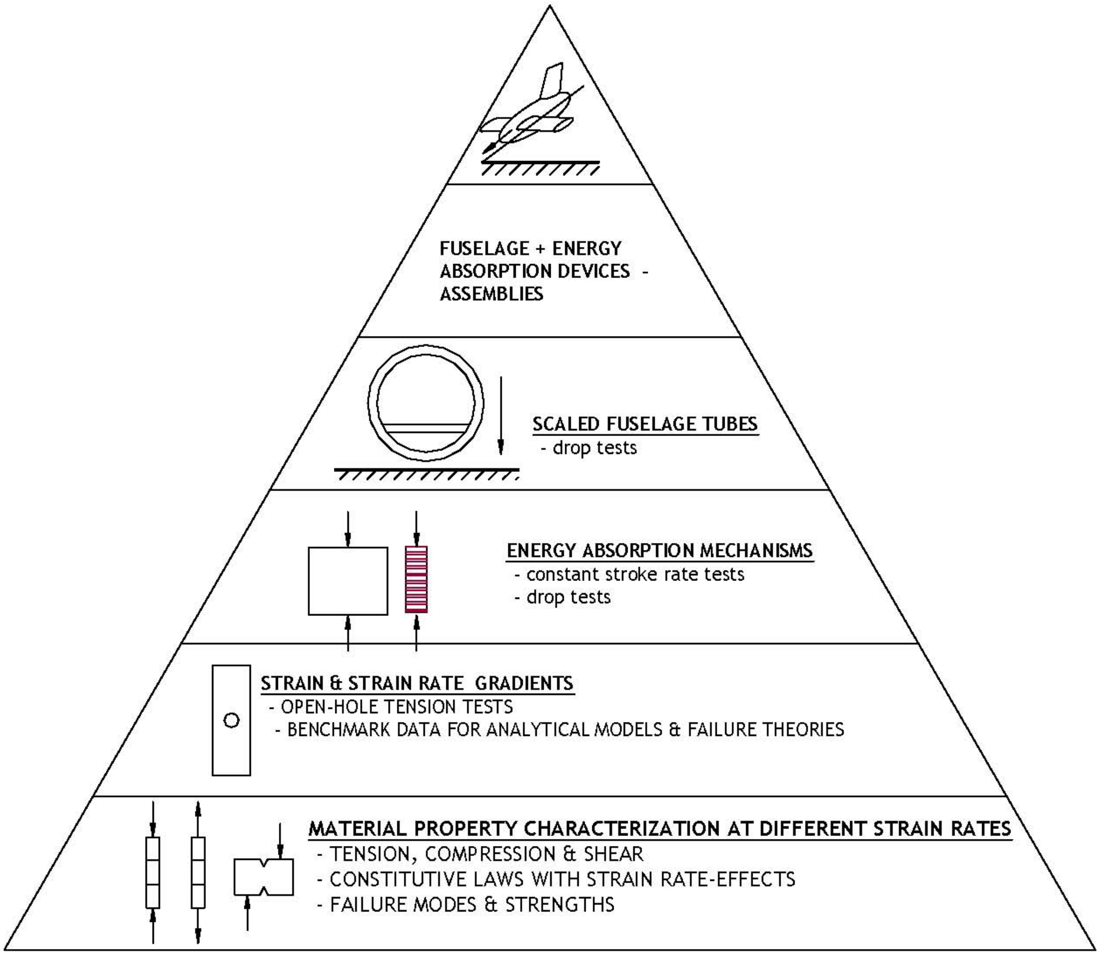

Figure 1: Building block approach for characterizing rate effects on composite airframe structures.

In the first phase of this investigation, the effects of strain rate on the in-plane tension, compression and shear properties of selected composite material systems were characterized experimentally. A limited number of off-axis and open-hole tension tests were conducted to investigate the rate effects under combined stress states and in the presence of strain and strain rate gradients. A considerable effort was focused on researching the appropriate method for high rate tests and the design, fabrication and assembly of apparatus for the current program.

In the second phase of the program, the interlaminar shear properties of the composite material systems, dynamic loading of sandwich and laminated beams, pin bearing strength and scaled cylindrical fuselage structures have been investigated.

In the ongoing phase of the program, the effects of dynamic loading on the fracture toughness properties of composite material systems are being investigated.