BLADE FRAGMENT ENERGY ANALYSIS

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Douglas effort in the field of blade fragment energy analysis has dealt primarily with two classes of fan blade fragments. The first is of relatively small size (.15 pound) and energy, and tends to rebound from the fan and case when liberated in an FOD encounter. These small fragments have relatively low secondary damage potential and are less demanding in terms of protection. The larger fan blade fragments are ejected in a more direct release trajectory with higher energy and hence can represent a higher potential hazard. Using available empirical and analytical techniques, plus additional Douglas analysis and testing, protection has been developed for both classes of fragment.

Some of the more basic work accomplished includes evaluation of the penetration resistance of composites, determination of armor coverage and weights if protection were aircraft furnished (FAA contract), and development of lightweight local protection concepts.

Simplified analytical methods have been used to describe blade fragment energy transfer kinematics, establish fragment energy levels, evaluate damage potential and configure protection. The approach, methodology, and application are discussed as a possible building block for other applications. Development of effective local protection using Kevlar is also discussed. Analysis methods developed and applied to the rebound fragment problem and to the large direct release fragment problem are described. Douglas testing yielded useful data on the capability of existing structures and verified the GE Watertown Arsenal energy absorption curve and British Aircraft Company empirical energy absorption curve and British Aircraft Company empirical energy absorption relationships as usable tools.

With the necessary tools available, an assessment of aircraft "designed-in" protection was made. This included assessment of the consequences of penetration of the engine section ahead of the inlet flange and assessment of the probability of penetration outside the nacelle. Areas of concern and protective features provided to handle failures from whatever cause, are reviewed. It was concluded that the fan blade fragments did not constitute an airworthiness issue but that, for an aft engine installation, fuel line protection of some form would further complement fire safety even though completely within a designated fire zone.

Analysis and testing of large high velocity fan blade fragments were also conducted to determine energy and penetration characteristics. This evaluation again resulted in the conclusion that damage potential was within design margins. However, as for the smaller fragments, additional protection for systems traversing the zone ahead of an aft engine inlet flange can substantially reduce the exposure to secondary damage and was considered a desirable improvement.

In examining design concepts for protection of the aft engine inlet area it was concluded that there had to be a better approach than plain metallic armor. A "flack jacket" concept using Kevlar cloth as the energy absorbing medium was selected as offering the most promise. By using a complete belt around the inlet bellmouth, the uncertainties and design and installation complications of armor support were avoided. The concept also offered a potentially lighter weight installation.

Because of the extreme variation in vendor design data and claims, a decision was made to undertake an in-house development program starting with the basic purchased cloth. The number of lamina required for containment was determined using a compressed air gun firing 1.1 pound "design fragments" at the selected 900 fps design velocity. Additional firings were made with the final thickness and construction to assure repeatability, and to demonstrate successful containment with respect to protection of adjacent systems.

Additional firings were accomplished to determine the energy absorption characteristics of commonly used honeycomb inlet materials. Firings were also made with steel plate targets to check the Watertown Arsenal curve and empirical energy absorption equation.

In summary, we believe that we have developed a simple analysis methodology adequate for our needs, added to the experimental data base, and developed an efficient and effective concept for local protection of areas ahead of the engine flange.

DISCUSSION

<u>A. Holms, NASA-Lewis</u>

What did you mean by dynamic shear strength? How is it measured?

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This is a property that differs from the normal static shear strength of a material; it is determined by actual ballistic testing. It is the shear strength exhibited by a material under dynamic penetration conditions (as against static shear). Each material has a characteristic value: e.g., steel = 188,500 psi, aluminum = 30,450 psi, titanium = 145,000 psi. It is the constant derived by dividing the energy loss of the test projectile by the product of the impact perimeter of the projectile and the square of the thickness of the material penetrated. Maybe the BAC folks can shed some more light on the actual test methodology they used; I believe they pioneered this approach.