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Probabilistic Study of Impact Threat to Civil Aircraft and Realistic Impact Energy

Authors : Ye Zhang, Chuanjun Liu

Abstract : In-service aircraft is exposed to different types of threaten, e.g. bird strike, ground vehicle impact, and run-way debris, or even lightning strike, etc. To satisfy the aircraft damage tolerance design requirements, the designer has to understand the threatening level for different types of the aircraft structures, either metallic or composite. Exposing to low-velocity impacts may produce very serious internal damages such as delaminations and matrix cracks without leaving visible mark onto the impacted surfaces for composite structures. This internal damage can cause significant reduction in the load carrying capacity of structures. The semi-probabilistic method provides a practical and proper approximation to establish the impact-threat based energy cut-off level for the damage tolerance evaluation of the aircraft components. Thus, the probabilistic distribution of impact threat and the realistic impact energy level cut-offs are the essential establishments required for the certification of aircraft composite structures. A new survey of impact threat to civil aircraft in-service has recently been carried out based on field records concerning around 500 civil aircrafts (mainly single aisles) and more than 4.8 million flight hours. In total 1,006 damages caused by low-velocity impact events had been screened out from more than 8,000 records including impact dents, scratches, corrosions, delaminations, cracks etc. The impact threat dependency on the location of the aircraft structures and structural configuration was analyzed. Although the survey was mainly focusing on the metallic structures, the resulting low-energy impact data are believed likely representative to general civil aircraft, since the service environments and the maintenance operations are independent of the materials of the structures. The probability of impact damage occurrence (Po) and impact energy exceedance (Pe) are the two key parameters for describing the statistic distribution of impact threat. With the impact damage events from the survey, Po can be estimated as 2.1x10-4 per flight hour. Concerning the calculation of Pe, a numerical model was developed using the commercial FEA software ABAQUS to backward estimate the impact energy based on the visible damage characteristics. The relationship between the visible dent depth and impact energy was established and validated by drop-weight impact experiments. Based on survey results, Pe was calculated and assumed having a log-linear relationship versus the impact energy. As the product of two aforementioned probabilities, Po and Pe, it is reasonable and conservative to assume Pa=PoxPe=10-5, which indicates that the low-velocity impact events are similarly likely as the Limit Load events. Combing Pa with two probabilities Po and Pe obtained based on the field survey, the cutoff level of realistic impact energy was estimated and valued as 34 J. In summary, a new survey was recently done on field records of civil aircraft to investigate the probabilistic distribution of impact threat. Based on the data, two probabilities, Po and Pe, were obtained. Considering a conservative assumption of Pa, the cutoff energy level for the realistic impact energy has been determined, which provides potential applicability in damage tolerance certification of future civil aircraft.

Keywords : composite structure, damage tolerance, impact threat, probabilistic
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