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Aircraft Vulnerability Assessment against Fragmentation Warhead

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This article presents the detailed methodology developed for the vulnerability assessment of the military aircraft against fragmentation warhead. Vulnerability assessment methodology consists of calculation of the dispersion of the fragments, determination of the hit locations, penetration calculations and probability of kill calculations for the aircraft utilizing the fault tree established for the particular aircraft studied. Based on the developed methodology, vulnerability assessment and survivability analysis of a generic aircraft is performed for different predefined approach angles of the missile threat. For the measure of the vulnerability, mean volume of effectiveness of the warhead is proposed as the metric which is defined as the volume integral of the probability of kill distribution around the aircraft for different intercept directions of the missile. Through the case study, it is shown that mean volume of effectiveness can be used as the single measure of the overall vulnerability assessment of the aircraft.

Nomenclature

A	:	Fragment projected area
A_f	:	Projected area of the striking fragment
A_p	:	Presented area
A_v	:	Vulnerable area
Az	:	Azimuth angle
C_D	:	Fragment drag coefficient
$\vec{D}$	:	Fragment drag force vector
D_x	:	Drag force component in x direction
D_y	:	Drag force component in y direction
D_z	:	Drag force component in z direction
e_i	:	Equivalence factor of each material in the component
El	:	Elevation angle
g	:	Gravitational acceleration
m	:	Fragment mass
m_r	:	Residual mass of the fragment after perforation
m_s	:	Striking mass of the fragment
MVE	:	Mean volume of effectiveness of warhead on the target
$\overline{MVE}$	:	Specific mean volume of effectiveness of warhead on the target
P_K	:	Probability of kill
$P_{k/h}$	:	Probability of kill given hit
$P_{k\,i}$	:	Probability of kill of each component
$\vec{P}_m$	:	Position vector of missile in global coordinates
$\vec{P}_{m/t}$	:	Position vector of missile relative to target
P_S	:	Probability of survivability
$\vec{R}min$	:	Missile miss distance vector
t	:	Thickness of the target
$\bar{t}$	:	Equivalent thickness
t_i	:	Thickness of each material in the component
$[T_{\vec{P}\to G}]$	:	Transformation matrix from local to global coordinates

1. Introduction

Survivability is defined as the ability to remain mission capable after a single engagement [7], or for military aircraft it can be defined as the capability of an aircraft not to be killed by the threats. The importance of the survivability is emphasized and several subjects related to the survivability of the aircraft are given by Ball in his famous book [7]. In MIL-HDBK-336 [2], kill categories are given in order to evaluate the survivability of the aircraft in terms of vulnerability. Attrition kill levels, (KK, K, A, B, C) are the common ones to evaluate the vulnerability of military aircraft. The survivability of a system can be described by fundamental principles shown as the rounds of a union in Fig. 1 [13]. The first principle for increasing the survivability of the aircraft is to be away from the threat area. If the mission needs to be performed in the range of threats, the aircraft should avoid being detected in order to increase the probability of survivability. If detected by the hostile threats, avoiding being acquired or being hit is crucial. In Fig. 1, these are shown as the outer rounds of the survivability union. However, accomplishing all or any of these is not always possible. Therefore, the vulnerability of the aircraft, which is related to the inner two rounds of the survivability union, has great importance for the survivability of military aircraft. Vulnerability assessment of the

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