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Fatigue Life Estimation of Helicopter Landing Probe Based on Dynamic Simulation

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This paper develops a framework of dynamic simulation driven fatigue life analysis of a landing probe system for a typical 12-ton tricycle landing gear helicopter for embarked operations on the typical frigate. By integrating a novel dynamic helicopter/ship interface simulation with the rainflow cycle counting method, fatigue spectra, including all possible probe load cases under the wide range of operating and environmental conditions, have been developed with a confidence level of greater than 99.9%: otherwise, they would be practically unobtainable, even by limited sea trial testing. Furthermore, the fatigue stresses of the probe assembly were obtained by the finite element method, and the cumulative fatigue damage analyses were conducted by monitoring the fatigue life of the critical locations on each component of the probe assembly using the Palmgren–Miner rule against the design life requirement. This new approach provides an innovative and efficient design tool, through virtual prototyping, that can speed up the design process and reduce cost.

Nomenclature

A = area of the oleo piston
$\overline{AB}$ = distance from the trailing-arm/fuselage attachment point to the oleo attachment point
$\overline{AC}$ = distance from the trailing-arm/fuselage attachment point to the axle attachment point
$A_{\mathrm{eq}x}$ = equivalent frontal area
$A_{\mathrm{eq}y}$ = equivalent side area
a_s = static load factor for radial probe loading
$b(q)$ = oleo stroke-dependent damping coefficient
b_s = static load factor for the vertical probe loading
c_1 = constant damping coefficient
c_2 = viscous damping coefficient
c_3 = hydraulic damping coefficient
D = damage contributions
D_t = total fatigue damage
d = tire diameter
F_D = oleo damping force
F_O = total oleo force
F_S = oleo spring force
F_T = vertical component of the tire force
F_{ext} = external force acting on the helicopter body
$F_{\max}$ = maximum static oleo friction force
F_r = radial probe load
F_t = tire force
F_v = vertical probe load
F_μ = oleo frictional force
K_c = corrosion factor
K_d = size effect factor
K_f = surface finish factor
K_l = impact load factor
K_r = reliability factor
K_t = temperature factor
k_{cable} = spring stiffness of the traversing cable
k_s = generic spring stiffness of the securing system
M_{ext} = external moment acting on the helicopter body
m = helicopter mass
m_s = mass of the securing system
m_w = unsprung wheel mass
N = number of cycles causing crack initiation
n = number of fatigue cycles
P = tire inflation pressure
P_r = rated tire inflation pressure
p_0 = initial oleo gas pressure
q = displacement of suspension in the local coordinate system
S_e = corrected fatigue endurance stress limit
S_{e0} = nondegraded endurance stress limit
V_{rel} = body velocity relative to freestream wind
V_0 = initial oleo gas volume
w = tire width
X = vector of translation displacement of the helicopter center of mass
x_s = displacement of the securing system
α = decay rate
γ = gas constant
δ = tire deflection
η_{cable} = viscous damping coefficient of the traversing cable
η_s = generic viscous damping coefficient of the securing system
μ = coefficient of friction
ρ = density of the air at sea level
σ = stress at critical locations
σ_a = alternating stress amplitude
σ_e = equivalent fatigue stress at zero mean stress
σ_m = mean stress
σ_y = material yield stress
τ = tire type

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