Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(5):637-642
DOI: 10.1016/S1001-6058(10)60159-X
www.sciencedirect.com/
science/journal/10016058

SIMULATION OF FLUID-SOLID INTERACTION ON WATER DITCHING OF AN AIRPLANE BY ALE METHOD*

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(Received March 21, 2011, Revised May 8, 2011)

Abstract: Ditching is considered as one of the important aspects of safety performances of airplanes. It is related primarily with the fluid-solid interaction, whose studies mainly depend on experiments at the present time. Numerical and analytical methods for fluid-solid interaction by using 3-D full scale airplane's model will reduce the dependence on the expensive model tests. Numerical studies can be used to estimate the safety of ditching and provide a reference for the crashworthiness design. This article proposes a 3-D dynamical structural model after the real shape of an airplane and an Arbitrary Lagrange-Euler (ALE) fluid-field model, to simulate the fluid-solid interactions caused by low speed ditching. The simulation is based on interaction computational methods, within LS-DYNA nonlinear finite-element code. The results of pressure distributions and accelerating time histories of the airplane's subfloor are discussed in the context of the safety of ditching, and the simulation results and the analytical methods are verified.

Key words: ditching, fluid structure interaction, Arbitrary Lagrange-Euler (ALE), finite element method

Introduction

Ditching means that a plane has no alternative but to land on water surface such as sea or lake, in view of the safety of crews and passengers. There are some cases of successful ditching, also some cases of crashes. Airline companies have strict rules for ditching[1]. According to structural dynamics, an airplane should be in very low speed when ditching, the deformation of an airplane can be approximately considered as elastic-plastic, and it is feasible to simulate an airplane's ditching by using numerical analysis methods such as finite element analysis.

Unlike a ground impact, a large area of the airplane's outer skin contacts with water in ditching. Thus, the fluid-solid interaction and some other mechanical problems should be primarily addressed. The problem of water entry and impact can be studied theoretically, experimentally or numerically. Von Karman (1929) developed the first theory for this problem. This pioneering work uses the concept of added mass for investigation of impact loads on a seaplane during ditching. The majority of the subsequent theoretical work in the early period was based on Von Karman's concept. The experimental techniques related with the problem were mainly developed by NASA since the late 1950s. Boeing airplanes were tested and the operating specifications of ditching were developed at that time. Recently, the numerical analysis is widely used in this respect.

Seddon and Moatamedi[2] reviewed the studies of water entry and impact between 1929 and 2003, and it is pointed out that the numerical analysis should be considered as a main choice, and accurate numerical models of fluid-solid interaction may replace expensive and time-consuming full-scaled tests. Brooks and Anderson[3] first used the finite element software, LS-DYNA, to investigate the water entry of spacecraft. The simulation results were validated by a comparison with the full-scaled test data, but the response after 30 ms-40 ms is not very satisfactory because the field of fluid was calculated as a kind of solids in this soft-

* Project supported by the Shanghai Key Basic Research Program of China (Grant No. 07JC14001).
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