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ScienceDirect

Procedia Technology 14 (2014) 20 – 27

Procedia Technology

2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014

Controlling damping force during aircraft arrestment using self-energized valve mechanism

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Abstract

This paper investigates efforts for controlling damping force during the aircraft landing on aircraft carrier. Since flow through restricted opening ensures damping in any system, the role of a variable orifice is significant. A new self-energized valve mechanism is conceptualized to control the damping force and a mathematical model for energy absorption and then dissipation by means of hydro-pneumatic arresting system is presented. The equation of motion is nonlinear and non-homogenous in nature and has been solved using Taylor's series expansion. Numerical simulation is carried out to extract the performance parameters. The model is capable of predicting the dynamic behavior of the arrester system for variable mass and velocity of landing aircraft. The area of orifice is controlled by self-energized valve mechanism as against contemporary constant run-out control valve. The behavior of arrester system with & without self-energized valve mechanism is compared.

Keywords: Hydro-pneumatic arresting system; Self energized valve mechanism; Simulation experiments; Aircraft carrier.

Nomenclature

A_o, Q_o, A_{ram}	orifice area, discharge and ram area
C_d , dt	coefficient of discharge and time increment for numerical calculation
F_c, F_{ram}, F_t, F_o	cable, ram, aircraft thrust force and force on valve mechanism plunger

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doi:10.1016/j.protcy.2014.08.004

h, L	valve mechanism plunger travel and half deck pendent length
M_a, M	aircraft mass & combine mass of aircraft and crosshead
N, k	number of reeves and aircraft thrust factor
P_1, P_2, P_o	ram pressure, accumulator pressure and valve mechanism accumulator pressure
W, H	width and height of orifice
X_a, $\dot{X}_a$, $\ddot{X}_a$	run out, velocity and acceleration of aircraft
X_c , V_{ram}	piston travel and ram velocity
γ, ρ	specific heat ration for air and fluid density
θ, Lc	angle of cable with its initial position and cable length over deck
V_1 , $\dot{X}_c$	cable and ram velocity
P_{fi} V_{fi}	accumulator initial pressure and volume
V_{oa}	volume of air inside valve mechanism accumulator
a_o, v_o	acceleration and velocity of valve plunger

1. Introduction

Aircraft generally required long runway for landing, but the same luxury is not available on aircraft carrier. On the aircraft carrier, the maximum available runway length is of the order of 150 m. In order to achieve safe landing, the use of an arresting system is mandatory. Such systems consist of a hydraulic arrangement, which absorbs the energy of the landing aircraft. The damping force is generated by flow of the fluid through restricted opening. The magnitude of this force can be controlled by varying the orifice area. Aircraft arrester systems have received constant attention since last few decades. Since then continual improvements are happening.

Cliff et al. [1] studied the role of constant run out control valve in the arrestment. The experimental reports about hydraulic aircraft arresting gear systems were also published by them. Dmitry et al. [2] used finite element method for modeling of the arresting gear and carried out simulation of aircraft landing using arresting gear. Kaidong et al. [4] studied constant run out control valve device and hydraulic cylinder device, which are two key parts of the arresting system. Kaidong et al. [5] described modeling and simulation of hydraulic aircraft arresting gear.

This paper presents a framework for investigating the dynamic behavior of the hydraulic aircraft arrestor gear system for those aircrafts which land on aircraft carriers. As a first stage of study a model with single degree of freedom has been suggested. The model is capable of predicting the dynamic behavior of the arrester system for variable mass and velocity of landing aircraft. The equation of motion is nonlinear and non-homogenous in nature and has been solved using Taylor's series expansion. The area of orifice is controlled by self-energized valve mechanism as against constant run out control valve. The behavior of arrester system with & without self-energized valve mechanism is compared.

2. System Description

2.1. Construction of Aircraft Arrester Gear with self-energized valve mechanism

The aircraft arrester gear system consists of seven components, viz., a wire rope, set of pulleys, a main hydraulic cylinder assembly, a valve mechanism, an accumulator, set of sheave dampers and a set of cable anchor dampers. The schematic diagram of aircraft arrestment with the hydro-pneumatic system is described in Fig.1(a). A wire rope is laid down across the runway and the same is extended to the main hydraulic cylinder assembly. The same is supported by set of pulleys to provide the desired direction. The wire rope is reeved a number of times on the main hydraulic cylinder assembly to reduce the stroke of piston. A self-energized valve mechanism that connects the main hydraulic cylinder to accumulator is introduced the arrester system. The accumulator is long cylinder having a floating piston with one side of the piston filled with air. A rectangular narrow opening is provided which act as an orifice. A plunger is provided in the valve system whose movement results in changing the orifice area.