JOURNAL OF AIRCRAFT
Vol. 44, No. 5, September–October 2007

Shape Memory Alloy Based Smart Landing Gear for an Airship

G. N. Dayananda,*,† B. Varughese,* and M. Subba Rao*
National Aerospace Laboratories, Bangalore 560 017, India

DOI: 10.2514/1.26811

The design and development of a shape memory alloy based smart landing gear for aerospace vehicles is based on a novel design approach. The smart landing gear comprises a landing beam, an arch, and a superelastic nickel–titanium shape memory alloy element. This design is of a generic nature and is applicable to a certain class of light aerospace vehicles. In this paper a specific case of the shape memory alloy based smart landing gear design and development applicable to a radio controlled semirigid airship (radio controlled blimp) of 320 m^3 volume is presented. A judicious combination of carbon fiber reinforced plastic for the landing beam, cane (naturally occurring plant product) wrapped with carbon fiber reinforced plastic for the arch, and superelastic shape memory alloy is used in the development. An appropriate sizing of the arch and landing beam is arrived at to meet the dual requirement of low weight and high-energy dissipation while undergoing "large elastic" (large nonlinear recoverable elastic strain) deformations to ensure soft landings when the airship impacts the ground. The soft landing is required to ensure that shock and vibration are minimized (to protect the sensitive payload). The inherently large energy-dissipating character of the superelastic shape memory alloy element in the tensile mode of deformation and the superior elastic bounce back features of the landing gear provide the ideal solution. A nonlinear analysis based on the classical and finite element method approach is followed to analyze the structure. Necessary experiments and tests have been conducted to check the veracity of the design. Good correlation has been found between the analyses and testing. This exercise is intended to provide an alternate method of developing an efficient landing gear with satisfactory geometry for a "certain class of light aerospace vehicles" such as airships, rotorcraft, and other light unmanned air vehicles.

Nomenclature

A_f = austenite finish temperature
A_s = austenite start temperature
E = Young's modulus
M_f = martensite finish temperature
M_s = martensite start temperature
δ_h = horizontal deflection
δ_v = vertical deflection
ε = strain
σ = stress
σ_{ult} = ultimate stress

I. Introduction

THE design and development of a landing gear encompasses several engineering disciplines such as structures, mechanical systems, aerodynamics, material science, and so on. The conventional landing gear design [1] and development for aerospace vehicles is based on the availability of several critical components/ systems such as forgings, machined parts, mechanisms, sheet metal parts, electrical systems, hydraulic systems, and a wide variety of materials such as aluminum alloys, steel, titanium, beryllium, and polymer composites. As the science of materials is progressing continuously it is natural that the use of new materials will replace older designs with new ones.

Energy absorption and crashworthy features are the primary design criteria that govern the development of landing gears. Del Monte [2] deals with the design and development of a crashworthy landing gear for rotorcraft that dissipates crash landing energy. Airodli et al. [3] deals with the design of the crashworthy landing gear adopting a crash tube as an energy-absorbing device in crash conditions. In this design a light alloy thin-walled tube is mounted coaxially to the shock absorber cylinder and during the severe impact condition, this collapses to enhance the energy absorption performance of the landing system. Like the landing gear of fixed wing aircraft, the landing gear of helicopters has also evolved over the past few decades. The different variants of helicopter landing gear include the wheeled gear, tricycle, quadricycle arrangements and the skid type landing gear. Among these, the skid type of landing gear for the helicopter has gone through extensive design and development and is now used in many helicopters as it meets their requirement.

Philips et al. [4] deals with the design of a crashworthy landing gear for helicopters which would lessen the magnitude of crash forces. In this design the skid stiffness was idealized as a bilinear curve. The first part of the curve represents elastic deformation and the second part plastic deformation of the skid.

Cheng-Ho Tho et al. [5] refers to the design and development of a high energy absorbing skid landing gear for helicopters. Stephens et al. [6] deals with the development of a dynamic analytical methodology for analyzing the structural behavior of a helicopter skid gear during a high-energy landing. This methodology was used in the correlation of impact loads for level landing at different conditions. Airoldi et al. [7] presents a numerical approach to the optimization of skid landing gears. The optimization technique is applied to investigate the tradeoff between landing performances and gear strength. Ashish et al. [8] discusses a nonlinear finite element based method of analyzing the structural behavior of helicopter skid gears during a high-energy landing.

Another class of energy-absorbing devices is skis, which are used for skiing on snow-filled surfaces, and their function is similar to that of skids in aircraft. Of late, a swiss ski [9] producer has tested composite skis in which laminated Cu–Zn–Al shape memory alloy (SMA) strips are embedded to improve energy-absorbing characteristics. The serious shortcoming in the designs in which

Received 27 July 2006; revision received 7 April 2007; accepted for publication 18 April 2007.

*Scientist, Advanced Composites Division, P.O. Box 1779, Airport Road.
†Scientist, Advanced Composites Division, P.O. Box 1779, Airport Road; dayanand@css.nal.res.in; gndayananda@yahoo.com (Corresponding Author).