Numerical simulation of soft-body impact on Shape Memory Alloys (SMA)

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Abstract

Bird impact generally occurs during taking off or landing of flights. It is termed as soft body impact and assumed to be a hydrodynamic body. Shape Memory Alloy is a smart material which gets its original shape by heating. The impact on plastic kinematic materials are analyzed for kinetic energy, internal energy and contact pressure by considering idealized bird model and compared with the Shape Memory Alloy material using LS Dyna finite element software.

Keywords: impact, SMA, Finite Element Techniques, Plastic kinematic elements, LSDyna.

1 Introduction

The impact of birds with aircraft structures is one of the main threats for flight safety. Due the considerable presence of birds in the vicinity of airports a large number of bird strikes occur. In the last two decades significant expansions in the use of different materials in aeronautical industry have been verified to obtain structures with optimum strength to weight ratios. In the bird-aircraft impact the former is characterized as a soft body. The bird behaves like a fluid in the impact event and the effects have on large area of the target [1]. The problem deals with complex aspects such as high strain rates, large deformations, complex constitutive relationships and damage to failure mechanisms, etc. Hence the complexity precludes application of analytical solutions to solve the impact based problems.

Experimental tests for bird impact problems are expensive and complex. Computational methods have been extensively used by the aircraft industry to minimize the number of experiments, reduce certification, and minimize development costs. Hence the method supports the design of efficient bird-proof structures. Nonlinear explicit codes have been successfully employed based on Finite Element Techniques to a large number of problems in the field of Continuum Mechanics since late eighties. The LS-Dyna code [2] is a general purpose finite element code for non-linear structural dynamics which has been largely employed to impact analysis [3–6]. The material behavior of the idealized bird is approximated as that of the water as suggested in the literature [4, 8]. Impact of bodies with low rigidity and hardness as those considered in the bird impact analysis has been treated in the aeronautical industry and research centers through the so-called ‘substitute birds’ [7, 8] materials whose mechanical behavior resembles real birds with advantages in uniformity and repeatability in the
Experimental tests usually conducted by using gas gun projectile launchers.

The paper deals with numerical simulation of the impact between a substitute bird and a Shape Memory Alloy (SMA) plate by using the LS-Dyna code. The obtained results are compared with plastic kinematic materials.

2 Problem descriptions

Here, a circular cylindrical soft body is considered as a bird which is horizontally launched on a vertically placed circular plate made up of SMA. The tested plate is of 250 mm diameter, 7 mm thick and length to diameter ratio of 2.0 is taken as geometry of the bird [8]. An initial velocity of 300 m/s has been provided to the bird to start the analysis.

3 Finite Element Modelling

Impact simulation has been performed using the explicit finite element code LS_DYNA Version 970. In this analysis the circular plate is used as the target and the cylindrical bird as the impactor. The finite element model of the target and the cylindrical bird is as shown in fig (1). Fine meshing was done for the entire plate to capture better results. The different parameters of the target and the impactor used in the analysis are shown below.

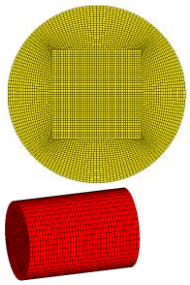

Figure 1 Finite element models of the plate and birds

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3.1 Disc Finite Element Model

The disc is modelled using 4-noded shell elements with Belytschko-Tsay element formulation. A relatively fine mesh density is chosen for capturing better results. The circular plate has the following dimensions.

Dimensions

Radius of the disc	= 250 mm
Thickness of the disc	= 7.0 mm

3.2 Bird Finite Element Model

The bird finite element model is modeled using 8-noded brick elements. A regular mesh is created near the contact area between the bird and the disc for obtaining better results. The bird has the dimensions of 80 mm diameter

4 Material models

Since the impact analysis of disc involves geometric and material non-linearity, the selection of material model is crucial for obtaining accuracy. The LS-DYNA provides numerous material models for modeling of materials but an appropriate selection has to be made.

Disc Material model

The material model used for the material modeling of the disc is MAT_PLASTIC_KINEMATIC and MAT_SHAPE_MEMORY respectively. The plastic kinematic element formulation is suited to model isotropic and kinematic hardening plasticity. It is effective material model for beam, shell, and solid elements.

MAT_SHAPE_MEMORY material model describes the super elastic response present in shape memory alloy, which is the peculiar material ability to undergo large deformation with a full recovery in loading and unloading cycle.

Bird Material model

The material model used for modeling the cylindrical ended bird is MAT_NUL. The following properties have been used.

Mass density, ρ= 1000 Kg/m^3

Equation of State

Generally, in the bird strike analysis, the bird model is modeled using null material. The Null material model should always be associated with an equation of state basic form

Pressure = f (Density, Specific internal energy)

The simplest equation of state is the gamma law equation of state. The only input required is the ratio of specific heats for an ideal gas. A polynomial equation of state is specified in this analysis for the bird model. In polynomial equation of state, the pressure is related to the relative volume and specific internal energy by a cubic polynomial. This can also be used to model viscous fluids.

Contact Type

Contact algorithms used in impact problems are significant to simulate the exact impact phenomenon. The transfer of energy from the impactor to the target and again from the target to the impactor takes place only when a proper contact is defined. In the present case, CONSTRAINED_LAGRANGE_IN_SOLID is used. This command provides the mechanism for coupling interaction between a slave such as Lagrangian mesh of shells, solids or beam to a master like ALE or Eulerian mesh.

Boundary conditions

The boundary conditions have to reflect the actual process in the real time situation. In this case the edges of the plate are fully constrained.

5 Results and discussion

Impact phenomenon is carried out and the results are obtained. The graph 1 and 2 shows the variation of the internal energy of the bird. The graph shows the decrease in the kinetic energy of the bird which indicates the impact of the bird on plate has taken place. The graph 3 and 4 shows the contact force variation on disc. Figure 2 shows the flow pattern of bird which shows the deformation at the centre.

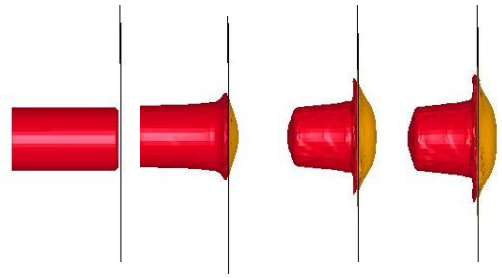
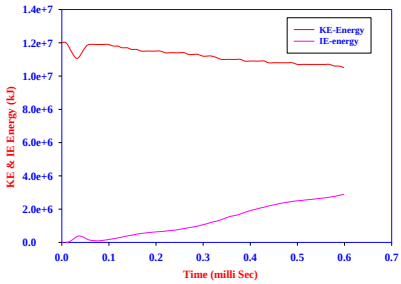
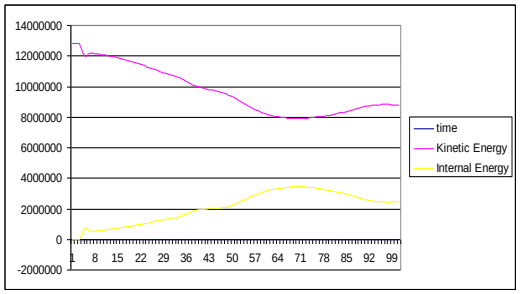


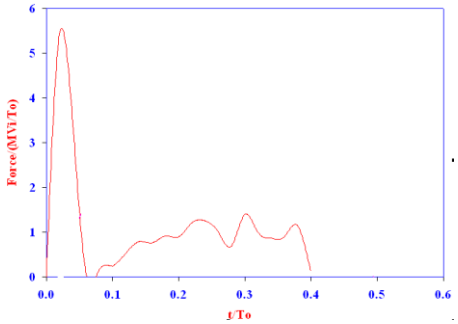
Fig 2: flow pattern of bird on deformable target



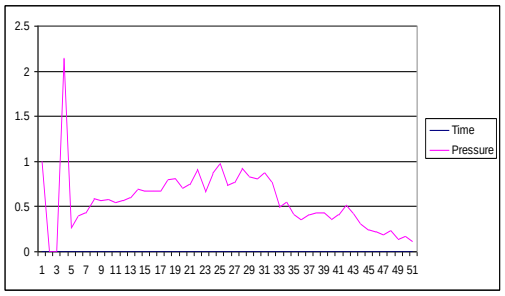
Graph-1: Kinetic and Internal Energy plot



Graph-2: Kinetic and Internal Energy plot of SMA



Graph-3: Contact force plot of bird on deformable target



Graph-4: Contact force plot of bird on SMA

6 Conclusions

The bird impact is a soft body impact which behaves like water. The bird impact on aircraft which generally made up of plastic kinematic material is analyzed. SMA material is used in place of plastic kinematic material for analysis. The results obtained such as kinetic energy, internal energy and contact pressure for SMA is compared with plastic kinematic material and found to be with closer approximation. Hence it is suggested to replace plastic kinematic material which is being used in aircrafts with SMA to have flexibility in recovering original shape by heating.

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