Performance evaluation of soft body impact on Ni-Ti shape memory alloy with conical model.

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Abstract: The response of soft body impact on a Ni-Ti shape memory alloy with conical model is investigated by using the non-linear finite element analysis method for obtaining Kinetic Energy, Internal Energy and contact force plot by considering idealized bird model with constant velocity.

Key words: Bird-Strike Phenomenon, Impact load, FEM, LS-Dyna

1 INTRODUCTION:

Impact events on aircraft structures, especially on and within the engines are critical to the safety of the aircraft. Because of this the aircraft, aero-engine and aerospace industries give lot of importance to the design of structures for impact loading. In light of this, developing an understanding of impacts is crucial. One of the major hazards to flight safety today is the in-flight impact of birds. Bird strikes or bird ingestion is one of the safety concerns plugging the aircraft industry since its inception[1]. Flocks of birds seem harmless enough when admiring them from the ground. However, experiencing them from the cockpit of an aircraft can prove lethal. A 12 – pound Canadian goose struck by an aircraft traveling at 150mph, generates an impact force of similar to that created by a 1000 – pound weight dropping from a height of 3m. More than 300 people have been killed by bird strikes since the fatality was recorded in 1912.

One of the structural requirements for airplanes is for them to be able to absorb with limited or no damage specified impacts due to ingested birds, ice balls or hail stone and hard body objects (engine component fragments), which is referred to as foreign object damage (FOD). In general, the impacting objects can be divided into two classes – small, hard objects like rocks and bullets; and large, soft or frangible objects like birds or hail. The former tend to produce primarily local damage, where as the latter can produce both local and gross damage.

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Shape Memory Alloys are alloys which are able to return to their original shape after being 'plastically' strained up to 8%, just by heating. This Shape Memory Effect is caused by a martensitic transformation, i.e. a change of crystal structure, which can be induced either thermally (cooling) or mechanically (stress), each of which has its boundary temperatures. The formation of variants plays an important role. The general opinion is that only alloys which exhibit thermoelasticity can be Shape Memory Alloys. Most Shape Memory Alloys show pseudoelastic behaviour, but this is not a condition. Currently there are three main groups of Shape Memory Alloys: Cu-based alloys, which are used commercially, rather recent Fe-based alloys, and Nitinol, a NiTi alloy, the most thoroughly investigated alloy showing the best Shape Memory behaviour. This report describes the main haracteristics of the Shape Memory behaviour and aims at Nitinol in particular.

The paper deals with numerical simulation of the impact between a substitute bird and a Ni-Ti Shape Memory Alloy (SMA) with conical model 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 conical model made up of SMA. The tested conical model is of 30^0 angle, 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 conical model 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 discussed below.

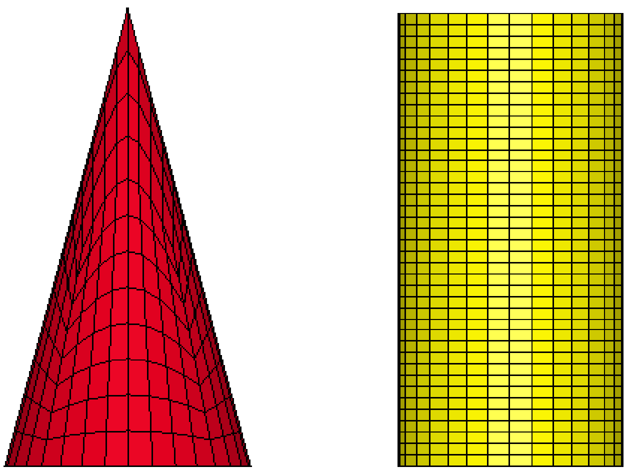

Fig 1 Mesh pattern of cones 30^0 and bird

3.1 Disc Finite Element Model

The cone 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

Angle of cone is = 30^0

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 cone is MAT_SHAPE_MEMORY. This 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

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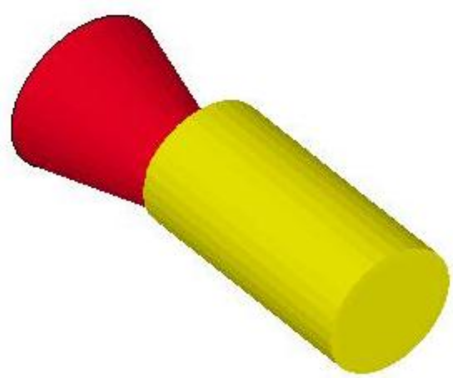
used. This command provides the mechanism for coupling interaction between a slave such as Lagrangian mesh of shells, solids or beam to a master like ALE or Eulerian mesh.

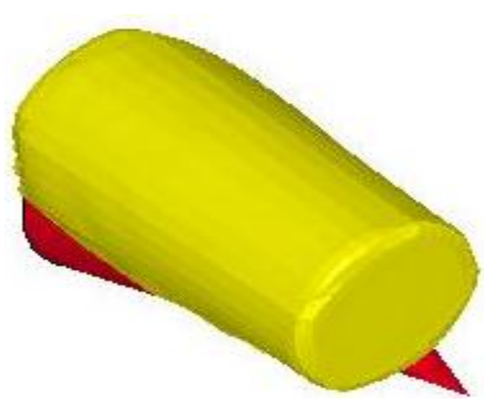
Boundary conditions

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

5 Results and discussion

Impact phenomenon is carried out and the results are obtained. The graph 1 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 2 shows the contact force variation on cone. Figure 2 and 3 shows the flow and stress pattern of bird respectively.





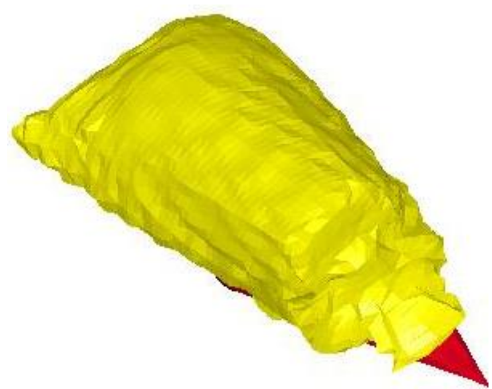
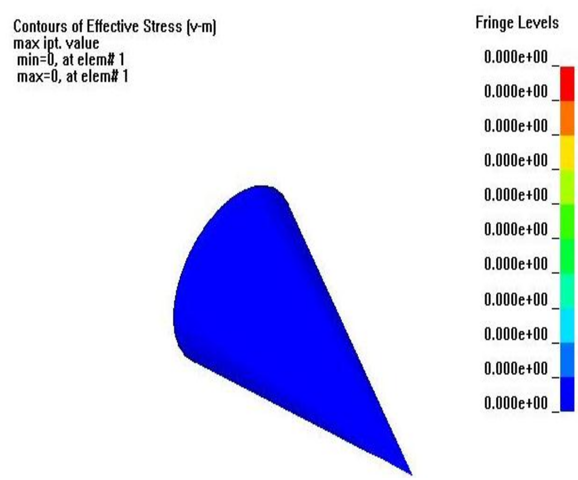


Fig 2: flow pattern of bird on cone



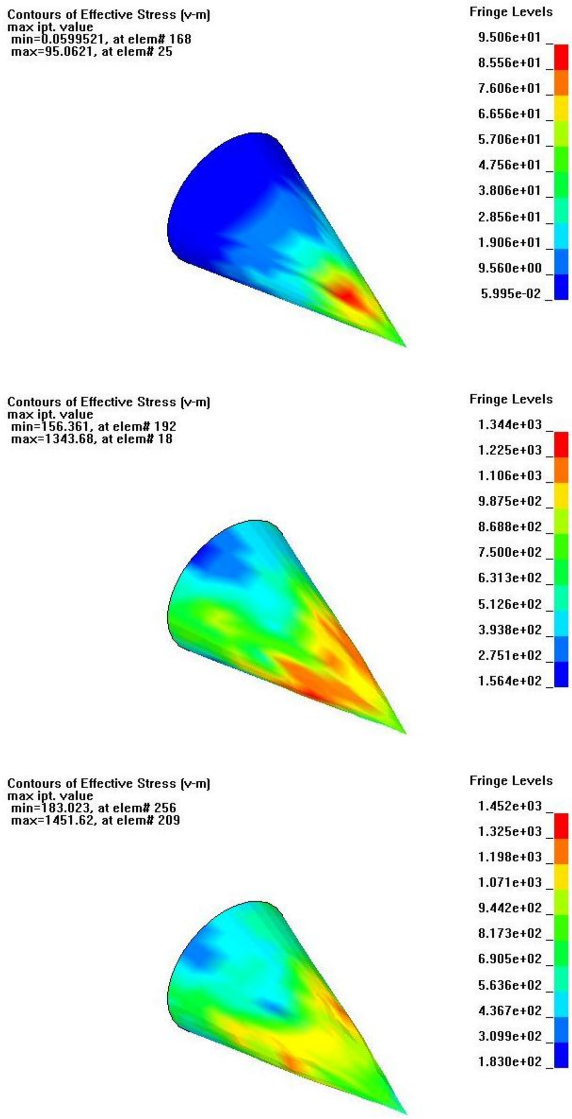
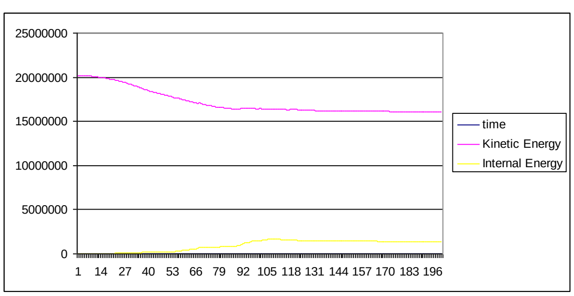
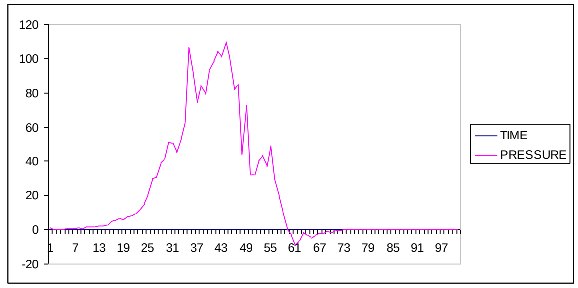


Fig 2: Stress pattern of bird on cone



Graph-1: Kinetic and Internal Energy plot



Graph-2: Contact force plot of bird on cone

6 Conclusions

The non-linear finite element analysis of a cone is performed by impacting it with a cylindrical bird moving with a constant velocity.

In this paper, we have introduced a conical model for describing the behavior of SMAs. From the result it is concluded that the performance of SMA is very good under the impact load.

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