

A stylized graphic of a rotor blade, composed of several curved segments in shades of blue and white, set against a dark blue background.

# Altair HTC09

Ludwigsburg 2nd-4th November 2009

Analysis with RADIOSS of a  
bird strike onto a helicopter  
blade and onto a rotor control  
chain

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# INTRODUCTION

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**The demonstration that bird strike does not compromise the flight safety is due as compliance to civil requirements (JAR 29.631).**

**The fulfillment of this requirement is usually done by test, which is however time consuming and expensive.**

**The work presented here is a first experience of AW-Italy with code RADIOSS and SPH bird formulation to simulate a case of bird strike first onto a rotor blade, which was tested a few years ago in 2002, and then onto a rotor control chain.**

**The purpose of the first part of the job was to gain confidence in the software, by comparing the experimental with the simulation results.**

**The second part was focused on the analysis of the bird strike effects on a control chain assembly. In this case no test evidence was available; the numerical evaluation has been carried out for preliminary design purposes only, as from the threat assessment bird strike substantiation was not required for this assembly.**

# INTRODUCTION

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**The work was done as a training-on-the job activity for Rotor System D&D with the consultancy of Altair people in September and November 2007.**

**The choice of RADIOSS was driven by the maturity of the SPH bird formulation, which was recognised as the most suitable for the kind of impact to be analysed on bodies having sharp shapes (pitch link and blade) likely to split the bird into parts and for the possibility to have a multi-impact problem.**

## ROTOR BLADE SIMULATION

### Objective

**As part of the compliance to the civil requirements, a bird strike test was carried out a few years ago on a representative blade portion.**

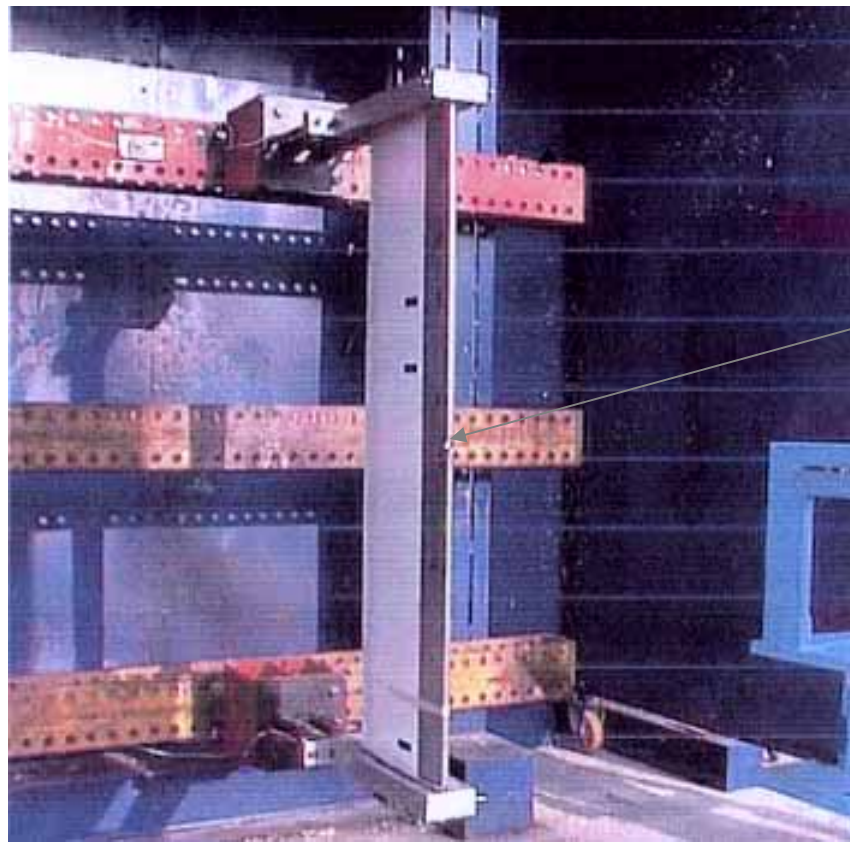
**The need to better understand the effectiveness of the numerical simulation in predicting the effects of bird strike, made it proper to manage first a problem, which could be correlated with experimental results.**

**The most proper “benchmark” to test the performances of an SPH bird formulation appeared to us to be the blade with its sharp leading edge, which caused the bird to be split into parts.**

# BIRD STRIKE ONTO ROTOR BLADE

## RIG SET UP

The blade specimen was clamped through a frame on which rubber had been bonded to get a good fit with the blade surface.



Target point

# BIRD STRIKE ONTO ROTOR BLADE

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## RIG INSTRUMENTATION

**One high-speed video camera was used for the test to observe and record the behaviour of the hit specimen and the correctness of the impact point.**

**The complete time history of the blade behaviour during the test was recorded by load cells and tie bars that were placed at the blade supports and by two accelerometers bonded to the blade surface**

**The accelerometers readings and the event phenomenological aspects captured by the video camera have been used as a means of correlation with the simulation.**

# BIRD STRIKE ONTO ROTOR BLADE

## FEM DESCRIPTION

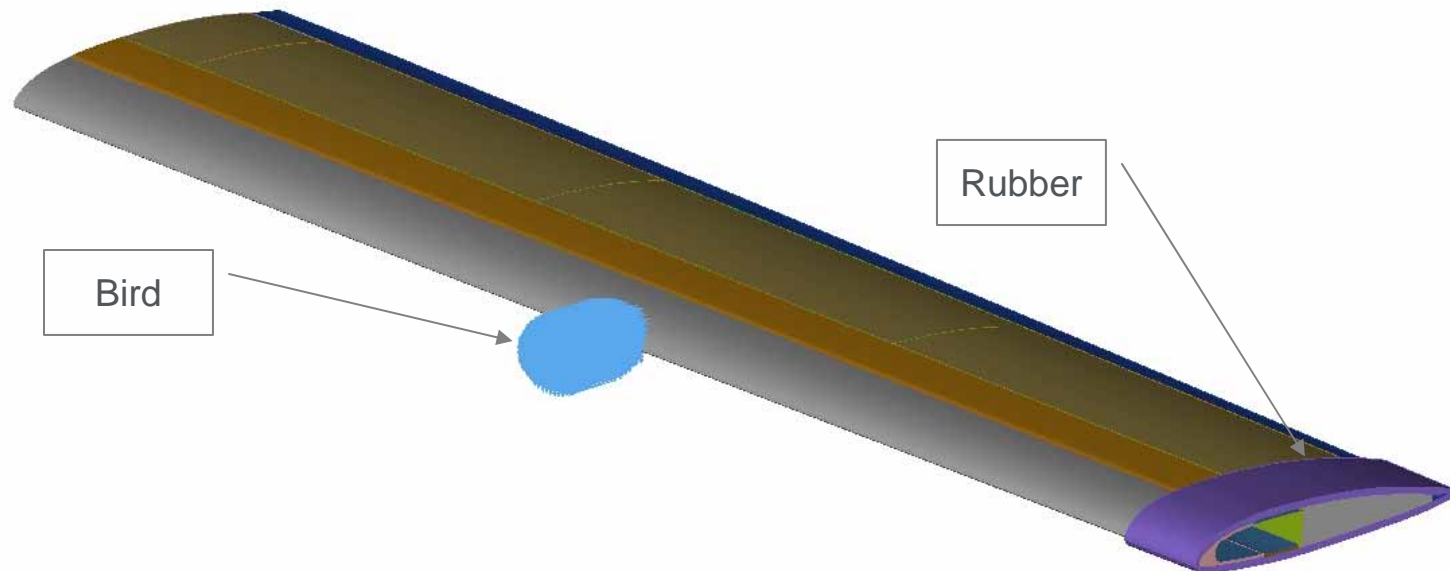
The blade is made of composite material and it has been modeled with solid and shell elements to simulate the fillers and the skins.

The FEM consists of:

- 22594 shell elements
- 24433 solid elements
- 2 rigid bodies
- 46879 nodes
- 18 property cards
- 11 material cards
- 5 sensors (two of which used for correlation)

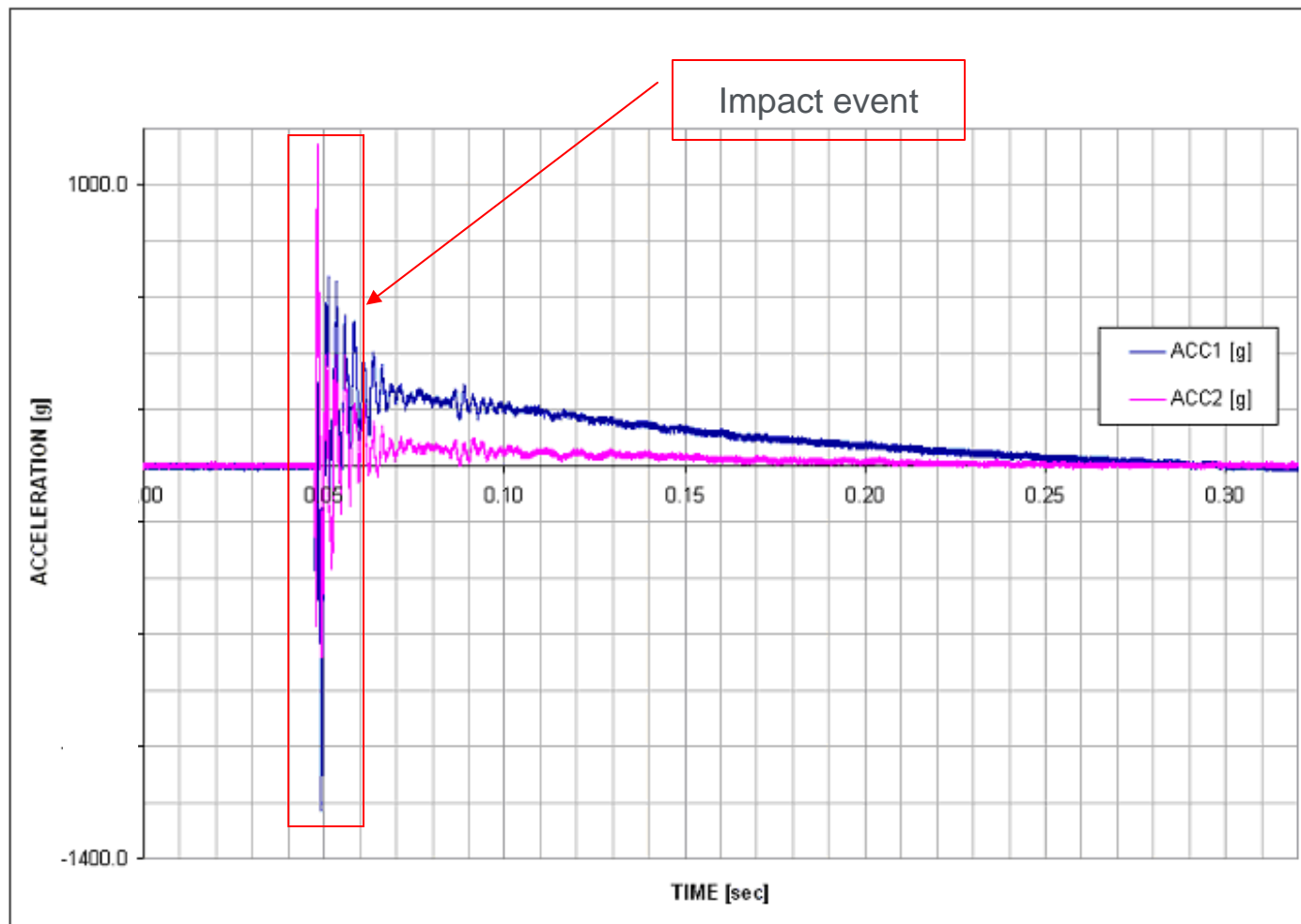
## BIRD STRIKE ONTO ROTOR BLADE

To simulate the clamp a layer of rubber wrapping the airfoil has been modelled, using the /MAT/OGDEN card for the material. A few trials have been made changing the  $\mu$  parameter and changing the type of constraint at the specimen ends, until the best correlation with test for the accelerometers signals has been found.



# BIRD STRIKE ONTO ROTOR BLADE

## TEST RESULTS: accelerations



# BIRD STRIKE ONTO ROTOR BLADE

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## **SIMULATION RESULTS: accelerations**

**As said, a few trials have been carried out changing the boundary conditions in order to match the experimental accelerations results:**

**Test 1:  $\mu=1.5$**

**Test 2:  $\mu=0.2$**

**Test 3:  $\mu=0.2$  Free-Clamp (one side clamped and one free)**

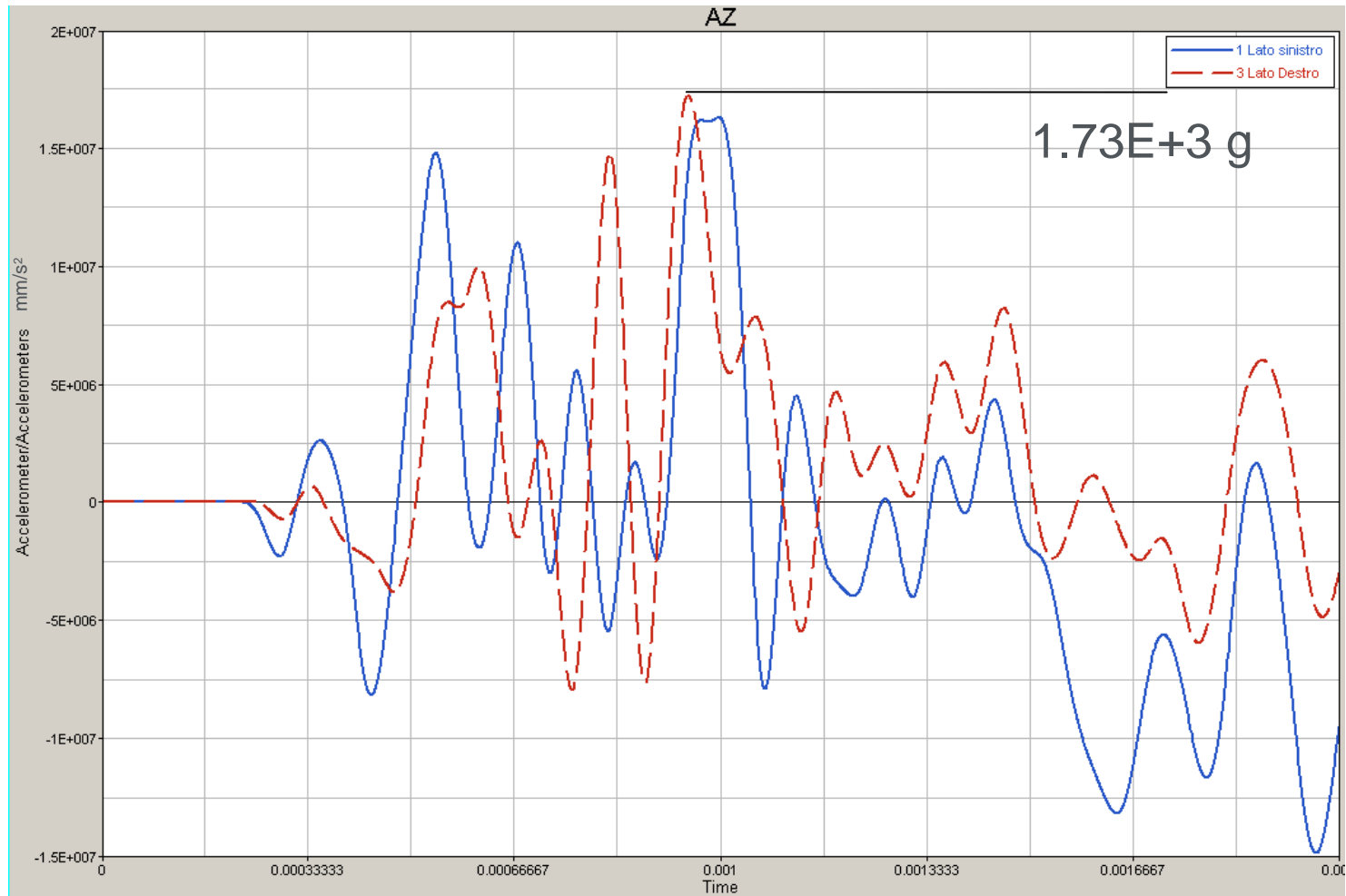
**Test 4:  $\mu=0.5$  Free-Clamp**

**Test 5: Free-Free (both sides free)**

**The best results have been obtained in Test 4 and Test 5**

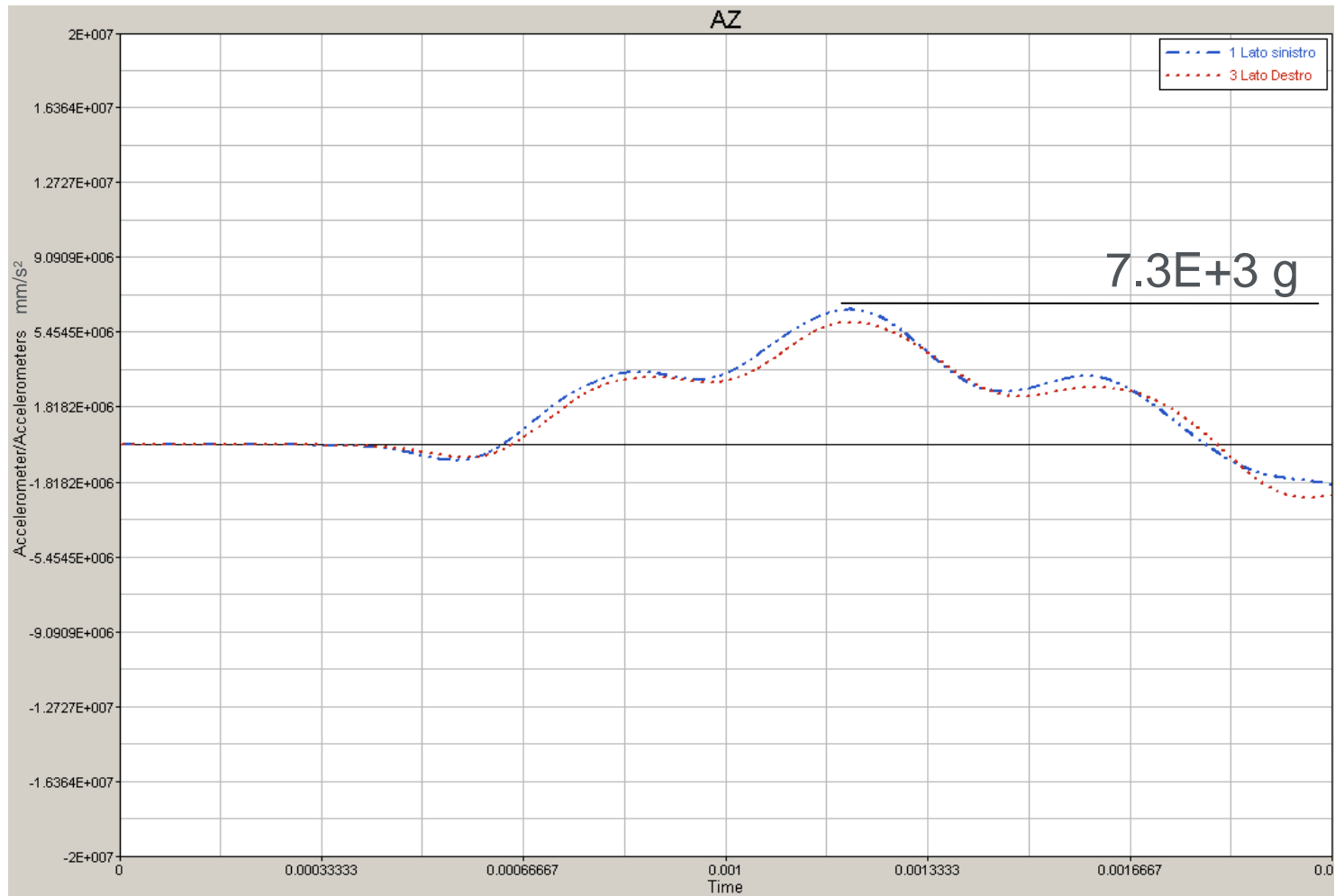
# BIRD STRIKE ONTO ROTOR BLADE

## SIMULATION RESULTS: accelerations – Test 4



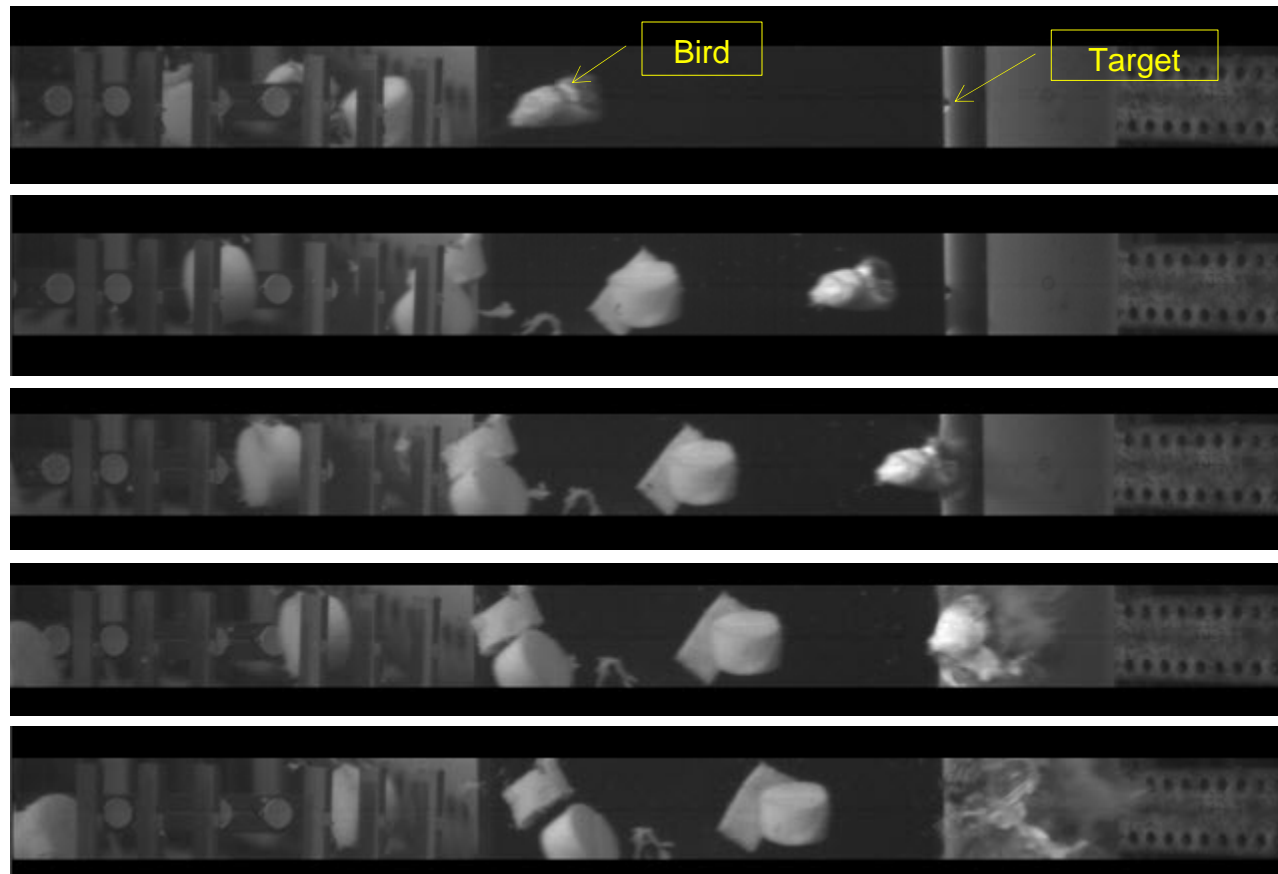
# BIRD STRIKE ONTO ROTOR BLADE

## SIMULATION RESULTS: accelerations – Test 5



# BIRD STRIKE ONTO ROTOR BLADE

## TEST RESULTS



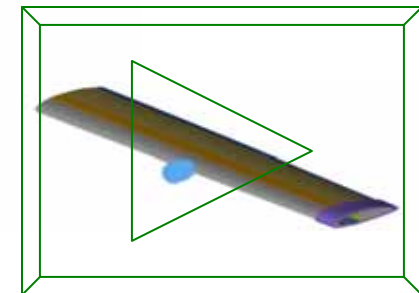
# BIRD STRIKE ONTO ROTOR BLADE

## SIMULATION RESULTS

0 ms



.8 ms



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN



## ROTOR CONTROL CHAIN SIMULATION

### Objective

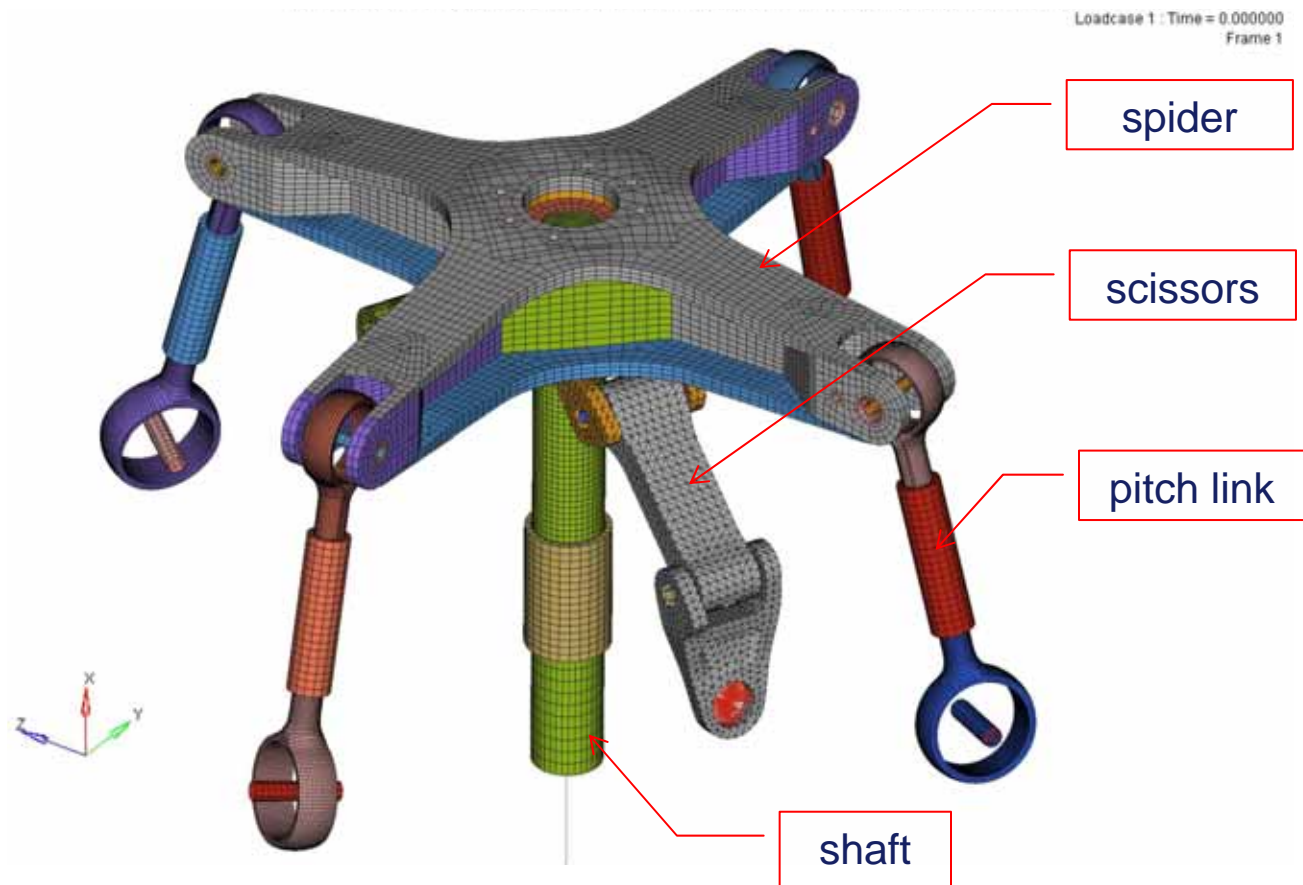
- To assess the level of stress and deformation in the components
- To assess the level of possible damage induced by the bird behaviour after impact

# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

## FE Model description

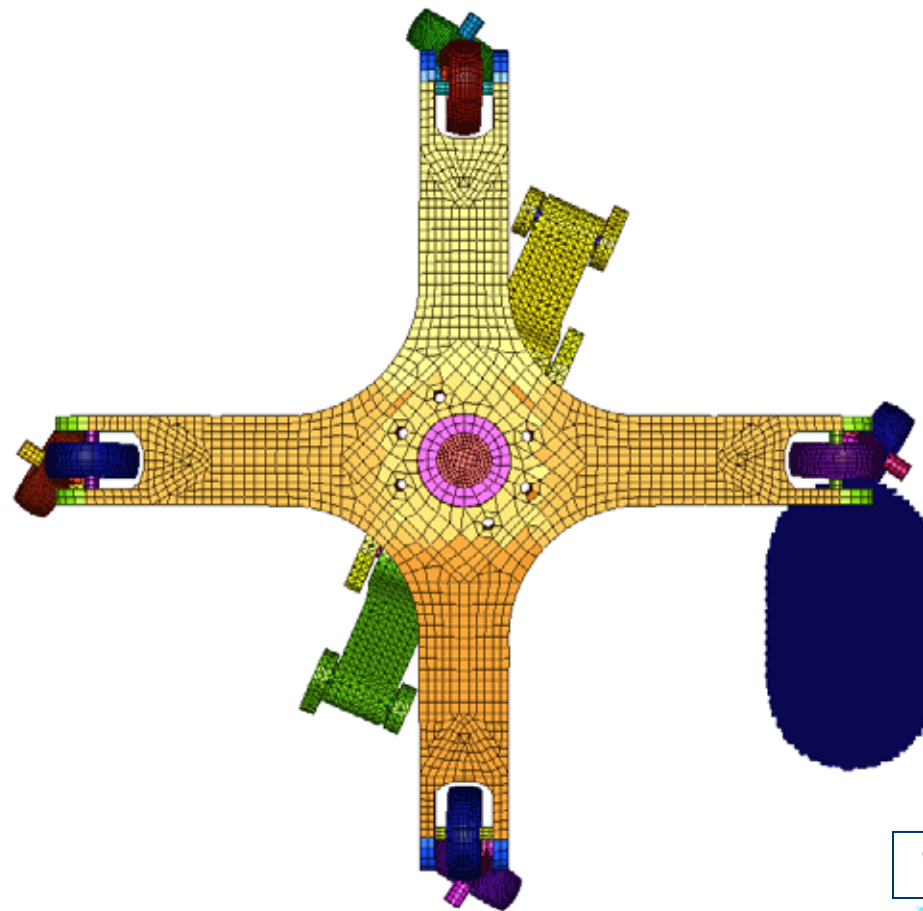
The final FEM consists of :

- 44 parts
- 27 materials (both anisotropic and isotropic)
- 39 property sets
- 186574 nodal points
- 15 boundary conditions
- 125891 3D solid elements
- 1840 shell elements
- 6 beam elements
- 15819 smooth particles (SPH cells) (3 lbs)
- 17 interfaces
- 23 rigid bodies



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

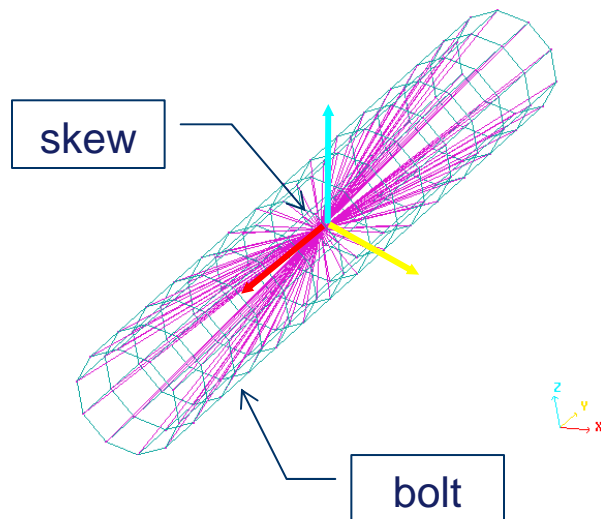
- Bird impact direction chosen to maximise torsion about the shaft and transversal load on the spider arm:



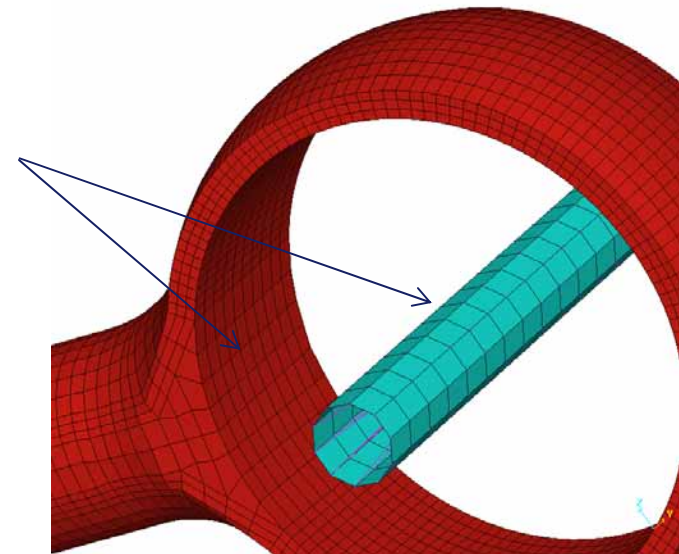
Top view

# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

A primary task of the modelling phase was the definition of the joints and the interfaces between the parts of the assembly. These include bolts with spherical bearings, elastomeric and metallic, stuck fittings and hinged joints with bolts. All bolts have been modelled using a rigid body connected to a cylindrical surface of shells and properly constrained with respect to local movable skews.



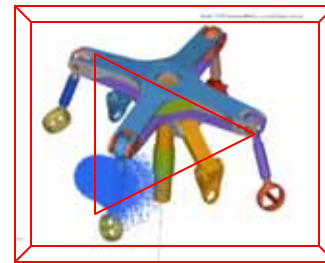
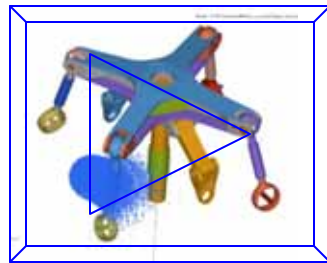
An interface (TYPE10) is defined between the shells of the bolt and the jointed part to simulate the bearing.



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

## Results

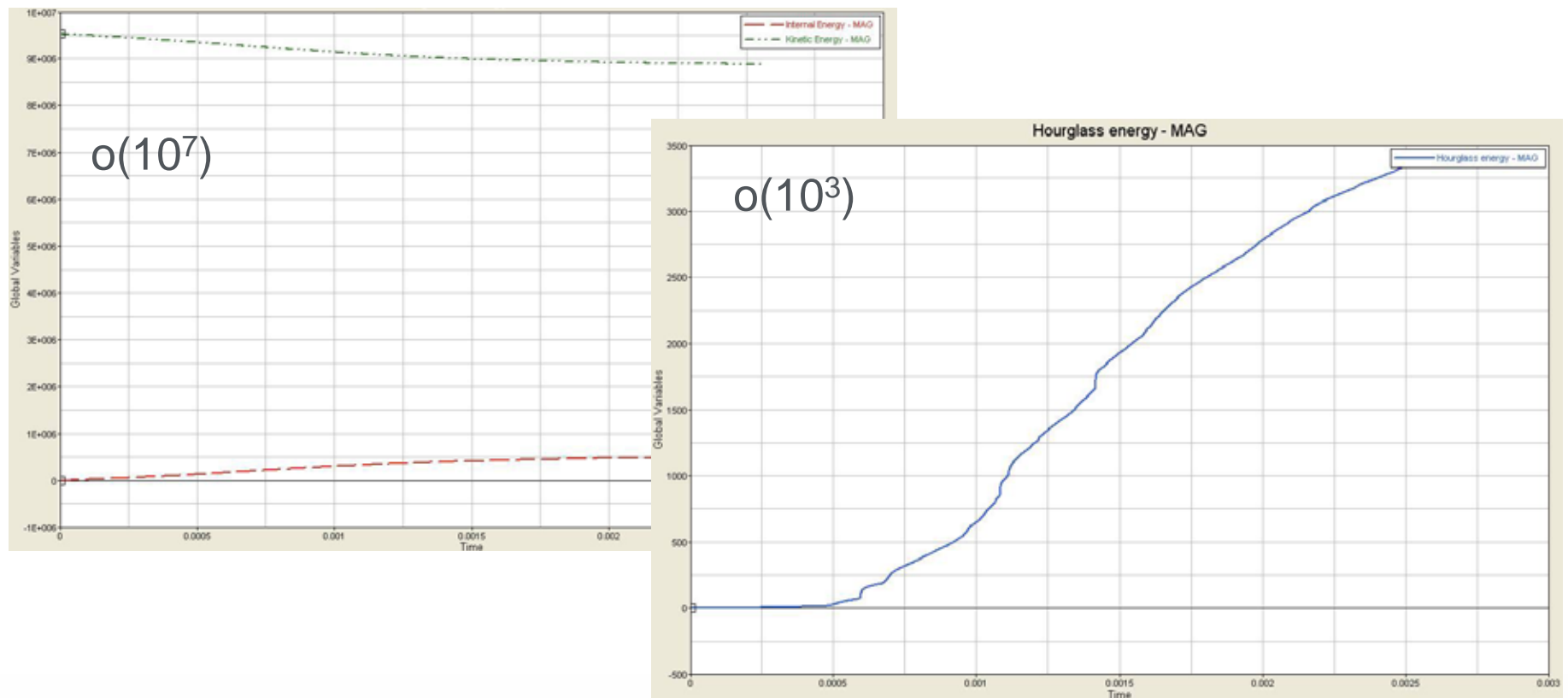
- The final simulation has been carried out with version 901, after the initial runs carried out with version 51, to fix a few issues on composite parts.
- The effect of the impact on the bird is a splitting of the body into parts, as a consequence of the small diameter of the hit pitch link.
- No stiffening effects from the centrifugal fields are present



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

## Simulation global parameters

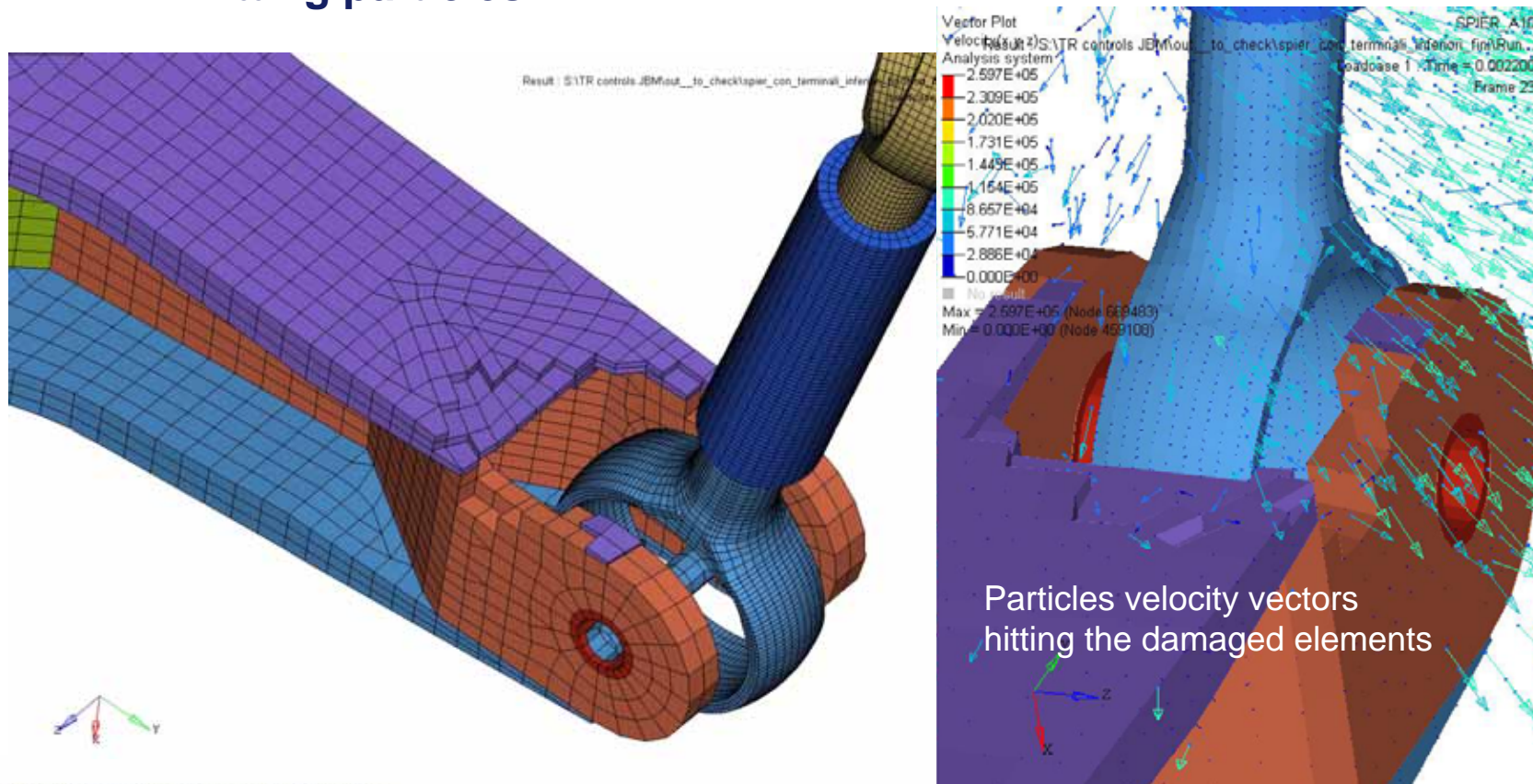
- The simulation global parameters, like Hourglass, internal and kinetic energy reveal the good quality of the run.



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

## Stress and deformation

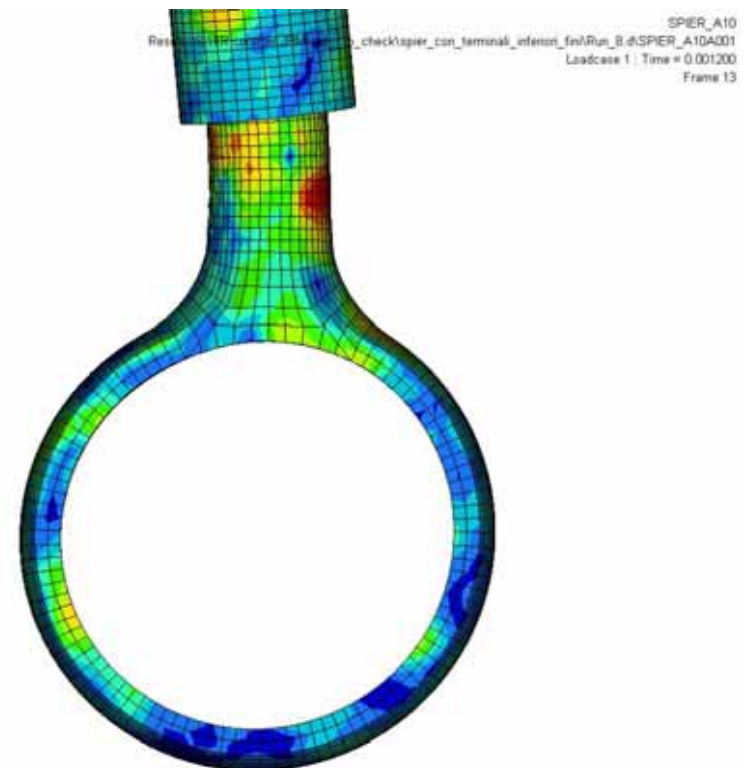
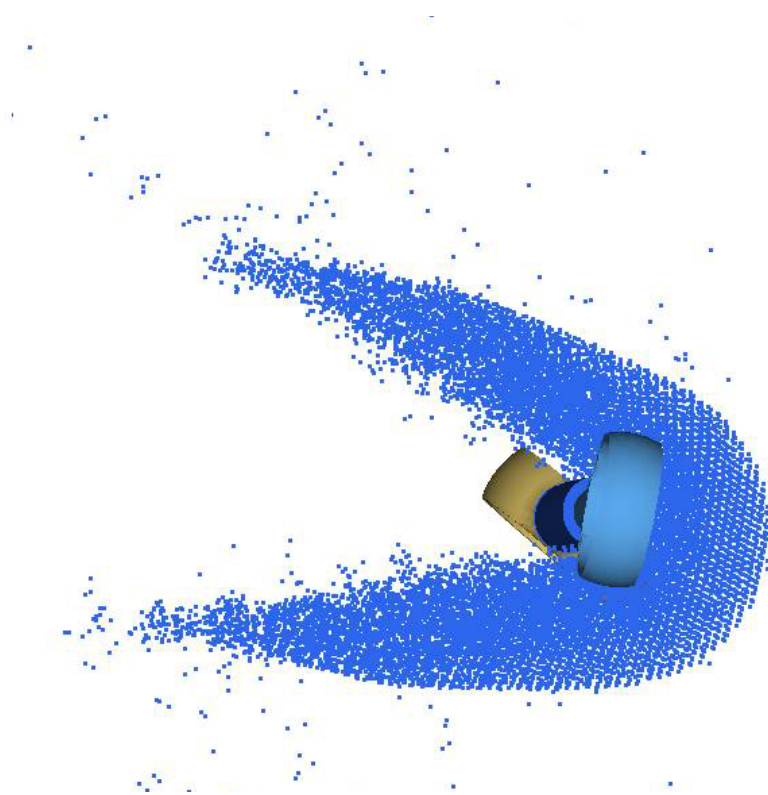
- Some damage found on the spider arm, due to the energy of the hitting particles.



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

## Stress and deformation

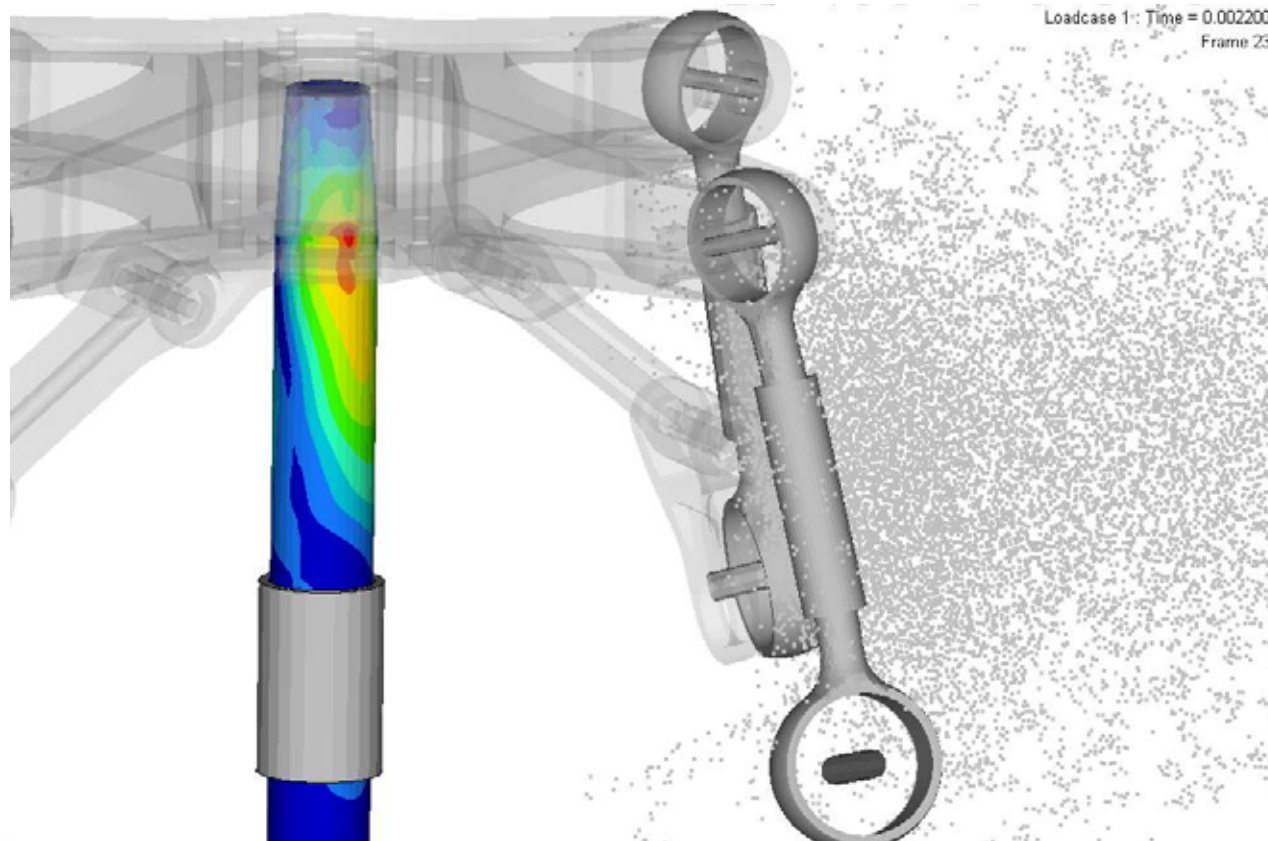
- Pitch link deformation.



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

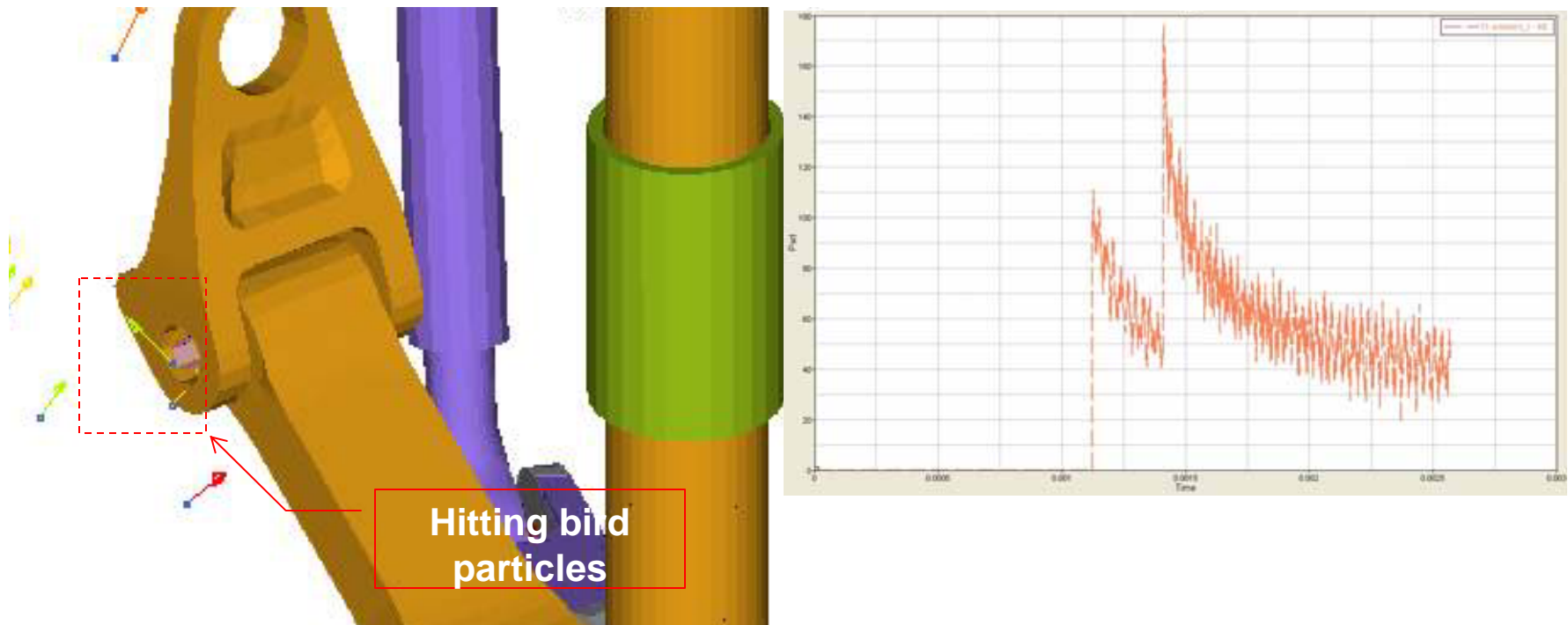
## Stress and deformation

- **Peak stress on the shaft occurs after the bird passage.**



# BIRD STRIKE ONTO ROTOR CONTROL CHAIN

- The hitting particles cause an increase of the kinetic energy of the hit scissers, in comparison with the no hit one (zero KE). No appreciable effects however are evident from the stress point of view.



## CONCLUSIONS AND POSSIBLE FUTURE WORK

- A bird strike event onto a rotor blade and a rotor control chain was simulated with code RADIOSS, using a SPH formulation for the bird.
- The work was done as a training on the job with Altair consultants, as this was the first experience with RADIOSS in AW-IT.
- It had the double aim to gain confidence in the code through comparison with experimental results and to gain further experience and knowledge on the code with a more complex assembly including mechanical joints (the control chain).
- The comparison with test gave satisfactory results of correlation with the available data and showed to well reproduce the behaviour of the bird, observed in the test.
- The simulation onto the chain assembly had investigation purposes only, being the bird strike substantiation not required in this case. Further on this work it could be carried out, when required, the evaluation of more case histories as far as the bird trajectories is concerned and the simulation of the stiffening due to the centrifugal force.