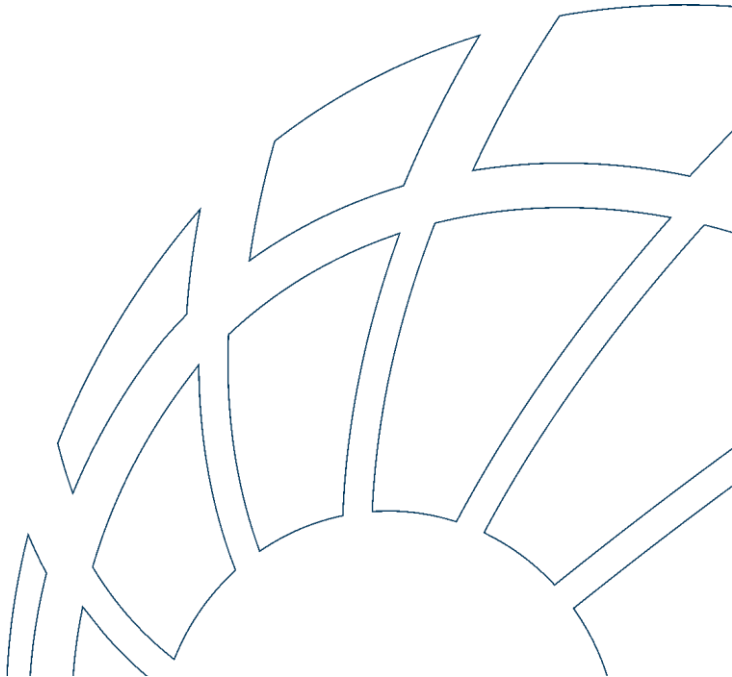
BMT Fleet Technology

"Where will our knowledge take you?"

Prediction of the Effect of Wind Turbine Failures on Buried High Pressure Pipelines

23rd February 2011

Bob Andrews & Lindsey Mortimer



Presentation Overview

- Introduction
- Problem Definition
- Modelling & Analysis
- Results
- Potential Developments
- Questions

The Future of UK Energy

- Renewable Energy Strategy target: 15% of UK's total energy from renewable sources by 2020
- Increased number of applications to build wind farms
- Proposed sites in rural areas where high pressure pipelines are routed
- Current IGEM guidelines developed by UKOPA state:

"The minimum proximity distance between any pipeline and any industrial/commercial sized wind turbine should 1.5 times the fixed mast height excluding turbine of the wind turbine."

Why have an exclusion zone???

http://www.youtube.com/watch?v=CqEccqR0q-o

Problem Definition

- Current assumption: failure of a turbine within 1.5 mast height will result in a pipeline failure
- Restrictions can lead to economically unviable developments
- Pipeline asset owner may be liable to compensate landowner for loss of revenue - typically in the region of £25000 per annum per mast, for a 20 year life
- Alternatives to compensation, e.g. Diversions may be cheaper
- Relaxing the 1.5 mast height restriction may result in substantial financial benefits for asset owners

Modelling & Analysis

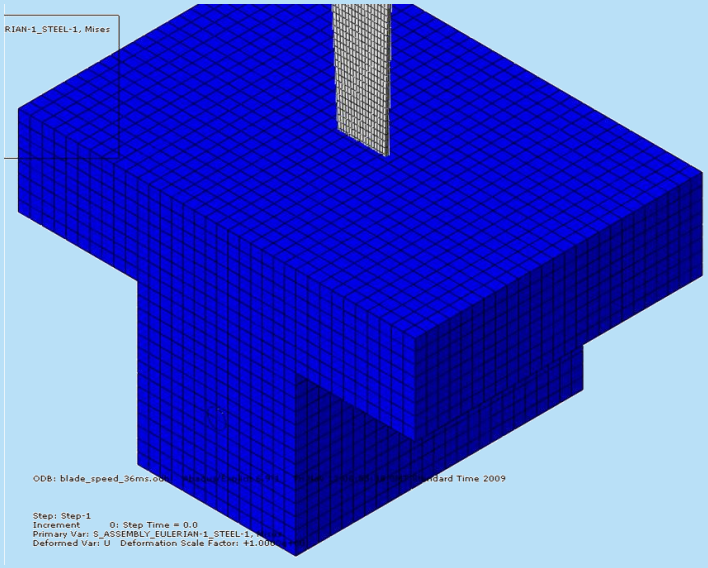
- BMT Fleet Technology have undertaken a preliminary investigation modelling effects of wind turbine impacts on pipelines
- Numerical analysis approach used to assess whether the current guidelines are overly conservative
- Modelling to consider if turbine impact onto the pipeline would result in the failure of the pipeline
- Considered option of protection to allow pipeline to survive wind turbine failure

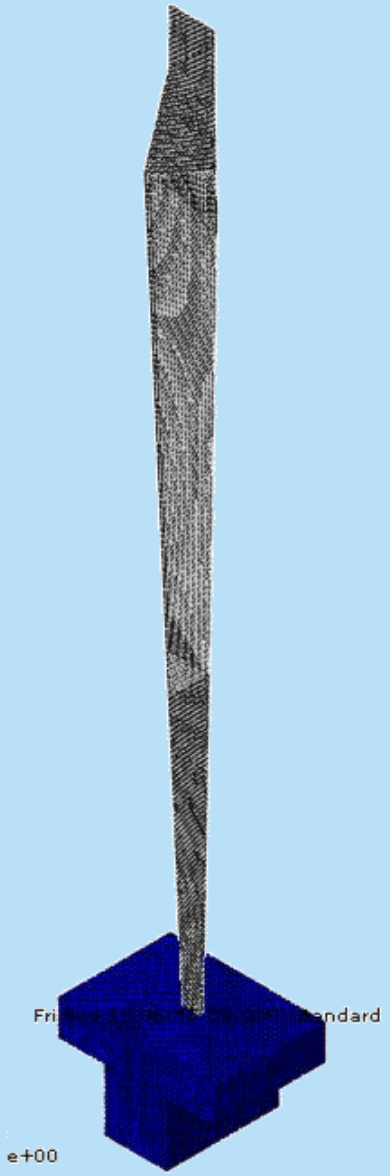
Modelling & Analysis

- **Modelled using Abaqus/Explicit 6.9.1**
- **Scenarios considered :**
- Effects of a single blade impacting the pipeline (blade-off failure)
- Including sensitivity to blade approach angle and speed
- Effects of the mast, with nacelle and rotor assembly, impacting the pipeline (mast failure)
- Effects of placing a concrete slab above the pipeline

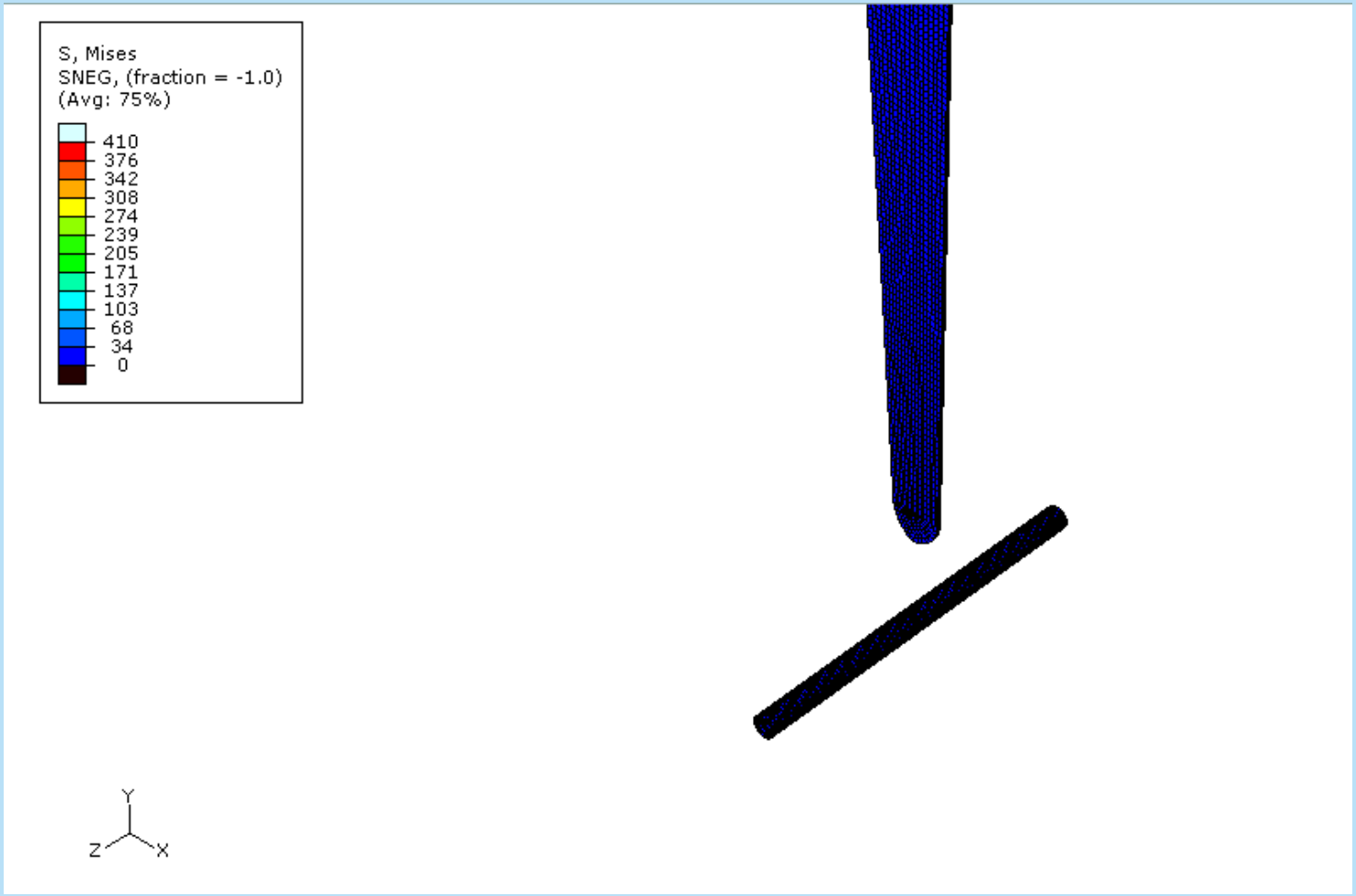
Modelling & Analysis (cont.)

- 3D continuum Eularian-Lagrangian model formulation
- Soil modelled using Eularian mesh – large displacement theory
- Blade & pipe modelled using Lagrangian meshes



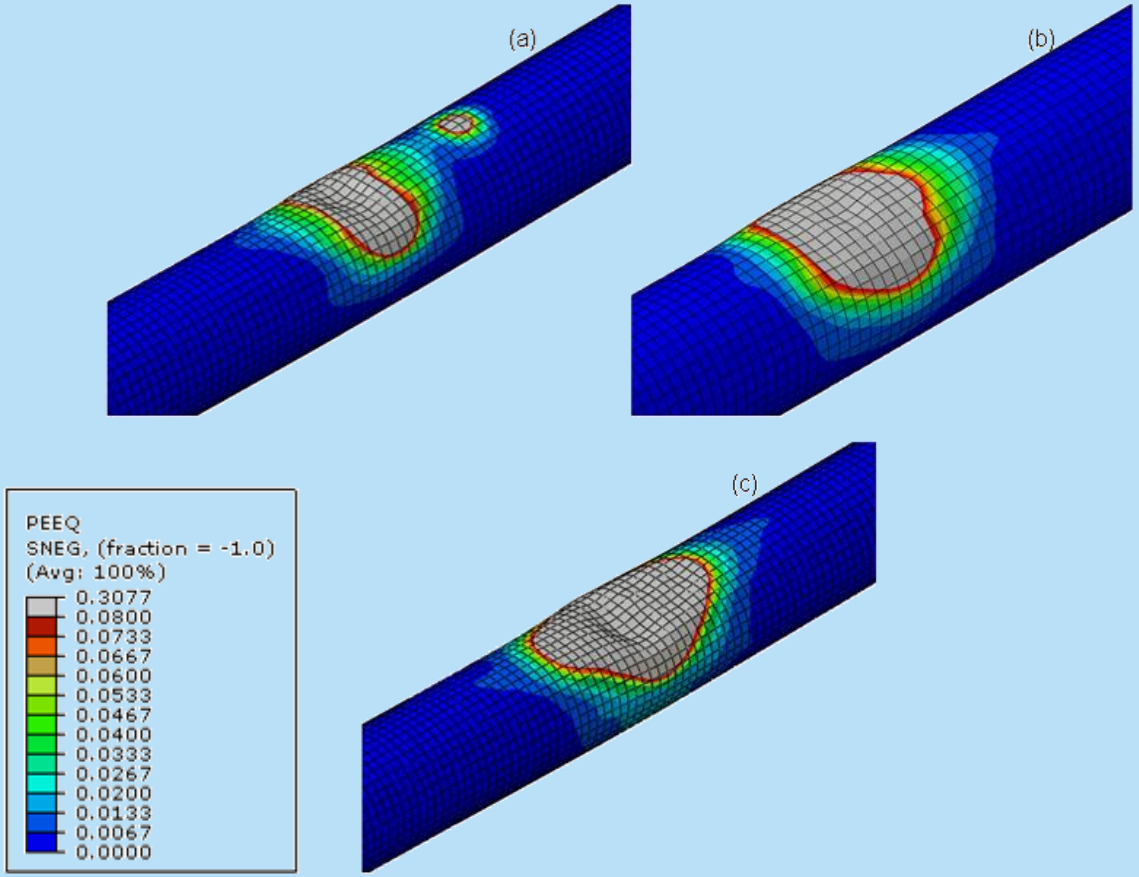


Wind Turbine – Blade Impact on a Buried Pipeline

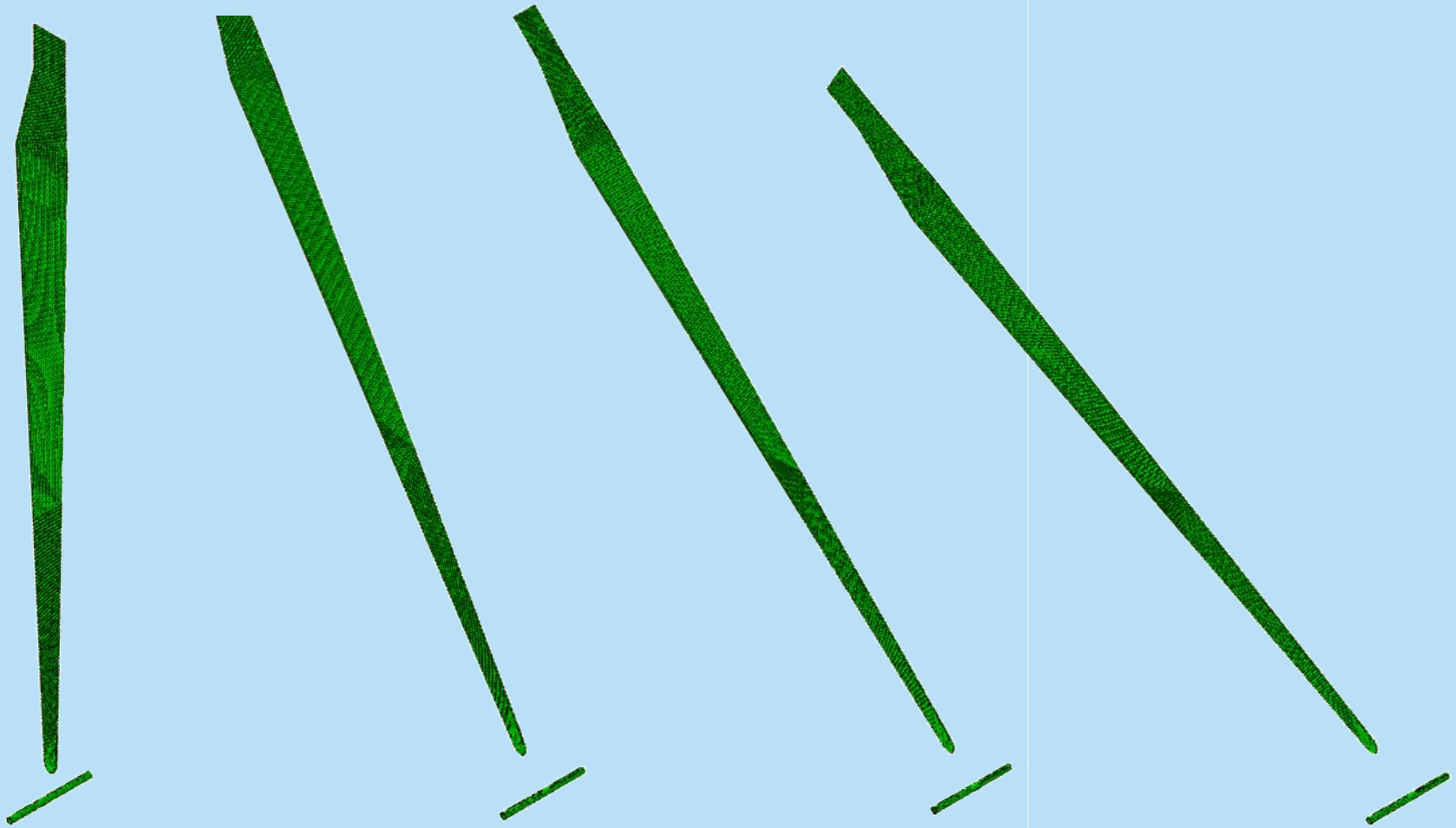


Wind Turbine – Blade Speed Effects

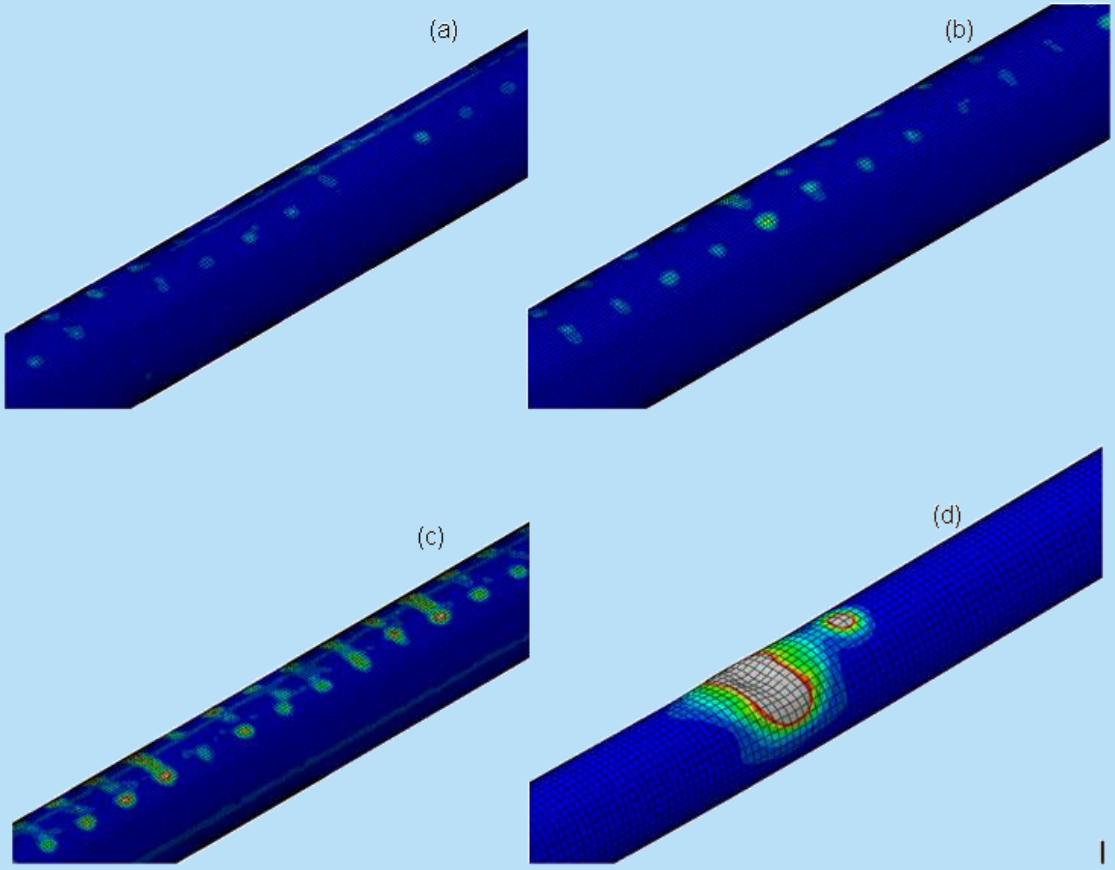
- Three blade approach speeds considered – (a) 36m/s, (b) 54m/s & (c)71m/s



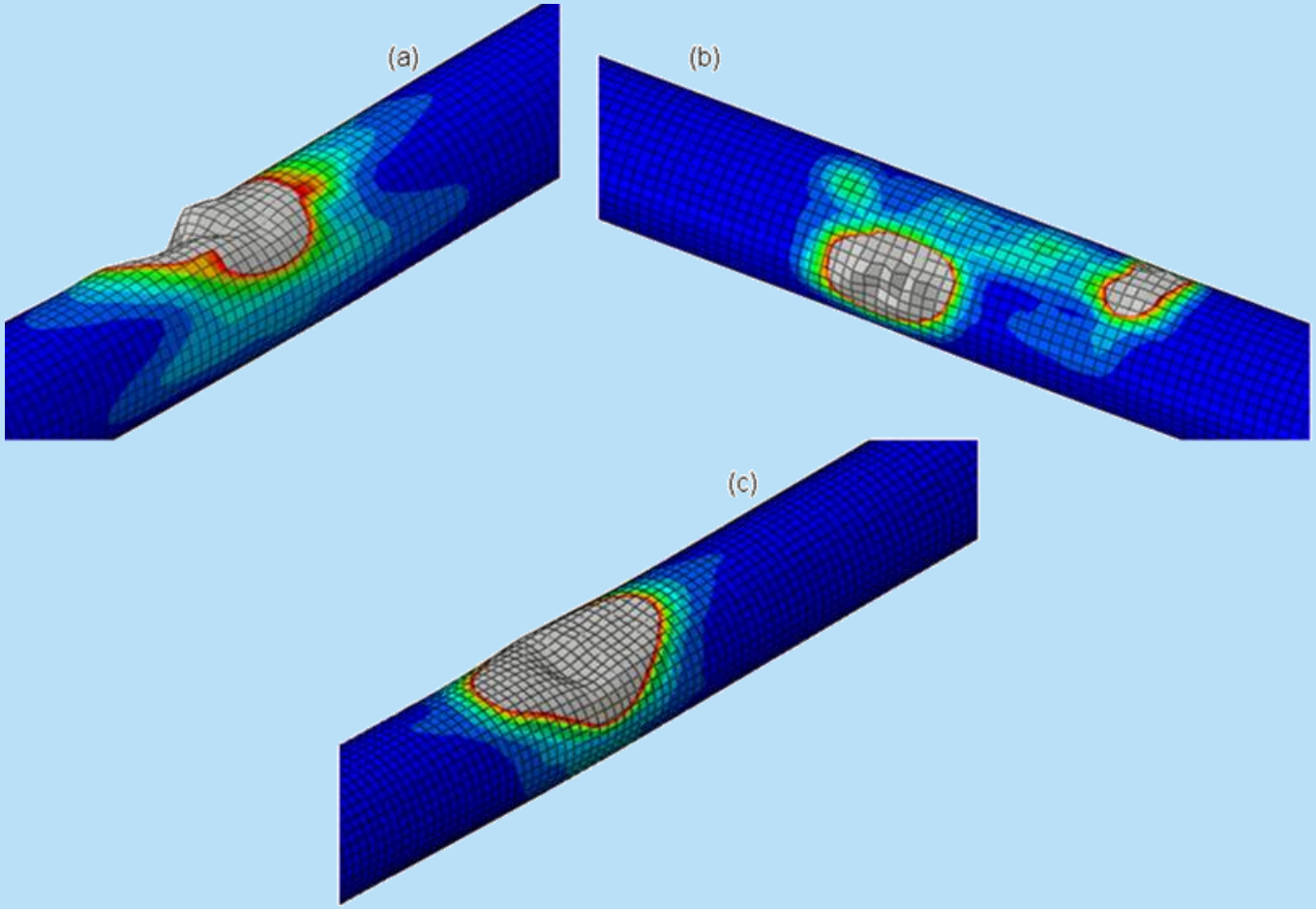
Wind Turbine – Blade Angle Effects



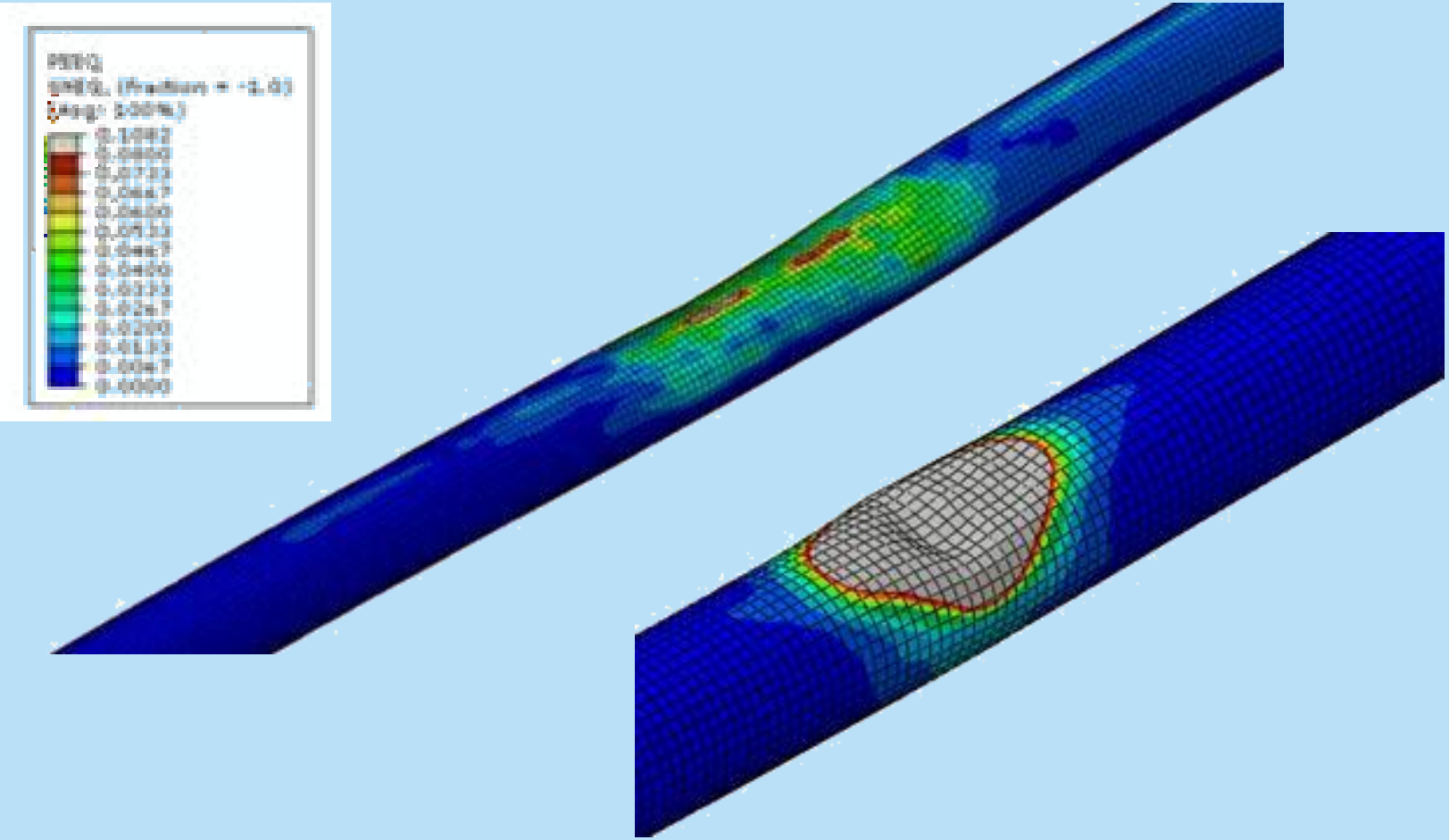
Wind Turbine Blade Angle Effects, 36m/s



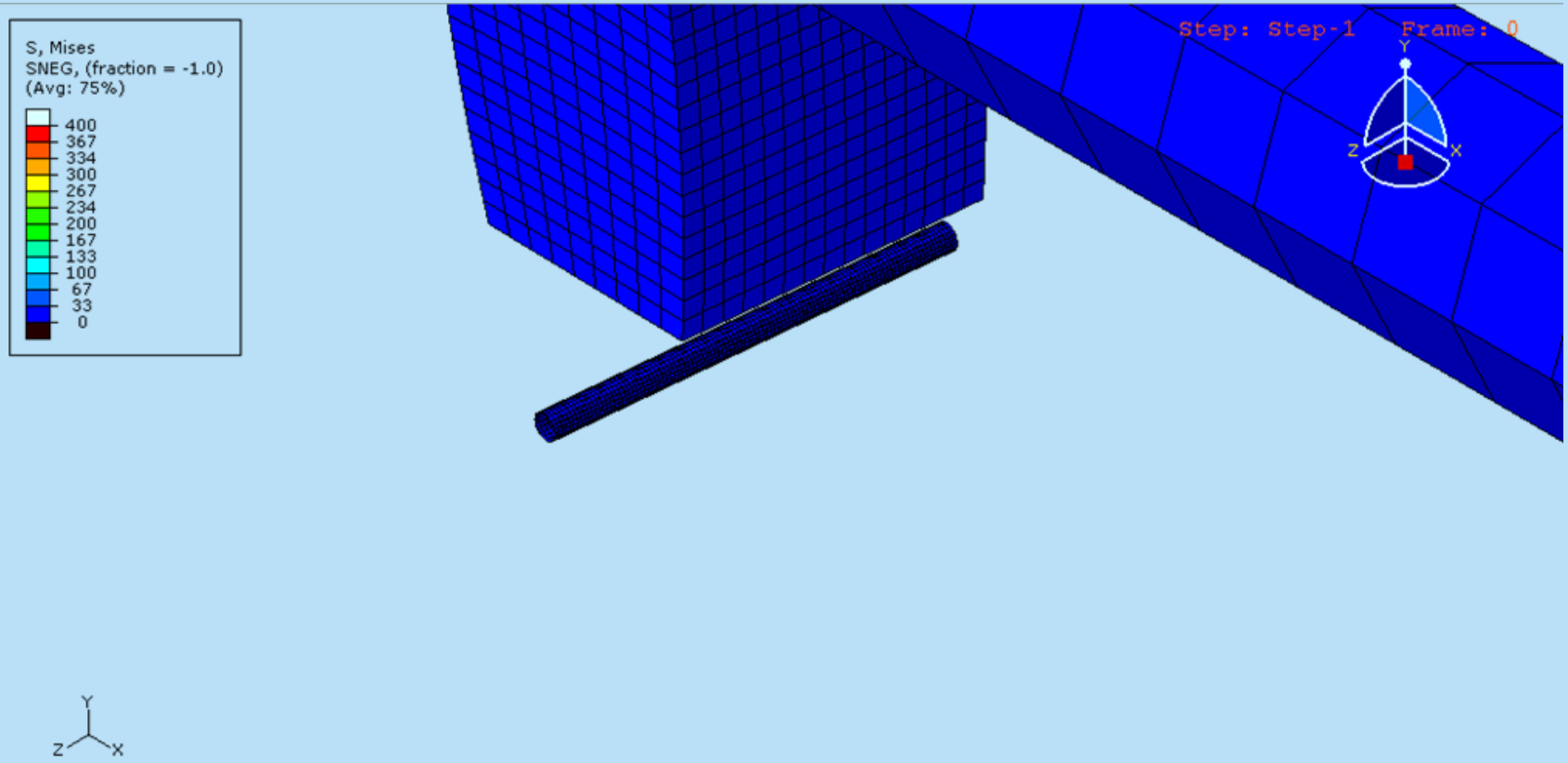
Wind Turbine Blade Angle Effects, 71m/s



Wind Turbine Blade Impact – Slabbing Effects



Wind Turbine Collapse – Mast Impact



Results Summary

- The model predicts that impact from the entire turbine assembly would cause pipeline failure
- Direct collision between a blade (90° approach) and pipeline is predicted to result in pipeline failure
- As the approach angle and speed of the blade reduce, stresses and strains observed in the pipe wall decrease
- At the lowest velocity and oblique angles, failure is deemed unlikely
- This suggests that for many possible blade impact scenarios pipeline failure is unlikely
- Installation of a standard concrete slab over the pipeline could reduce if not eliminate the likelihood of failure in the blade-off scenario.
- In contrast, slabbing has little effect for mast collapse – it can also concentrate forces onto pipeline due to cracking of the concrete.

Potential Developments

- **With further development of the models, there is a potential for restriction zones to be reduced**
- **This may result in considerable financial benefits for asset owners due to reduced compensation claims/need to divert**
- **Suggested developments:**
- Improve model performance by removing assumptions
  - Improve modelling of blade geometry and material properties
  - Incorporate relevant material failure models
  - Kinematic failure study to determine likely parameters/combinations of blade approach speed and angle

Potential Developments

- **Extend study to include a range of:**
- Pipe diameters & wall thicknesses
- Pipeline grades
- Internal pressures
- Blade sizes
- Blade impact conditions including impacts at an oblique angle to the pipe axis
- Soil types and cover depths

Potential Developments

- **Further developments could include:**
- Performance of validation tests to confirm model performance
- Analysis of a number of slab designs to suggest optimum design

Contacts:

Lindsey Mortimer
BMT Fleet Technology Limited
Tel: +44 1509 621814
Email: lmortimer@fleetech.com

Bob Andrews
BMT Fleet Technology Limited
Tel: +44 1509 621814
Email: bandrews@fleetech.com

Thank you