UNIVERSITY OF Southampton

Engineering and the Environment

Aeronautics, Astronautics and Computational Engineering

Using manufacturing variability of turbine disc firtrees in analysis – 'uncertainty propagation'

UTC for Computational Engineering

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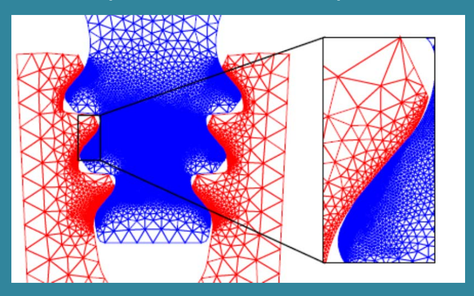
XWB high pressure turbine (HP) disc life

The problem:

- Precipitation hardened Nickel alloy in contact under centrifugal loading at cruise
- Assume **life ∝ peak notch principal stress** ⇒ performance = peak stress

Property	Value
Rotational velocity, ω	1250 rpm
Density, ρ	8000 kg/m^3
Poisson's ratio, ν	0.4
Young's modulus, E	175 GPa

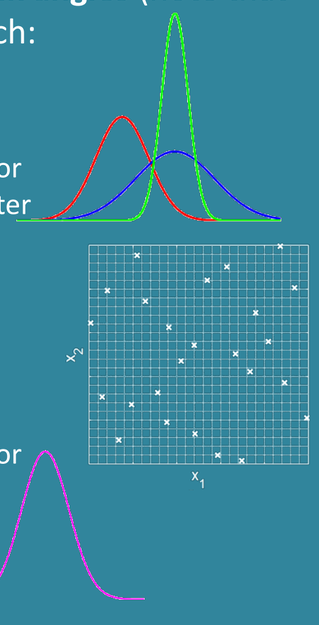


- **How does manufacturing variability affect peak notch principal stress?**

Propagation of geometric uncertainty

Assessment of the effect of variations in the **disc slot flank angles** (note that blade geometry is nominal) requires a **stochastic** approach:

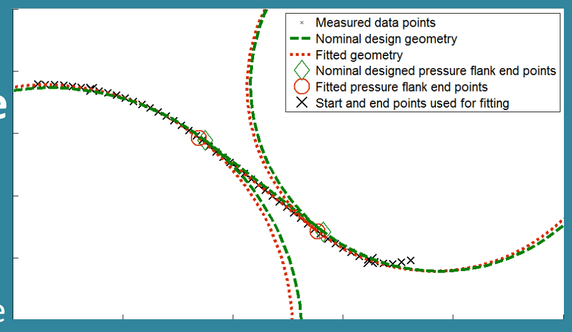
	Deterministic	Stochastic
INPUT:	Single nominal parameter set	Statistical distribution or limits for each parameter
ANALYSIS:	Single analysis (FEA)	Multiple analyses (sample plans) (FEA)
OUTPUT:	Single performance prediction	Statistical distribution or limits for performance



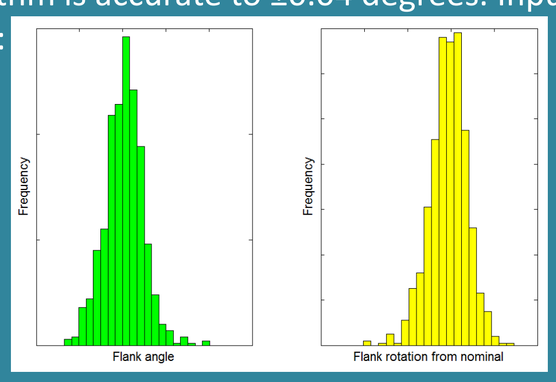
Characterization of pressure flank from coordinate measuring machine (CMM) data

Calculate flank angle:

- Extract approximate flank data set
- Use a least squares based approach to find the best fit line and curves
  - 8 variables (arc centres and radii, and start and end points of cloud data)
  - search using single objective global optimisation (particle swarm based)



Fitting algorithm is accurate to ±0.04 degrees. Input set of angles:

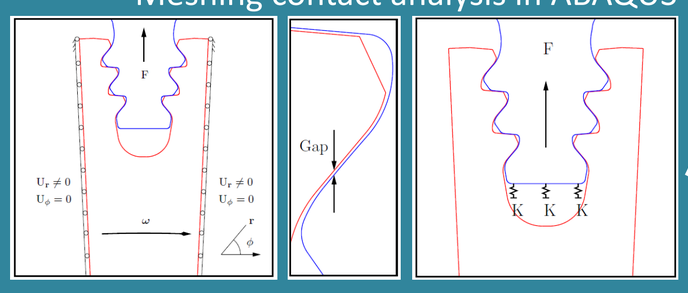


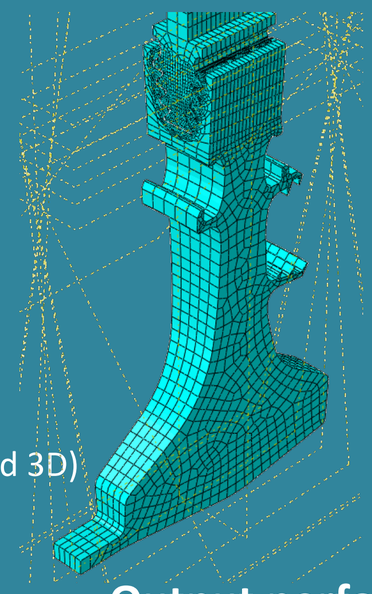
Finite element analysis

Parametric NX part generation

Model generation using Python script

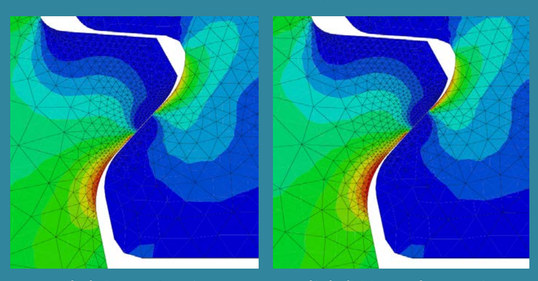
Meshing contact analysis in ABAQUS™ (2D and 3D)





Output performance variation

Distribution of worst principal stress in notch

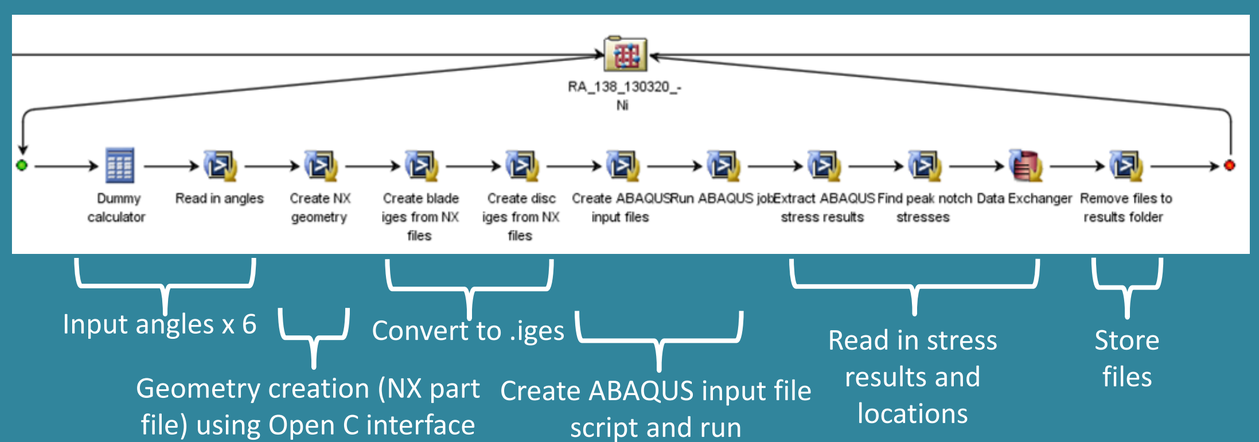


(a) Nominal (b) 'Worst' notch

Principal stress in bottom left flank, worst slot (4.125% increase) ((a) to (b))

Automated firtree flank angle uncertainty propagation using Isight™

Workflow allows alteration or addition of new measurement data to a database and multiple sampling of uncertain geometries or probability distributions of geometries for performance uncertainty prediction.



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