UNIVERSITY OF Southampton

Engineering and the Environment

Aeronautics, Astronautics and Computational Engineering

Automatic geometry manipulation for the representation of measured turbine blade flanks for analysis

UTC for Computational Engineering

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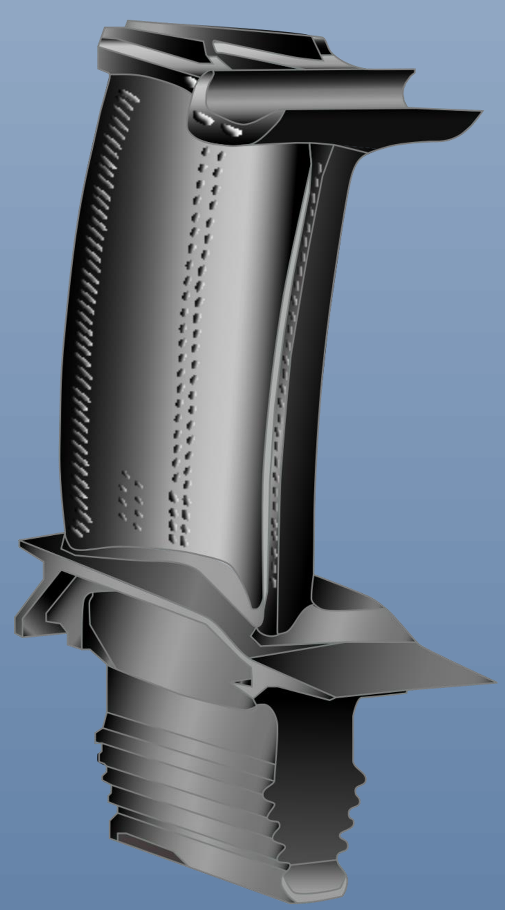
Design context

The lifetime of high-pressure turbine discs and blades is dependent upon the stress field in the critical region of the blade to disc attachment. The blades are held in place circumferentially by contact of a flank, or number of flanks, on the blade root firtree, with corresponding flanks on the disc slot. In particular, notch stresses in the disc slot are drivers for catastrophic disc failure.

Stresses are sensitive to the geometry of both blade and disc contact regions. Analysis of this region for life prediction is routinely performed using nominal, or idealized geometric manipulations using set parameters (notch radii, flank length, and straight line or arc locations, for example). Computer aided design (CAD) and finite element analysis (FEA) models are therefore constructed using these idealized parameters. The ability to represent as-manufactured geometry in key regions or surfaces within parametric CAD and FEA models in an automated fashion can enable study of the effects of true variation to inform design decisions.

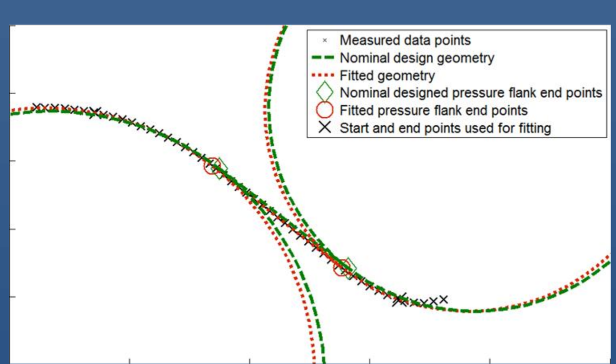


Depiction of a turbine blade

Disc slot representation

(previous work)

- Point cloud data set depiction of slot cross-section at two locations (no through thickness data), made using contact probe coordinate measuring machine (CMM)
- Characterization of slot using existing parameters (8 variables)
- Least-squares approach for fitting simple curves to data cloud (particle swarm based single objective optimization for each set of data)



Result of fitting algorithm

Example point cloud data set for a single flank

Blade flank data

- Point measurements along apex of barrelled flank at equal intervals using contact probe CMM, central portion is not measured due to part support
- Apex located using 4 additional points, 2 at each end of the flank, the locations of which are not stored
- Measurements given as perpendicular distance from top flank apex, *d*
- Measured 'stagger' also provided

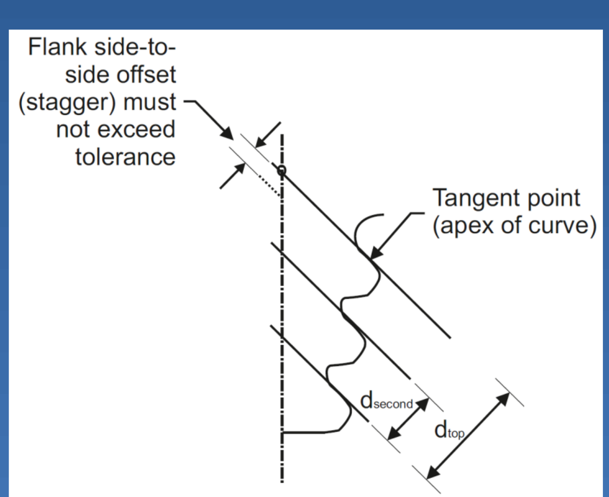
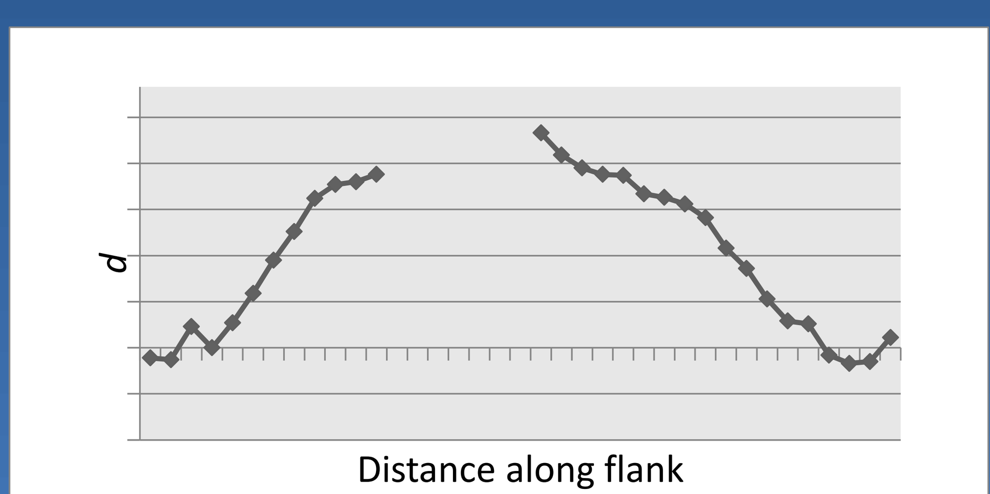


Illustration showing measurement location in cross-section

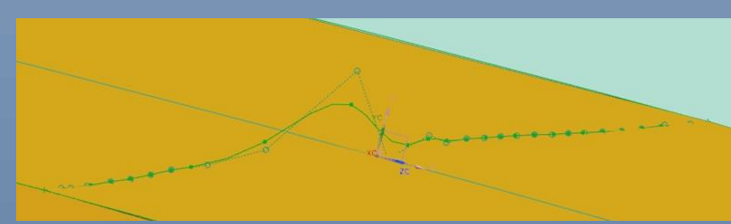


Example data set for single flank (shown along flank), x and y axes not equal scale

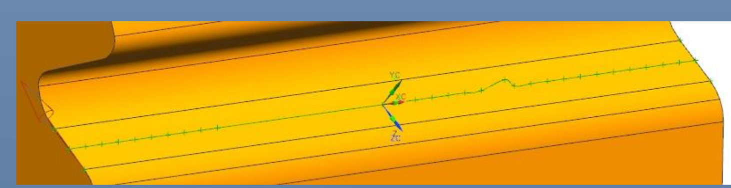
Blade flank work flow

Using NX (CAD software), replace the existing surface with one generated from measurement data. Automated using NXOpen interface.

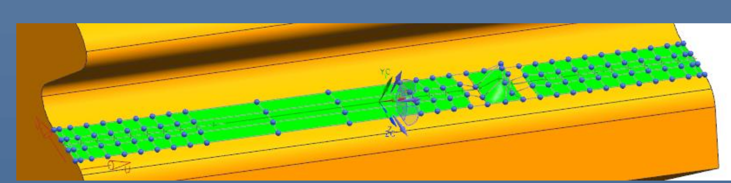
1. Create readable text file for data from existing Excel spreadsheet data sets
2. Create spline along flank apex using imported points
   - Either by 'fitting' (regression)
     - results in 'false hump' in unmeasured region



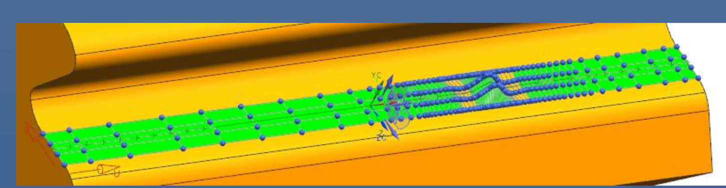
   - or through points (interpolation)
     - no 'hump', illustration includes fictitious point to illustrate spline



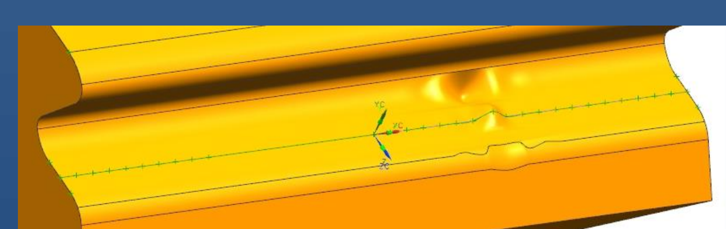
3. Create new surface based on spline and existing surface edges in barrelled region
   - Either 'swept' surface (degree 3 illustrated)



   - or 'mesh' surface (degree 3 illustrated)



4. Replace face of solid body with new surface for meshing and analysis
   - Face replacement can fail, or create undesirable features in the notch region, with the current surface generation method
     - all of the surface generation methods in NX result in surfaces with anomalies along the straight edges that adjoin the fillet faces, resulting in an inability to directly replace the face with the new surface (whether or not continuity of tangency is included at the edges)



Further development of this workflow is the subject of current investigation.

- Consider creating 'b-spline' surfaces directly from an array of points in NXOpen or manipulating a solid block inserted using a Boolean operation

Benefits

Modelling the true, and potentially unavoidable, deviations of geometry from nominal can enhance the ability to design for robustness, resulting in greater understanding of the uncertainty in predictions from analysis resulting in possible extensions of usable life for components. Such an understanding could further inform tolerance specification and reduce scrap and rework.

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