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Effects of mesh definition on quality of stress-optimal shapes for effective NC manufacture

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Abstract

The context of this present work is shape optimisation of local structural features to reduce peak stresses and increase fatigue life. This relates to; (i) design of new components, or (ii) in-service reshape repair. In either case, the optimised shape will be typically manufactured by NC machining methods of some form.

The designed optimal shapes can be free-form (i.e. a series of points, or circular arcs) or based on parametric functions. For NC manufacture, the shape needs to be defined by a series of points and segments in the form of straight lines and/or circular arcs. Here it is also important to ensure "smoothness" of radius of curvature values along the shape boundary.

One key challenge in shape optimisation is not only the accuracy in stress estimation, but also the appropriate shape definition for effective manufacture. In practice, geometry may need to be transferred between multiple FEM/CAD or manufacturing codes. This can cause some inconsistencies and inaccuracies in both stresses and geometry, which may not be initially envisaged. It appears this that issue has not been fully considered in the literature.

Hence in the present paper we seek to develop some simple guidelines to address this issue. The investigation makes use of both FEA and analytical benchmarks, such as optimised holes and fillets under biaxial and uniaxial loading, covering both 2D and 3D geometries. Mesh definition is considered; specifically, the effect of h-element mesh refinement and/or p-element order on stress accuracy and shape accuracy and smoothness are quantified. The effect of transferring optimal shapes between different FEA/CAD and NC machining codes is also considered. The results are summarised in non-dimensional form.