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# Higher Order Shear Deformation Plate Theory for Polymeric Materials in Medical Applications: Numerical Analysis and Experimental Validation

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## Abstract

Plate analysis is basically a three-dimensional problem that is simplified to a two-dimensional analysis for ease of calculations and reduce computational cost. Considerable progress has been made in the analysis of plates and many theories were developed for this purpose. Many of these theories suffer either from satisfying the free traction condition or thickness extensibility which may necessitate derivatives continuity across elements that imposes extra computational effort. This work presents a Higher-order Shear Deformation thickness-extensible plate Theory (HSDT) for the analysis of plates that satisfies the free traction condition a priori to the consistency of transverse shear strain energy which had been rarely considered by similar theories in the area. Implementing the theory in finite element procedure necessitates the derivatives continuity across elements. This was resolved by implementing the penalty enforcement technique with derivative based nodal degrees of freedom across the standard 9-nodes Lagrange element. The theory was tested for linear elastic bending deformation of PolyEther-Ether-Ketone (PEEK) which is one of the basic materials for medical implants. The present plate theory showed good accuracy compared to experimental data of the three-point bending test. The same theory was then implemented with standard 16-node Lagrange element. The sixteen-noded element performed much better than the previous nine-noded element. Using the 16-noded element made possible the convergence of results with much less refined mesh while also using less time, computational power and memory. Hence, all parametric studies done in this thesis used the 16-noded element.

However, continuing with the flat plate element would not be as accurate unless curved plate element was introduced. The third finite element presented and implemented in this study is the four-node curved plate element. The present HSDT was also tested for different conditions, for isotropic and orthotropic materials with a wide range of aspects ratios (thin to thick plates) and different boundary and loading conditions. The accuracy of the proposed HSDT was verified through these conditions against exact solutions and through commercial FEM software ABAQUS, which showed the advantage over other approaches and commercial finite element packages. This makes the presented HSDT suitable for critical applications like medical implants.


Keywords: higher order, plate theory, PEEK, thickness-extensible, medical implants.