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A KRIGING-BASED FINITE ELEMENT METHOD FOR ANALYSES OF SHELL STRUCTURES

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ABSTRACT

Originated from the element-free Galerkin method with moving Kriging interpolation [1], an enhancement of the finite element method using Kriging shape functions (K-FEM) was developed and applied to solve 1D and 2D elastostatic problems [2]. The K-KEM preserves the advantages of mesh-free methods as follows: (1) high order shape functions can be easily constructed, (2) field functions and their derivatives can be obtained with remarkable accuracy and global smoothness. A distinctive advantage of the K-FEM is that it inherits the computational procedure of the conventional FEM so that existing general-purpose FE programs can be easily extended to accommodate this new concept. The method has been improved and developed for analyses of Reissner-Mindlin plates [3].

A drawback of the K-FEM is that its interpolation function is not continuous (incompatible) along inter-element boundaries. The effect of the incompatibility on the convergence has been recently studied [4]. It was found that the K-FEM with appropriate choice of correlation function passes the weak patch test and therefore the convergence is guaranteed.

In the present study, the K-FEM is developed and applied to analyze general shell structures. The governing equations are derived based on degenerated 3D elasticity theory. Kriging shape functions are constructed using a set of nodes encompassing several layers of triangular elements. The shape functions are used to approximate both the displacement and geometry. In approximating the geometry, the parameterization of the shell mid-surface is performed element-by-element by mapping curved triangular elements onto flat planes passing through the element nodes. Shear and membrane lockings are alleviated by using high order polynomial basis, i.e. cubic or higher order basis. The developed curved triangular shell element is named K-Shell.

Several shell benchmark problems are solved to test and compare the accuracy and convergence of the K-Shell. One of the problems is the well-known Scordelis-Lo roof (Figure 1). The resulting averaged membrane force and bending moment along the central section are shown in Figure 2 together with their respective reference solutions. The results show that the K-Shell can produce very accurate displacements and internal

forces provided that the mesh is fine enough to relieve the shear and membrane lockings. The results also show that the K-Shell has excellent convergence characteristics.

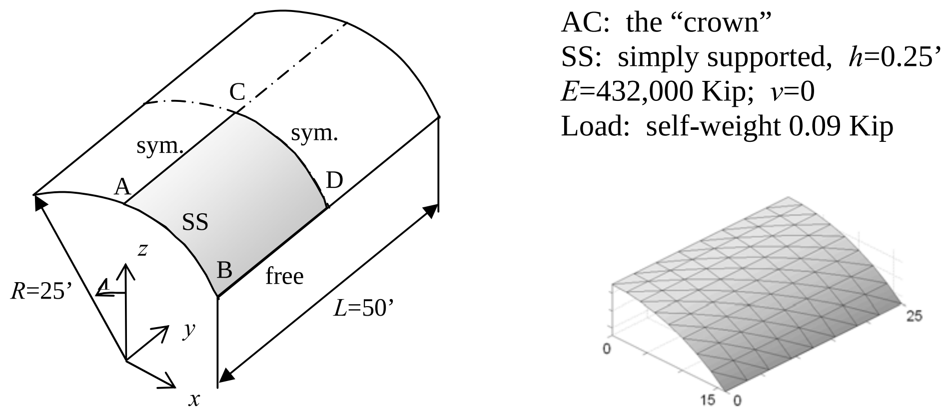
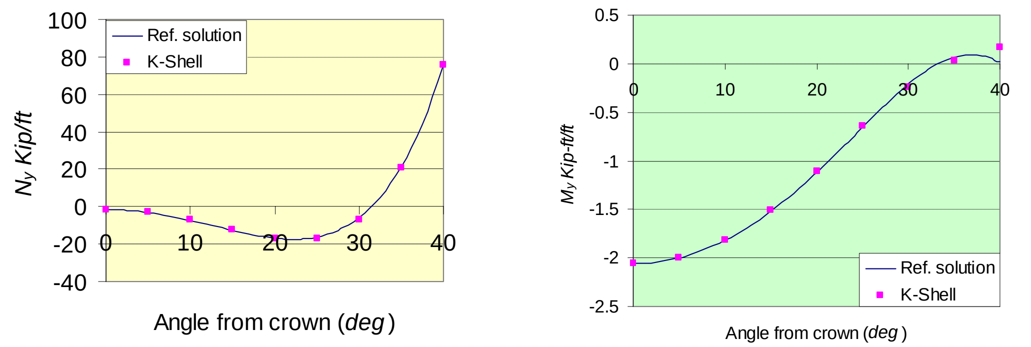


Figure 1. Scordelis-Lo roof and the mesh of a quarter of the roof



(a) (b)

Figure 2. (a) Averaged longitudinal normal force and (b) Averaged transversal bending moment along the central section (arc CD)

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