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Testing and isogeometric structural analysis of membranes subject to large deflections

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In this paper, we describe newly developed NURBS (Non-Uniform Rational B-Spline) Finite Elements for the structural analysis of membranes with geometrically large deformations. The simulation technology is based on variational structural mechanics that enable us to effectively perform analyses of structures with geometrical nonlinearities [1]. The structural geometry is defined by NURBS curves as is common in Computer Aided Design and this geometry is then directly used in the variational analysis without model translation.

The development and application of curved, inextensional, two-dimensional membrane finite elements are first described. Results also include the development of a six degree of freedom element including applied normal and shear pressure, and structural mass. The newly developed six-degree-of-freedom model has been verified for various loading scenarios and also includes extensional strain energy and bending strain energy in its formulation. Promising applications include the use of the elements in the analysis of inflatable structures and elastically deformable seal systems in marine craft design (e.g. surface effect ships), and particularly for rapid analysis of fluid/structure interaction problems [2].

A physical test program is also described and compared with analytical results for verification purposes. A differential pressure tank has been constructed to provide higher air pressure to the top of a light-weight membrane with water supplied below the membrane. This test devise is used to replicate the conditions used in the NURBS finite element analyses. The deflections of the membrane are then recorded for various pressure conditions and water immersion depths with comparisons made to the nonlinear structural analyses.

Figure 1 represents the side view of the physical test program systems. Figure 2 shows the results of the NURBS finite element analyses for a variety of pressure differential applications. Figures 3 and 4 represent the end view of the seal applying the same pressure in the top, 176.52 Pa, and water depths of 22.1234 cm and 24.1046 cm, respectively.

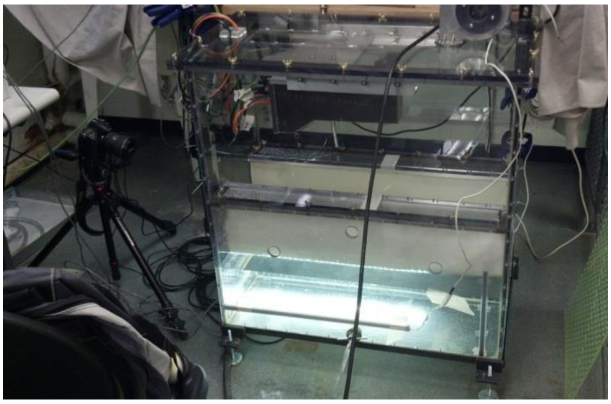

Figure 1: Side view of fluid-structure interaction experimental apparatus.

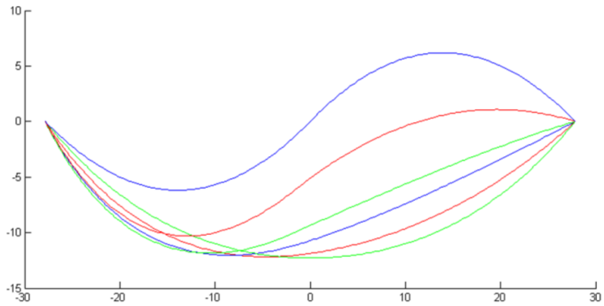

Figure 2: End view finite element predictions for various pressure distributions.

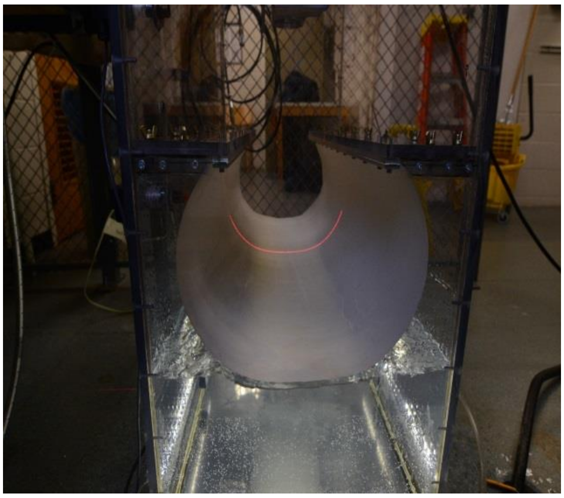

Figure 3: End view with seal detail, lower water level

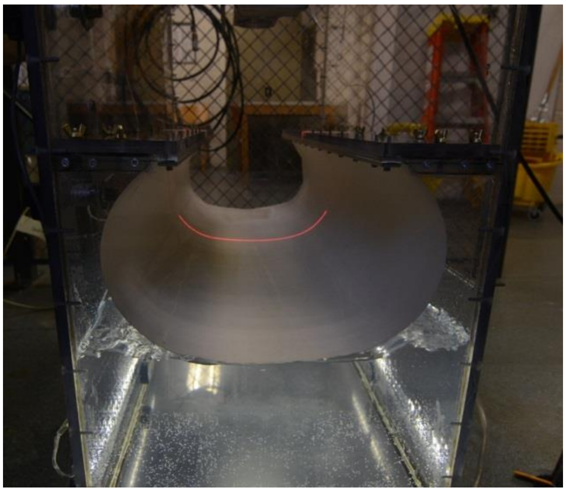

Figure 4: End view with seal detail, higher water level.

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