

Polyhedrally Stiffened Shells for Undersea Pressure Hulls

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ABSTRACT

The polyhedrally-stiffened cylindrical (PC) shell is a structural concept that offers a design alternative to the conventional ring-stiffened cylindrical shell for undersea pressure hulls. Both the defense and commercial ocean industries have a continuing requirement for pressure hulls in underwater systems. A significant percentage of these systems operate in water depths from near surface to 1,500 m, depths well suited to PC pressure hulls. Examples of marine applications include pressure housings for autonomous underwater vehicles, remotely operated vehicles, submersibles, buoys and sonobuoys. In this paper, previous research on PC shells is expanded to include a broader range of materials suitable for undersea pressure hulls. Findings similar to those obtained for composite materials reported earlier have been obtained for aluminum, titanium and steel alloys. Parametric design studies using finite element analysis show that the PC shell can be advantageously used with any of these materials. The undulated polyhedral geometry is shown to provide a substantially greater operating depth than a comparably sized circular cylinder with less control of fabrication tolerances needed. Thus, the PC hull behaves as a stiffened cylinder with the advantage of potentially lower fabrication costs.

STRUCTURAL CONCEPT

The PC shell concept has been discussed in prior publications, including Miura (1969), Knapp (1977), Knapp and Szilard (1978), Knapp and Dumlao (1979), Knapp, Kudo and Auksmann (1980), and Knapp and Le (1996a and 1996b), but is briefly reviewed here for completeness. The conventional view of a buckled cylinder is that it is a failed structure (Fig. 1a); however, it has been proposed that the buckled cylinder can be treated as a new unfailed structural form described here as a polyhedrally-stiffened cylindrical (PC) shell. If designed initially in the ideal buckled pattern depicted in Fig. 1b, it has been shown that the PC shell possesses higher buckling resistance than a comparable circular cylinder (Knapp and Dumlao, 1979; Knapp and Le, 1996a and 1996b). It is proposed that such structures can perform well as undersea pressure hulls and may be cost-competitive with conventional circular cylindrical (CC) and ring-stiffened cylindrical (RC) pressure hulls.

Fig. 2 depicts this geometry with the amplitude of undulation given by the radial distance, A . This undulating surface, much like the structural action of corrugated sheet metal, adds structural stiffness to the shell. It has been confirmed by numerical analysis and experimental investigations that a hydrostatically loaded PC shell may possess several times the buckling resistance of a comparably sized circular cylinder having the same wall thickness and overall dimensions.

Since the PC shell is out-of-round by design, small variations in its shape do not affect buckling strength to the degree they would a circular cylinder. Thus, it may be possible to relax fabrication tolerances and reduce manufacturing costs. Where the cylinder must be formed accurately into a circular shape, the PC shell can be formed less accurately in a modular fashion from flat triangular plates or by laying up composite materials on a mold. Molding is

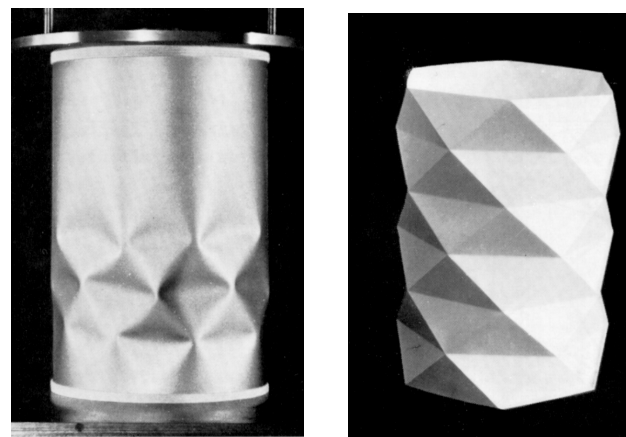


Fig. 1 (a) Buckled cylinder (b) Ideal PC shell

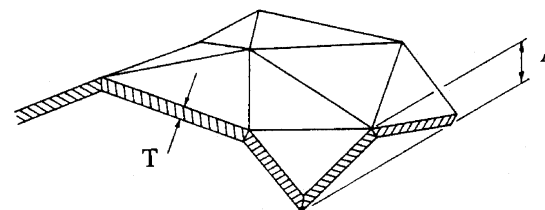


Fig. 2 Undulated PC shell geometry

simplified by taking advantage of the developable PC shell surface. Since the PC shell has a developable surface, composite materials can be laid up around a PC shell mold without stretching or distortion of the fabric. Further, as the PC shell is an inherently stiffened cylinder, stiffening rings used in circular cylindrical hulls are unnecessary, hence manufacturing costs are relatively lower.

Recent efforts to develop ring-stiffened composite hulls have been disappointing due to the difficulties in joining or integrally molding rings to the cylindrical shell. Also, ring geometry must include fillets to reduce stress concentrations that add appreciably

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