膜形状解析における計算精度について

ACCURACY OF RESULTS OBTAINED BY THE ANALYSIS ON MEMBRANE STRUCTURE FORMS

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1. INTRODUCTION

An isotonic surface like a soap film is quite different from actual membrane structures, because the soap film element does not have the real stiffness in itself and the shape is formed with only the geometric stiffness and the tension in the bar members of the triangular element. The purpose of this paper is to demonstrate the accuracy of the result obtained by the soap film form using the triangle as the element subjected to the tensile stress over the edges of the triangular element whose thickness is assumed to be unity. In this study, the proposed fractional models can determine nodal displacement values which are easily comparable with the minimum surface of revolution.

2. THE DETERMINATION OF THE AREA-MINIMIZATION

The analytical solution of the minimum surface of revolution can be obtained to minimize the well-known equation as follows

$$S(y(x)) = 2\pi \int_{x_0}^{x_1} y\sqrt{1+y'^2}\, dx \qquad (1)$$

which result as

$$y = C_1 \cos\frac{x - C_2}{C_1} \qquad (2)$$

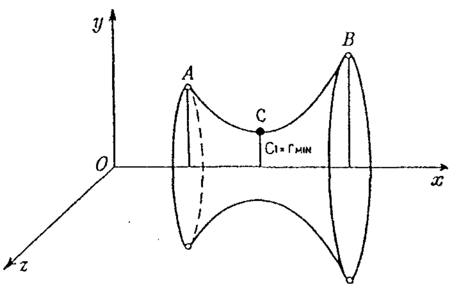

Fig. 1 Minimum Surface of Revolution

This is the equation of a catenary, in which the parameters C1 and C2 can be determined by the diameter positions with respect to the boundary supports A and B, where C1 means the measure at the (r min.) diameter, as shown in Fig. 1. The revolution surface is axisymmetric with respect to the axis X because the soap film form, which is supported at the upper and lower rings, is coincident with the solution of the area-minimization. The basic measures of the area-minimization form in this procedure are: the radius at the lower ring R=1.0, the radius at upper ring r=1.0 and the height h=1.0. The axis direction and the basic measures have been determined as shown in Fig. 2.

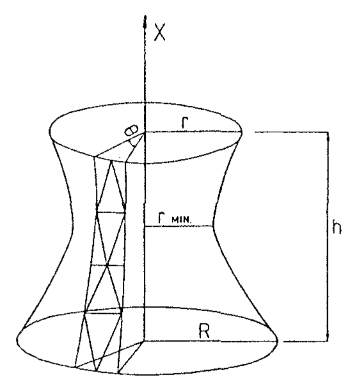

Fig. 2 The Area-minimization

3. DISCUSSION ON THE ACCURACY OF THE PROPOSED METHOD

The proposed fractional models can determine nodal displacement values of the soap film form, which are comparable with the previously mentioned theoretical solution. In order to verify the stable shape of the structural models composed by triangular elements, extensive tests were conducted by using different types of fractional models designed as shown in Fig. 3.

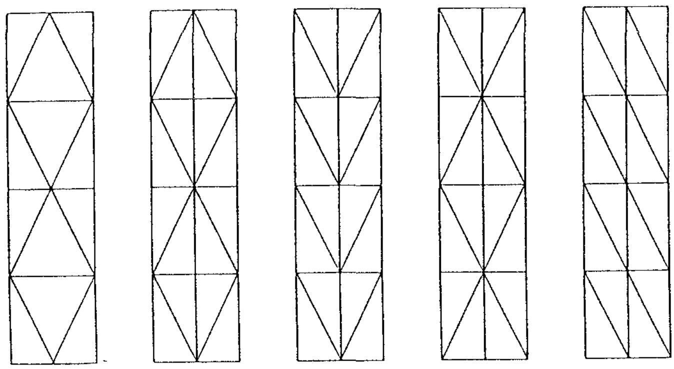

Fig. 3 Structural Models Composed by Triangular Elements

The tests shows that the stable solution can be obtained only by the model (a). The remaining models does not determine the deformation of the minimum surface of revolution, because there is not equilibrium state on the free nodes having the approximatelly rectangular angle.

As a result of the evaluation, three fractional models presented as ENTOU4, ENTOU8 and ENTOU16, were used to determine the nodal displacement values for the comparison. In the calculation of the area-minimization using this models, the unbalanced forces certainly converge and the curved surface can be determined after only a few iterations. In this case, the range of tolerance E=0. 00001t is the same for the three fractional models, where the tensile stress t=1. 0 N/m, is used. The geometric characteristics of the fractional models, are shown in Fig. 4.

The comparison between the theoretical solution and the nodal displacement values of the proposed models, shows that the results are almost in complete agreement. Specially for the result obtained by the ENTOU16 model with respect to the evaluation at (r min.), where h=0. 5. Table 1 shows the comparison between the displacement values with the theoretical solution.

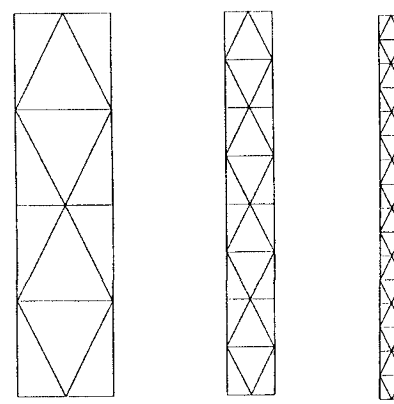

Fig. 4 Fractional Models

Table 1 Nodal Displacement Values

INITIAL POSITION		FINAL POSITION		THEORY
X	Y	X	Y	Y
0.5000	1.0000	0.5000	0.8485	0.8483
0.4375	1.0000	0.4424	0.8506	0.8503
0.3750	1.0000	0.3844	0.8564	0.8562
0.3125	1.0000	0.3256	0.8667	0.8663
0.2500	1.0000	0.2657	0.8810	0.8809
0.1875	1.0000	0.2038	0.9009	0.9006
0.1250	1.0000	0.1398	0.9261	0.9260
0.0625	1.0000	0.0719	0.9590	0.9587
0.0000	1.0000	0.0000	1.0000	1.0000

4. CONCLUSIONS

A comparison to demonstrate the accuracy of the results obtained by this method, was presented. The proposed fractional models can determine nodal displacement values which were easily comparable with the theoretical solution of the minimum surface of revolution. It was proved that, the ENTOU16 model can determine with accuracy the area-minimization form in addition to a very rapid convergence. A limitation was founded with respect to some models, because there is not equilibrium state on the free nodes having the approximatelly rectangular angle.