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EXPERIMENTAL INVESTIGATION OF THE STABILITY OF REINFORCED CYLINDRICAL SHELLS SUBJECT TO AXIAL COMPRESSION

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The paper presents the results from experimental study of the influence of reinforcement (rectangular plates) on the buckling loads and stresses of two sets of cylindrical shells subject to axial compression

Keywords: cylindrical shell, reinforcements in the form of plates, critical loads, critical stresses, axial compression

An analysis of the experimental data reported in [1–7] on the stability of cylindrical shells subject to axial compression shows that the experimental and theoretical values of critical loads differ significantly. The root causes of this difference are the initial deflections of test shells and the discordance between the boundary conditions adopted in design and implemented in experiment. Moreover, as the axial load rises, the initial deflections increase accompanied by snaps, which excite vibrations at the minimum natural frequencies and may reduce the general buckling loads [4, 5]. Since thin shells are widely used in aircraft construction, shipbuilding, and in space engineering, it is of importance to study, by way of experiments, the influence of various types of reinforcement on the load-bearing capacity of such structures under axial compression. One method to increase the buckling stresses of cylindrical shells subject to axial compression was outlined in [8–11]. It was proposed therein to reinforce shells with rectangular plates. The present study is concerned with the influence of the number of such plates on the buckling stresses.

1. Characteristics of the Test Shells. Two sets of cylindrical shells were tested. Three shells of the first set (Nos. 1–3) have equal radii $R = 9$ cm, lengths $L = 33$ cm, and thicknesses $h = 0.05$ cm. Shell No. 1 has no reinforcements. Shells Nos. 2 and 3 are reinforced with plates fastened with screws to the inside surface along meridians. The plates have the following length, width, and thickness: $L = 29.5$ cm, $b = 16$ cm, and $h = 0.05$ cm in shell No. 2 and $L = 29.5$ cm, $b = 9.5$ cm, and $h = 0.05$ cm in shell No. 3. Each plate has two 0.8 cm flanges, and each flange has five screw holes spaced at 7 cm. Shells Nos. 2 and 3 are reinforced with three and six plates, respectively (Fig. 1). The shells and plates of the first set are made of OT4-1 titanium alloy.

The nonreinforced shell of the second set (No. 4) was made of a Lavsan (polyethylene terephthalate) film on a precision cylindrical mandrel by applying a BF-2 adhesive. Its radius, length, and thickness are $R = 8$ cm, $L = 20.5$ cm, and $h = 0.0175$ cm. The other shells of this set (Nos. 5–7) were made from this nonreinforced shell by attaching plates with equal length and thickness $L = 18.2$ cm and $h = 0.0175$ cm. The plates in shells Nos. 5–7 differed in number ($k = 3, 6, 9$, respectively) and in width ($b = 15.6, 9.2, 6.5$ cm, respectively). The plates were also glued to the inside surface of shell No. 5. After tests, these plates were withdrawn from the shell, and their contact areas were wiped clean with acetone. Next, other plates were glued to shell No. 6 and then to shell No. 7. The cross section of one of the shells reinforced with six plates is shown in Fig. 1.

2. Determined Buckling Loads. The shells of the first set were tested on a 30-ton Baldwin testing machine (USA, 1950). The loading method and the set-up were detailed in [4, 5]. The shells of the second set were tested on a set-up described in [2]. The local buckling of all the shells was accompanied by snaps and occurrence of dents, which deepen with increasing load. It occurred under loads of approximately $0.75P$ (P is the general buckling load) in the shells of the first set and $0.8P$ in the shells of the second set. The test was stopped once a great drop in the load taken up by the shell was observed. After general buckling,

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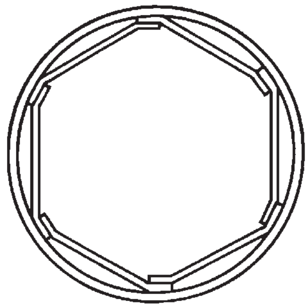

Fig. 1

TABLE 1

Shell number	k	P, kg	$\sigma_{cr} \cdot 10^5$, Pa
4	0	27.55	30.39
		27.36	30.18
		27.76	30.62

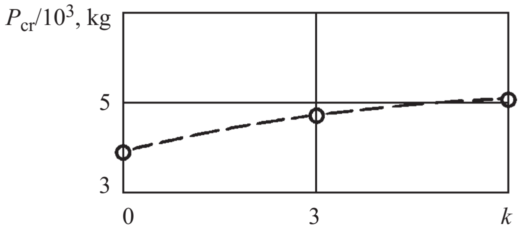

Fig. 2

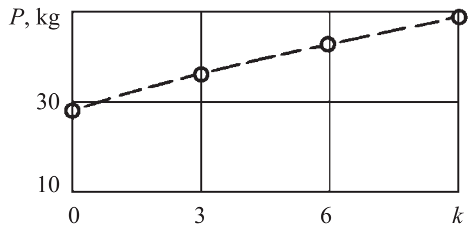

Fig. 4

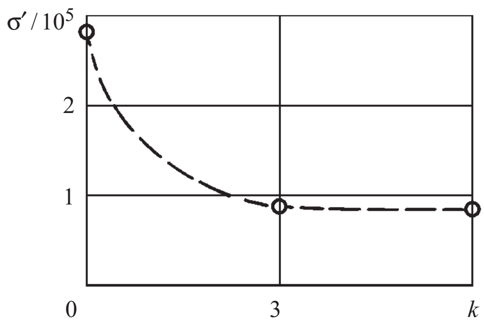

Fig. 3

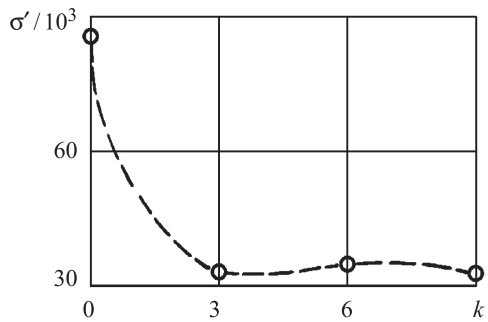

Fig. 5

shells acquired a relatively small number of meridional and circumferential waves. For example, there were five to six circumferential waves in shells of both sets. Table 1 summarizes the results of three tests for shell No. 4.

It follows from the table that the buckling loads did not change in repeated tests. This is why shell No. 4 was reasonably used to make shells Nos. 5–7.

3. Processing and Analysis of Experimental Data. Figures 2 and 4 show (by open circles) the buckling load as a function of the number k of reinforcing plates for the first and second sets of shells, respectively. Figures 3 and 5 show (by open circles) the efficiency (σ^1) of the reinforcement as a function of k for the first and second sets of shells ($\sigma^1 = \sigma_{cr} R^2/G$, where G is the shell weight). The circles in Figs. 2–5 are connected by dashed lines as guides for an eye.

Conclusions. The test results indicate that the possibility exists of increasing greatly the buckling loads by increasing the number of reinforcement plates.

From the results of tests on the second set of shells, which were assumed to have equal initial deflections and were made from one shell, we may conclude that the influence of initial geometric imperfections can be reduced structurally. One way is to increase the flexural stiffness of shells by reinforcing them with a great number of plates.

Since a small number of shells have been tested, it is necessity to continue studying the effect of structural changes in shells.

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