AN EXPERIMENTAL INVESTIGATION OF THE DYNAMIC AXIAL BUCKLING OF CYLINDRICAL SHELLS USING A KOLSKY BAR*

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ABSTRACT: Several experiments were performed with a Kolsky Bar (Split Hopkinson Pressure Bar) device to investigate the dynamic axial buckling of cylindrical shells. The Kolsky Bar is a loading as well as a measuring device which can subject the shells to a fairly good square pulse. An attempt is made to understand the interaction between the stress wave and the dynamic buckling of cylindrical shells. It is suggested that the dynamic axial buckling of the shells, elastic or elasto-plastic, is mainly due to the compressive wave rather than the flexural or bending wave. The experimental results seem to support the two critical velocity theory for plastic buckling, with $V_{c1}$ corresponding to an axisymmetric buckling mode and $V_{c2}$ corresponding to a non-symmetric buckling mode.

KEY WORDS: dynamic buckling, stress wave, Kolsky Bar

I. INTRODUCTION

The traditional experimental techniques to investigate the dynamic buckling of cylindrical shells are the dropping weight and the air gun. The dropping weight technique is a low speed large mass impact. On the contrary, the air gun launches a bullet of small mass with high velocity to impact the specimen. The pulse-time history often is far from smooth and neat. By use of the air gun, Vaughan\cite{1} found a critical velocity or threshold velocity of dynamic plastic buckling of cylindrical shells. Lindburg and Florence\cite{2} proposed a criterion for the elastic dynamic buckling of shells in terms of critical stress. Wang et al.\cite{3}, using an air gun, studied various aspects of the problem of dynamic buckling of cylindrical shells. They observed that there exist two different critical velocities. The first one, $V_{c1}$, equivalent to Vaughans's threshold velocity, was the critical velocity corresponding to the axisymmetric buckling mode. The second one, $V_{c2}$, was the critical velocity for a non-symmetric buckling mode. They also found in their later investigations that if the ratio of radius to thickness of the shell was above some value, only the non-symmetric buckling mode was present.

Strictly speaking, the dynamic responses of structures are the final result of the stress wave effects. The usual dynamic analysis ignores the transition because the velocities of the material particles are of the order of $10^{-2}$ to $10^{-3}$ of the stress wave speed. Thus the displacements of the material particles during the transition are deemed too small to have any significant effect. The neglect of the stress wave effects, however, is not always suitable in the case of dynamic buckling. The high speed photographs given by Lindberg

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and Florence\cite{2} call for more attention. The pictures for the long rod subjected to an impact indicated that at the time of 18\(\mu\)s, when the compressive wave only traveled 90mm, one eighth of the total length of the rod, the rod was slightly buckled while the stress state in the rod was far from uniform. Their pictures for the thin wall tube are even more impressive. At the time of 3\(\mu\)s, visible buckling occurred at the impact end of the shell. The concern of stress wave effects on the dynamic buckling problem is apparently desirable. The objective of the present paper is to investigate the suitability of using the Kolsky Bar apparatus to study the dynamic buckling of cylindrical shells, particularly stress wave effects on the dynamic buckling.

II. THE KOLSKY BAR APPARATUS

The Kolsky Bar was originally designed\cite{4} for measuring material stress-stain relations at high rates of strain\cite{5}. It consists of a striker bar, an input bar and an output bar, Fig.1. The striker bar is launched to impact the input bar to generate a fairly good square incident wave in the input bar which could be picked up by a strain gauge mounted on the input bar. It is a loading device as well as a measuring device. The incident wave and reflected wave measured in the input bar combined with the transmitted wave measured in the output bar will provide the information about the stress and end-displacement of specimen during the test. From the one-dimensional elastic wave theory

\[ u = C_0 \int_0^t \varepsilon dt \]  

where \(u\) is the displacement at time \(t\), \(C_0\) is the elastic wave velocity of the bar material and \(\varepsilon\) is the axial strain. The displacement \(u_1\) (Fig.1) of the face between the input bar and the specimen is the result of both incident wave pulse \(\varepsilon_I\) and the reflected wave strain pulse \(\varepsilon_R\).

\[ u_1 = C_0 \varepsilon_I dt + (-C_0) \int_0^t (\varepsilon_I - \varepsilon_R) dt \]  

Thus

\[ u_2 = C_0 \int_0^t \varepsilon_T dt \]  

The displacement \(u_2\) of the face between the specimen and the output bar is obtained from the transmitted wave strain pulse \(\varepsilon_T\).