Other Possible Material Limitations

It has been postulated that a compressive mean stress may benefit the material fatigue strength under cyclic fluid pressure. However, triaxial fatigue behavior under compressive mean stress is unknown.

Also unknown is the possible fracture of high-strength steels under large compressive stresses. Pugh and Green[17] and Crossland and Dearden[18] found for cast iron that the fracture strain and ductility (and the maximum shear stress at fracture) are increased by superimposing hydrostatic pressure. This is a favorable result, but the possibility of similar behavior for the high-strength steels should be investigated.

The effect of a brittle-ductile transition in high-strength steels on the fatigue behavior near and above the transition temperature is another factor which may need to be considered.

Huge outer cylinders are required for some of the high-pressure container designs – cylinders up to 10 to 50 feet in diameter with 1- to 3-foot wall thicknesses are necessary in some designs. As mentioned previously, fabrication of such large, forgings may be extremely difficult or impossible. Even transportation of such large forgings is another problem.

RECOMMENDATIONS

Proposed Materials Study

The possible material limitations discussed in the preceding section suggests that a materials study be conducted. The triaxial fatigue behavior of high-strength steels under compressive mean stress should be investigated. The objective of the study would be to establish a fatigue criterion for these materials. The effect of large pressures, of magnitudes one to three times the ultimate tensile strength, upon the flow and fracture characteristics of high-strength steels should also be studied. Moreover, a brittle-ductile transition in high-strength steels may influence fatigue behavior at elevated temperatures – an investigation of this factor may also be worthwhile.

Suggested High-Pressure Container

The results of the investigations on various containers have shown that fluid-pressure support is beneficial and that prestress is also beneficial in increasing the predicted fatigue strength under cyclic pressure loading. Use of high-strength steels for the liners of the containers was also found necessary. Although the controlled fluid-fill design, Figure 10, uses the fluid-support principle, the required size and complexity of the fluid-fill apparatus for fatigue application makes this design impracticable. Use of shrink-fit to provide compressive prestress can reduce the required size and the number of pressure annuli as the ring-fluid-segment design indicates. Although the latter design has the benefit of prestress from shrink-fit, it requires large interferences because of large deformations of the segments and large outer cylinders because the segments offer no hoop support.

A suggested design which appears to minimize the problems introduced by segments is shown in Figure 11. It is made up of two multi-ring units and a fluid-pressure support annulus. Three rings are shown in each part in Figure 11, but the number of rings can be varied to give the best design. For example, for containers having small bores, one ring is sufficient in the inner part. It is easily shown (using the tensile fatigue criterion for the inner ring) that a cyclic bore pressure of 450,000 psi is possible with one inner ring of wall ratio, $k_1 = 2.0$ and a support pressure of 250,000 psi. A multi-ring container for the outer part can be designed for 10^4 to 10^5 cycles at 250,000 psi as shown in this study.

It may be that the fluid-support pressure should not be reduced to zero with the bore pressure but reduced to some minimum value in order to provide some prestress in the outer cylinder of the inner part. Controlling the pressure in one annulus does not present as many difficulties as it does in the controlled fluid-fill container design where there are many annuli.

The suggested design can be analyzed using analyses similar to those used in this study. It is suggested that this be done.