BASIS AND METHOD OF ANALYSIS

In this study the four design concepts for high-pressure containers are evaluated on the basis of a selected strength criterion for the component materials. Different strength criteria could be chosen, each of which could lead to different predictions of maximum pressure capability. If rupture under static load is the strength criterion then a burst pressure can be predicted. This pressure would be higher than the yield pressure predicted on the basis of static yield strength. However, a vessel subject to a great number of cycles of pressure less than the yield pressure could fail by fatigue. A high-pressure container for commercial hydrostatic extrusion should, of course, be capable of repeated use without frequent failure. Therefore, it was considered essential that a fatigue strength criterion be used as the basis of evaluation in this study.

It also has to be ascertained what kind of stress and strain analysis is needed – elastic, plastic, or elastic-plastic. This is determined from the fatigue life desired. Manson and Hirschberg(12) have shown that for most materials, failure by low-cycle fatigue (life less than about 1000 cycles) involves almost entirely plastic strain. Above about 1000 cycles life the amount of plastic strain is appreciably smaller, and above 100,000 cycles life the plastic strain is negligible. For the relatively high-strength materials, however, the strain at fracture is predominantly elastic for lifetimes as low as 100 cycles. Because lifetimes greater than 1000 cycles are desirable in commercial applications, and since high pressures require use of high-strength materials, elasticity theory rather than plastic or elastic-plastic analysis is used. Use of elastic theory rather than elastic-plastic theory also aids the study because elasticity solutions are easier to formulate and can be superimposed.

For the analysis, equations are derived that relate the interface pressures and the radial deformations between components. Elasticity solutions for stresses and deformations are used together with fatigue relations to determine formulas for maximum bore pressures.

METHOD OF PARAMETER NOTATION

The components of each design are identified from the inside out by the numbers 1, 2, 3, ..., N. N refers to the outermost component. As indicated in Figure 8, the components have the following radii:

r_0, r_1 = inner and outer radii, respectively, of component 1, the liner

r_{n-1}, r_n = inner and outer radii, respectively, of component n, n = 1, 2, ..., N. (1)

For the multi-ring container all the components are circular hollow cylinders. For the ring-segment and ring-fluid-segment containers, component 2 refers to the segments. The only exception to the notation on the radii occurs in the pin-segment design where the segment is divided for analysis into two parts and where r_2 is the radius to the inside of the pins as shown in Figure 8(d).

The bore pressure and interface pressures are identified as follows:

$p_0 = p =$ internal, bore pressure on liner

p_{n-1}, p_n = operating interface pressures acting on component n at r_{n-1} and r_n, respectively, when $p \neq 0$

q_{n-1}, q_n = residual interface pressures acting on component n at r_{n-1} and r_n, respectively, when $p = 0$.

Because the outer radius of each container refers to a free surface, the pressure there is zero,

$$p_N = 0, \qquad q_N = 0 \tag{3a, b}$$

The definition of the q_n gives

$$q_0 = 0 \tag{4}$$

Wall ratios for each component are defined as follows:

$$k_n = \frac{r_n}{r_{n-1}} \tag{5}$$

where k_n is the wall ratio for component n. The over-all diameter ratio of the container is defined as

$$K = \frac{r_N}{r_o} \tag{6}$$

From Definitions (5) and (6) we find that the following relation exists between K and the k_n:

$$K = k_1 k_2 k_3 \ldots k_N \quad . \tag{7}$$

FATIGUE CRITERIA

Two fatigue criteria are formulated here in order that both relatively low-strength ductile materials and high-strength, more brittle materials may be used in one design. The intention is to use high-strength steels as liner materials and lower strength ductile steels for the outer cylinders in order to prevent catastrophic brittle failure.