Technical Physics

THE PROBLEM OF STRENGTHENING HIGH-PRESSURE VESSELS

M. G. Gonikberg, D. S. Tsiklis and A. A. Opekunov

N. D. Zelinskii Institute of Organic Chemistry, Academy of Sciences, USSR;
State Institute of the Nitrogen Industry

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Rupture of a high-pressure vessel occurs when the stresses which arise under the action of the internal pressure in the walls of the vessel attain a definite magnitude, whose value depends on the strength of the material used for making the vessel.

Usually, the design of a vessel leads to a determination of the pressure at which the stress at the inner wall attains the yield strength of the material. An approximate solution of this problem is given by numerous theories of strength. It is known from experiment that thick-walled vessels sustain, before rupture, a pressure substantially larger than that calculated from these theories. This happens as a consequence of the fact that a significant amount of work-hardening of the material occurs during plastic deformation, and the stress distribution is improved in the so-called plastic zone [1]. However, even for the best modern steels, the rupture pressure of vessels, in which a plastic layer is spread over the entire thickness of the wall, does not exceed 20,000 to 25,000 kg/cm^2. In order to increase the pressure which a vessel can sustain, it is necessary either to lower the stresses in the walls of the vessel, or to have materials for its construction which possess much higher strength than contemporary steels.

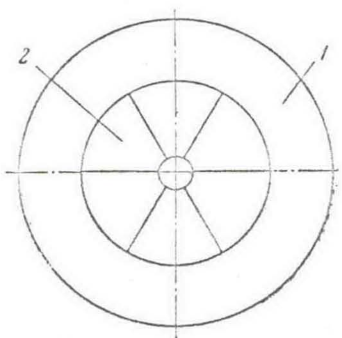

Fig. 1. Principle of the construction of the wedge vessel.

Various methods, described repeatedly in the literature, are used for lowering the stresses in the walls of a vessel — methods of hydraulic and mechanical backing, the method of concentrating the basic load on an area surrounded by a large mass of unloaded material, etc. [1].

In recent times, an important trend in the construction of high-pressure apparatus is the method of replacing tensile stresses in the structure by compressive stresses. This makes use of the fact that the strength in compression of such materials as tungsten carbide and hard steels is 3 to 4 times as large as the strength in tension. This principle is applied, for example, in a structure which is known under the name of a tetrahedral anvil [2], and it permits, even now, the attainment of pressures up to 200,000 atmos in conjunction with very high temperatures inside the apparatus.

In this structure, four pistons move in a highly viscous medium (pyrophyllite) in a direction toward a common center. The triangular plane ends of these pistons, between which is the pyrophyllite packing supporting them, form a tetrahedral "vessel" for high pressure. Thus, two fundamental problems are solved in the tetrahedral anvil structure: support of the moving piston, and the creation of a "vessel" for high pressure sustaining extremely large stresses and high temperatures.