The Effect of Hydrostatic Pressure (14kbar) on the Ultimate Compressive Strength of Various Sintered Materials

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INTRODUCTION

The strength of materials plays a prominent role in the design of most equipment and is especially important in the design of high-pressure apparatus. The maximum pressure obtainable in a simple piston-cylinder apparatus is limited to the ultimate compressive strength of the piston material. Higher pressures with a given material may be obtained by employing such techniques as the massive support principle (1)[2] used in Bridgman anvils and preloading with binding rings used in most solid medium devices (2). A third and more interesting means of raising the ultimate compressive strength of a piston is to radially support the piston while it is axially loaded. An excellent example of an apparatus employing this technique is the Kennedy (3) apparatus which radially supports the piston by pressure developed in the surrounding bismuth medium.

By considering the failure of a piston to be an energy-releasing process, one notes the ultimate compressive strength will be determined by tensile strains perpendicular to the applied load. Thus radial compressive loading will increase the ultimate axial compressive load the piston will withstand. By assuming the critical tensile strain to be a constant, one finds the increase in the ultimate compressive strength should be proportional to the radial loading divided by Poisson's ratio of the material. This implies the enhancement may be as high as three to four times the radial loading.

Bridgman employed these ideas when he built an apparatus within an apparatus (4) to increase his pressure range, and he also performed several experiments (5) to determine the effect of hydrostatic pressure on the ultimate compressive strength of materials. Considering the investigation of the phenomenon to be valuable, we have performed a series of similar experiments on larger samples at lower support pressures and obtained more detailed data.

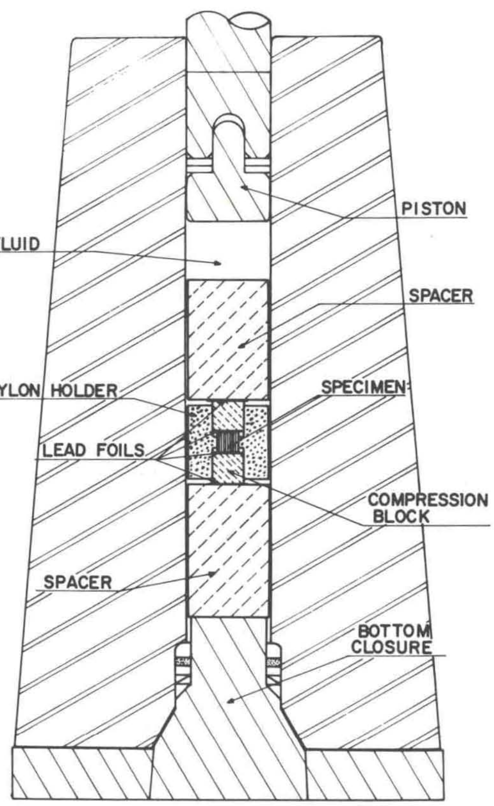

Fig. 1 Schematic representation of testing arrangement, piston travel monitoring device (not shown) was attached between press frame and piston of driving ram

In our experiments the ultimate compressive strengths of 11 brittle, low-compressibility materials were investigated as a function of hydrostatic support pressure using precision ground specimens 0.250 in. dia by 0.250 in. high.

EXPERIMENT

In most cases six specimens of each material were compressed to failure at six different hydrostatic support pressures ranging from 1 atm to

[2] Numbers in parentheses designate References at the end of the paper.

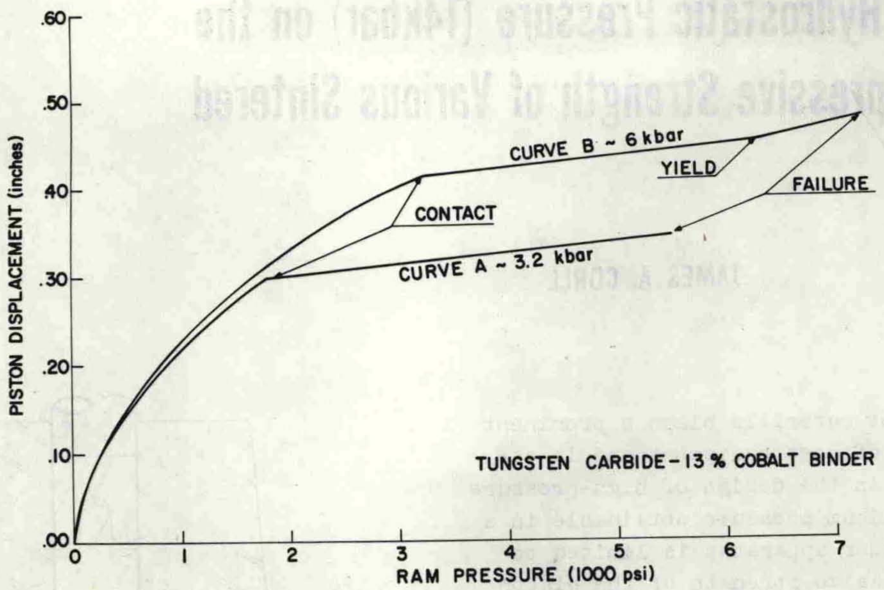

Fig. 2 Experimental data recorded during tests. Curve A typifies brittle failure and curve B typifies yielding before failure

14 kbar. All specimen surfaces were ground to at least a number sixteen finish with the ends plane and parallel. As shown in Fig.1, the specimens were compressed in a nylon holder between two tungsten-carbide compression blocks 0.375 in. in diameter. To reduce contact friction, and thereby minimize barreling, 0.001-in. lead foils were placed between the specimen and the compression blocks. The nylon holder guaranteed alignment of the sample in the pressure chamber and was shaped so that it provided no resistance to the compressive forces or radial support to the specimen.

The hydrostatic support pressures and the compressive forces were provided by the advancing piston of a commercial 30 kbar pressure apparatus (6). The advancing piston increased the hydrostatic support pressure by compressing the fluid (a mixture of n-pentane and isopentane) until contact was made with the tungsten-carbide spacers, Fig.1. Further advance of the piston applied the compressive loading to the specimen through the spacers and compression blocks. The hydrostatic pressure obtained before piston contact was varied by varying the length of the spacers.

During the experiments the pressure applied to the ram driving the piston and the displacement of the piston were continuously monitored on an x-y recorder. A marked change in slope of the piston displacement versus applied ram pressure curve occurred when the advancing piston contacted the spacers indicating the start of direct compressive loading. A discontinuous increase in the piston displacement indicated sample failure and was usually accompanied by an audible bang from within the pressure apparatus.

The pressure apparatus was calibrated at the start and at intermediate times during the course of this series of experiments. The applied ram pressure versus sample chamber hydrostatic-pressure calibration curve for the apparatus remained constant throughout the experiments and was determined by correlating the resistance of a manganin wire coil and applied ram pressure. The pressure coefficient of the manganin wire resistance was determined during the calibration experiments by the freezing pressure of mercury at room temperature.

DATA REDUCTION AND INTERPRETATION

The experimental data of two runs on specimens of 87 percent WC with 13 percent Co binder which are shown in Fig.2 are representative of the two types of failure encountered during the experiments. Curve A is typical of specimens which exhibited brittle failure without yielding and curve B is typical of specimens which yielded before failure. Note that in Fig.2, both specimens were of the same material and that, with sufficient hydrostatic support pressure, the normally brittle material exhibited yield and considerable deformation before failing. All experimental data curves displayed approximately the same slope after the piston contacted the spacers. Referring to curve A of Fig.2, over 90 percent of the displayed piston displacement between the contact point and the failure point can be ac-