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DISCUSSION

A. R. Bobrowsky[2]

The authors are to be congratulated on a clean cut investigation of a little-investigated topic.

The discusser has had occasion to bend both thick and thin beryllium sheet (under Department of Navy sponsorship), in pressure environments up to 450,000 psi, with results previously published as in the authors' reference [3]. The discusser has also bent under pressure Ti-6A1-4V with each of two kinds of heat treatment in proprietarily sponsored tests, at pressures up to about 250,000 psi, about five or six years ago.

Some of the conditions and aspects of those tests arise as questions on the current paper whose topic is the bending under pressure of three titanium alloys and Be-1.5 percent BeO.

The discusser employed three-point loading for bend tests; the authors employ a shaped punch and die. What differences would be expected from the differences in test fixtures? Was anticlastic curvature (saddle shape) ever observed on the bent specimens as was the case with the thicker of the discusser's specimens? Would the test specimens be thought to be thin enough to simulate plane-strain conditions?

The discusser gave as results bend angle as a function of pressure; the authors employ bend radius similarly. Both kinds of results seem to be linear with increasing pressure. Is there a known correlation?

The authors mention formation of "orange peel" finish when bending titanium specimens. The discusser found the same appearance but interpreted it as ductile slip in the grain boundaries of the titanium sheet. Such ductile slip as also found in Be tensile specimens pulled under high pressure (350,000 psi and higher). Is this phenomenon possibly characteristic of hexagonal close-packed crystal structures, or even of noncubic crystal structures in general? It has not yet been published for materials with cubic crystal structures.

The authors state, "Pressurized fluid has been shown to cause changes in the stress distribution of bend specimens such that much tighter bends can be formed at room temperature." The discusser sees no evidence that stress distribution has been changed, only that ductility has increased as the environmental pressure increased, previously a known phenomenon for bend as well as for other kinds of mechanical tests (e.g., tension, torsion, compression) when conducted under pressure.

From a practical viewpoint, tighter bends can be achieved than indicated by the data of this paper, by use of tooling that suitably alters the stress state of the metal being bent under pressure.

Was environmental pressure constant during a bending operation? If not, it is no major matter, as previously indicated by Bridgman for tensile tests under pressure, characterized by the final pressure.

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The authors are to be commended for their efforts in collecting and presenting valuable data on the bend behavior of titanium and beryllium sheet in high pressure environments. The data presented further substantiates the thesis that formability can be enhanced by the application of suitable pressure environments.

The authors state that "No relationship was evident between mechanical properties of the sheet and the influence of ambient pressure on minimum bend radii." Pendleton has shown in his paper on "Forming of 7075-T6 Aluminum in High Pressure Environments" (ASME Paper No. 71-WA/PT-11), that there is a correlation, at least for aluminum, between the fracture stresses and strains obtained in tension tests and in bending tests. Perhaps the key for correlating test data is to define pressure as being the hydrostatic component of the stress state at a point. This definition would include environmental as well as load induced pressures. It would be a worthwhile investigation to analyze the data of Meyers, et al., in the manner illustrated by Pendleton.

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