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EFFECT OF MACHINING DAMAGE ON TENSILE PROPERTIES OF BERYLLIUM

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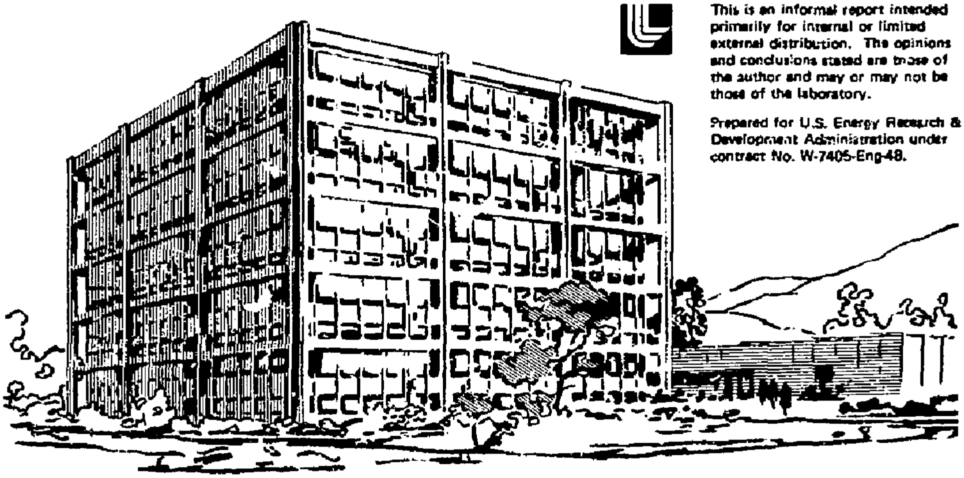

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EFFECT OF MACHINING DAMAGE ON TENSILE PROPERTIES OF BERYLLIUM

ABSTRACT

It is well established that damage introduced at the surface of beryllium during machining operations can lower its mechanical properties. Recently, we have conducted some tensile tests to illustrate this on beryllium presently being used for parts in the W79 program and similar to the new powder-processed beryllium specified for production (tentative specification MEL 76-001319). The objective of this study is not to dwell on specific machining operations but rather to quantitatively illuminate the importance of controlling machining damage in this particular grade of powder-processed beryllium.

BACKGROUND

The machining damage may consist of (1) microcracks, (2) residual stresses, (3) surface texture, and (4) twinning. The effects of the first three types of damage are readily apparent in a notch-sensitive, anisotropic material such as beryllium. However the last type of damage, twinning, is often the most harmful in beryllium. A twinned grain in a metal is one in which there is a mirror image of the crystal lattice. It is believed that in beryllium, the crystallographic interface (twinning plane) acts as an obstacle to dislocation movement and results in submicroscopic stress concentrations. The seriousness of the machining damage can vary considerably with the exact machining procedure and the depth of damage can range from negligible up to perhaps tenths of milimeters.

While many aspects of the machining operation are important (e.g., sharpness of tool and speed of cut), in practice the damage is usually controlled by (a) specifying the depth of cut on the last few passes, (b) removing the damaged material by chemical means, or (c) removing the twins by annealing above about 1025 K (750°C) although microcracks would remain.

Specifying the depth of cut on the last few passes can be quite effective in minimizing the damage if the particular machine shop is knowledgeable in machining beryllium and follows good practice. This is the most common procedure with a typical sequence being 0.13, 0.08, 0.03 mm (0.005 in., 0.003 in., 0.001 in.) for the last three cuts. Somewhat more conservative procedures are suggested by the Materials Advisory Board of the National Research Council (MAB-205-M, March 1966). Different, but also conservative, procedures are specified for W79 parts at LLL.

RESULTS

The tested beryllium is lot 0925 from Brush Wellman (BW) and can be considered a "select" version of the Brush Wellman commercial grade S65 introduced in 1973. It is within the new tentative LLL specification for beryllium, MEL 76-001319. Two parts for the W79 Program were made from this lot 1925 for gun firing. Extensive testing and study of this billet has been conducted under the Advanced Beryllium Technology Program, independent of the W79 Program.

A total of nine tensile specimens were fabricated with no specific requirements on the machining procedure. Three orientations were considered (a) tensile axis parallel to axis of the cylindrical pressed block (longitudinal), (b) tensile axis perpendicular to axis of pressed block and parallel to the radius (transverse radial), and (c) tensile axis perpendicular to axis of pressed block and also perpendicular to the radius (transverse circumferential).

Six specimens, two from each orientation, were tested in the "as machined" condition without further preparation. The remaining three specimens were etched to remove 0.15 mm (0.006 in.) from the diameter. The mechanical property results are summarized in Table 1 and are compared to the Brush Wellman certified values. The ultimate strength and elongation at fracture of the longitudinal specimens are lower than those of the transverse tensile specimens. Billet 0925 had been hot-pressed and thus, this anisotropy in mechanical properties is to be expected. It should be noted that certified values from both KBI and BW employ careful machining and etching methods as outlined in MAB-205-M for fabricating their tensile specimens and hence, the certified tensile properties should be comparable to those obtained for the etched specimens in this study. Indeed, this was found to be the case.

The tensile specimens with the "as machined" surfaces failed at a substantially earlier stage for all orientations than did the etched specimens This resulted in lower ultimate strengths and lower elongation at fracture but did not affect the yield strength significantly.

The cause is readily apparent in Fig. 1. The "as machined" surface adjacent to the fracture surface is shown in Fig. 1a. Evidence of fairly deep cuts can be seen underlying the polished (smeared) tensile specimen surface. On a macroscopic level, this surface appears as a smooth and perhaps as an acceptable surface finish. The microscopic damage (twinning) can be seen to extend about 0.075 mm (0.003 in.) into the specimen (Fig. 1b). In contrast, the surface of an etched tensile specimen is shown in Fig. 1c. The etching has removed all evidence of machining marks; the removal of most of the machining damage is confirmed by examination of the microstructure at the edge of the specimen (Fig. 1d).

SUMMARY

The effect of machining damage on mechanical properties was demonstrated on a high strength, high ductility beryllium that corresponds to the new tentative LLL beryllium specification. In this study, the presence of damage to a depth of 0.08 mm (0.003 in.) lowered ultimate strength about 70 MPa (10 000 psi) and elongation from about 6% to 1.5% (transverse) and about 4% to 1% (longitudinal). The predominate type of damage is twinning. Mechanical properties of beryllium are ordinarily determined on specimens that have been carefully prepared to eliminate machining damage. Hence for valid design calculations, this same care must be takin in the fabrication of actual beryllium parts.

Table 1. Effect of Machining Damage on Beryllium Block 0925: Tensile Properties.

Orientation	Specimen Condition	Ultimate Strength[a] MPa	(psi)	Yield Strength[a] MPa	(psi)	Elongation[b] %
Longitudinal	"As machined"[c]	290	(42 100)	259	(37 500)	0.8
	Etched[d]	355	(51 500)	247	(35 900)	4.3
	BW certification[e]	363	(52 600)	238	(34 500)	3.7
Transverse	"As machined"[c]					
	Circumferential	314	(45 600)	257	(37 300)	1.5
	Radial	319	(46 300)	256	(37 100)	1.4
	Etched[d]					
	Circumferential	376	(54 500)	242	(36 000)	5.6
	Radial	376	(54 500)	250	(36 200)	5.3
	BW certification[e]	395	(57 300)	238	(34 500)	6.3

[a] Values rounded to nearest 1 MPa and 100 psi.

[b] Values rounded to nearest 0.1%.

[c] Average of two tests.

[d] One test.

[e] Average of tensile properties from top, middle, and bottom of billet.

PLL/gw

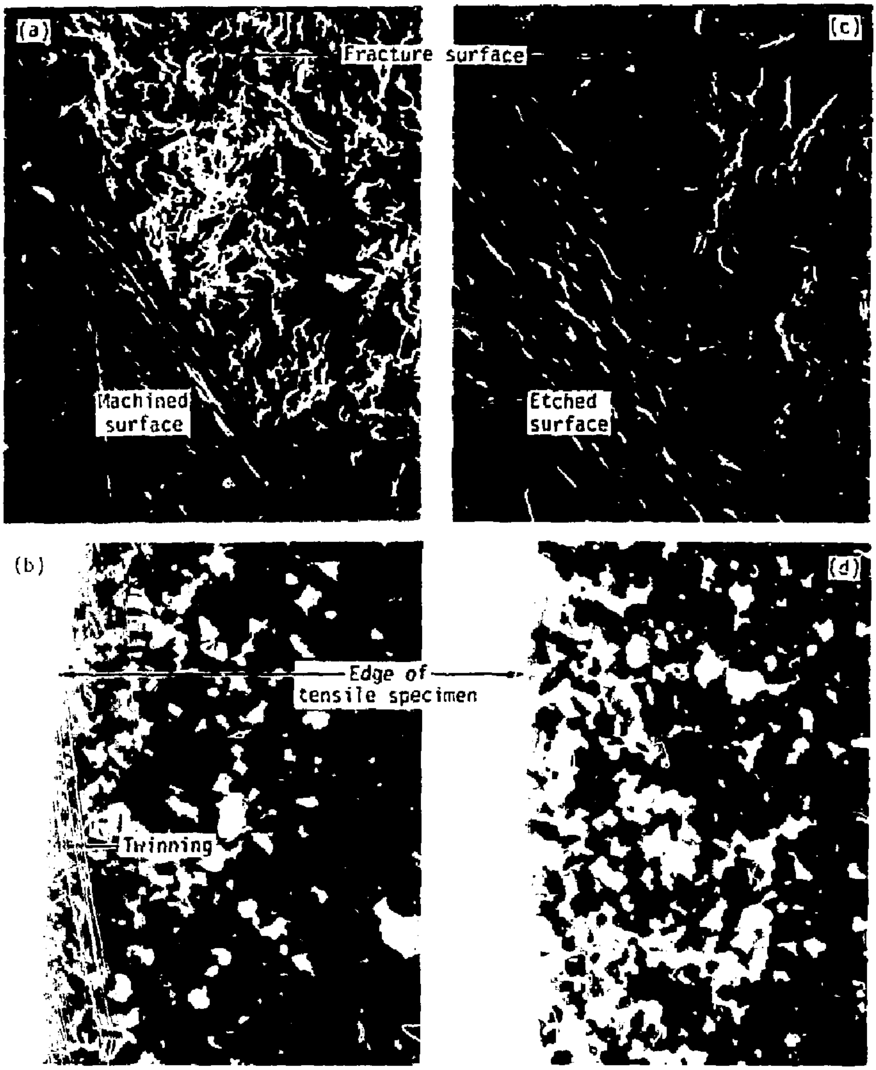

Fig. 1. Beryllium tensile bars showing effect of machining damage followed by chemical removal of 0.08 mm (0.003 in.) of material from the surface. (a) "As machined" specimen showing fracture surface and excessive working from machining of surface on outer diameter of gage length (220X). (b) Polished cross section of "as machined" specimen showing extensive twinning at surface (200X). (c) Etched specimen showing fracture surface and etched surface on outer diameter of gage length (220X). (d) Polished cross section of etched specimen showing absence of twins at surface (200X).

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