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MASTER

DETERMINATION OF YIELD STRENGTH (Y^0)
FOR BALLISTICALLY IMPACTED CYLINDERS
OF BERYLLIUM

Charles A. Honodel

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Impacted Cylinders of Beryllium

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For our continuing program of Y^0 determinations⁽¹⁾⁽²⁾, we have recently added two new materials to the list in Table 1. Beryllium samples of material specification 71-001162A were received from Kaweck and Be samples of material specification 76-001319A were received from Brush Wellman. The parts were fabricated per drawing 79-102216-OD TAB 12, Fig. 1. Fourteen samples of each specification were supplied and they were fired in our .30 caliber smoothbore gun as set up on the firing table at Site 300, Bunker 812.

O.S.P. 812

Since our earlier Be work was performed in the now dismantled Vault 2 of Building 341, where the Be HEPA filter system allowed the tests to be performed, we were forced to relocate the apparatus to a safe handling area. O.S.P. 812-800428 was written for this test series and it attends to the safe firing, handling and clean up procedures that were followed.

The shots were fired on February 5 and 6, 1981, by E. McCollough, T. Cuddihy, R. Kaster and myself. Fig. 2 shows the placement of the apparatus on the 812 table. The gun and target carts have since been decontaminated and returned to storage in Building 345.

Test Firing

The Be samples were breach loaded in the gun and were positioned into battery by the following brass case. The powder charge was loaded into the brass case after being weighed in the transportainer outside the bunker. The Be projectile is not crimped into the case. The firing pin is actuated by a solenoid which is energized from the console in the bunker. This console contains the firing chassis, the velocity trap power supply and the T.I.M.'s for readouts. The fired samples were recovered and their crushed length was measured. They were wiped and bagged and sent to the lab for photographing.

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Starting with this series we initiated a new measurement of the undisturbed residual length of each fired sample. It may be possible to relate the distance that the plastic wave has travelled down the sample to the degree of work hardening experienced by the sample. We will have some of the earlier material samples measured using the same technique. The results of the Be groups are discussed later in this report.

Photographs of the recovered samples have been taken by Metallurgy. They reveal the surface cracks and fractures as well as the profile of the final deformed shape.

Data

Table 1 is a continuation of the table reported in my memo of 7/25/79. It lists the critical measurements and the calculated values used to determine an average Y^0 for each material. For this report I have included a column headed Z which is the length of "unswollen" projectile remaining after recovery. Appendix A describes the gauge block used to determine this value. Figures 3 through 8 display the derived data from the shot series.

APPENDIX A

Measurement of Z

For our Be shots at S-300 we will use a gauge block to establish the undisturbed length of the projectile.

what is length Z when $d = D_{proj} + .004'' \pm .001''$
and $D_{proj} = .3015''$

POST-FIRED SPECIMAN

y Given

x measured with depth micrometer

$$Z = y - x$$

Need gauge block: $y = 1.000''$

1.000 ± .010

MATL-TOOL STEEL
ANNEALED

References

- (1) "Fifth Progress Report of Light Armor Program" Wilkins M. L.,
Landingham R. L., Honodel C. A., UCRL-50980, Jan 1971, Appendix E.
- (2) "Impact of Cylinders on a Rigid Boundary, Wilkins M. L., Guinan M. W., JAP
VOL. 44, No. 3 3/73

Tables

Table 1 measured and calculated shot data.

Figures

1. Test material sample.
2. Be series set up photograph
3. Verification graph.
4. L_F/L_0 vs γ^0 for well-behaved Cu and Nb compared with the complicated brittle Be reaction.
5. L_F/L_0 vs impacting velocity for Be projectiles. Be brittle fractures badly as evidenced by the shallow slope with fractures beginning before L_F/L_0 reduces to 90 percent.
6. Measurement Z with respect to L_F/L_0 where the gauged diameter is set at 0.004" over projectile diameter (101.3 percent).
7. Velocity/powder load curve for the Be projectiles.
8. Relationship between the measured muzzle velocity and the lock time of the .30 cal. gun. Lock time is defined as the delay from trigger pulse to the near muzzle time velocity station.

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Table 1. Measured and calculated values

SHOT NO.	PROJ. MATL.	L ₀ (in.)	L _F (in.)	U (cm/μsec)	ρ ₀ (Mg/m ³)	γ ₀ (mb)	ρ ₀ U ² / 2γ ₀	L _F /L ₀	Z (in.)	COMMENTS/RESULTS as of 8/82
1	Cu	.9248	.854	.0095	8.93	.0044	.0916		.527	New R _c 60 Target Added KB (WC); Cracked Dented Targ .004"
2		.9250	.850	.0097		.0044	.0955		.528	
3		.9248	.7162	.0178		.0048	.2947		.323	
4		.9245	.3762	.0325		.0042	1.123		-	
5		.9250	.5155	.0273		.0048	.6933		.281	
6	Al (6061)	.9243	.7945	.0253	2.70	.0049	.1746		.460	
7		.9241	.6570	.0383		.0050	.3985		.422	
8	Ta	.9250	.8170	.0114	16.65	.0076	.1424			
9		.9243	.420	.0284		.0069	.9731		.5875	
10		.9248	.616	.0207		.0075	.4756		-	
11		.9249	.862	.0093		.0089	.0810		.4055	Second Targ. Block added Must be loose target block
12		.9246	.710	.0208		.0118	.3055		.6455	
									.5145	
13		.9247	.4135	.0286		.0069	.9894		-	Added Vasco 350 front targ. plate Free standing targ. block
14		.9234	.4450	.0287		.0077	.8885		-	
15		.9242	.569	.0281		.0115	.574		.3975	
16		.9247	.480	.0281		.0083	.7907		-	New back-up block W/(WC) target "bad" New STD setup best test
			.494			.0087	.7535		-	
17		.9238	.432	.0278		.0069	.929		-	
18	Ag	.9252	.8270	.00954	10.49	.0037	.1285	.8939	-	γ ₀ x̄ = .00405 mb
19		.9252	.496	.0247		.0043	.7490	.5361	-	S.D. = .00025
20		.9254	.3702	.0293		.0039	1.145	.4000	-	S.E.
21		.9252	.6316	.0192		.0043	.4472	.6827	-	S _x = .0-001
22		.9253	.7646	.0128		.0039	.2198	.8263	-	
23		.9253	.4344	.0273		.0042	.9234	.4695	-	
24	Ti	.9253	.8889	.01566	4.53	.0125	.0446	.9607	.6115	γ ₀
25		.9250	.8405	.02572		.0137	.1096	.9086	.453	x̄ = .0131 mb
26		.9248	.8172	.02828		.0128	.1418	.8837	.4825	S.D. = .0004
27		.9252	.8018	.03088		.0131	.1644	.8666	.430	S.E.
28		.9247	.8804	.01795		.0130	.0560	.9521	.572	S _x = .0002
29		.9246	.8543	.02323		.0135	.0904	.9240	.471	
30	Mo	.9251	.8907	.01230	10.21	.0179	.0432	.9628	.705	γ ₀
31		.9255	.7474	.02673		.0148	.2468	.8076	.5195	x̄ = .0150 mb
32		.9255	.6425	.0324		.0126	.4269	.6942	.306	S.D. = .0017
33		.9254	.7747	.02393		.0143	.2046	.8372	.560	S.E.
34		.9250	.8574	.01612		.0153	.0867	.9269	.6415	S _x = .0007
35		.9243	.7917	.02291		.0151	.1780	.8565	.562	
36	Nb	.9255	.8406	.01324	8.59	.0068	.1101	.9083	.592	γ ₀
37		.9255	.7278	.02136		.0070	.2781	.7864	.4935	x̄ = .0070 mb
38		.9258	.6066	.02053		.0070	.4973	.6552	.411	S.D. = .00011
39		.9259	.5512	.03173		.0070	.6160	.5953	.365	
40		.9254	.8086	.01596		.0071	.1548	.8738	.556	
41	Ti 6Al-4V	.9247	.8952	.0174	4.42	.0181	.0369	.9681	.646	γ ₀ (w/o 43)
42		.9237	.8789	.02088		.0170	.0567	.9515	.609	x̄ = .0169 mb.
43		.9234	.7955	.0316		.0129	.1712	.8615	.5705	S.D. = .0012
			Frac.							
44		.9240	.8306	.0290		.0152	.1220	.8889	.5475	
45		.9238	.8695	.0232		.0172	.0691	.9412	.565	
46									.560	

SHOT NO.	PROJ. MATL.	L ₀ (in.)	L _F (in.)	U (cm/μsec)	ρ ₀ (Mg/m ³)	Y ₀ (mb)	ρ ₀ U ² 2Y ₀	L _F /L ₀	Z (in.)	COMMENTS/RESULTS as of 8/82
47	HASTALLOY	.9231	.8154	.01766	8.32	.0091	.1422	.8833	.311	Y ₀ (w/o 49)
48		.9233	.7412	.02560		.0107	.2538	.8028	.2035	
49		.9233	.6895	.03088		.0117	.3393	.7468	.229	
50		.9233	.7198	.02842		.0117	.2883	.7796	.211	S.D. = .0012
51		.9231	.7998	.01977		.0099	.1646	.8664	.2845	
52		.9230	.8604	.01299		.0088	.0802	.9322	.434	
53	V	.9171	.8512	.01317	6.10	.0062	.08518	.9281	-	Y ₀
54		.9252	.7737	.02078		.0064	.2059	.8362	-	
55		.9270	.6834	.02840		.0069	.3556	.7372	-	
56		.9242	.5300	.03435		.0067	.5361	.6348	-	S.D. = .0003
57		.9182	.4300	.03777		.0067	.6548	.5772	-	
58		.9244	.8721	.01171		.0063	.06645	.9434	-	
59	CESALLOY	.9232	.8477	.01374	7.79	.0075	.09754	.9182	.4585	Y ₀
60		.9236	.8078	.01785		.0081	.1537	.8746	.392	
61		.9237	.6837	.02832		.0089	.3499	.7402	.2745	
62		.9238	.6109	.03393		.0092	.4860	.6613	.242	S.D. = .0009
63		.9235	.5306	.03983		.0094	.6606	.5745	.2295	
64		.9238	.8825	.00987		.0073	.0521	.9553	.561	
65	Cu	.924	.7845	.0139	8.93	.0046	.188	.849	.424	Verify set-up
66		.9245	.4648	.0287		.0044	.8325	.5028	-	
67		.9246	.698	.0187		.0048	.326	.755	.3225	
68		.9242	.654	.0209		.0048	.4038	.7076	-	S.D. = .00019
69	SS304	.9239	.8625	.0153	7.84	.01169	.0785	.9335	-	Y ₀
70		.9241	.7902	.0246		.01319	.1799	.8551	-	
71		.9241	.7537	.0288		.01383	.2351	.8156	-	
72		.9244	.8595	.0158		.01177	.0831	.9298	-	S.D. = .00096
73		.9239	.8484	.0175		.01232	.0975	.9183	-	
74		.9242	.6955	.0340		.01372	.3301	.7525	-	
75	21-6-9	.9243	.8664	.0123	7.89	.00808	.0738	.9374	-	Y ₀
76		.9241	.7810	.0203		.01040	.1935	.8452	-	
77		.9237	.6928	.0298		.01048	.3342	.7500	-	
78		.9243	.7658	.0227		.00938	.2167	.8285	-	S.D. = .00092
79		.9242	.8016	.0190		.00872	.1634	.8673	-	
80		.9242	.8251	.0164		.00817	.1299	.8928	-	
81	Be (76-001319A from Brush)	.9244	.8745	.02283	1.851	.0076	.0633	.9460	.683	Y ₀
82		.9242	.8760	.02319		.0081	.0611	.9478	.363	
83		.9245	.868	.02542		.0083	.0719	.9389	.318	
84		.9247	.8695	.0250		.0082	.0702	.9403	.325	S.D. = .0009
85		.9246	.8645	.02672		.0086	.0767	.9350	.295	
86		.9250	.8640	.02670		.0085	.0779	.9341	.302	
87		.9247	.8435	.03392		.0101	.1051	.9122	.260	Fractured
88		.9248	-	.03680					.250	
89		.9240	.846	.03190		.0093	.1008	.9156	.254	
90		.9252	.892	.01782		.0071	.0416	.9641	.542	
91		.9240	.8765	.02251		.0078	.0602	.9486	.364	
92		.9246	.885	.01987		.0073	.0499	.9572	.436	
93	Be 71-001162A from Kawecki	.9260	.878	.02088	1.849	.0066	.0607	.9482	.340	Y ₀
94		.9245	.868	.02386		.0073	.0720	.9389	.305	
95		.9248	.855	.02797		.0081	.0897	.9245	.286	
96		.9246	.8585	.02693		.0079	.0847	.9285	.2845	Fractured Not Used In Calc. Frac.
97		.9240	.860	.02818		.0090	.0820	.931	.293	
98		.9242	.8364	.03319		.0089	.1142	.905	.243	
99		.9245	.844	.03070		.0084	.1042	.9129	.248	
100		.9246	-	.03646					.277	
101		.9238	.8865	.01778		.0062	.0470	.9596	.429	Y ₀
102		.9250	.8745	.02197		.0070	.0640	.9454	.307	
103		.9246	.8795	.02006		.0065	.0570	.9512	.370

FIGURE 1

FIGURE 2

CURVE RELATING L_F/L_0 TO $\frac{\rho^0 u^2}{2Y^0}$ WHERE:

$$L_F/L_0 = \left(1 - \frac{h}{L_0}\right) e^{-\frac{\rho^0 u^2}{2Y^0}} + \frac{h}{L_0} \quad \text{WHEN: } \frac{h}{L_0} = 0.12$$

 SPECIMEN PLOTTED:
 ○ Be BRUSH & KAWECKI
 △
 □

FIGURE 3

461510

K&E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

LF/L_0

FIGURE 4

BARREL: .30 SMOOTHBORE #2 DATE: 2/5/81

POWDER: 1MR 3031

PROJECTILE: Be 76-001319A

WT: 1.99 gm.

MATL: Be

P_0 : 1.85

FIGURE 7

461510

K&S 10 X 10 TO THE CENTIMETER 18 X .75 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

LOCK TIME (ms) 0 - SPARK 4

FIGURE 8

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