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AECD-3852

METALLURGY AND CERAMICS

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UNITED STATES ATOMIC ENERGY COMMISSION

EXTRUSION AT REVERE COPPER AND BRASS,
INC., MARCH 1, 1949

By
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EXTRUSION AT REVERE COPPER AND BRASS, INC., MARCH 1, 1949

By S. V. Arnold

In order to produce several sections of beryllium from which 3.018" squares 40" in length could be machined, six sound 8.0" diameter billets and three trial billets containing casting defects were extruded on March 1, 1949, at the Detroit plant of Revere Copper and Brass, Inc., using their #218 press of 2000-ton capacity.

All billets (except #30) were provided with heavier 0.180" thick cans fashioned from tubular, gas-welded blanks the forward ends of which had been spun to the proper conical contour and closed by welding in steel discs. This procedure was suggested by Dr. A. R. Kaufmann to alleviate spinning difficulties and obviate the circumferential weld heretofore present behind the conical portion of the can. Some trouble was experienced in cold spinning this heavier metal, however. All cans were plated with 0.004" - 0.006" copper. Introductory steel "cones" were of standard design (60° incl. angle $\times$ 5 $\frac{5}{8}$ ID). Billet #30 was similarly canned with a jacket of #11 gage steel as by former practice.

Billets were heated in graphite containers to extrusion temperatures ranging from 1680° to 1840°F. Steel dies to our Dwg. 1626-3 were used with good life considering the exposure time and surface temperature. A 30" long guide tube incorporated in the die head was used throughout with excellent results.

The first trial billet, #33, was pushed at 1840°F at a ram travel speed of 1.05"/sec. The can parted at the leading end and the 48" long section was cracked transversely 22" from the front. Examination of the cone showed the press to be concentric within $\frac{3}{16}$ ", a considerable improvement over the last time.

A second trial billet, #802, at 1830°F was extruded at a ram travel of 1.00"/sec. into a good section.

Billet #812, extruded at 1830°F and 1.00"/sec., was cracked at one point 30" from the front of the 46" length.

Billet #79 was cooled to 1740°F and extruded at a ram travel of 0.50"/sec. The rear portion broke into a series of transverse ruptures similar to those of preceding sections but at intervals of about an inch.

In the hope that extrusion at lower temperatures would improve matters, the next furnace charge was heated to approximately 1700°F container temperature.

Billet #77 was extruded at 1660°F and 0.50"/sec. ram travel into a good section with ruptures confined to the extreme rear portion.

Billet #58 was fitted with a mild steel plate $\frac{3}{8}$ " thick immediately preceding the cone. This billet at 1680°F and 0.55"/sec. ram travel produced 40" of apparently sound metal followed by 12" of snaked material. The plate served to prevent most of the splitting at the head of the extrusion and did not increase starting pressure. Some "sucking through" of the plate occurred in the initial stages of extrusion so that corners of the section were impaired slightly but not enough to prevent machining to size.

Billet #59 canned by standard practice and extruded at 1710°F and 0.50"/sec. ram travel ruptured badly over its rear portion.

Billet #45 equipped with the $\frac{3}{8}$ " thick plate (as billet #58) was extruded at 1700°F and about 0.5"/sec. ram travel. Some minor "sucking through" of the plate was noted in this instance also. The last 12 inches of the section broke up badly as before.

Billet #30 canned similarly, but with #11 gage steel instead of the $\frac{3}{16}$ " thickness on other billets, was extruded at 1710°F and 1.00"/sec. ram travel speed. All but the first 12 inches were ruptured. The spacing of the ruptures was slightly greater than usual and the jacket was parted more in accordance with the underlying beryllium, which in prior extrusions had failed without necessarily breaking the adjacent jacket.

Discussion

The ruptures were of a type observed previously on sections extruded at low reduction where peripheral friction retards adjacent metal to an extent that more central metal could be expelled with greater ease were it not for the restriction of the section itself. This restraining mechanism places the surface of the section in tension which initiates transverse rupture as the metal leaves the die. This rupture proceeds inward relieving the restraint and momentarily allowing the center to advance further than the surface metal. This relative motion implemented by external friction causes the outer metal to peel away from the center until internal forces within the billet return toward normal. Since the extruding section soon carries the rupture to a point where its relief can no longer affect the conditions maintaining at the orifice, the stresses may accumulate again causing successive ruptures usually referred to as "snaking."

Although the mechanism which caused the ruptures in the extruded sections seems reasonably clear, it is less apparent why fracture should begin after extrusion of a section had proceeded satisfactorily over a considerable portion of the billet, or why single fractures rather than a series sometimes occurred. Presumably borderline conditions maintained at best so that minor deviations would cause rupture.

It has been suggested that a heavier can would protect the beryllium from the severe surface stresses, and also that a heavier copper plate on the exterior of the can would decrease the surface friction to the same effect. These measures are not held as preventive solutions by themselves. Such partial inspection of macroetched transverse sections as has been completed shows that a moderately fine structure is developed even at the center of these heavy sections. At the forward end of these pieces, where reduction was much less than that existing over the major portion of the billet, no transverse rupturing occurred and indeed rupture did not take place in any of these extrusions until full reduction had been in effect for a considerable length. Intergranular separation was observed at the corners of some, but not all, sections, nor necessarily on all corners of a specific section. The fact that such separation occurred at or within the die orifice is established by noting that the separations are present in equal prevalence and unaltered condition on either side of a transverse rupture (which ruptures have already been allocated to the exit side of the die orifice). Actually it seems that these separations formed somewhat within the orifice and indicate that the corners, although they did fill completely, were under very little compression so that grains could come apart in a longitudinal direction.

In past experiments more pronounced concavity of similar shapes or a small reduction ratio has resulted in producing sections which did not fill the corner extremities. When the unsupported corner metal is stressed in tension by the tendency of the less restrained center to extrude more readily intergranular separation at the corners or other difficulties arise. If this corner metal were under a compression comparable to that at other portions of the die periphery, presence of tensional forces would be much less likely to cause rupture. It is proposed on the basis of this preliminary analysis (1) to direct more metal toward the corners in an effort to equalize peripheral compression and (2) to alleviate friction at the corners in order to decrease the differential in metal striction between these points and the billet interior. These objectives may be attempted by altering present approach contours and by varying the width of the land so that friction at the corners is lessened.

Another method of moderating the relative differentials would be to effect a larger reduction by using billets of greater diameter. Extruding the subject section with 10" D. billets (from a 10.5" I.D. container) would give a 6:1 reduction ratio and require about $\frac{1}{3}$ more pressure. If other sections of this size are to be required in the future, the problem of producing billets for them should be attacked now.

Extrusion Data Obtained March 1, 1949
Revere Copper & Brass, Inc., Detroit, Michigan

(All Sections Extruded Through Concave Square Die, Dwg. 1626-3)

Billet*	Condition†	Temperature	Ram Travel Speed (inch/second)	Water Pressure‡	Comments
33	Cracked	1840°F	1.05	3500 psi	Single crack 22" from front, remainder, OK.
802	Cracked	1830°F	1.00	3100 psi	Good section.
812	Sound	1830°F	1.00	2650 psi	Single crack 30" from front, remainder OK.
79	Sound	1740°F	.50	3300 psi	
77	Sound	1660°F	.50	3600 psi	Good section, snaked at rear.
58	Sound	1680°F	.55	3600 psi	Last 12" snaked, $\frac{3}{8}$ " plate before cone.
59	Sound	1710°F	.50	3500 psi	Rear portion badly snaked.
45	Sound	1700°F	.50	3700 psi	Last 12" snaked, $\frac{3}{8}$ " plate before cone.
30	Cracked	1710°F	1.05	3700 psi	Thinner #11 gage can, all but first 12" snaked.

*All billets, except where noted otherwise, were within $\frac{3}{16}$ " thick mild steel cans, plated on the exterior with .004-.006" copper and fitted with introductory steel cones of 60° included angle.

†Billet condition as ascertained by radiographic inspection.

‡Pump pressure limit set at 5000 psi.