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HOT WORKABILITY OF ALPHA BRASSES

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Hot workability of alpha brasses

Uranium additions shown to have beneficial effect in the presence of lead and bismuth

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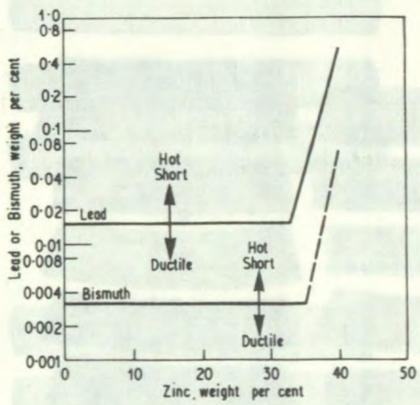
Both lead and bismuth have a deleterious effect on the hot working properties of alpha brasses. The work reported in this article shows that the element uranium, when present in the alloy in such proportions as to form stable high melting point intermetallic compounds with all of the bismuth or lead, is a highly effective agent in removing the characteristic hot shortness in hot-rolled contaminated alpha brass. It is suggested that melt treatment by uranium may thus afford considerable production economies in terms of scrap utilization, casting shop practice, hot fabrication, etc. The principle may be extended to other alloys susceptible to impurity effects during hot working, and, indeed, to other problems where the fixation of one constituent is desirable for any reason. This is a condensed version of a report issued by the Department of Mines and Technical Surveys, Ottawa, Canada. The authors are, respectively, at the Canadian Uranium Research Foundation and the Non-Ferrous Section of the Department of Mines and Technical Surveys

MALLEABILITY of metals and alloys at high temperature is occasionally seriously reduced by contamination with certain elements of Groups IVB, VB and VIB of the Periodic Table. Such impurities, injurious at fractions of 1 per cent, are generally insoluble in the base material, and consequently appear at grain boundaries in the cast bloom or slab either in the elemental or combined form. At hot working temperatures, they gave rise to a brittle film or a liquid phase, which, under the action of deformation stresses, destroys the high temperature cohesion of the grains and produces the low ductility characteristic known as hot shortness.

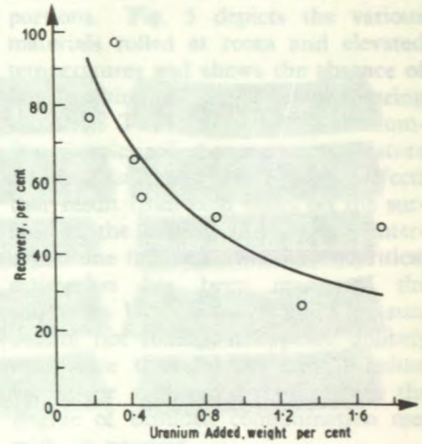
The avoidance of such failures can be achieved by invoking a fundamental change in fabrication procedure (for example, extrusion or cold rolling with intermediate annealing instead of hot rolling), but this is generally more costly. The more attractive way of suppressing hot shortness is by treating the molten metal to eliminate, or render harmless, the impurity concerned. In practice, the removal of such elements as oxygen, carbon, sulphur and, to a lesser extent, silicon and nitrogen, from molten metals has become an integral part of metal treatment for many non-ferrous alloys.

These elements are either oxidized out of the molten metal or rendered inactive by combination with another element added to the bath.

Since it is not possible in many cases to oxidize preferentially other deleterious contaminants (germanium, tin, lead, arsenic, antimony, bismuth, selenium and tellurium), their fixation by the highly reactive and insoluble element uranium has been considered as a means of redeeming the hot working characteristics of the base material. In theory, two conditions must be satisfied for this technique to be successful. First, the intermetallic compound forming tendency between the uranium and the contaminant should



Above: Fig. 1—Limiting lead and bismuth contents for successful hot rolling of brasses (after Baldwin)



Above right: Fig. 2—Relationship between recovery of uranium and amount added to alpha brass

Below: Fig. 3—Effect of uranium on the cracking of hot rolled 70 : 30 brass containing lead. Rolling reduction 50 per cent in one pass at temperatures shown below

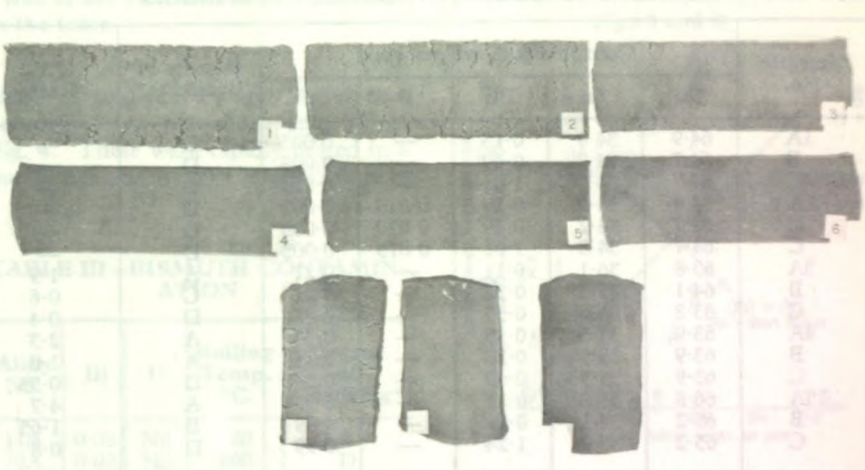


TABLE I—URANIUM ADDITIONS TO 70:30 BRASS

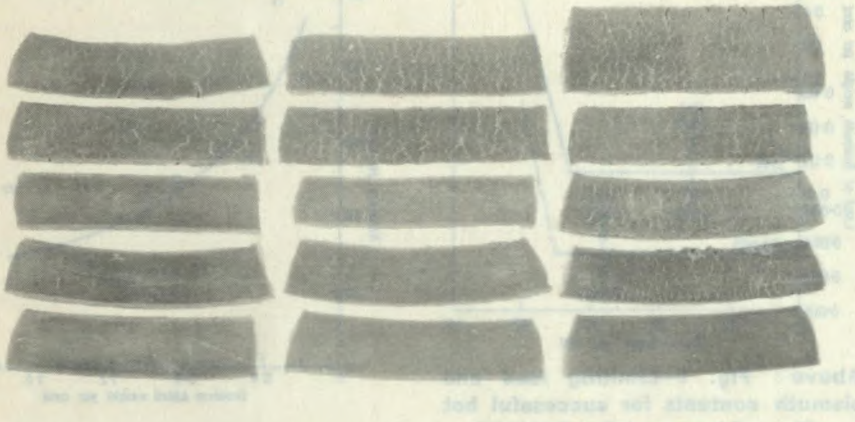
Sample No.	Composition, wt per cent				Rolling Temperature °C	Degree of Cracking*	U/Pb Ratio
	Cu	Zn	Pb	U			
1	72·7	27·0	0·06	—	600	D	—
2	72·7	27·0	0·06	—	725	D	—
3	72·7	27·0	0·06	—	800	C	—
4	72·7	27·0	0·06	0·40	600	A	6·7
5	72·7	27·0	0·06	0·40	725	A	6·7
6	72·7	27·0	0·06	0·40	800	A	6·7
7	69·2	30·6	0·07	—	750	D	—
8	69·2	30·6	0·10	0·42	750	A	4·2
9	69·2	30·6	0·19	0·42	750	A	2·2

*A — crack-free B — fine cracking of rolled surface C — few cracks, mostly at edges D — massive cracking be as great as, or greater than, the reactivity of uranium toward other components of the molten bath. Secondly, the uranium compounds formed should in no way restrict the normal hot workability of the alloy.

The efficacy of malleablization treatment by uranium has been investigated in copper- and nickel-base alloys deliberately contaminated with those elements particularly deleterious to them. Only that part of the work concerned with the remedial effect of uranium on the hot shortness caused by the presence of lead and bismuth in alpha brass is considered in this article.

Lead and bismuth are both extremely harmful to the hot working properties of brasses and deoxidized coppers. The upper limit for lead, beyond which successful hot rolling becomes difficult, is variously reported as lying between 0·01 and 0·02 per cent for alpha alloys, though it has been suggested that under controlled conditions the maximum permissible lead content in 70:30 brass may be increased to 0·025 per cent for hot rolling and 0·05 per cent for extrusion. Bismuth in amounts exceeding 0·003 per cent is known to be deleterious in hot rolling alpha brasses, whereas 0·01 per cent can be tolerated in the 60:40 alpha-beta alloy. The effect of alloy composition on impurity limits is illustrated in Fig. 1 and shows the increase in tolerance for both lead and bismuth as the amount of beta phase increases. Although the effect of rolling temperature on tolerances for lead and bismuth is not well documented, it is generally acknowledged that higher working temperatures produce better results with contaminated alloys.

In practice, material contaminated in excess of the above limits is either remelted or may be relegated to cold rolling, since tolerable impurity limits are thereby increased by a factor of about ten. It should be noted, however, that the mechanical properties of the cold rolled product may be substantially reduced, particularly where bismuth is the contaminant.



A B C

Fig. 4—Effect of phosphorus de-oxidation and uranium: lead ratio on hot cracking during rolling of leaded 65 : 35 brass. Rolling temperature 750°C, 50 per cent reduction in thickness in one pass

TABLE II—URANIUM IN LEADED L5 : 35 BRASS

Sample No.	Composition, wt per cent					Degree of Cracking*	U/Pb Ratio
	Cu	Zn	Pb	P	U		
1A	64·9	34·9	0·13	—	0·003	D	—
B	64·7	34·2	0·49	—	0·003	D	—
C	64·7	34·8	1·01	—	0·003	D	—
2A	64·9	34·9	0·13	0·013	0·003	D	—
B	64·7	34·2	0·49	0·010	0·003	D	—
C	64·7	34·8	1·01	0·015	0·003	D	—
3A	63·8	36·1	0·11	—	0·21	A	1·9
B	64·1	35·6	0·32	—	0·21	C	0·6
C	63·8	35·6	0·55	—	0·21	D	0·4
4A	63·9	35·5	0·15	—	0·34	A	2·3
B	63·9	35·5	0·35	—	0·34	A	1·0
C	63·9	35·5	0·62	—	0·34	D	0·55
5A	66·8	33·0	0·21	—	0·99	A	4·7
B	65·2	34·1	0·6	—	0·99	B	1·65
C	65·2	33·0	1·24	—	0·99	D	0·8

*A — crack-free B — fine cracking of rolled surface C — few cracks, mostly at edges D — massive cracking

In this Table, Group 1 samples are those in the top row of Fig 4, Group 2 the next row below, and so on.

Of the several reported attempts made to negate the effect of lead on hot malleability and reduced high temperature ductility in different alloy systems, calcium, chromium, zirconium, cerium, and boron, have all been mentioned as effective bath additions.

Lithium has been shown to be effective in removing the hot cracking associated with bismuth.

Uranium is known to form stable intermetallic compounds with both lead and bismuth and is at present receiving attention as a scavenger and malleablizer in non-ferrous alloys.

In the work reported here, 150 lb melts of 70 : 30 and 65 : 35 copper-zinc alloys containing various amounts of uranium and lead or bismuth were made in silicon carbide (Tercod) crucibles in a lift coil induction furnace. No melt cover or fluxing agents were used. Additions of pure lead, or pure bismuth, and uranium were made 1 min before pouring at 1,020° to 1,050°C into A.S.T.M. keel block test bar moulds in green sand. Uranium was added as a 75 : 25 copper-uranium eutectic alloy. Recoveries of between 26 to 97 per cent of the contained uranium were obtained, dependent on the amount added, as shown in Fig. 2. No deoxidant was employed, unless otherwise noted. Autoradiographs of several uranium-bearing castings were taken to check the uniform dispersion of uranium in the metal and the freedom from inclusions of uranium oxide.

Sections, 4 in by 1½ in by 1 in, cut from the cast keel blocks, were soaked at the rolling temperatures indicated for 30 min in an electric muffle furnace. They were then reduced 50 per cent in thickness in one pass on an 18 in reversing mill running dry at 200 ft/min. After air cooling, the rolled samples were then examined for evidence of edge cracking and tranverse intergranular rupture. No attempts have been made to estimate hot malleability by tensile, torsional, or forging data as these tests have limitations with respect to the application of their results to rolling practice.

The hot-rolled samples of 70 : 30 and 65 : 35 alpha brasses are illustrated with the pertinent fabrication and composition data in Figs. 3, 4 and 5. The cracking observed was noted to be of the type normally associated with grain boundary rupture and has been classified into four degrees of severity to assist interpretation of the photographs. These are:

(A) Crack-free.

(B) Fine cracks extending across the rolled surfaces.

(C) Small number of gross cracks at edge.

(D) Massive cracking, originating at

edges but extending across the rolled surfaces.

It is probable that these arbitrary groups are different stages of the same process of failure and that the malleablizing effect of uranium evident from these tests acts in such a way as to increase the level of hot reduction which can be sustained before grain boundaries begin to rupture.

Effect of Lead

Since it has been established that hot shortness and permissible degree of hot reduction are related differently for different alloys, the relationship between uranium and lead concentrations and cracking, given in Fig. 6, can only be said to be applicable to the conditions of that particular run of experiments, viz., 50 per cent reduction of alpha brass in one pass at 750°C (1,380°F).

With this proviso in mind, it is seen that at U : Pb ratios equal to or greater than unity, lead-contaminated brasses have responded to malleablization treatment by uranium, and it has been possible to hot roll successfully uranium-treated alloys which otherwise would have been completely broken up. It will be appreciated that the critical ratio of 1 : 0 has been chosen more for the convenience of a reference point rather than because it is an accurately established value of significance.

To examine the effect of uranium, lead, and combinations of both on cold working, test pieces of the alloys tabulated in Fig. 4 were cold rolled from the as-cast condition in stages of 5 per cent reduction without any intermediate annealing. All samples commenced edge cracking at around 35 to 40 per cent reduction in thickness, with no readily apparent differences in behaviour due to addition elements. A cursory examination of the fire-cracking susceptibility of the cold worked materials was carried out using sound pieces of cold-rolled plate (50 per cent reduced) from alloys 1A and 3A of Fig. 4. These were rapidly heated in a muffle furnace to 650°C (1,200°F), held for 1 hr, then water-quenched. There were no visible surface cracks on the planar surfaces of either specimen before or after this heat-treatment. However, the possible existence of micro-cracks, detectable by bend testing or by further rolling, was not investigated. It is expected that to the extent that fire-cracking is caused by lead, it could be removed by uranium additions to the alloy.

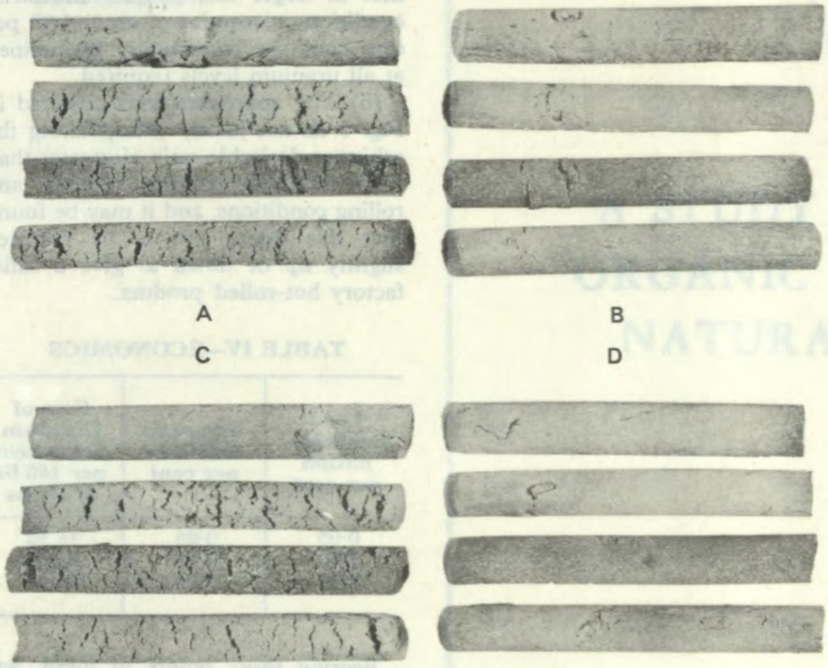


Fig. 5—Edge views of rolled specimens of bismuth-contaminated 70 : 30 brass. Groups A and C are untreated, while Groups B and D are corresponding alloys after uranium additions. Rolling reduction was 50 per cent in one pass at temperatures shown in the table

TABLE III—BISMUTH CONTAMINATION

Alloy No.	Bi	U	Rolling Temp. °C	Degree of Cracking*
11A	0·02	Nil	20	A
12A	0·02	Nil	600	D
13A	0·02	Nil	700	D
14A	0·02	Nil	800	D
11B	0·02	0·09	20	A
12B	0·02	0·09	600	A
13B	0·02	0·09	700	A
14B	0·02	0·09	800	A
11C	0·07	Nil	20	A
12C	0·07	Nil	600	D
13C	0·07	Nil	700	D
14C	0·07	Nil	800	D
11D	0·07	0·36	20	A
12D	0·07	0·36	600	A
13D	0·07	0·36	700	A
14D	0·07	0·36	800	A

*A — crack-free
B — fine cracking of rolled surface
C — few cracks, mostly at edges
D — massive cracking

In Fig. 5, No. 11 is the top row of each group, No. 12 the next below and so on.

Effect of Bismuth

Bismuth was added to two heats of 70 : 30 brass, each heat being split into uranium - free and uranium - treated portions. Fig. 5 depicts the various materials rolled at room and elevated temperatures and shows the absence of hot cracking in the uranium-bearing samples. The latter, and the uranium-free samples rolled at room temperature do, in fact, show some edge defects that result from cold shuts on the surface of the casting and are not intercrystalline failures. Although no critical estimation has been made of the minimum U : Bi ratio required for successful hot rolling, it appears unlikely that more than 0·1 per cent uranium would be required to counteract the degree of bismuth contamination met with in practice.

With regard to the economics of melt treatment to fix impurities in the case of alpha brass contaminated by lead, for example, the producer will require to know how much uranium to add, taking recoveries into account, to malleablize the alloy, and whether this amount can be justified by the operational saving of hot rolling as opposed to cold rolling. It will be appreciated that the results described here only illustrate an effect and should not be used quantitatively to calculate the increased cost of malleablization for two reasons, viz.:

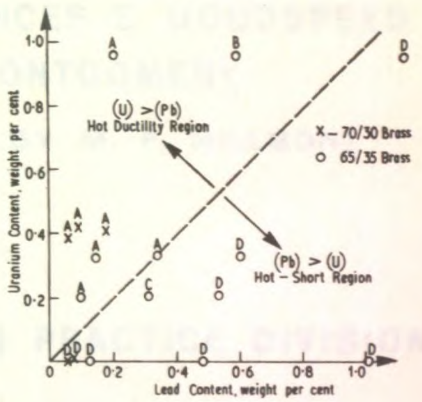


Fig. 6—Relationship between uranium and lead contents with respect to rolling performance (using data from Figs 3 and 4)

(a) The recovery figures shown in Fig. 2 will apply only to the experimental melting conditions, namely, relatively small melts in an induction

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unit with no melt cover. It is expected that in larger melts under industrial conditions recoveries of around 90 per cent could be consistently maintained at all uranium levels required.

(b) The approximations involved in Fig. 6 do not justify extrapolating the arbitrary desirable ratio of greater than 1 to industrial melting, casting and rolling conditions, and it may be found that this figure has to be adjusted slightly up or down to give a satisfactory hot-rolled product.

TABLE IV—ECONOMICS

Lead Contamination per cent	Uranium Addition per cent	Cost of Uranium Treatment per 100 lb of Brass
0·05	0·06	1s 3d
0·10	0·13	2s 6d
0·50	0·63	13s 4d

Bearing these points in mind, and assuming a requirement of 1·25 : 1 with 100 per cent recovery, the cost per 100 lb of brass may be calculated. Some specimen figures are shown in Table IV using a price for uranium of £1 per lb. This latter is an arbitrary value for depleted uranium and does not take into account the cost involved in making a suitable copper-uranium master alloy.

Thus, since the current price of rolled brass sheet is £8 6s 8d to £8 16s 0d for 100 lb, depending on the alloy, it will be seen that the additional cost of uranium treatment is not excessive and might be readily recovered by the use of cheaper scrap and the more efficient casting and rolling processes coincident with hot working.