The characteristics of high strength and lead-free machinable α-β duplex phase brass Cu-40Zn-Cr-Fe-Sn-Bi alloy

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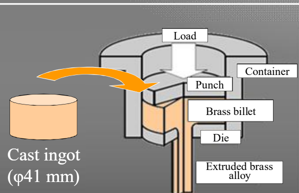
Introduction

Brass alloys are used for pipes, valves, and fittings in systems that transport water and other aqueous fluids because of their excellent corrosion resistance. Pb at levels of 2-5 mass% is also added to traditional brasses to improve their machinability. However, addition of Pb to these materials is a significant, severe hazard to the environment and human health. Thus, material designs must consider safety according to the regulations of the Restriction of Hazardous Substance (RoHS) and Waste Electrical and Electronic Equipment (WEEE) Directives. **New high-strength, Pb-free machinable α-β duplex brass alloys with dispersed Bi particles** were produced using a casting and extrusion process. The effects of Bi dispersoids on the mechanical properties and machinability of the extruded specimens were investigated.

Materials and methods

Alloys	Sn	Pb	Zn	Fe	Cr	Bi	Cu	Vickers micro hardness /Hv0.025 α-phase	β-phase
CAST1	0.59	-0.005	40.86	0.22	0.34	---	Bal.	110	170
CAST2	0.595	-0.005	40.81	0.229	0.256	0.994	Bal.	108	165
CAST3	0.6	-0.005	40.64	0.23	0.26	2.02	Bal.	111	168
CAST4	0.578	-0.005	40.83	0.219	0.22	2.85	Bal.	112	169

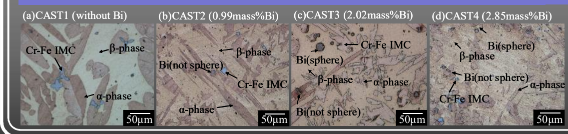
Cu-40Zn alloy
α-phase: 100 Hv
β-phase: 144 Hv



Hot extrusion

2000 kN hydraulic direct press machin
Extrusion speed: 3 mm/s
Diameter of extruded specimen: 7 mm
Pre-heading conditions: 923 K for 180 s in Ar gas atmosphere

The extruded CAST1-4 specimens are denoted as EXT1-4 in this study.

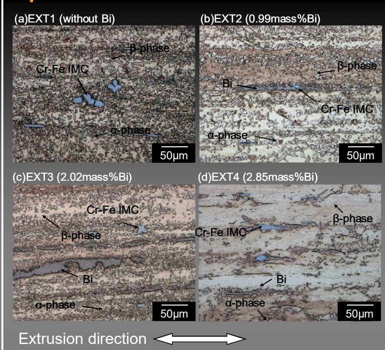


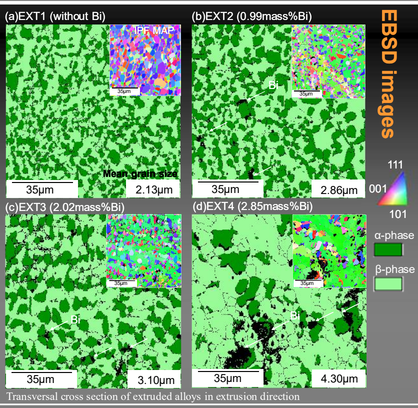
Optical microstructures

Bi in the β-phase formed spherical particles; however, irregularly-shaped Bi particles formed in or around the α-phase. The difference in surface tension between Bi particles and the matrix decreased as the elemental Zn content in the matrix increased, and spherical Bi particles then formed in the β-phase which contained higher elemental Zn concentration than the α-phase.

Microstructural and mechanical properties of extruded specimens

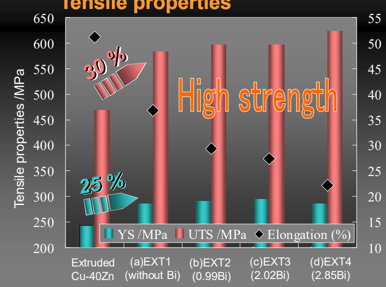
Optical microstructures





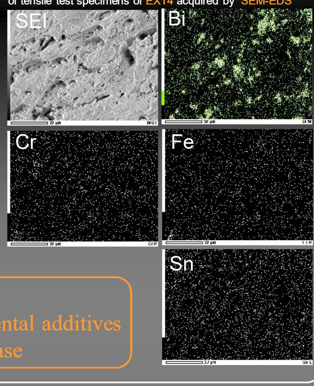
Transversal cross section of extruded alloys in extrusion direction

Tensile properties



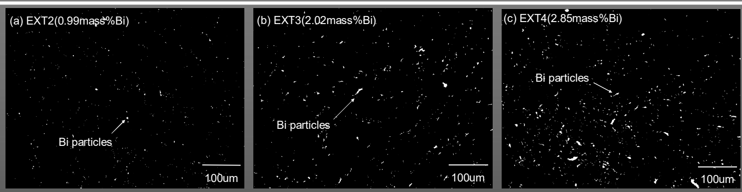
Fractured surfaces

of tensile test specimens of EXT4 acquired by SEM-EDS



The main strengthening mechanism;
- Solid solution strengthening with elemental additives
- Increased area present as the hard β-phase

Relationship between distribution of Bi particles and Machinability

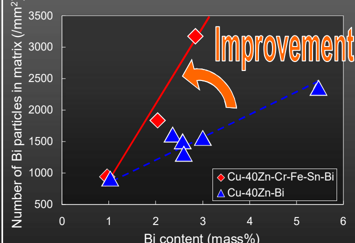


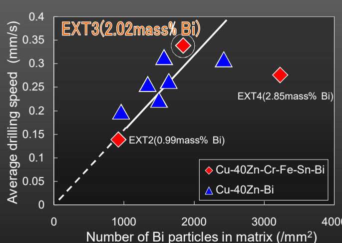
Transversal cross section of extruded alloys in extrusion direction

Back scattered electron images

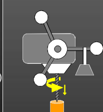
of EXT2 (0.99mass% Bi) (a), EXT3 (2.02mass% Bi) (b), and EXT4 (2.85mass% Bi) (c) by SEM.

Matrix
Bi particles





Machinability test

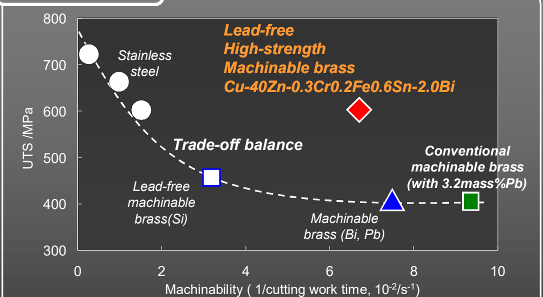


The drilling time to make a hole with a 5 mm depth was measured; after repeating this drilling test 10 times, the average drilling speed was used as a machinability parameter for the extruded specimens.

- Rotating speed, N 700 [rpm]
- Cutting speed, V 164.0 [mm/s]
- Axial thrust load 100 [N] (10 [kgf])
- Drill diameter, D 4.5 [mm]
- Drill helix angle 30 [degree]
- Drill point angle 120 [degree]

The extruded Cu-40Zn-Cr-Fe-Sn-Bi alloys exhibited a better dispersion of Bi particles than that of the extruded Cu-40Zn-Bi alloys. Bi morphology in an extruded specimen depends significantly on that of the cast alloy. As above mentioned for the cast alloys, because spherical Bi particles are formed in the β-phase domains, these in β-rich brass become finer than those in α-rich brass.

Conclusion



The extruded Cu-40Zn-Cr-Fe-Sn-Bi alloys consisted of α-β duplex phases containing the fine, uniform Cr-Fe IMCs and Bi particles. Average YS and UTS of the extruded Cu-40Zn-Cr-Fe-Sn-Bi alloys were 288 MPa and 601 MPa, respectively. The machinability of the extruded Cu-40Zn-Cr-Fe-Sn-Bi also maintained 75 % of the machinability of a Cu-40Zn-Pb alloy; thus, the extruded Cu-40Zn-Cr-Fe-Sn-Bi deviated from the traditionally observed trade-off between hardness and machinability in conventional machinable brass materials.