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Letter to the Editors

A model for the prediction of the corrosion of steels in flowing liquid lead alloys

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Abstract

The values of the solubility and diffusion coefficients of iron in the eutectic liquid alloy Pb–17Li to be used in a corrosion model of Balbaud-Célérier and Barbier should be taken from the corrosion data of Borgstedt and Röhrig. These data are consistent with the Einstein–Sutherland equation and values for diffusion coefficients of metal atoms in liquid metal solutes. They are lose to those in pure lead or in the eutectic Pb–Bi alloy, and the model generates correction corrosion rates with their application. © 2002 Elsevier Science B.V. All rights reserved.

Recently Balbaud-Célérier and Barbier reported on their studies on a corrosion model applicable for corrosion of steels in lead and its alloys with bismuth and lithium [1]. This model seems to be a useful tool to estimate corrosion rates for different geometries of flows. However, the authors of [1] used values of a solubility of iron and also a diffusion coefficient at 773 K (500 °C) in the discussion of corrosion of the martensitic steel 1.4919 in the Pb–17Li alloy, which differ by orders of magnitude from those in lead. Borgstedt and Röhrig found a saturation concentration of iron in the alloy of $c_s^{Fe} = 0.044$ wppm in accordance with their corrosion data [2], and this value is close to the saturation concentration of iron in unalloyed lead published in the literature. Contrary to this saturation concentration, a much higher value of the saturation concentration, $c_s^{Fe} = 47$ wppm, was deduced from a solubility equation established by Sample, Barker and Coen [3,4], and this value was used by [1]:

$$\log c_s^{Fe}[\text{wppm}] = 2.524 - 655.0 \cdot T^{-1}\ [\text{K}^{-1}]. \quad (1)$$

In the model of [2], such a high solubility of iron in the Pb–17Li alloy would cause a catastrophical corrosion at 773 K. The argument of [1] that the higher solubility values of [3,4] were supported by concentration values which were found in the loop of [1] is a doubtful one, since undissolved iron may migrate through the loop piping even in the presence of magnetic traps due to supersaturation in the cooler pipes and contribute to the analytical results. The solubility of iron in Pb–17Li alloy should not strongly be influenced by the solubility in lithium, since the alloy has to be considered as a quasi binary alloy of the type Pb–LiPb [5]. But even in pure lithium, the solubility at 773 K should be much lower than 47 wppm [6]; it is at a level of 10^{-2} wppm or lower, if lithium does not contain larger amounts of nitrogen.

The corrosion rates of martensitic steel in Pb–17Li alloy elaborated by various laboratories listed in [1] are quite close together; they are proportional to the solubility and the diffusion coefficient in power 0.64–0.74. That means, the product of the solubility and the diffusion coefficient is constant. If a too high solubility is introduced into one of these models, a too low diffusion coefficient must be assumed.

The model of [2] used a diffusion coefficient close to that of iron in lead, which is $D_{Fe(Pb–Li)} = 2.5 \times 10^{-9}$ $m^2\,s^{-1}$ at 773 K [2]. A diffusion coefficient in the order of $D_{Fe(Pb–Li)} = 10^{-14}$ $m^2\,s^{-1}$ was preferred by [1], and this value is significantly differing from that in lead. The authors of [1] accept, however, a diffusion coefficient of

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iron in lead bismuth alloy very similar to that in pure lead. It is not understandable that the diffusion coefficient should be changed by a factor of 10^{-5} by the addition of the alloying element lithium.

The diffusion of metal atoms in liquid metal solvents can be calculated using the Einstein–Sutherland equation

$$D_{\mathrm{M}} = kT/4\mu_{\mathrm{M}} r_{\mathrm{M}}^{\mathrm{d}} \pi \qquad (2)$$

with k as the Boltzmann constant, $r_{\mathrm{M}}^{\mathrm{d}}$ the radius of the diffusing metal particle (atom or solvated atom) and μ_{M} the viscosity of the solvent metal. Guminski has shown in [7] that the diffusion coefficients of dissolved metals in liquid metal solvents are within one order of magnitude at a given temperature; large differences depending on the solvent metal cannot be expected on the basis of the Einstein–Sutherland equation. Solvation of Fe atoms by Li atoms is unlikely, since the Pb–17Li alloy is a quasi binary alloy of Pb–PbLi; that means that lithium certainly interacts much more with Pb than with Fe atoms.

Thus, a solubility of iron in Pb–17Li alloy higher by a factor of 10^3 has to be considered as questionable as well as a diffusion coefficient lower by a factor of 10^{-5}. The corrosion model of [1] would result in similar mass loss rates, if the authors would use the solubility value and the diffusion coefficient of [2].

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