DIFFUSION GALVANIZING OF BRASS

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Diffusion galvanizing of brasses (L-62, L-68, and LS-59-1) offers a means of producing zinc-rich diffused coatings whose microhardness is 3-4 times higher than that of a given brass. The wear resistance of surface coatings of this kind (measured against a hard steel disk under pressures of 30-450 g/mm² and at a circular speed of 1.2 m/sec) is 5-10 times higher than that of uncoated brasses.

When brass is used as a structural material in instrument making, it is often necessary to increase the hardness of certain parts to ensure high wear resistance. Mechanical methods of surface hardening are not very effective in this case: moreover, they cannot be applied to parts of irregular shape.

One of the possible solutions of this problem is the use of a chemithermal method of surface hardening by producing zinc-enriched surface layers on brass whose hardness sharply increases when its zinc content is raised to 60-70%. Although this increase in hardness is obtained at the expense of tensile strength and ductility, the formation of hard zinc-enriched surface layers on strong and ductile brass substrates could be used to increase the wear resistance of brass parts in the same way as carburizing, nitriding, cyaniding, and boriding are used on steel. As far as we know, the first extensive investigation of this problem was carried out by Prof. Gebalski [1].

Microhardness of the Substrate Material (α-brass) and Surface Diffused Layers

<table>
<thead>
<tr>
<th>Test location</th>
<th>Minimum hardness, $H_{\mu}$ kg/mm²</th>
<th>Maximum hardness, $H_{\mu}$ kg/mm²</th>
<th>Modal value, $H_{\mu}$ kg/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate material</td>
<td>57--65</td>
<td>91--95</td>
<td>80--90</td>
</tr>
<tr>
<td>Inner zone</td>
<td>93--100</td>
<td>120--125</td>
<td>110--120</td>
</tr>
<tr>
<td>Outer zone</td>
<td>290--310</td>
<td>350--380</td>
<td>360--380</td>
</tr>
</tbody>
</table>

Fig. 1. Microstructure of a surface-diffused layer (x160).

The aim of this work was to study the diffusion galvanizing of brass and especially the properties of the resulting zinc-enriched surface layers.

The experiments were carried out on both single-phase α-brasses (L-68, LO-70-1) and two-phase (α+β)-brasses (L-62, LS-59-1) conforming to GOST. The experimental specimens were in the form of thin-walled (22-20 mm) tubes and 5 mm diameter rods. The diffusion galvanizing was done in two mixtures: 97% zinc powder + 3% ammonium chloride (mixture No. 1) and 50% zinc powder + 47.7% brick powder + 2.3% ammonium chloride (mixture No. 2).

Galvanizing tests were carried out at 340-360 and 380-415°C with holding times of 0.5, 1.0, and 2.0 hr. The results showed that preference should be given to mixture No. 2 and that the optimum galvanizing temperature and time are 380-415°C and 1-2 hr.

Irrespective of the galvanizing conditions and brass composition, the surface diffused layer consists of two zones. The inner zone adjacent to the substrate material is usually rather thin (10-30 μ), the outer zone being much thicker. Increasing the galvanizing temperature and time produces an increase in the diffused layer thickness, mostly as a result of the growth of the outer zone, which in our experiments was 30-100 μ thick; the outer zone (Fig. 1) consists of a zinc-rich solid solution (probably the γ-phase).

The mechanical properties of galvanized coatings were determined by microhardness measurements carried out on a PMT-3 tester using a 10 g load.

The results of a large number of tests on specimens of various brasses galvanized under various conditions showed that the microhardness of the outer zone is 3-4 times higher than that of the substrate material (see table). In addition, the strength of adhesion of the diffused layer to the substrate material was qualitatively estimated by...
bending 1.0-mm-thick strip specimens over a 2-mm-diameter mandrel. The first transverse cracks in the diffused layer appeared when the specimens were bent through about 15°, their number and size increasing with an increase in the bending angle. However, no separation of the diffused layer from the substrate material was observed in these tests.

The residual stresses in diffused layers were determined on thin (21.6/20 mm) ring specimens galvanized only on the outer surface by slitting them longitudinally and measuring the resulting increase in the diameter [2, 3]. Only the average circumferential residual stress in the diffused layer was determined from the formula

\[ \sigma_b = \frac{E^3 \alpha}{3D^4 t} \Delta D, \]

where \( E \) is the modulus of elasticity, \( \delta \) is the ring wall thickness, \( D \) is the mean diameter of the ring, \( \alpha \) is the stiffness coefficient, equal to 1.1, \( t \) is the diffused layer thickness and \( \Delta D \) is the change in ring diameter.

Irrespective of the brass composition and galvanizing conditions, only tensile residual stresses are produced in the diffused layers. The average of 12 residual stress measurements on specimens galvanized in mixture No. 1 was 6 kg/mm², the average of 14 measurements on specimens galvanized in mixture No. 2 being 4 kg/mm².

There are two reasons for the appearance of residual stresses in the surface diffused layers under consideration: 1) difference in the specific volumes of the zinc-rich diffused layer and the substrate material and 2) their different thermal expansion coefficients; the former produce compressive residual stresses and the latter are responsible for the appearance of tensile residual stresses.*

It should be concluded on the basis of our experimental data that the predominant part in producing residual stresses in diffused layers is played by the difference in the thermal expansion coefficient. Evidently this is because the compressive stresses are produced mainly at elevated temperatures and become markedly reduced as a result of relaxation.

Ordinary (ungalvanized) brasses with residual tensile stresses in their surface layers become, under certain conditions, susceptible to stress corrosion [2]. It was therefore interesting to determine the stress-corrosion susceptibility of zinc-rich diffused layers in the presence of residual stresses. No formation of surface cracks was observed in tests lasting 130 hr and carried out on galvanized L-62 and LO-70-1 brass ring specimens in two media usually employed in tests of this kind (vapors of a 28% ammonia solution and a 2% HgNO₃ + 2% HNO₃ solution). This indicated that the zinc-rich \( \gamma \)-phase is less susceptible to stress corrosion than \( \alpha \)-(\( \alpha + \beta \))- and \( \beta \)-brasses. In tests at relatively higher stresses (10–

* The specific gravity of the \( \alpha \)-brass (substrate material), which contains 32% Zn, is 8.6 g/cm³ and its thermal expansion coefficient at 20-100°C is \( 13 \times 10^{-6} \); the corresponding values for the \( \gamma \)-phase (diffused layer), which contains 64% Zn, being 7.7 g/cm³ and \( 22 \times 10^{-6} \) [4, 5].

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