STRUCTURE AND PHASE COMPOSITION OF TRANSITION ZONE IN TITANIUM—STAINLESS STEEL BIMETAL

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A survey of the work done on transition zones of titanium—steel bimetals [1-9] shows a lack of agreement on the structure and phase composition of the zones.

We investigated the structure of the transition zone of the titanium (VT6S)—steel (Kh18N10T) bimetal by different methods.

The titanium—stainless steel bimetal was produced by rolling in vacuum in the "170" rolling mill [10] at 950°C in two to three passes with a total reduction of 40-45%. The breakaway strength of the joined metals was 22-24 kg/mm^2. After annealing at 900°C for 1 h the strength of the joint dropped to 12-14 kg/mm^2.

The structure of the steel was revealed by electrolytic etching in a 10% aqueous solution of oxalic acid; the titanium was chemically etched in a reagent consisting of equal parts of nitric and hydrofluoric acids and glycerin. The microhardness of the zones was measured with the PMT-3 apparatus under a load of 20 g.

After rolling, dispersed titanium carbide and a zone of titanium of varying etchability with an elevated microhardness (H 458), consisting of a solid solution of iron in titanium, is formed at the interface (Fig. 1a).

After annealing at 1000°C a new structural component appears (Fig. 1b). Next to the steel is a fairly wide zone (10-12 μ) with veins of a second phase, followed by two narrow (1-2 μ) white layers differing slightly from each other in color, and then a gray zone (4-5 μ) with dispersed titanium carbide inclusions and separate inclusions of this same phase in titanium. The dispersed titanium carbides are located in the grain boundaries of the β solid solution of titanium; in the given case this region is widened as the result of the alloying of titanium with iron in the process of diffusion. The sharply defined boundaries on both sides and the high microhardness of the diffusion zones (H 750-800 for the white zone and H 580-700 for the gray zone and the islands of it in titanium) are the basis for the assumption that intermetallic compounds are formed at the titanium—steel interface during annealing. The hardness of these intermetallic layers matches that given in [11].

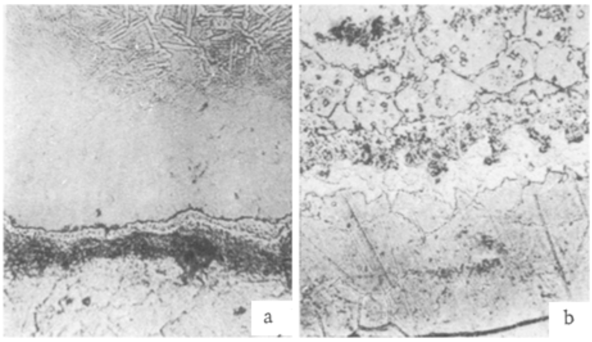

Fig. 1. Microstructure of interface in titanium—steel bimetal rolled at 950°C with 40% reduction (cross section, ×500). a) Original condition; b) annealed at 1000°C.

X-ray structural analysis of the surfaces of samples split along the light thin layers (on the steel side of the boundary zone) showed the presence of α and γ iron with slightly different parameters (apparently due to alloying elements in the steel) and the $TiFe_2$ compound. This compound remained after the thin white layer was ground off the surface.

Apart from iron and the $TiFe_2$ compound, at small diffraction angles we observed weak lines which do not belong to any of the well-known Ti—Fe compounds.

To determine the composition of the transition zone we used a new method – secondary ion–ion emission. This method makes it possible to determine the composition of the surface layer of a metal and the composition of the metal and impurities occurring in it. A diagram of the experimental apparatus is shown in Fig. 2.

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The beam of primary He^+ ions with energies of 4 keV, formed in the source 1 and passing through a system of three slits 5, bombards the surface of the microsection 2 of titanium—steel prepared in the plane of the bimetal perpendicular to the interface. The size of the ion beam was 1 × 10 mm and the ion current density was 10^{-7} A/mm^2.

The samples of the bimetal were placed in the chamber in such a way that the primary beam falling on the target completely covered the titanium—steel transition zone. The secondary ions knocked out of the surface by the primary ion beam were focused by a three-electrode electrostatic lens 3 on the inlet slit of the mass spectrometer 4. The secondary ions, separated by mass, were detected by an electron multiplier connected with an ÉMU-3 electrometric amplifier. During the experiment the target was subjected to a vacuum of 5 × 10^{-6} mm Hg by means of three DRN-50 mercury pumps.

The resolving power of the mass spectrometer under the given conditions was two to three masses in the range of mass numbers from 100 to 200.

After preparation of the bimetallic microsections they were etched, washed in distilled water, and placed in the chamber of the apparatus, in which a pressure of 5 × 10^{-6} mm Hg was attained in 25-30 min. Then we determined the mass spectrum of the secondary ions from the surface of the sample, which was at room temperature.

In the mass spectrum of the secondary emission from the interface of the bimetal there was a large group of positive and negative ions associated with the presence of a film of adsorbed gases on the surface of the sample ($H^\pm$, $H_2^\pm$, $C^\pm$, $CH^\pm$, $CH_2^\pm$ $N^\pm$, $O^\pm$, $OH^\pm$, $H_2O^\pm$, $C_2^\pm$, $C_2H^\pm$, $C_2H_2^\pm$, $[N_2^+ + CO^+]$, $O_2^\pm$). In addition there was a large number of positive ions associated with the presence of various impurities and chemical compounds on the surface and in the bulk of the titanium, steel and the transition zone.

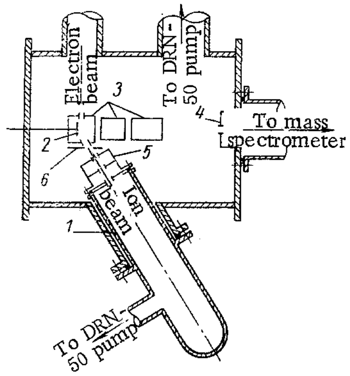

Fig. 2. Diagram of experimental apparatus.

Figure 3 shows the mass spectrum of positive secondary ion emission from two samples of titanium—steel at room temperature. Both samples were produced by rolling in vacuum at 950°C with 45% reduction; one of them (dashed line) was subjected to diffusion annealing at 1000°C for 2 h after rolling. The mass spectra coincided with each other except for mass numbers 148 (Ti_2Fe), 160 ($TiFe_2$), and 216 ($TiFe_3$), which are absent for the sample not annealed.

For the annealed sample the intensity of the TiC line is 1.7 times higher, and that of TiFe three times higher, than for the rolled sample.

The results of the secondary ion–ion emission study lead to the conclusion that during hot rolling carbon diffuses from the surface layers

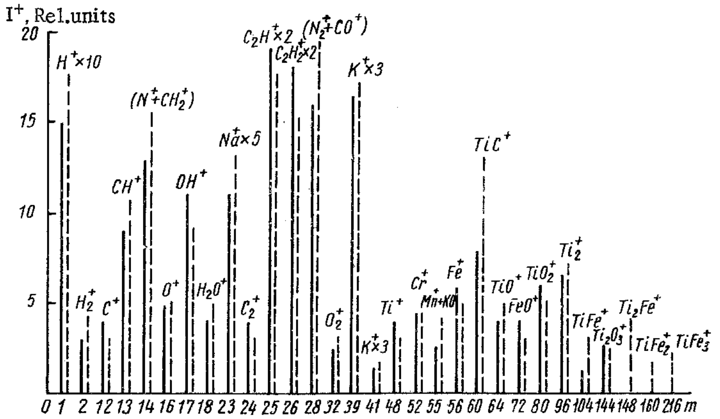

Fig. 3. Mass spectrum of positive secondary ion-ion emission from the interface of two titanium—steel samples. ——) Directly after rolling; ---) after rolling and annealing at 1000°C for 2 h.

of steel into titanium, and TiC is formed in the transition zone of the titanium—steel bimetal. The β solution and the intermetallic compound TiFe form as the result of interdiffusion of titanium and iron. The results obtained agree with the data in the literature [1-9].

During annealing the diffusion processes are more active and new phases are formed at the interface along with growth of the previously formed phases. The zone of the β solid solution of iron in titanium widens considerably. On the steel side this zone is followed by a zone consisting, apparently, of a mixture of Ti_2Fe and TiC. However, Ti_2Fe is unstable and during annealing can decompose into TiFe + β solid solution of titanium. Next come TiFe and $TiFe_2$, one after the other. The compound that is distinctly white ($TiFe_2$) forms a thin vein between layers and along the boundary of the crystals of the wide layer following them.

According to x-ray structural analysis, the wider layer adjoining the steel is a solid solution of alloying elements in α iron. The columnar structure of this layer is evidently due to phase recrystallization of γ into α iron [12]. The sharply defined boundary may be the result of the difference in the solubility of titanium in α and γ iron.

The $TiFe_3$ phase was not observed metallographically. It is possible that it is in the form of finely dispersed precipitates along the boundary of the crystals of the solid solution of α iron.

In the shear and breakaway tests the samples failed along the veins of the intermetallic phases TiFe and $TiFe_2$. This leads us to assume that the $TiFe_2$ and TiFe phases affect the brittleness of the joint in a series of bimetallic compositions.

CONCLUSIONS

Different physical methods were used to investigate the structure and composition of the diffusion zone at the interface of the titanium (VT6S)—steel (Kh18N10T) bimetal in relation to the rolling conditions and subsequent heat treatment.

The $TiFe_3$ phase was found in the transition zone by the direct secondary ion—ion emission method.

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