The service properties of hard alloy parts can be improved by suitably varying the distribution of cobalt over their cross section [1, 2]. Such parts are produced by a technique based on infiltrating molten cobalt into alloys in the fully sintered condition [2]. Now this infiltration process has so far received very little investigation. The only relevant data published in the literature up to now are concerned with the thermodynamics of migration of a liquid phase into hard alloys [3]. In this connection, the present work was undertaken with the aim of studying the kinetics of penetration of molten cobalt into hard alloys in the fully sintered condition.

Experiments were carried out on specimens, 5 × 8 × 35 mm in size, made in VK6 and VK32 (32 Co and 68 wt.% WC) alloys.* Metallographic examinations established that the porosity of the specimens did not exceed 0.2% and that the materials were free from graphite and γ1 phase. In addition, eutectic alloy (64 Co and 36 wt.% WC [4]) specimens of 0.9-cm³ volume were prepared. VK6 and VK32 alloy specimens were placed with their 5 × 8-mm faces against eutectic alloy specimens, after which they were introduced into a vacuum furnace with a residual pressure of 10⁻² mm Hg and heated at a rate of 45-50°C/min to 1370°C. At this temperature, the γ phase of the hard alloys and the eutectic alloy specimens were in a liquid state. The specimens were held in contact with the cobalt melt for 1.5, 3, 5, 8, 13, 18, and 25 min. The contact times were chosen so that the maximum depth of penetration of the cobalt melt into the specimens was less than 33-35 mm. In this way, conditions similar to those prevailing in the migration of liquid phase into a semiinfinite rod were measured. The specimens were then cooled, ground on their 8 × 35-mm faces, and examined metallographically under an MIM-8M microscope.

The quantitative distribution of cobalt along the specimen length was determined by the x-ray spectral technique, using a Mikroskan-5 apparatus. The cobalt contents of the specimens were found by comparing ratios of intensities of the tungsten and cobalt characteristic lines for the specimens with similar intensity ratios for reference standards. As reference standards, specimens of VK2, VK6, VK8, VK10, VK15, VK20, VK25, and VK32 alloys were used, the cobalt contents of which were determined by chemical analysis to 0.1 wt.%. To prevent alloy structure from affecting results of cobalt content determinations, intensities were recorded in a zone of 1.3-mm length at an electron probe width of 1 μ. Thus, averaged intensities were measured for the elements investigated. The intensity measurement zones were located on 8 × 35-mm faces along lines perpendicular to their longitudinal axes. On each such line, five recordings of intensities of the elements were made. Beginning at the point of contact between the specimen and the melt, the first 10 lines of measurements were located at distances of 0.5 mm from each other, while the subsequent lines were spaced out 1.0 mm apart. Absolute error in the cobalt content determinations did not exceed ±0.5 wt.% for the VK6-VK20 alloys and ±0.8 wt.% for the VK25 and VK32 alloys.

The results yielded by the x-ray spectral investigation of VK6 alloy specimens (Fig. 1) show that the distribution of cobalt along their lengths was described by almost linear plots. The highest binder metal content (32 wt.%) was found in the specimen layer in direct contact with the cobalt melt. This amount of γ

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* The letters VK denote WC + Co hard alloys, the figure following them representing their cobalt content. – Translator.
Fig. 1. Variation of cobalt content along specimen length (l): 1-7) times of contact with cobalt melt 1.5, 3, 5, 8, 13, 18, and 25 min, respectively.

Fig. 2. Variation of cobalt content with time of contact between specimens and melt: 1-4) in layers at distances of 1, 3, 5, and 7 mm from contact surface, respectively.

Fig. 3. Dependence of thickness (l) of layer of increased γ phase content on time (t) of contact with cobalt melt.

Fig. 4. Variation of rate of absorption of cobalt melt by VK6 hard alloy with contact time.

The phase in the specimen layer was attained after a holding period of 8 min, and then remained unchanged with subsequent increase in contact time (Fig. 2, curve 1). The layers at distances of 3, 5, and 7 mm from the surface contained less binder metal, but at holding times of 18 and 25 min their cobalt content, too, tended to rise to 32 wt.%. In experiments on the VK32 alloy, no molten cobalt penetration into specimens was observed. The experimental data obtained show that hard alloys possess a "limit of impregnation" with the liquid phase, which corresponds to a cobalt content of about 32 wt.%. The "limit of impregnation" with the liquid phase found for these alloys can be explained by considering the thermodynamics of the process.

It has been shown [3] that the change in isobaric-isothermal potential (ΔZ) brought about by a change in solid/solid interfacial contact area (ΔSS) for such a system is given by the expression

$$ΔZ = ΔSS σ_{sl} K,$$

where $σ_{sl}$ is the surface tension at the solid/liquid interface and K is a constant.

When the cobalt content of an alloy attains 32 wt.%, the amount of liquid phase is about 60 vol.%. Under such conditions, the particles have only point contacts and are thus almost completely separated by the liquid phase [5]. Because of this, when molten cobalt penetrates into such an alloy, we have $ΔSS = 0$ and $ΔZ = 0$, which means that a spontaneous increase in the amount of liquid phase in the alloy is impossible, and the process comes to an end.