THE EFFECT OF SMALL ADDITIONS OF DISPERSE ALUMINA INCLUSIONS ON SOME CHARACTERISTICS OF SINTERED NICKEL

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The need to investigate the influence of small amounts of disperse alumina inclusions (up to 5 vol. %) on the technological characteristics of sintered nickel was pointed out in [1].

The compositions studied in the present investigation contained 0, 0.5, 1, 2, 3, 4, and 5% Al$_2$O$_3$ (alumina contents are given in vol. % throughout this paper). Nickel powder containing various amounts of disperse alumina inclusions was obtained by the hydrogen reduction of nickel oxide mixed with alumina powder. The preparation of a mixture of nickel oxide with alumina powder, reduction, compacting, and sintering were performed under the same conditions and with the same starting materials as in [1]. The data plotted in the graphs for the compositions with 10% Al$_2$O$_3$ were taken from that investigation.

Experimental data on the influence of disperse Al$_2$O$_3$ inclusions on the apparent density of nickel powder and the relative density of pressed compacts are presented in Fig. 1. The maximum apparent density is exhibited by a mixture containing 1% Al$_2$O$_3$ (Fig. 1, curve 1).

It was shown in [1] that the increase in apparent density at small amounts of disperse oxides is due to the fact that the inclusions prevent the growth of only some nickel powder particles. Consequently, nickel powder with a small quantity of inclusions consists of particles of different sizes and has a relatively high apparent density.

To study the influence of disperse inclusions on the compactibility of nickel powder, determinations were made of the relative density of green compacts containing disperse Al$_2$O$_3$ inclusions. The compacts were produced by pressing from one side in steel dies of 10-mm diameter (2-g powder batch) at pressures of 196 and 392 MN/m$^2$.

Increase in compacting pressure from 196 to 392 MN/m$^2$ is accompanied by increase in the relative density of green compacts. Curves of the relative density of green compacts vs the amount of alumina have a maximum corresponding to 1% Al$_2$O$_3$ content of the mixture (Fig. 1, curves 2 and 3). This may be
attributed to the fact that a mixture of this composition has the maximum apparent density and the highest powder densification capacity during compaction.

A study was made of the influence of alumina on the shrinkage and relative density of specimens compacted at pressures of 196 and 392 MN/m² and sintered at different temperatures. Sintering was conducted in a furnace with a graphite tube in a hydrogen atmosphere. The specimens were heated together with the furnace and held at 1075°K for 45 min, after which the furnace was heated to the sintering temperature during a period of 30 min and held at that temperature for 2 h. With increasing compacting pressure, the relative density of the specimens sintered at 1275, 1475, 1525, and 1575°K increased (Figs. 1–2).

Figure 3 shows curves of bulk shrinkage vs Al₂O₃ content for specimens compacted at a pressure of 392 MN/m² and sintered at different temperatures. In the case of specimen compaction at a pressure of 196 MN/m², bulk shrinkage is greater than for specimens compacted at a pressure of 392 MN/m², but the shape of the curves is identical. Raising the sintering temperature from 1275 to 1475°K is accompanied by a marked increase of bulk shrinkage. During the subsequent increase of the sintering temperature to 1575°K, shrinkage exhibits practically no increase.

For specimens compacted at pressures of 196 and 392 MN/m² and sintered at different temperatures, addition of 0.5% Al₂O₃ is accompanied by an insignificant decrease of relative density, while introduction of 1% Al₂O₃ results in a sharp drop of relative density. Raising the alumina content beyond 1% increases the relative density of sintered compacts. The maximum relative density is exhibited by specimens containing 8% Al₂O₃ and sintered at 1275°K, as well as specimens with 5% Al₂O₃ after sintering at 1475, 1525, and 1575°K.

The bulk shrinkage of compacts produced at pressures of 196 and 392 MN/m² and sintered at different temperatures decreases slightly upon addition of 0.5% Al₂O₃ and attains a minimum when 1% Al₂O₃ is added. Raising the alumina content to 5% brings about an increase of bulk shrinkage. With further increase in Al₂O₃ content, shrinkage decreases. Alumina inclusions apparently exert a dual influence on the sintering process [1]. On the one hand, by disturbing the contact between the nickel powder particles, these inclusions oppose shrinkage. On the other hand, by decreasing shrinkage, they impede the formation of closed porosity and promote the evacuation, up to the instant of closing of pores, of the water vapors in consequence of the more complete reduction of the nickel oxide during sintering.

It appears that, when present in small amounts, the inclusions are mainly effective in disturbing contact between the nickel particles, but exert no influence whatever on the elimination of water vapors from compacts, which decreases shrinkage and relative density. When specimens contain 5% Al₂O₃ the strongest influence on