The structural dependence of the properties of hard alloys is widely used to obtain alloys with the requisite properties. However, the trends of this dependence are by no means fully known. The relation between wear-resistance and grain size has been investigated to a greater or lesser extent and is therefore known, but the analogous relation for static strength (bending and tensile strengths) has not been clearly determined, although some authors claim to have solved the problem [1].

One of the causes of error in research into the structural dependence of strength is that the characteristics of the structure of the hard alloy used by different investigators are not the same. Unfortunately many of them (both at home and abroad) have formed conclusions on alloy structure from indirect evidence, not direct research (optical and electron microscopy); even when the first results of such investigations were published, they did not receive the merited attention.

Furthermore, direct research data lead to clear-cut conclusions which agree with the results of indirect research if these are correctly analyzed. [2, 3] show that an examination of the structure of WC-Co alloys, using an electron microscope, reveals the continuous nature of the carbide phase (this is also shown in photographs), while the cobalt phase is concentrated in inclusions which are isolated from one another (Fig. 1). Each examination shows a similar picture for polished sections of alloys with 6-20% Co, obtained with the electron microscope. The excellent photographs in paper [4] completely agree with this structural pattern (Fig. 2).

The cobalt inclusions which are apparently isolated from one another in the polished section are linked to one another in the body of the alloy. These results have sometimes led to the opinion that the two-phase hard alloy should be regarded as spatial lattices of carbide and cobalt imbedded in each other (i.e., the carbide and cobalt phases are continuous [12].

In recent years this representation of the structure has been confirmed by metallographic investigation of coarse-grained (5-30 μm) alloys. Fine details of the structure of such alloys can be investigated with an optical microscope.

Further, electron-microscopic examination of the structure of fine-grained (0.5-2 μm) and medium-grained (1-3 μm) alloys do not reveal essential differences from the structure of coarse-grained alloys as revealed by the optical microscope. Thus, in many respects, coarse-grained specimens can be used as models for the structure of conventional (medium-grained) alloys.

The continuity of the carbide phase in a coarse-grained alloy containing 6-15% Co is readily traced from edge to edge (Fig. 3a, b). With increasing cobalt content (25-50 mass %) grains in contact with only one neighbor appear, and finally isolated grains (Fig. 3c, d).

However, by employing quantitative microstructural analysis (see for instance [5]), it is readily shown that the individual grains or groups are not actually isolated by cobalt from the other grains. Within the alloy as a whole they are generally in contact with other grains, though the area of contact does not come within the plane of the polished section. In [6] these methods were used to show that the average number of contacts is approximately six per grain in a 35% Co alloy.

From the appearance of the section it is far easier to form a well-founded conclusion with regard to the presence, rather than the absence, of contact between the grains (or other items of the structure). By way of example,
picture shows infrequent round pores, but for the most part they are linked to each other (outside the plane of the section), which is indicated by the virtual total filling-up of the pore space with impregnating fluids, and by the high gas-permeability of the sintered specimen.

In the same way, the appearance of a polished section of a 6% Co alloy gives a false impression of the isolated character of the cobalt inclusions in the carbide matrix, because although most of the cobalt sectors in the section are not joined to one another, the cobalt can be almost entirely removed by dissolving in hydrochloric acid, owing to the fact that practically all the cobalt sectors interconnect. In a 50% Co alloy many grains are in contact with their neighbors in the plane of the polished section; therefore within the alloy as a whole all the carbide grains must be interconnected.

Further evidence of the connection between the carbide grains is provided by the following. When an article containing 35–50% Co is sintered it retains its shape. If the carbide particles were disconnected by liquid during sintering, as a result of gravity and surface tension forces acting on the outside of the article the edges would become rounded and the article be deformed.

The absence of these phenomena indicates the presence of a rigid carbide skeleton which only strengthens during crystallization of the liquid phase of the alloy due to decomposition of the carbide in the contact cracks. The use of coarse-grained alloys has allowed a fuller examination of the nature of the intercrystalline boundaries in the hard alloy skeleton.

It has been suggested that the continuity of the carbide phase as revealed under the microscope or the electron microscope is only apparent, because in actual fact the carbide grains can be divided by ultra-fine interlayers of cobalt (not revealed by the electron microscope). The amount of cobalt in these interlayers can be judged by measuring the relative size of the crystal interface and the amount of cobalt remaining in the alloy after the matrix has been dissolved in hydrochloric acid. Thus in a 6% Co alloy with grain size of 2 μm, 0.04 wt % Co remained after treatment with HCl.

Measurement (by metallographic examination of an etched section) of the contact surface showed this area is ~58% of the surface of the carbide particles (Gurland gives a figure of 65% for a 6% Co alloy). It is readily calculated that the amount of cobalt in the crystal interface (provided it is evenly distributed) is 0.08 mg per 100 cm² surface. This corresponds to a cobalt layer thickness of about 10 Å.

Thus, it is difficult to speak of an "interlayer" of cobalt, because the plastic and strength properties of cobalt will not be manifested where the interlayer is only a few atoms thick. Further, it is more likely that the cobalt remaining in the carbide residue is enclosed in individual, isolated cells completely surrounded by carbide, cobalt being completely or virtually absent at the contact surface.

It should be mentioned that a certain number of cobalt atoms may be present at the intercrystalline boundary due to normal adsorption of the atoms of the medium on the surface of growing crystals. However, these atoms as a