THEORY, PRODUCTION TECHNOLOGY, AND PROPERTIES OF POWDERS AND FIBERS

SOME FEATURES OF STRUCTURE FORMATION AND DENSITY VARIATION IN THERMALLY REACTIVE TITANIUM—BORON POWDER MIXTURES

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The behavior of thermally reactive mixtures of the transition metal—carbon (boron) type during heating has been the subject of many investigations, including [1-3]. However, certain features of the sintering of powders under conditions of exothermic reaction and of the morphology of resultant structural components have not yet received sufficient study. For example, very little is known as yet about the effect of particle shape and size on the structure and density of materials obtained in such a process. In the present work use was made of spherical titanium powders and of irregular-shaped amorphous and crystalline boron particles of various sizes (Table 1). The charge composition was calculated so as to obtain titanium diboride, the thoroughness of the mixing of the starting components being controlled by the attainment of identical sintering results. The specimens employed were pressed 10-mm-diameter by 20-mm-high cylindrical compacts. The formation of the boride was initiated locally by means of a tungsten spiral. After each experiment, which was conducted in an argon atmosphere, the specimen was measured and subjected to density and phase composition determinations, and its character of fracture was examined by scanning electron microscopy.

After the reaction of mixtures of spherical titanium with amorphous boron (Fig. 1a-c), particles of round shape, often with internal flaws (pores and voids), were visible at low magnifications. The appearance of the reaction products of mixtures of titanium with crystalline boron was different (Fig. 1d and e): Very little of the original spherical shape of the titanium particles had been retained. The macrostructure in this case was made up of blocks. It is interesting to note that, with increasing boron and titanium particle size, the density of packing after the reaction grew (Table 2). This influence of particle size on the density of compacts differed from that usually observed in the sintering of, e.g., loosely poured powders. It is reasonable to assume that transformation of fine fractions of the starting components into the boride took place in a shorter time, and the beneficial effect of liquid-phase (titanium and boron) interlayers on densification was less pronounced. X-ray structural analysis revealed the presence of only a titanium diboride phase in the specimens.

Examinations of the products of thermal synthesis of the titanium—boron system at high magnifications revealed the existence in the structure of crystals of various types: tetrahedral and hexahedral (Fig. 1f), round (Fig. 1g), and elongated "saberlike" (Fig. 1h). The formation of crystals of each type could be influenced by varying the fineness of the titanium and boron powders in the mixture. For example, increasing the size of the titanium spheres in a mixture with amorphous boron resulted in the crystal structure of the reaction products becoming transformed from faceted to round. The reaction of titanium with crystalline boron

TABLE 1. Characteristics of Starting Powders

Powder	Fraction, μm	Particle shape
Titanium	100—160	Spherical
	160—200	Same
	200—300	» »
Boron*	0,1—1	Irregular
	50—60	Same

*Both the amorphous and crystalline boron particles were irregular-shaped.

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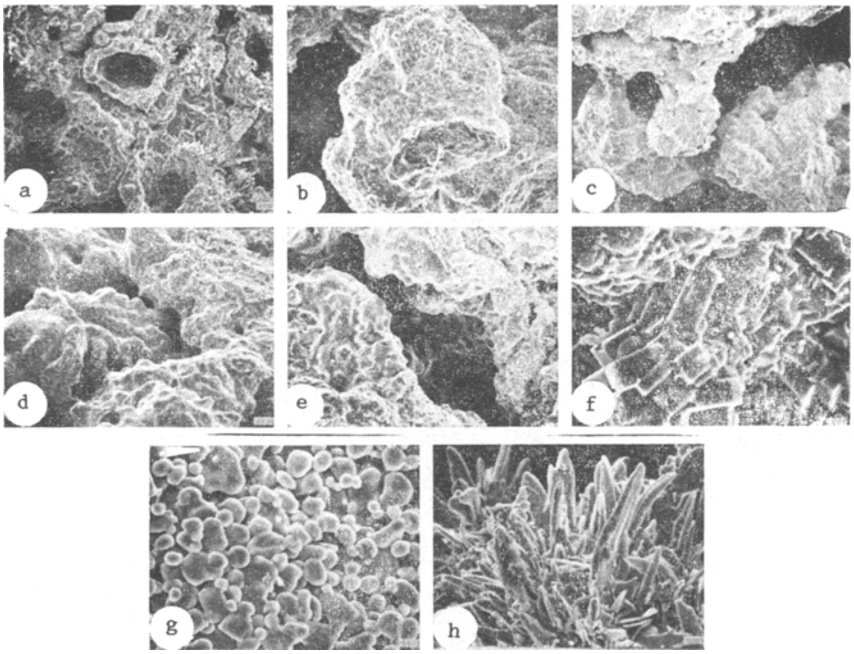

Fig. 1. Structures of products of thermal reaction of titanium with amorphous (a-c) and crystalline (d and e) boron and crystal types revealed (f-h). Titanium particle size: a, d) 100-160; b, e) 160-200; c) 200-300 μm. Magnification: a, b, d, e) ×120; c) ×50; f-h) ×1200.

TABLE 2. Densities and Porosities of Specimens after Thermal Reaction

Particle size, μm, of		Density, g/cm^3 (porosity, %)	
titanium	boron	starting	final
100—160	0,1—1	1,4(63,4)	1,8(60)
	50—60	1,8(52,6)	2,3(49)
160—200	0,1—1	1,4(63,4)	1,95(56,5)
	50—60	2,0(47,7)	2,8(38)
200—300	0,1—1	1,3(65,9)	2,1(53,5)

led mainly to the formation of crystals of round shape. When data yielded by a study of the dependence of the combustion rate on particle size were compared with the findings of the examination of the morphology of the crystals, it was established that the faceted structure corresponded to the specimens in which the combustion wave propagated with higher velocities, and the round shape, to the specimens in which the combustion wave propagated more slowly. The approximate range of velocities in which faceted crystals became transformed into round was 0.5-0.8 cm/sec. At lower velocities of thermal synthesis of titanium and boron only round crystals were formed, and at higher velocities, only faceted crystals.

Faceted crystals were apparently formed in those parts of specimens where, for some reason, a high temperature had been maintained for a period of time sufficient for recrystallization to take place under more or less equilibrium conditions. Titanium diboride, whose elementary cell is, like that of tungsten carbide, of the hexagonal type, is in all probability characterized by anisotropy of surface energy, and consequently, after liquid-phase sintering, its crystalline grains would be expected to be faceted. The round crystal shape is a nonequilibrium one, and forms in those regions where a high temperature is maintained for a comparatively short time. The presence in the structure of elongated and even "saberlike" crystals is probably attributable to gradient fluxes generated during the propagation of the combustion wave in a specimen and its subsequent cooling.

The above hypotheses concerning the effect of particle size on the densification of thermally reactive titanium—boron mixtures (Table 2) and the possible mechanism of formation of various morphological types of titanium diboride (Fig. 1f-h) will, of course, require further investigation, but the findings of this work will undoubtedly already be of interest to high-temperature materials scientists.

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PRODUCTION OF POWDERS FROM CAST IRON SWARF AND SOME FEATURES OF THE MANUFACTURE OF PARTS FROM THEM.

II. SOME FEATURES OF THE MANUFACTURE OF P/M PARTS AND THEIR STRUCTURE AND PROPERTIES

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The addition of a cast iron powder to an iron-base charge makes it possible to synthesize, by sintering, an alloyed P/M material of high wear resistance and good physicomechanical properties [1]. The development of wear-resistant iron-base P/M materials with white cast iron, which are sometimes alloyed with a Kh30 (30% Cr) chromium steel powder, has been reported [2, 3]. Iron-base alloys with gray and alloy cast irons are also known to have been developed [4, 5]. However, structure formation in P/M iron—cast iron alloys and their physicomechanical properties have not yet received sufficient study.

In part I [6] it is shown that comminution of low-alloy cast iron swarf in a ball mill offers a suitable means of producing powder for the manufacture of sintered parts. Let us now consider some features of the production, by single pressing and sintering, of wear-resistant iron-base P/M materials with alloy cast iron for domestic air conditioning installations.

In contrast to the usual mixing procedures, in our work the cast iron powder was added to a prepared ZhGr0.65D2N1 charge. The charge contained* powders of PZh2M3 iron (GOST 9849—74 standard) — 96.35%, PMS-1 or PMS-2 electrolytic copper (GOST 4960—75) — 2%, PNK-OT1 carbonyl nickel (GOST 9722—79) — 1%, and GK-3 graphite (GOST 17022—76) — 0.65%, which were mixed together in a Y-shaped mixer for 40 min. Next, 10-50% low-alloy cast iron powder (Table 1) of particle size less than 63 μm and 0.7% grade Ch zinc stearate (TU 6-09-4262—76) were added to the charge, which was followed by mixing in the same mixer for 30 min. In this way, charges of five compositions were obtained, with cast iron powder contents of 10, 20, 30, 40, and 50% (arbitrary grades 90ZhGr0.65D2N1-10Ch, 80ZhGr0.65D2N1-20Ch, 70ZhGr0.65D2N1-30Ch, 60ZhGr0.65-D2N1-40Ch, and 50ZhGr0.65D2N1-50Ch, respectively).

The presence of ductile and chemically pure iron, copper, and nickel powders in the charge compensated it for the poor compactibility and sinterability of the cast iron powder. On the other hand, the addition of a fine cast iron powder to a prepared alloyed charge increased, in the authors' opinion, the homogeneity of the mixture and hence of the finished alloy. The addition of less than 10% of the cast iron powder to the ZhGr0.65D2N1 charge would not ensure that the sintering of the material in an endothermic gas took place under nondecarburizing conditions, while the addition of more than 50% of the powder would adversely affect the compressibility of the charge.

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*All amounts of components in this paper are expressed in weight percentages.

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