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New Experimental Method for Consolidation some Refractory and Nonmetallic Powders

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Abstract. In order to obtain high-dense cylindrical compacts the coated powders on the base of tungsten, tungsten carbide and graphite were consolidated by hot shock wave compacting technology. As investigation showed utilization of coated powders has some advantages and enables to obtain compacts near theoretical density with high value of hardness. It was established that at high temperatures under shock loading W and WC base coated powders have quite different mechanism of deformation - like deformation under very high pressure and individual grains are characterized by intensive fragmentation.

Résumé. Pour obtenir les modèles cylindriques d'haute densité, les poudres plaquantes basées sur wolfram, carbure de wolfram et graphite ont été consolidées à l'aide de technologie de choc-onde.

Les investigations font preuve des avantages d'utilisation des poudres plaquantes et de possibilité d'obtenir les modèles pressées d'haute dureté et avec la densité pareille à la valeur théorique.

On avait établi, que sous les températures hautes et choc-onde chargement les poudres de wolfram ont le mécanisme de déformation différent, pareil à la déformation sous la pression très haute et les grains isolés sont caractérisés par la fragmentation intensive.

1. INTRODUCTION

Shortage of data concerning the study of compacting of the refractory and non-metallic alloy powders is caused by large number of technological difficulties bound with shock-wave processing. Difficulties are related to the impossibility of direct compacting of powders on WC, W and graphite base. The problem is that necessary pressure for plastic flow of consolidated particles for formation of common boundaries exceeds ultimate strength of steel container. In [1-3] is shown the positive role of high temperature in the processes of consolidation of hard alloy powders. Application of high temperatures allows the consolidation mechanism to work on which is characterized by plastic flow and mutual collision on compacting particles resulting in the melting of their surfaces and formation of common boundaries.

Using the coated powders as a starting materials in comparison with mechanical mixtures must have some advantages and enable the consolidation mechanism to work on at essentially low intensity of loading.

In the present paper the results of investigation, dedicated to the compacting of coated W, WC and graphite powders by hot shock wave technology and obtaining of high-dense cylindrical compacts are described.

2. EXPERIMENTAL

In order to compact coated refractory graphite powders in hot conditions there was used axisymmetrical scheme of loading presented in fig.1.

Figure 1: The experimental arrangement of high temperature shock wave compacting.

1. Cylindrical Steel container 2. Consolidating powder 3. Thermo isolation layer. 4. Heating plugs. 5. Cylindric paste - board. 6. Explosive powders. 7. Detonation cord.

Consolidating powder (2) is placed inside of container (1) with preliminary density of 70-75% (from Theoretical density). The container is shut from both sides with plugs. Simultaneously, the plugs are used a heating contacts (4).

Around the container is situated cylindring paste - board (5) filled with explosive powder (6). Using the method of resistance the heating of assembly up to desired temperature is reaching, while initiation of explosive materials-using the detonator and detonating cord (7).

The experiments were carried out in the region of temperature 20-1200°C. The ammoniate (detonation velocity 3.6 km/sec) was used as an explosive material.

It is worth mentioning that all indicated pressure values corresponds to the pressure value on the steel container's wall.

The fig. 2 illustrate the powders of W and graphite coated with Ni and WC coated with Co which were used as a starting materials for commixing.

Macrostructures shown in the fig. 4 demonstrate a positive pole of temperature and of hot shock wave compacting technology. Utilization of graphite coated powders and the compacting at 800° enable obtaining non-porous compacts of C-Ni compositions with graphite content up to 50% (fig. 4b). Under usual conditions the maximum graphite content does not exceed 30% [4]. The comparison of W-Ni Compacts macrostructures to each other (fig. 4c,d) shows that while the temperature increases the possibility of cracks formation decreases and under 800° (fig. 4d) no cracking occurs and high quality compacts are obtained.

The fig. 5 demonstrates the results of the hardness distribution investigation in compacts produced at different compacting conditions.

As is seen from the hardness distribution the loading intensity and compacting temperature have a substantial impact on the hardness value of compacts.

Figure 2: Coated starting powders.

a) W-Ni composition; b) WC-Co composition; c) Ni-C graphite composition

Growth of the loading intensity under compacting equal temperatures (fig.5a) results in producing compacts with higher value of hardness. It is likely to be occurred due to strengthening of the nickel matrix. Compacting process under high temperatures results in producing high dense compacts, however with low value of hardness and this can be explained by disstrengthening of the nickel matrix.

In contrast to above mentioned, during W-Ni compacting process the growth of temperature is accompanied with the increase of the obtained compacts hardness and distribution of hardness along the cross-section becomes stable. At 800°C compacted samples are characterized with a very high hardness which is rather unusual for these compositions.

In the fig. 6 are shown microstructures of compacted WC-Co formed from mechanical mixtures as well as from coated powders under equal loading conditions.

Figure 3: Macrostructure of compacts of Ni-50%C graphite and W-20%Ni composition compacted from coated powders with intensity of loading 10 GPa.

a) Ni-50%C compacts. T=20°C. b) Ni-50%C compacts. T=800°C.
c) W-20%Ni compacts. T=200°C. d) W-50%Ni compacts. T=800°C.

As is seen from microstructures the carbide grains differ essentially from each other. If in case of mechanical mixture there are observed in WC grains the traces of plastic deformation as sliding lines and twinnings (fig. 6a), having dealt with coated WC grains we can observe the traces of strong fragmentation (fig. 6, b). Such an evident difference between microstructures might be explained by different deformation mechanisms on the shock wave front.

It can be supported that under high temperatures 800-1000°C and more, there occur a melting of coated Co layer during the loading on the shock wave front and separate WC particles become subjects of hydrodynamic influence. It is likely that the mechanism of deformation intrinsic for very high pressure takes place, grains are being strongly compressed and all this results in an intensive fragmentation. The oval shape of WC grains and their symmetric fragmentation contribute to the aforementioned.

Figure 4: Hardness distribution in compacts obtained from coated powders by shock wave loading. a) C-Ni composition. b) W-Ni composition.

Figure 5: Microstructures of WC-Co powders hot compacted at T=1000°C and P=10 GPa. a) Mechanical mixtures of WC-Co. b) WC coated by Co.

In the fig. 7 there are shown curves of hardness distribution for heavy alloys compacted from mechanical mixtures as well as from coated powders.

As it is seen from the hardness distribution, alloys obtained from coated powders with the by far highest content of "soft" phase (W-20%Ni) are characterized with substantially higher values of hardness than mechanical mixtures. The above mentioned once again confirms above stated suggestions regarding the deformation hydrodynamic mechanism and outlines its practical advantages.

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suggestions regarding the deformation hydrodynamic mechanism and outlines its practical advantages.

Figure 6: Distribution of hardness in compacted heavy alloys at $T=800^{\circ}\text{C}$ and $P=10$ GPa.

In conclusion it can be stated that the simultaneous utilization of coated powders as initial materials and of shock wave compacting technology permits to obtain compacts from refractory and graphite based powders with a density near theoretical values and with high physical-mechanical properties.

All this favours to contemplate the proposed experimental method as attractive and prospective one for producing materials with new properties.

FINAL REMARKS

Utilization of coated powders as initial materials and of hot shock wave compacting technology allows under relatively low pressures (up to 10 GPa) to snap into action the mechanism of deformation characteristic for very high pressure and to obtain compacts of refractory and graphite based powders near theoretical density with improved physical-mechanical properties.

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