EFFECT OF CRB_2 REINFORCEMENT ON THE MECHANICAL PROPERTIES OF CERAMIC MATRIX COMPOSITES (CMCS) AND METAL MATRIX COMPOSITES (MMCS)

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Both ceramic matrix composites (CMCs) and metal matrix composites (MMCs) are widely used in the tool applications [1-2]. Among others, reinforced with diamond grit, they constitute superhard material suitable for well drilling through the rock formations [3]. The tools working in such a harsh conditions should exhibit, apart from high hardness and Young modulus, also elastic deformation resistance that can be expressed by ratio H/E, and resistance to plastic deformation H^3/E^2 [4].

In the frames of the research program aimed to obtaining enhanced tool materials, several composites with various reinforcements were tested. In particular, CrB_2 was used as the particulate reinforcing material both for CMCs [5] and MMCs designed for drill bit cutting inserts [6]. Interestingly, the effect of the addition was quite different. Figure 1 (left) illustrates the impact of CrB_2 percentage on the hardness of the composite. For the MMCs, the trend is almost proportional, and with increased CrB_2 concentration, the hardness increased, too. Noteworthy, hardness of the specimens with 8 wt.% of CrB_2 was more than two times larger than that of Fe-Cu-Ni-Sn matrix with no reinforcement. In turn, CMC matrix composite exhibited opposite trend with decrease of hardness for larger percentage of CrB_2 reinforcement, so that with 8 wt.%. of CrB_2 the hardness dropped down by ca. 15%.

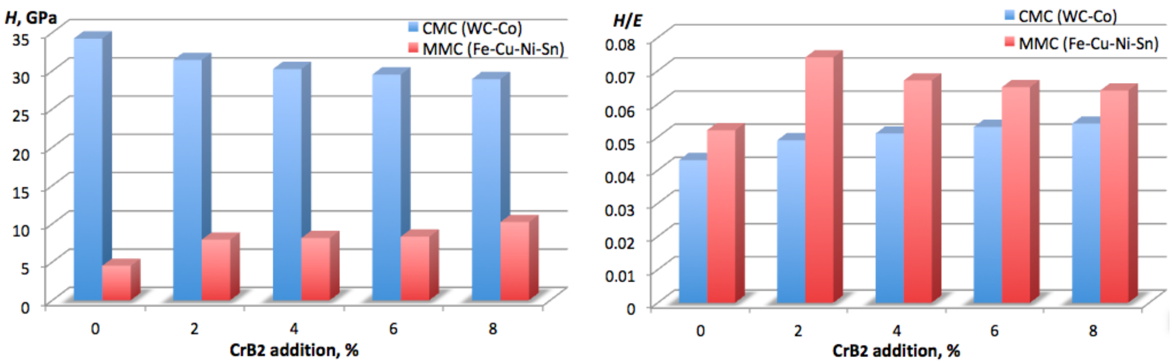

Fig. 1. Effect of the CrB_2 percentage in the Fe-Cu-Ni-Sn-based MMC and in the WC-Co-based CMC on the microhardness *H* (left) and elastic deformation resistance ratio *H/E* (right)

Noteworthy, even though both hardness and elastic modulus of tested MMC were smaller than that of CMC, the ratio H/E was higher for the MMC. However, the elastic deformation resistance index H/E exhibited more complex dependence on the reinforcement amount. As it can be seen in Fig. 1 (right), CMC exhibited improvement of H/E index with the increase of CrB_2. However, for the MMS, it was not the case. All the samples with CrB_2 reinforcement had elastic deformation resistance higher, than that of the pure Fe-Cu-Ni-Sn matrix, but the highest index H/E = 0.074 exhibited the composite with 2 wt.% of CrB_2. Further increase of the reinforcement percentage resulted with elastic deformation resistance decrease. Compared to the pure matrix, addition of CrB_2 provided 25% improvement of the elastic deformation resistance index H/E in the case of WC-Co-based CMC, while in the case of Fe-Cu-Ni-Sn-based MMC the improvement by 42% took place. The difference between CrB_2 effect on CMC and MMC appears even more spectacular when analyzing resistance to plastic deformation index H^3/E^2. After addition of 2 wt.% CrB_2 to the CMC, H^3/E^2 increased by 25%, while in the case of MMC the index increased 3.4 times.

The observed relations can be explained by the dependence of the modulus E on the CrB_2 reinforcement percentage. Presumably, CrB_2 powder served a grain growth inhibitor in WC-Co system during sintering process. As a result, reduction of the grain side took place with the increase of interfaces area in the WC-Co-CrB_2 composite. For Fe-Cu-Ni-Sn MMC, the dimensions of grains the main components appeared to be the smallest in presence of 2 wt.% of CrB_2 powder. Here, even a nanoscale inclusions were found between the matrix grains. However, at higher percentage of CrB_2, excessive chromium diboride due to its brittleness [7] might have formed structures that contributed to decrease of the composite resistance to elastic deformation. It can be concluded, that further improvement of the tested composites may be reached through application of the initial nanopowders that would ensure smaller grains, and through other sintering methods with shorter holding times, preventing from grain growth.

References:

[1] Parikh V.K., Patel V., Pandya D.P., Andersson J. Current status on manufacturing routes to produce metal matrix composites: State-of-the-art. Heliyon, 2023;9(2):e13558.

[2] Lu Y., Sun P., Yang X., Guo X., Li X., Ming W. Review of Research Progress in Nontraditional Machining of Ultrahigh-Temperature Ceramic Matrix Composites. Coatings. 2023;13(1):187.

[3] Sun Y., Li X.S., Harbers C., Williams D., Boland J.N. Wear and cutting temperature of thermally stable diamond composite tipped pick in hard rock cutting. Wear, 2023;523:204848.

[4] Beake B.D. The influence of the H/E ratio on wear resistance of coating systems – Insights from small-scale testing. Surface and Coatings Technology, 2022;442:128272.

[5] Ratov B.T., Mechnik V.A., Bondarenko M.O., Kolodnitskyi V.M. Physical and Mechanical Properties of WC–Co–CrB_2 Matrices of Composite Diamond-Containing Materials Sintered by Vacuum Hot Pressing for Drilling Tool Applications. Journal of Superhard Materials, 2022; 44(4),240–251.

[6] Mechnik V.A., Bondarenko N.A., Kolodnitskyi V.M., Zakiev V.I., Zakiev I.M., Ignatovich S.R., Yutskevych S.S. Mechanical and Tribological Properties of Fe−Cu−Ni−Sn Materials with Different Amounts of CrB_2 Used as Matrices for Diamond-Containing Composites. Journal of Superhard Materials, 2020;42(4):251–263.

[7] Paul B., Okamoto N.L., Kusakari M., Chen Z., Kishida K., Inui H., Otani S. Plastic deformation of single crystals of CrB2, TiB2 and ZrB2 with the hexagonal AlB2 structure. Acta Materialia, 2021;211:116857.