საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 7, №2, 2013
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 7, no. 2, 2013

Materials Science

Economical Assessment of the Production of Efficient Hard Alloy Materials by Reprocessing Tungsten-Containing Residues

Zurab Mirijanashvili*, Giorgi Tavadze, Aleksandre Kandelaki*, Vazha Garibashvili***

* *Ferdinand Tavadze Institute of Metallurgy and Materials Science, Tbilisi*
** *Academy Member, Ferdinand Tavadze Institute of Metallurgy and Materials Science, Tbilisi*

ABSTRACT. The indispensable condition for further development of modern technologies is creation of economically justified powder materials with special properties. These materials enable improvement of the exploitation parameters of machines and mechanisms. Metal and ceramic properties should be efficiently combined in these powders, enabling the increase of the firmness along with acceptable resilience.

Stages for the technology of obtaining hard materials imply injection of metal chlorides (WCl_6, $NiFeCl_6$) obtained via processing of armor-piercing missile cores and liquid hydrocarbon compound at the temperature range of 750÷900°C; implementation of a simultaneous process of reduction and selective carbide formation. Consequently powder will be obtained, each particle of which will contain tungsten carbide (WC) and cementing metal (NiFe or Co).

Optimal technological parameters developed will provide nanocrystal (<50 nM) structure of components and high degree of blending. The structure of powders affects the increase of the quality of manufactured items as compared to traditional materials and their items or products, where sizes of particles are 1-4 μm. Through compaction of such powders products with the following parameters are obtained: MRA>91; σ_B1100°C>400 MPa. Analysis of the business plan data for producing powders of metal-ceramics has shown that the technologies developed are characterized by high economical efficiency. Namely, in the case of production of 1 kg ready-made product from an abrasion-resistant powder. Its net price is by 20-25% less than of similar conventional products. This is due to the simplicity of technology and high outrun of products. Hard alloys produced by means of nanotechnologies are characterized by homogeneous structures and significantly increased (by ~3 times) abrasion resistance. *© 2013 Bull. Georg. Natl. Acad. Sci.*

Key words: *powder, hard alloy, wear-resistant.*

The indispensable condition for further development of modern technologies is creation of economically justified powder materials with special properties (such as hard alloys of carbide base: composition materials enforced via nanodimensional inclusions, etc.). These materials enable improvement of the exploitation parameters of device and machine components. Metal and ceramic properties should be efficiently combined in these powders, enabling the increase of the firmness along with acceptable resilience.

Continuous increase of demand for the production of materials with new advanced properties is noticed in developed countries as well as in the CIS countries (Ukraine, Belarus and Russia). The following enterprises are wide consumers of such products: mechanical engineering enterprises, aviation and metallurgical factories, oil refinery companies, stone carving, jewelry and mineral processing enterprises, etc.

Current chemical-metallurgical methods do not allow industrial scale reusability of expensive metal components (tungsten, nickel, cobalt) obtained by means of reprocessing hard alloys from the remains of metal tungsten (scrap metal and useless missile cores). The commercial price of such technogenic scrap metal is 8-10 times less than of its component powders and 15-20 times less than the market price of products made from these powders.

Scientific-technological researches of leading companies producing refractory materials are aimed to reduce the sizes of particles of components (such as WC, Co and Ni and other metals) in hard materials to nano-dimensions. This is the most essential resource that allows raising this traditional branch of industry to a higher level. By means of nanotechnologies it is possible to obtain physical and mechanical properties that cannot be achieved by traditional technologies, particularly the limit for bending firmness - 4500 MPa (450 kg/mm) and resilience up to -0.5 mg/sq.m.

The above-mentioned level will make it possible for the producers to increase the firmness and viscosity of tools made from hard materials; to increase wear-resistance by 30 - 50% and the cutting speed of alloyed steels by 10 - 40%.

Science-technology policies of well-known companies such as Sandvik Coromant (Sweden), PFERD da Titex Plus (Germany), RAMET (Czech Republic), SGS Tool Company (USA), MITSUBISHI CARBIDE (Japan) etc. are oriented to the utilization of nanotechnologies.

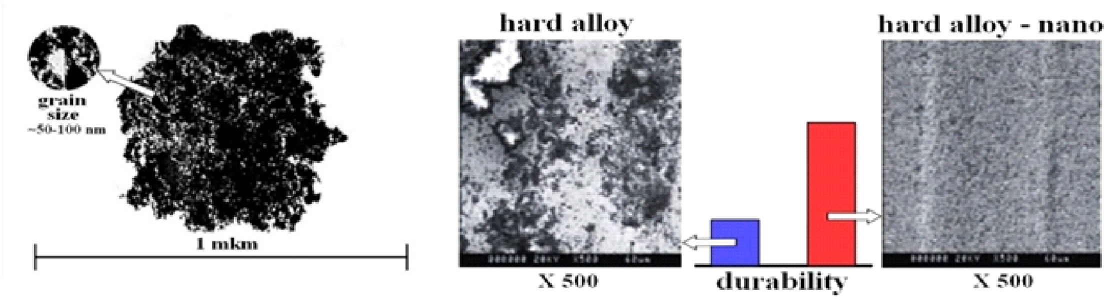
The primary problem is: material expenditures necessary for obtaining ultradispersed or nano-dimensional hard alloys significantly increases the price of the product. We believe that our innovative technology design is one of the possible efficient ways to solve this problem. Its commercial interest is determined by following: obtaining high quality and cheap initial components (metal chlorides WCI_6, $NiFeCl_6$, or $CoCl_2$) for burden, basing on the widespread raw materials (primarily tungsten-containing residues) that are transitional products for metal powders and hard alloys; production of homogeneous metals or nanocrystal sized powders of hard alloys with advanced physical and chemical properties by hydrogenous or metal-thermal reduction of chloride-oxide burdens; implementation of autothermal processes and reducing energy losses by 25%; simplifying technological cycles and non-standard equipment; providing wasteless technologies or ecological concern.

Stages of the technology of obtaining hard materials imply injection of metal chlorides (WCL_6, $NiFeCl_6$) obtained via processing of armor-piercing missile cores and liquid hydrocarbon compounds at the temperature range of 750÷900°C; implementation of a simultaneous process of reduction and selective carbide formation. Consequently, powder will be obtained, each particle of which will contain tungsten carbide (WC) and cementing metal (NiFe or Co) (Fig. 1a). Hard alloys, produced by means of nanotechnologies are characterized by homogeneous structures and significantly increased (by ~3 times) abrasion resistance.

The developed optimal technological parameters will provide nanocrystal (<50 nM) structure of components and high degree of blending. The structure of powders affects the increase of the quality of manufactured items as compared to traditional materials and their products, where sizes of particles are 1-4 μm. Through compaction of such powders products with the following parameters are obtained: MRA>91; σ_B1100°C>400 MPa.

Innovative nanotechnology of obtaining hard materials from armor-piercing missile cores is promising, as it allows to obtain a new generation and qualitatively better product from hard materials: cutters, gears, locks for oil pipe-lines, sprayers for water-jet cutters, camshafts for high pressure compressing.

These factors are important for the commercial effectiveness of a business plan. Steady increase of



a) b)

Fig. 1. a) Nanopowders obtained from anti-armour missile cores; b) Microstructure and abrasion resistance of hard alloys obtained by means of conventional and nanotechnologies.

demands for products made from hard refractory materials is noticed worldwide. There are no companies producing goods from hard alloys across the region of Georgia, Azerbaijan, Armenia and Turkey. Domestic demand for the above-mentioned products is basically met through imports from the companies: Saturn – Vladikavkaz, Russia, Toreztverdosplav - Ukraine and ISCAR – Israel. Annual demands are shown in the bar chart.

According to current information, the following Georgian companies are interested in the consumption of hard alloys (WC-NiFe type) in order to raise exploitation characteristics: Rustavi Metallurgical Plant, Railway Carriage-Building Factory in Tbilisi, Tbilisi Aircraft Factory, Elmavalmshenebeli Factory in Tbilisi, Tbilisi Transport Company (underground), Madneuli Ore Concentrating Plant, etc.

Price analysis of various products of refractory materials has shown that they are proportional to their weights. This makes easier to use the price of the product of 1 kg hard material (WC-NiFe) as a reference price for further calculation so that the accuracy of financial accounting is preserved.

Technical-economical calculation has shown that utilization of 5 T/year anti-armour missile cores 4.45 T of hard alloy nanopowder on the basis of tungsten-carbide of WC-NiFe type can be obtained. Its net cost is $35, which is 2-2.5-times cheaper than that of conventional hard alloy powders.

Analysis of the obtained data has shown that the technology of processing of anti-armour missile-cores has a promising commercial potential, which, in the case of establishing a small enterprise, will determine its future competitive advantage on the internal or external markets.

Basing on the existing material and technological resources of the Institute of Metallurgy and Material Sciences, at the initial stage it can be planned to produce 1500 kg of items of hard materials annually, which covers 6% of the regional market.

High quality of the product is achieved via implementation of nanotechnologies and its low price is determined by the inexpensiveness of initial raw material - scrapped anti-armour missile-cores.

The advantage of hard/refractory materials obtained from the utilization of used missile-cores, compared to similar products, results from the following scientific and technological results:

- Implementation of nanotechnology in obtaining hard alloy products of WC-NiFe;
- Low price of the equipment involved.

At the same time the developed innovative nanotechnology allows to transform the leftovers of tools-industry into items of hard materials.

Analysis of the business plan data for producing powders of metal-ceramics has shown that the technologies developed are characterized by high economic efficiency. Namely, in the case of production of 1 kg ready-made product from abrasion-resistant powder its net price is by 20-25% less than of similar conventional products. This is caused by simplicity of technology and high outrun of products.

The new type powders and the products made of them (coatings) are characterized by advanced technical and economic parameters. This advantage will be used in developing the pricing strategy for "pushing" the product to the market, which implies selling the product at 15-20% lower price.

The mentioned strategy enables us to use efficiently the economic and technological advantages of producing powders. Namely, low expenses at all points which affect the final net cost of the product: cheap initial raw material (the residues of metal production, scrap-metal, useless missile-cores, etc.), low energy losses, high efficiency and the advanced quality of the product gives opportunity to vary the price in a significant range.

Acknowledgement. The work is supported by Shota Rustaveli National Science Foundation (Grant No GNSF/ST 1-7/87).

მასალათმცოდნეობა

ვოლფრამის შემცველი ნარჩენების გადამუშავებით კონკურენტუნარიანი სალი შენადნობების ნაკეთობების წარმოების ეკონომიკური შეფასება

ზ. მირიჯანაშვილი,* გ. თავაძე, ა. კანდელაკი,* ვ. ღარიბაშვილი***

* *ფ. თავაძის მეტალურგიისა და მასალათმცოდნეობის ინსტიტუტი, თბილისი*
** *აკადემიკოსი, ფ.თავაძის მეტალურგიისა და მასალათმცოდნეობის ინსტიტუტი, თბილისი*

თანამედროვე ტექნიკის შემდგომი პროგრესის აუცილებელი პირობაა ეკონომიკურად გამართლებული ისეთი სპეციალური თვისებების მქონე ფხვნილოვანი მასალების შექმნა, რომლებიც საშუალებას იძლევიან გაუმჯობესდეს მანქანათა და მექანიზმების დეტალების ექსპლუატაციური პარამეტრები. სალი მასალის მიღების ტექნოლოგიის ეტაპები ითვალისწინებს ჯავშანგამტანი ჭურვის გულარის გადამუშავებით მიღებული ლითონური ქლორიდებისა (WCl_6, $NiFeCl_4$) და თხიერი ნახშირწყალბადების ნარევის ინჟექციას 750-900 °C ტემპერატურულ ინტერვალში; აღდგენითი და სელექციური კარბიდიზაციის ერთდროული პროცესების წარმართვას, რის შედეგადაც მიიღება ფხვნილი, რომლის თითოეული ნაწილაკი შედგება ვოლფრამის კარბიდისა (WC) და აცემენტებელი ლითონისაგან (NiFe ან Co). დამუშავებული ოპტიმალური ტექნოლოგიური პარამეტრები უზრუნველყოფენ კომპონენტების ნანოკრისტალურ (< 50 ნმ) სტრუქტურას და მაღალი ხარისხით შერევას. ფხვნილების სტრუქტურა განაპირობებს ნაკეთობების ხარისხობრივ ზრდას იმ ტრადიციულ მასალებთან და მათგან მიღებულ ნაკეთობებთან შედარებით, რომელთა მარცვლის ზომა 1-4 მკმ-ის რიგისაა. ასეთი ფხვნილის კომპაქტირებით მიიღება ნაკეთობა შემდეგი პარამეტრებით: MRA > 91; σ_B 1100°C > 400 მპა. ლითონკერამიკული ფხვნილების წარმოების ბიზნეს-გეგმის მონაცემების ანალიზით დადგინდა, რომ ცვეთამედეგი ფხვნილიდან 1 კგ მზა პროდუქციის წარმოების შემთხვევაში მისი თვითღირებულება 20-25%-ით ნაკლებია ანალოგიური ტიპის ნაწარმის თვითღირებულებაზე. გამოწვეულია იაფი საწყისი ნედლეულის (წარმოების ნარჩენების) გამოყენებით, მინიმალური ენერგეტიკული დანახარჯებით, პროცესის მაღალი წარმადობითა და WC-NiFe-ის ნანოფხვნილებით მნიშვნელოვნად (3-ჯერ) გაზრდილი ცვეთამედეგი პროდუქციის მიღებით.

Received March, 2013