Journal of Applied Mechanics and Technical Physics, Vol. 50, No. 4, pp. 658–660, 2009

EFFECT OF POROSITY ON ELASTIC CHARACTERISTICS OF TiC/TiNi HARD ALLOYS

V. V. Akimov, M. V. Akimov,
M. S. Korytov, and M. V. Plastinina

UDC 621.762.4:539.32

A substantial effect of porosity on elastic properties of TiC/TiNi hard alloys is found. It is demonstrated that application of these materials in various elements and devices of modern engineering is inspired by a combination of their properties, such as high strength, hardness, wear resistance, and resistance to oxidation and thermal shock.

Key words: *tungsten-free hard alloys, porosity, strength, hardness, wear resistance.*

Depending on the method of obtaining materials on the basis of titanium carbide with a TiNi cementing binding phase, their porosity can exert a significant effect on elastic characteristics, such as hardness and strength. The porosity of hard alloys is known to increase if the pressing and sintering temperature deviates from the optimal value [1]. The dependence of elastic properties of TiC/TiNi hard alloys on their composition was described in [2]. As far as the authors are aware, there are no data on the influence of porosity on characteristics of elasticity of this class of materials.

The object of the present study is the effect of porosity on elastic characteristics (Young's modulus E, shear modulus G, volume deformation modulus K, and Poisson's ratio μ) and plasticity of the hard alloy $q = K/G$ [3].

The samples were produced by standard methods of powder metallurgy. Titanium carbide TiC and titanium nickelide TiNi powders were mixed in a mechanical mixer for 24 h. A 6% solution of a plasticizer (natural rubber) in pure gasoline was added to the well-stirred 50 : 50 mixture of TiC and TiNi powders. The mixture was stirred again and then dried for 24 h at a temperature $t = 20°$C; finally, the mixture was bolted through a sieve with a cell size of 800 μm. The samples were obtained by the method of cold pressing at a pressure $p = 100$–200 MPa in a special press mold and then sintered in a laboratory vacuum furnace.

Sintering was performed at a temperature $t = 1350°$C for 10 min with subsequent rapid cooling together with the furnace [4]. The samples were shaped as cylinders 18 mm in diameter and 8–10 mm high.

Samples of the 50/50 TiC/TiNi composite hard alloy with parallel faces (the deviation was less than 10^{-3} rad) with different values of porosity after their sintering were used in experiments in an ultrasonic setup. The roughness of the treated sample surface was Ra = 1.25–0.63. The sample characteristics were measured by an ultrasonic resonance method in a setup similar to that described in [2]. The error of determining Young's modulus, shear modulus, Poisson's ratio, and volume deformation modulus with a confidence probability of 0.95 was smaller than 1–3%.

Porosity exerts a significant effect on elastic properties of TiC/TiNi hard alloys (Fig. 1). As the porosity is increased from $P = 0$ to $P = 15\%$, Young's modulus decreases by 30–50 GPa, and Poisson's ratio decreases by 0.08.

Siberian State Automobile–Road Academy, Omsk 644080; kms142@mail.ru. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, Vol. 50, No. 4, pp. 136–138, July–August, 2009. Original article submitted June 4, 2008.

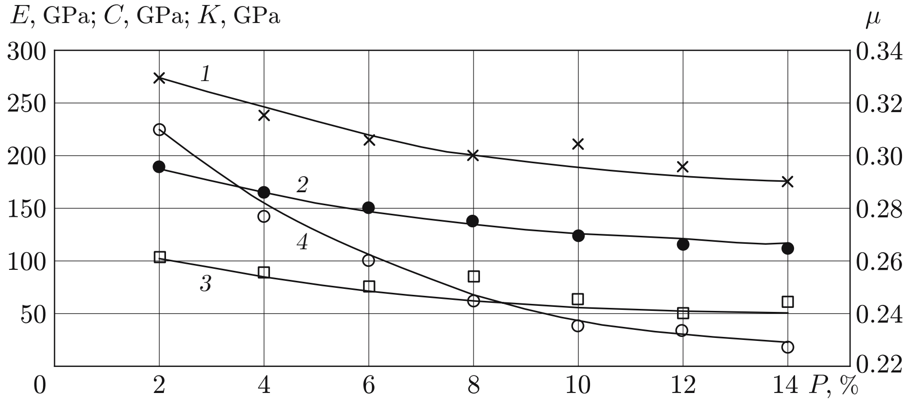

Fig. 1. Elasticity characteristics E (1), K (2), G (3), and μ (4) of a 50/50 TiC/TiNi alloy versus porosity.

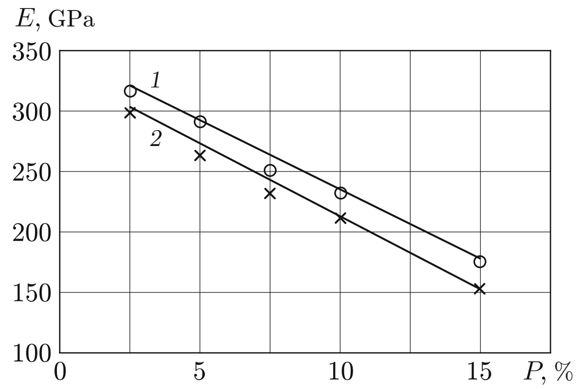

Fig. 2. Experimental dependence (1) and calculated dependence (2) of Young's modulus of a 50/50 TiC/TiNi alloy versus porosity.

Apparently, with increasing porosity, elastic and mechanical characteristics of hard alloys decrease owing to reduction of strength of interparticle contacts and also to the emergence of stress concentrations around pores; these stress concentrations are determined by the pore size, shape, and orientation [5]. It is difficult to quantify the effect of pores as stress concentrators. For this reason, theoretical relations between the elastic properties of a given material and porosity cannot be obtained.

The results of extrapolation of Young's modulus for the 50/50 TiC/TiNi hard alloy calculated by formulas derived in [2] are in good agreement with the results of theoretical calculations by the formula

$$E = (E_{\rm TiC} v_{\rm TiC} + E_{\rm TiNi} v_{\rm TiNi})/v, \tag{1}$$

where $E_{\rm TiC}$ and $E_{\rm TiNi}$ are Young's moduli of titanium carbide and nickelide; $v_{\rm TiC}$ and $v_{\rm TiNi}$ are the volume fractions of titanium carbide and nickelide in the alloy (Fig. 2).

Moreover, despite the difference in the phase composition of the samples and also in the technology of manufacturing of the samples, Young's moduli of TiC/TiNi hard alloys calculated by Eq. (1) almost coincide with experimental data.

Thus, the results obtained confirm the assumption that the material porosity affects the behavior of Young's moduli under standard conditions.

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