



补充到期刊发行1 - 2016
中华人民共和国 / CHINA

Executive Editor (執行主編)
ROMAN DAVYDOV

Editorial Board (編輯委員會)

Dr. RISBAY DJURAEV
Dr. JOSE RANZOLA
Dr. JEWGENIJA REINELT
Dr. DMYTRO RYAZANOV
Dr. ELVIRA LUZIK
Dr. MARYNA PASHKEVYCH

Peer-review (同行評審):

This issue is peer-reviewed by the Panel of Experts from the United States, Canada, European Union, China, Japan, South Korea, Singapore and Australia.

Indexation (指數化):

Index Copernicus®; CrossRef®; EBSCO™; Google Scholar®; WorldCAT®;
CNKI Scholar (中国知网); Bielefeld Academic Search Engine®;
CiteSeerX® by the Pennsylvania State University

照片积分:

中华人民共和国教育部

THE ADVANCED SCIENCE JOURNAL

ISSN 2219-746X (印刷媒体); 2219-7478 (网络媒体); TITLE DOI: 10.15550/ASJ

为中国特刊 VOLUME 2016 ISSUE 1

ISSUE DOI: 10.15550/ASJ.2016.01



出版者 Publisher:

SCIREPS CORPORATION
2964哥伦比亚省街，办公32.268，
托兰斯，加利福尼亚州90503
美国

Contact us:

Tel.: +1.42.42.71.41.11 E-mail: mail@advancedscience.org www.advancedscience.org

The Advanced Science Journal © 2010-2016 Scireps Corporation. All Rights Reserved.

THE EFFECTIVE MECHANICAL PROPERTIES OF METAL-GLASS MATERIALS AND COATINGS

Yuliya Kazymyrenko

Admiral Makarov National University of Shipbuilding, Mykolaiv, Ukraine
u.a.kazymyrenko@gmail.com

Received 26-JAN-2016; Accepted 27-FEB-2016; Online 01-MAR-2016

Abstract: The article is devoted to the problems of strength of new metal-glass materials and coatings, which were produced by hot-pressing method and electric-arc spraying method. Composite materials and coatings with steel and aluminum matrix filled with hollow glass microspheres, powders of sodium silicate and leaded glass are perspective for the production of protective constructions of vessels and floating facilities, aircrafts, underwater vehicle. The technique has been developed, which is in contrast to existing techniques, takes into account structural features of compositions, allows identifying and predicting the mechanical properties of structurally inhomogeneous composite materials without expensive experimental studies: conventional modulus of volumetric compression of the metal matrix, conventional compression modulus of glass inclusions, the effective temperature coefficient of linear expansion, the effective shear modulus. The analytical description, which establishes the influence of porosity, shape and volume content of glass inclusions on the effective mechanical characteristics, has been obtained. The results can be used for prediction of thermomechanical characteristics and stress-strain state of composite constructions, which operate under temperature changes, full hydrostatic compression, heat and ionizing radiation. Prospects for introduction are associated with shipbuilding, energy and engineering industries.

Keywords: metal-glass materials, coatings, hollow glass microspheres, glass inclusions, effective mechanical properties.

Introduction

Modern technologies of creation of aircrafts, specialized vessels and underwater technical facilities envisage the use of new types of composite materials and coatings such as "syntactic": polymeric compositions filled with hollow glass microspheres (Chittineni, 2010). New technologies of their manufacturing are associated with increasing of the ability to absorb heat and ionizing radiation (Wawryk, 1988; Ostrik, 2003). To increase the reflectivity, microspheres are exposed to metallization (Zhang, 2005); that creates the effect of reflection of rays in the polymer matrix. However, having a low thermal conductivity, polymer syntactics are being destroyed at high temperatures under the influence of accumulated quantity of heat or destruction processes. The new kind of materials and coatings, which provides comprehensive protection for constructions of technical facilities from the influence of heat and ionizing radiation, are metal-glass compositions with steel and aluminum matrix (Kazymyrenko, 2013, 2014). These are composite materials produced by hot-pressing method, followed by isothermal exposure of aluminum powder mixture with hollow glass microspheres, and electric-arc coatings based on welding wires Sv-08G2S and Sv-AMG-5 filled with hollow glass microspheres, powders of sodium silicate and leaded glass (Kazymyrenko, 2015). Metal-glass composite materials and coatings are structurally inhomogeneous; the porosity of the metal matrix, depending on the technology, can reach 25%. The matrix and the filler have a significant difference in the values of temperature coefficient of linear expansion; that can lead to destruction in conditions of uneven heating and temperature changes. Determination of strength properties (elastic modulus, shear modulus, Poisson's ratio, and linear thermal expansion coefficient) of porous compositions, using experimental techniques, is difficult. It is advisable to use computational and experimental techniques, where effective mechanical characteristics are introduced as the criteria. The definition of effective constants of elasticity is solved in works (Landau, 2007) on simple models for the first time. In classic works (Vanin, 1985; Librescu, 2006; Tashkinov, 2010) the analytical description of the mechanical properties is considered using the theory of effective elastic modules, methods of regulation and harmonization, successive approximations to stochastic boundary value problem. The structural features such as volume content, size and shape of inclusions, the surface of the phase boundary, structure of the matrix, influence on the processes of deformation and destruction of the composite materials and coatings directly. The closest analogues are works of Vanin (1985), Korolev

(1971), Krzhechkovskiy (1976), which were developed for the prediction of strength indicators of polymer syntactics. However, the existing methods and models cannot be used to determine the mechanical properties of new compositions due to their structural features. The analytical dependence, which was given in classical works in the field of micromechanics and radiation material science (Landau, 2007; Librescu, 2006; Was, 2007), does not allow us to describe the mechanical properties of highly porous materials under elevated temperature conditions and ionizing radiation.

The prediction of the strength characteristics of new compositions, in accordance with their structural features, represents the scientific interest and requires the development and approbation of new calculation techniques.

Results

The development of new technique is based on a model of metal-glass composite materials and coatings (Fig. 1), which has been drawn up on the basis of the researches of features of their structure (Kazymyrenko, 2014).

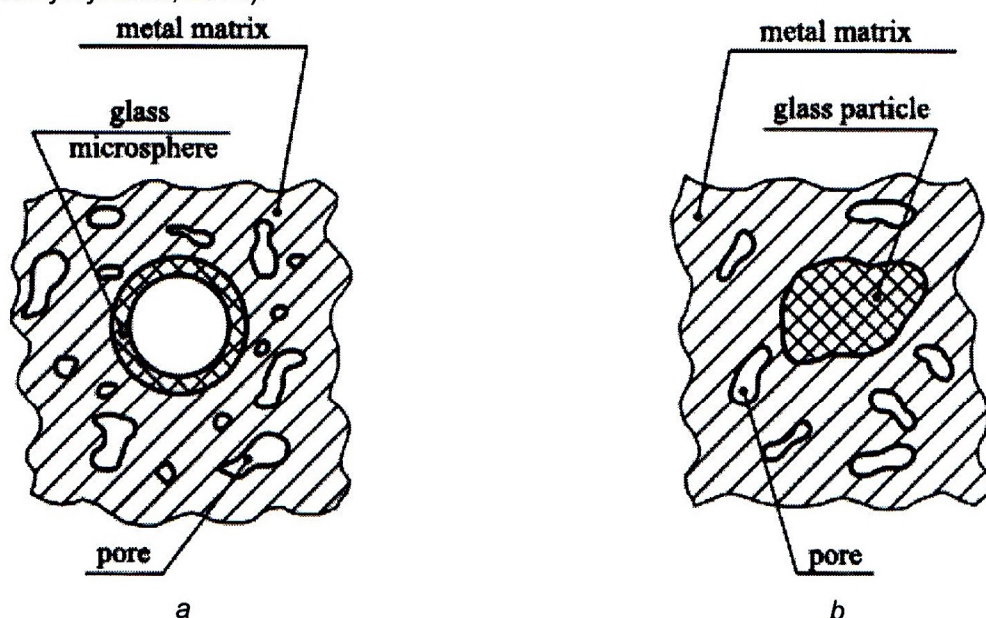


Fig. 1. The model of the cell of metal-glass materials and coatings: a - filled with hollow glass microspheres; b – filled with solid glass particles

The density of the samples with different volumetric content of glass 10 ... 50% has been determined experimentally as a result of hydrostatic weighing. Open porosity has been calculated by volume filled with distilled water. The following assumptions have been introduced in work: the strength properties do not depend on the size of the glass inclusions; the calculations do not take into account the size of the transition zone; volume content of hollow glass microspheres is equal to the volume of porosity, which is enclosed in microspheres; temperature coefficient of linear expansion of the materials and coatings does not depend on the temperature; the Poisson's ratio of the metal-glass composition is equal to the Poisson's ratio of metal matrix. The following notations have been introduced in this work:

ρ - the density of metal-glass material and coating;

α^* - the effective temperature coefficient of linear expansion of the composite material or coating;

ρ_m, ρ_c - the density of the metal of the matrix and the glass density;

ρ_s - the density of microspheres;

E_m, E_{cm} - the elastic modules of the metal matrix material and glass;

ν_m, ν_c - the Poisson's ratio of the metal matrix and glass;

α_m, α_s - the temperature coefficients of linear expansion of the matrix materials and glass;

$\mathcal{G}_m, \mathcal{G}_s$ - the volume content of the metal and glass;

η_o – the porosity of the metal matrix;

η_s – the closed porosity inside of hollow glass microspheres;

K'_m, K'_c – the volumetric modules of elasticity of metal matrix and glass inclusions;

K_m, K_s – the conventional modulus of volumetric compression of the metal matrix and glass sphere;

G^* – the conventional shear modulus of composite materials and coatings

The results are presented as the effective mechanical characteristics, which are expressed for idealized nonporous structures and compositions with the porosity of 10 ... 20%.

The conventional modulus of volumetric compression of the metal matrix for nonporous materials and coatings can be expressed as

$$K_m = \frac{K'_m \cdot g_m}{1 + \rho(1 - g_m)} \quad (1)$$

where

$$K'_m = \frac{E_m}{3(1 - 2\nu_m)} \quad (2)$$

Taking into account the porosity, the expression for finding the conventional modulus of volumetric compression of the metal matrix takes the form:

$$K'_m = \frac{E_m}{\left(\frac{\rho_m(0,0026\rho_m + \rho)}{\rho^2} + 0,0016 \frac{\eta_o \pi (\rho_m - \rho)(1 + \nu_m)(2\nu_m^2 + \nu_m + 5)}{\rho_m \left(\sqrt[3]{\frac{\rho_m}{\rho_m - \rho}} - 1 \right)^3} \left(1 + 10 \sqrt[3]{\frac{\rho_m}{\rho_m - \rho}} - 1 \right)^2 \right)^2} \quad (3)$$

Figure 2 graphically illustrates the influence of the porosity and volume content of microspheres on the conventional modulus of volumetric compression of the metal matrix.

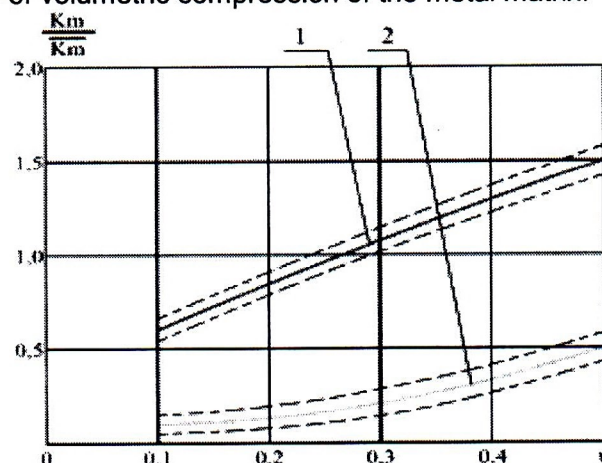


Fig. 2. The calculated values of the relative modulus of volumetric compression of the metal matrix $K_m / \bar{K}_m$: 1 - for compositions with steel matrix; 2 - for compositions with aluminum matrix

The volumetric modulus of elasticity of volume compression of a hollow sphere, taking into account the density of compositions with different volume content of the microspheres, is expressed as:

$$K_s = \frac{K_{cm} \cdot \psi}{1 + \rho(1 - \psi)} \quad (4)$$

$$\psi = \frac{\rho_s}{\rho_c} \quad (5)$$

It is taken into account that with the increasing of the volume content of the hollow glass microspheres in compositions, the density of materials and coatings is reduced.

The volumetric modulus of elasticity of hollow glass microspheres in the content of compositions, with enclosed in them porosity, can be calculated as:

$$K_c = \frac{E_{cm}}{\left[\frac{\rho_c(0,0026\rho_c + \rho)}{\rho^2} + 0,0016 \frac{\eta_s \pi (\rho_c - \rho)(1 + \nu_c)(2\nu_c^2 + \nu_c + 5)}{\rho_c \left(\sqrt[3]{\frac{\rho_c}{\rho_c - \rho}} - 1 \right)^3} \left(1 + 10 \left(\sqrt[3]{\frac{\rho_c}{\rho_c - \rho}} - 1 \right)^2 \right)^2 \right]} \quad (6)$$

Let us express the assumption about the approximation of the form of solid glass inclusions to a spherical form. Then, for metal-glass coatings filled with solid glass particles, in formula (5), we accept $\rho_s = \rho_c$, then $\psi = 1$.

Taking into account the mechanical properties of the matrix and glass, the effective temperature coefficient of linear expansion α^* is expressed as:

$$\alpha^* = \frac{(\alpha_s - \alpha_m) \cdot \vartheta_s (1 + \rho)}{\frac{K_m}{K_s} (1 - \vartheta_s) + \rho + \vartheta_s} + \alpha_m \quad (7)$$

The effective shear modulus G^* is possible to determine on the basis of Hashin-Shtrikman assessment; for two-phase compositions it is expressed as (Librescu, 2006)

$$G^* = \frac{3}{4} \frac{K_m}{\rho} \quad (8)$$

Table 1

The effective mechanical characteristics

Metal-glass compositions	K_s , GPa	K_m , GPa	$\alpha^* \times 10^6$, K^{-1}	G^* , MPa
Metal-glass materials (aluminum dust+microspheres 10...50 % volum.)	30,0...34,0	37,45...41,25	1,4...7,05	15,25...15,74
Metal-glass materials (aluminum powder+microspheres 10...50 % volum.)	31,45...34,5	38,15...41,5	1,43...6,4	16,1...16,5
Sv-AMg5 – hollow glass microspheres (10...40 % volum.)	31,66...37,3	39,65...44,12	1,45...8,78	17,05...19,00
Sv-08G2S – hollow glass microspheres (10...40 % volum.)	32,0...37,0	130,0...173,5	0,7...4,0	15,5...21,75
Sv-AMg5 – sodium-silicated glass (10...40 % volum.)	41,72	40,0...41,15	1,4...5,6	17,5...18,0
Sv-AMg5 – leaded glass (10...40 % volum.)	41,72	40,25...45,65	1,1...4,43	17,65...18,5
Sv-08G2S – sodium-silicated glass (10...40 % volum.)	41,72	120,0...155,0	0,55...2,7	12,8...16,7
Sv-08G2S – leaded glass (10...40 % volum.)	41,72	120...172	0,45...2,4	12,82...21,30

The values of apparent density have been taken into account in calculations: for steel - microspheres coatings 6400 ... 5990 kg / m³, for aluminum - microspheres coatings 1000 ... 1700 kg / m³, for steel - glass coatings 6000 ... 7255 kg / m³, for aluminum-glass coatings 1700 ... 1900 kg /

m3. The porosity values have been taken in the range of 10 ... 25%. The calculation results are summarized in Table 1.

The influence of the structural characteristics has been detected: the influence of porosity and volume content of the glass filler on the effective mechanical properties of metal-glass materials and coatings:

- effective mechanical characteristics increase when the volume content of the glass components in the range of 10 ... 50% in metal-glass compositions increases;
- the presence of the porosity in 1.5 ... 2 times reduces the apparent modulus of the metal matrix K_m ;
- conventional modulus of volumetric compression K_m of electric-arc coatings based on Sv-08G2S is 3 times higher than K_m of coatings based on Sv-AMg5 and K_m of hot-pressed aluminum-matrix compositions; herewith the values of the effective temperature coefficient of linear expansion α^* of steel compositions are 2 times lower;
- the kind of glass fillers insignificantly influences on the effective mechanical characteristics of metal-glass materials and coatings.

Discussion

The results can be used to predict the thermomechanical properties and the stress-strain state of the constructions.

The analytical description of the thermomechanical properties for new metal-glass materials and coatings has been done; the description is based on a model approach to the structure, which was formed by hot-pressing method and by method of electric-arc spraying; that allows to identify and predict the stress-strain state in conditions of short-term temperature loads of up to 500° C.

References

- Chittineni, K. and Woldesenbet, E. (2010) Energy Absorption of Integrated Functionally Gradient Syntactic Foam. *Journal of Cellular Plastics*, 46 (4), pp. 295-319. Available at: <http://dx.doi.org/10.1177/0021955X10368321>
- Kazymyrenko, Y. (2013) Zakonomernosti formirovaniya metallostekljannyh materialov i pokrytij s povyshennymi rentgenozashitnymi svojstvami. *Tehnologicheskij audit i rezervy proizvodstva*, 6/2 (14), pp. 45 – 55.
- Kazymyrenko, Y. (2014) Patterns and mechanisms of interaction of radioactive cargo radiation with metal-glass layer of watercrafts structure. *The advanced science journal*, (12), pp. 45 – 48. Available at: <http://dx.doi.org/10.15550/ASJ.2014.12.045>
- Kazymyrenko, Y. and Shlapackaja, V. (2015) Radiacionnaja stojkost' metallostekljannyh pokrytij dlja plavuchih kompozitnyh sooruzhenij. *Sudostroenie i morskaja infrastruktura*, 1(3), pp. 111 – 121.
- Korolev, V. (1971). *Uprugoplasticheskie deformacii obolochek*. Moskva: Mashinostroenie.
- Krzhechkovskij, P. et. al. (1976) Temperaturnye usadochnye naprjazhenija i deformacii v kompozitah, napolnennyh stekljannyimi mikrosferami. *Tehnologija sudostroenija*, pp. 70-77.
- Landau, L. and Livshic, E. (2007) *Teorija uprugosti*. Moskva: Fizmatiz.
- Librescu, L. and Song, O. (2006) *Thin-Walled Composite Beams: Theory and Application*. Berlin: Springer.
- Ostrik, A. (2003) *Termomechanicheskoe deistvie rentgenovsogo izlucheniya na mnogoslojnye pregrady v vosduhe*. Moscow: NTZ Infortehnika.
- Tashkinov, M., Videl'man, V. and Mihajlova, N. (2010) Metod posledovatel'nyh priblizhenij v stohasticheskoy kraevoj zadache termouprugosti strukturno-neodnorodnyh sred. *Mehanika kompozicionnyh materialov i konstrukcij*, 16 (3), pp. 369 – 383.
- Vanin, G. (1985) *Mikromehanika kompozicionnyh materialov*. Kiev: Naukovadumka.
- Was, G. (2007) *Fundamentals of radiation materials science*. Berlin: Springer.
- Wawryk, R. and Rafalowicz, J. (1988) Heat transfer in microsphere insulation. *Journal of Thermal Analysis*, 34 (1), pp. 249-257. Available at: <http://dx.doi.org/10.1007/BF01913391>
- Zhang, Q., Wu, M. and Zhao W. (2005) Electroless nickel plating on hollow glass microspheres. *Surface and Coatings Technology*, 192(2-3), pp. 213-219. Available at: <http://dx.doi.org/10.1016/j.surfcoat.2004.06.013>

TABLE OF CONTENT

<i>Megan Smith</i> Computer Science for All	5
ECONOMICS, LAW, PUBLIC POLICY AND INTERNATIONAL RELATIONS	
<i>Petro Yaremovych</i> Priorities for Internationally Growing Commodity Markets	8
<i>Vitaliy Gorev</i> Shaping a Product Strategy for a Diversified Manufacturing Corporation	12
<i>Oleksandr Rudkovskyi</i> Organization of the State Regulation of Corporate Governance	19
<i>Nataliya Goncharenko</i> Development of Theoretical and Methodological Fundamentals of Environmental Controlling for Production and Supply of Organic Livestock Products	23
<i>Kateryna Demyanenko</i> The Essence of Environmental Management and Company's Competitiveness	27
<i>Aysulu Elmuratova</i> Impact of Gender Differences on Economic Efficiency of Business	33
<i>Vitaliy Kovalchuk</i> The Organs of Constitutional Justice in the Mechanism of Human Rights and Democracy Protection: the European and Ukrainian Experience	36
<i>Zafar Amirov</i> Important Issues of Increasing the Role of Non-Governmental Non-Profit Organizations in Preventing Violation of Laws	42
<i>Turgunoy Egamberdieva</i> The Factors Increasing the Activity of Women in the Formation of State and Society in Uzbekistan	47
<i>Durbek Sayfullaev</i> Parliamentary Diplomacy in Making of Foreign Policy	52
<i>Otabek Khasanov</i> Parliamentary Oversight and Effective Governance: Implications for Central Asian Transition Democracies	55

EDUCATION, LANGUAGES AND LETTERS

Roman Padalka

- The Psychological Constitution of Environmental Consciousness in Primary School Students** 58

Margarita Tsoy

- From Innovations in Improving Learning Informatics Sphere at Schools to Increase Effective State Management** 63

Andriy Grabovy

- Applied Chemistry Experiment as Factor of Innovative Experimental and Methodological Training of Future Chemistry Teachers** 66

Kateryna Shevchenko

- Training Future Teachers in Lecturing Skills in China and Ukraine** 76

Nozimakhon Mamadjanova

- Comparative Analysis of the Present Tense Forms in the English and Uzbek Languages** 79

Nataliya Naumenko

- Stylistic Diversity in Creation of the Poetics of a Literary Work for Children (based on T.S. Eliot's *Old Possum's Book of Practical Cats*)** 82

HEALTH SCIENCES

Aniuta Sydorchuk, Vasyl Moskaliuk, Yurii Randiuk, Leonid Sydorchuk

- Influence of Bacteriotherapy on Nasal and Tonsillar Microbiota in Influenza Patients** 86

MATERIALS SCIENCE

Yuliya Kazymyrenko

- The Effective Mechanical Properties of Metal-Glass Materials and Coatings** 90



Disclaimer: Liability: Publisher and its affiliates does not warrant or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information or product represented in this book. No Implied Endorsement: Publisher does not endorse or recommend anything. The views of the authors that have submitted their articles to this book are owned by them alone and do not necessarily reflect the views of the Publisher, its management team or owners. Further, Publisher does not recommend any product or service found via any advertisement within this book. No Warranty: When using this book, you may find many links to 3rd party Internet sites. Publisher is not responsible for the content or availability of these 3rd party sites. Publisher does not warrant or guarantee the products, services, or information found on external or 3rd party sites. The articles in our book do not dispense medical, legal or professional advice, nor do they prescribe any treatment or strategy that should be tested without the advice of a professional. Information presented in this book is for educational and research purposes only. You are responsible

for your own actions should you use any information found in this book. To reprint you must respect the copyrights of the authors by publishing the entire article as it is with no changes.