Gradient surface layers from tool cermets formed pressurelessly and sintered

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Abstract

Goal: *The goal of this monograph is development of the tool materials being the outcome of the concept of merging the surface engineering as the domain of knowledge with technology which is the powder metallurgy. The result are the fabricated materials with the gradient, cermet surface layers on steel substrate, combining the mutually exclusive mechanical properties like the high surface hardness and ductility of a tool. Three powder forming techniques were used for fabrication of the materials, out from which the authorial pressureless forming method is the best one, owing to properties of the completed tool. Development and implementation of the new pressureless forming method is possible thanks to elucidation of the effect of the polymer binding agent used in the contemporary powder forming methods and carbon from its degradation on activation of the sintering process. Feasibility of employing the modern powder forming methods, and especially of the pressureless coatings forming technique, was assessed based on analysis of the complex technological tests, including selection of components, conditions of mix homogenisation conditions, forming, and binding agent degradation, and also investigation of the structural transformations during sintering and heat treatment.*

Project/methodology/approach: *Modern powder forming technologies were used for fabrication of the developed tool materials, e.g., powder injection moulding, pressureless forming, and classic compacting. Technologies employing the binding agent are known and widely used in production of elements from polymer materials. Mostly the thermoplastic polymers are of significant importance during moulding of powders and play a role of the binding agent reducing viscosity and making forming the polymer-powder slurry possible. Detailed structure examinations and tests of properties of the obtained semiproducts were carried out at every fabrication stage, including tests of the technological properties of powder- and polymer-powder mixtures, their rheological properties, selection of the extrusion- and injection moulding and pressureless forming conditions. Selection of the optimum powder injection moulding conditions was preceded by modelling of this process using Cadmold program, widely used for modelling of injection moulding of the thermoplastic materials. Investigations were made on the effect of the solvent- and thermal degradation of the binding agent on growth of carbon concentration, which was the base for working out the complete debinding and sintering process cycle for the injection moulded- or pressurelessly formed materials.*

Sintering was carried out in the vacuum or protective atmosphere conditions, which makes direct material hardening possible from the sintering temperature. Specimens hardened from the sintering temperature, and also hardened classically from the austenitizing temperature were subjected to triple tempering, ensuring the maximum surface hardness. Testing of mechanical properties encompassed hardness testing, bending strength testing, and determining the abrasion wear resistance. Detailed structural examinations were carried out to determine the effect of temperature and atmosphere during sintering on type and size of the carbide- and carbonitride precipitations. Moreover, retained austenite portion was determined after hardening and tempering.

Achievements: *The original achievement is development of the method of the polymer-powder slurry moulding for fabrication of coatings which, because of the binding agent degradation and sintering, form the homogeneous or gradient cermet surface layers (CSL) on the steel substrate- completed or fabricated in the same technological process. Tool materials fabricated with this method are characteristic of high ductility of the steel core and high hardness of the surface layer.*

Limitations of research/applications: *The assumption of the powder injection moulding technique is forming of the small elements with complex shapes and, therefore, this technology is not designed for fabrication of tools with the big overall dimensions. In case of the pressureless forming of the surface layers from cermets on the steel core or in case of regeneration of the tool worn out, the limitations come only from the heating device chamber size and the necessity to heat up the entire treated element.*

Practical applications: *It is anticipated that the worked out and fabricated tool materials of the new generation will fill a gap in respect of the mechanical properties between the relatively ductile high-speed steels and the brittle sintered carbides. The newly developed method may be used in the mass- or piece production conditions making, e.g., regeneration possible of the costly tools' surfaces. The application potential of the powders forming techniques for constituting materials or only CSL with the gradient structure seems to be more extensive than for the tool materials alone. The solutions obtained may also find applications for elements of machines and equipment operated in the abrasion wear conditions.*

Originality/value: *Employment of the modern powders forming techniques, and especially of the pressureless forming and sintering in the flowing nitrogen-hydrogen mixture atmosphere, makes it possible to fabricate tool materials with the layered or gradient structure with the multidirectional growing portion of the hard carbide- or carbonitride phases. In spite of the great interest in materials with gradient structure making merging hardness and ductility of tools possible, apart from the PVD and CVD techniques no inexpensive and relatively simple method was developed so far to obtain tools with the layered or gradient structure.*

Keywords: *Powder injection moulding; Pressureless forming; Sintering; Heat treatment; Tool materials; Gradient materials; Cermets*

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Wykaz ważniejszych oznaczeń i skrótów

ASP23 – stal szybkotnąca spiekana z gatunku HS6-5-3 wytwarzana metodą prasowania izostatycznego na gorąco,

CMC (ang. Ceramic Matrix Composite) – kompozyty o osnowie ceramicznej,

C_E – współczynnik ekwiwalentu węgla,

DSC (ang. Differential Scanning Calorimetry) – różnicowa kalorymetria skaningowa,

EBSD (ang. Electron Backscatter Diffraction) – dyfrakcja elektronów wstecznie rozproszonych,

EDS (ang. Energy Dispersion Spectroscopy) – spektroskopia energii,

HDPE – polietylen o wysokiej gęstości,

MW – mieszanina węglików WC, TiC, TaC i NbC (ang. Tetra Carbides), o udziale objętościowym wynoszącym odpowiednio 47, 14, 33, 6%,

MMC (ang. Metal Matrix Composite) – kompozyty o osnowie metalowej,

M2 – Stal szybkotnąca HS6-5-2 oznaczona wg normy ASTM,

μPIM (ang. Micro Powder Injection Moulding) – wytwarzanie elementów o wielkości poniżej 1 mm przez formowanie wtryskowe proszku.

PIM (ang. Powder Injection Moulding) – formowanie wtryskowe proszku,

PEM (ang. Powder Extrusion Moulding) – wyciskanie proszku,

PLF (ang. Pressureless Forming) – formowanie bezciśnieniowe,

PM (ang. Powder Metallurgy) – metalurgia proszków, w szczególności klasyczne prasowanie w matrycy zamkniętej i spiekanie proszków,

PP (ang. Polypropylene) – polipropylen,

PW (ang. Parafin Wax) – parafina,

SA (ang. Stearic Acid) – kwas stearynowy,

Sw – współczynnik nachylenia krzywej rozkładu wielkości cząstek proszków,

TGA (ang. Thermogravimetric Analysis) – analiza termograwimetryczna,

TGM (ang. Tool Gradient Materials) – gradientowe materiały narzędziowe,

T15 – Stal szybkotnąca HS12-1-5-5 oznaczona wg normy ASTM,

WDS (ang. Wavelength Dispersion Spectroscopy) – spektroskopia długości fal,

WWP – węglikostalowe warstwy powierzchniowe,