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New Technological Trends of Using SHS

Abstract. Tools are usually obtained by joining the cutting part to a steel harder (by brazing, welding, gluing and by other methods). New ways of fabricating tools have been devised in which self-propagating high-temperature synthesis (SHS) heat is used not only to the cutting alloy, but also to simultaneously weld it to steel holder of the tool. High heat ability is obtained by combining aluminothermy (the thermite process) with the SHS of carbide alloys, including “carbonsteel”. The latter is a form of carbide alloys in which cobalt is replaced by tool steel.

Rezümé. A szerszámok általában úgy készülnek, hogy a vágó rész csatlakozik az acél alapra (forrasztással, hegesztéssel, ragasztással és más módszerekkel). Új eszközöket fejlesztettek ki, amelyekben az önterjesztő magas hőmérsékletű szintézist (ÖMS) nemcsak szintéziséhez, hanem az eszköz acéltartójához történő hegesztéshez is használják. A magas hőképességet úgy állítják elő, hogy az aluminotermiát (a termit folyamatot) a karbidötvözetek ÖMS-jével kombinálják, beleértve a „karbidosztált” vegyületet. Az utóbbi egyfajta keményfémötvözet, amelyben a kobaltot acélszerkezet váltja fel.

Резюме. Інструменти, як правило, отримуються шляхом приєднання ріжучої частини до сталевої основи (пайкою, зварюванням, склеюванням та іншими способами). Розроблено нові способи виготовлення інструментів, у яких тепло саморозповсюджувального високотемпературного синтезу (СВС) використовується не тільки для синтезу різального сплаву, а й одночасно для його приварювання на сталеву державку інструменту. Висока теплова здатність отримана шляхом комбінування алюмотермії (термітного процесу) з СВС при створенні карбідних сплавів, у тому числі "карбідосталі". Остання – це вид карбідних сплавів, у яких кобальт заміщений інструментальною сталлю

Introduction

SHS has been lately introduced into science and technology by A.G. Merzhanov and co-workers [1] as a means of obtaining refractory high-hard alloys and phases by using the chemical heat as a result of synthesis.

Very high burning temperatures (several thousand degrees Centigrade) can be attained by combining aluminothermic reactions (producing elemental metals – *Fe*, *Cr*, *V*, *Mo*, *W*, by reducing their oxides with the aid of Al powder) with the

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oxygen-less burning of these metals in carbon powder. Such combined reactions were called “hybrid” processes [2-5].

Medium high heat evolution processes have been used for hard-fazing of castings with carbides and /or borides surface layers by the in-mould route [3, 6-9].

In the present work high heat evolution processes have been employed in the production of medium size cutting tools in order to compensates high heat losses because of rather small volumes of reacting powder mixtures and also in order to simultaneously weld the carbides metal obtained on the steel holder of tools.

Theory and experiment

The “hybrid” high temperature processes devised can be described by the following reactions:

Stage 1 (thermite process):

$$(Me'+Me'')O_m+(2m/3)\cdot Al\rightarrow Me'+Me''+(m/3)\cdot Al_2O_3+Q_1 \tag{1}$$

Stage 2 (oxygen-less burning):

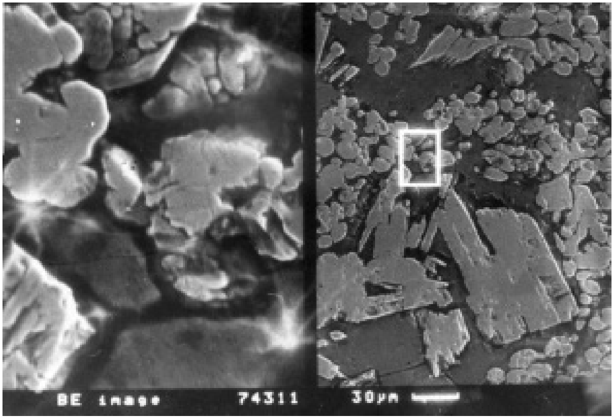
$$Me'+n\cdot C\rightarrow Me'C_n+Q_2 \tag{2}$$

Total:

$$(Me'+Me'')\,O_m+(2m/3)\cdot Al+nC\rightarrow(Me'C_n+Me'')+(m/3)\cdot Al_2O_3+(Q_1+Q_2) \tag{3}$$

Here *Me’* is the carbide-forming element (e.g. *W*) and *Me”* is the metal that is not combined with carbon but forms the plastic matrix which binds together the hard carbides $Me'C_n$. In usual carbide alloys *Me”* is cobalt. In “carbonsteel” [2] *Co* is replaced by alloyed tool steel, e.g. 12% *Cr* or high-speed stell (HSS). In Eq. 1 and 3 the ratio *Me’/Me”* is not specified. This ratio is very important because it influences the total heat evolution $Q=Q_1+Q_2$ and also the ratio carbide phase/cobalt or tool steel matrix in the carbide alloy or in “carbonsteel”. In case of the synthesis of “carbonsteel” surplus carbon must be added to the powder mixtures as per Eq. 2 because this extra amount is necessary to carburise the austenite+martensite metal matrix. When this matrix is alloyed with *Cr* or with *W+Cr* the dissolution of carbon in the liquid iron-based highly hard alloyed solution gives a small additional evolution of heat Q_3 which supplements the sum Q_1+Q_2. A programme for computer aided calculations of Q_1, Q_2 and Q has been elaborated and has been used in ref.3. In fig. 1 we have shown the microstructure of "carbiostal" and of its steel matrix.

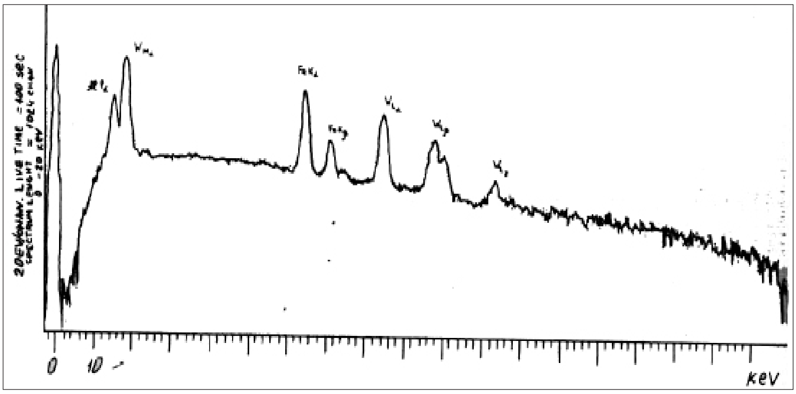
Figure 1. **Microstructure of a “carbonsteel” produced by the SHS (self-propagating hightemperature synthesis): a - massive WC carbides in an ultra high-carbon high-tungsten steel matrix (magnification x 100); b-matrix with spheroidized complex carbides (magnification x 400)**



This “carbonsteel” has been obtained by the "hybrid" process using Fe_2O_3, Cr_2O_3, WO_3 graphite and aluminium powder mixtures. Tungsten binds most of the carbon into large *WC* carbides, shown in fig. 1. Another part of tungsten binds carbon into small *WC* carbides forming the complex eutectic matric. This matrix may also contain small amounts of other carbides: Me_7C_3, $Me_6W_6C_2$ et al. In fig. 1 we can see that these eutectic carbides have been strongly spheroidised during recasting, when sharp edges have been rounded up.

Fig. 2 shows the x-rey spectrum of this alloy obtained in $Cu_{K\alpha}$ radiation. Only the *WC* and W_2C carbide phases are seen in it. The iron-rich phase is α′-martensite obtained after self-quenching and triple tempering at 570^{0}C. The hardness of the alloys obtained in such a new way is 72-75 *HRA* [2].

Figure 2. ***X*-ray spectrum of "carbidostal" obtained in Cu $_{k\alpha}$ radiation**



20 ev/chan, spectrum lenght = 1024 chan 0-24 kev

Medium size cutting tools have been obtained by burning thermite+*SHS* powder mixtures in a highly refractory combustion chamber placed over a small refractory mould surmounting the preliminarily heated steel holder of the tool.

The combustion chamber and the mould must be separated by a thin titanium sheet.

The exothermic mixture is ignited by a small amount of *Mg* or *Ti* powder, which is ignited itself by an ordinary match. When burning reactions end the slag floats up and the extremely hot liquid phase burns through the titanium sheet and fills the ceramic mould, being thus automatically welded to the steel holder of the tool. Such technology excludes brazing and other operations, designed to join the carbide alloy to steel.

A number of different types of tools for metal cutting and rock boring have been produced in such a novel way with good exploitation features in semi-industrial and laboratory conditions. The further work must be focused on augmenting the content of primary *WC* carbides in the "carbonsteel" obtained, the partial replacement of WO_3 by TiO_2 and other subjects of investigations. $\mathrm{TiO_2}$ is much less prone to oxidise *Al* than WO_3, the thermite-type reaction being much less exothermic in case of replacement of *W* by *Ti*. Therefore, such full replacement is impossible. Yet the *SHS* reaction $Ti+C=TiC$ is very "hot", the adiabatic temperature of such an oxygen-less burning being 3200 K. More exact computations and experiments must reveal the extent of partial replacements of that type.

One of the directions of application of SHS

The laser surface hardening (LSH) of metals was discovered in 1965. Nowadays in the whole world hundreds of patents have been awarded to branch inventions including those dealing with combination of LSH with SHS (self-propagating high-temperature synthesis). In the given investigation the mixture of powders *Ti* (68%), carbon in black state (18%) and *Fe* (14% by mass). The mixture was damped by solution of 2 % latex in gasoline, then it was put on the surface of stalls of mark 10 and 20 and was dried in an open air, forming the layer 80, 200 or 500 mkm thick. Those layers were burnt by CO_2 laser of continuous action with longitudinal pumping of "Cardamon" type 850 *W* of power under tightness of power 15-20$\mathrm{W \cdot m^{-2}}$, the speed of scanning was being changed in the limit of 10-20 $\mathrm{mm \cdot c^{-1}}$. After the experiment was made macro- and microhardness in alloy layer, in the zone of thermal influence and in the base metal were being measured.

Typical microstructure of metal consists of ~50% particles *TiC* and ~50% (by volume) metallic link – instrumental carbon steel of type 48. The investigations made proved that the microhardness of carbides *TiC* is almost 10 times higher than the hardness of steel and reaches *HV* 1400 (14000 MPa). The substitution of a part of iron in the SHS-mixture by ferrochrome increases greatly corrosion resistance of "carbonsteel" and decreases its oxidizing wear in the process of its exploitation. The substitution of carbon in SHS-mixtures by the powder is also long-range.

Conclusions

Combination of LSH and SHS in one operation allows to solve the whole complex of technical problems connected with producing of materials with high hardness like "carbonsteels" and hard alloys on metal surface: 1) evolution of inner chemical heat in SHS-mixtures allows to decrease the power of laser radiation; 2) new complex technological process allows to build up wearied surfaces of parts of machines and devices to the high of 0,5 mm; 3) laser ray as a source of heat may be substituted by electronic ray or by another carrier of energy.

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