

PERSPECTIVE HARDENING TECHNOLOGIES ARE BASED ON LASER SURFACE HARDENING AND SELF-PROPAGATING HIGH-TEMPERATURE SYNTHESIS

ZHIGUTS, YURIJ¹–KUDLOTYÁK, CSABA²–PALLAY, DEZSŐ³

¹D.Sc. in Technical Sciences, professor, Uzhhorod National University

²adjunct, Ferenc Rákóczi II Transcarpathian Hungarian College of Higher Education

³adjunct, Ferenc Rákóczi II Transcarpathian Hungarian College of Higher Education

The article is devoted to the study of the influence of combined surface material processing, which combines self-propagating high-temperature synthesis and laser surface hardening. The authors carried out theoretical calculations of the adiabatic temperature of the synthesis reaction. In addition, the authors discovered the microstructure of steel after a combined treatment, which consists of classical carbon steel (base) and carbides of various types. A separate study revealed the properties of phases and the microhardness of the surface material and the possible applications of synthesized alloys.

ABSTRACT

A cikk a kombináltanyag-feldolgozás hatásának tanulmányozására irányul, amely ötvözi az önterülő magashőmérsékletű szintézis és a lézeres felületi keményedést. A szerzők elvégezték a szintézisreakciót és kiszámították az adiabaticus hőmérsékletét. Ezenkívül a szerzők egy kombinált kezelés után fedezték fel az acél mikrostruktúráját, amely klasszikus szénacél (bázis) és különböző típusú karbidokból áll. Egy külön kutatás felfedezte a fázisok tulajdonságait és a felszíni anyag mikrokeménységét, valamint a szintetizált ötvözettek lehetséges alkalmazását.

INTRODUCTION

The laser surface hardening (*LSH*) of metals was discovered in 1965. It has won strong positions in the technology of metals [1]. 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). One of them is dedicated to combining of *LSH* (Laser Surface Hardening) with *SHS* (self-propagating high-temperature synthesis) [2-4]. Formerly *SHS* was combined with other technologies of surface hardening of components [5-9].

THEORETICAL AND EXPERIMENTAL RESEARCH

The important problem within the *LSH* is the decreasing of the losses of beam energy because of its reflection by the surface of metal under machining. In the given investigation, as well as in the invention [1,2], the mixture of powders *Ti* (65%), carbon in black state (18%) and *Fe* (14% by mass) were used in the role of light-absorbing paint. The mixture was damped by solution of 2 % latex in gasoline, and then it was put on the surface of stalls of mark 10 and 20 and was dried in an open air, forming a 80, 200 or 500 mkm thick

layer. Thermochemical calculations showed that in such a mixture practically all *Ti* interacts, thanks to non-oxygen combustion, with carbon, forming the carbide *TiC*. The excess plus of carbon and a very small amount of *Ti* alloy the iron forming liquid steel of condition, which under fast cooling turns into troostite in 80 mkm thick layers.

This reaction is strongly exothermic and is accompanied by great decreasing of Gibbs free energy:

$$\Delta G^{\circ} = -183,0246 + 0,01008T \text{ kJ}\cdot\text{mol}^{-1}, \\ T = 298 - 1155 \text{ K};$$

$$\Delta G^{\circ} = -186,9709 + 0,01325T \text{ kJ}\cdot\text{mol}^{-1}, \\ = 1155 - 2000 \text{ K}.$$

The adiabatic temperature of non-oxygen combustion of equiatomic mixture *Ti-C* equals to 3200 K. The real temperature of combustion of selected mixture 68% (% in mass particles) is more than 1850 K that provides the formation of hard-liquid dross (*TiC*-melting) with the large interval liquids solid use. The formation of dross instead of one-phase alloy influences positively the quality of surface of hardened layer after its full growing hard and cooling as well as the supporting of this layer even on inclined planes.

It is important to note that in the mentioned non oxygen combustion none of nonmetallic phases is formed. Welding of hardened layer with basic metal is obtained automatically „metallurgic ally”, excluding the necessity of soldering or other methods of connecting one alloy (e.g. instrumental) with another (e.g. with the basis of cutting tool).

In typical microstructure of metal in cross-cut of hardened layer got under density of power 17 W·m⁻², diameter of „spot” – 0,4 mm, the speed of scanning 12 min/s and expense of argon (for the defense of *Ti* from air oxidation) – 0,5 l/s

is shown. The thickness of alloy is ~500 mkm. This layer consists of ~50% particles *TiC* and ~50%(by volume) of metal link-instrumental carbon steel of type “Y8” (fig. 1).

The investigations made have proved that the microhardness of carbides *TiC* is higher than the hardness of steel almost 10 times. Thus, in the given work we managed to organize the SHS process in comparatively thin layer thanks to using of LSH technology simultaneously for solving of two tasks: for heating, flashing and carbonating of an iron; for flashing *Ti* particles and its „combustion” in carbon with forming of carbides *TiC*.

In the figure, the two *TiC* carbides during their synthesis “burnt” steel with high local heat release and deeply rooted in the bond, shown with two vertical arrows (fig. 1). It is also evident that in the zone of intense thermal influence the microstructure of steel acquired a very shallow columnar structure with a slight inclination of thin dendrites.

Figure 2 demonstrated full cross section of the microstructure, and the range of changed microhardness by depth of structural components of the surface layer (*Fe-C-Ti* system) within 1220-1570 HV.

The substitution of a part of iron powder by the powder of carbon ferrochrome (e.g. 12%*Fe*+2%*FeCr* instead of 14%*Fe* in the formulae of SHS mixture) allows to get layers of carbidosteel with the link not in the shape of steel “Y8” but from alloyed steel “X12” which after fast cooling of these layers thanks to accelerated drain of heat to cold metal of the basis gets austenite-martensite-carbide structure. In the process of work of the instrument such metal link additionally grows hard thanks to pre-transforming of austenite into martensite and getting harder than the latter one. The hardness of such a carbidosteel reaches HV1400 (14000 MPa).

Fig. 1. Microstructure of the strengthened layer with semi-fused TiC particles

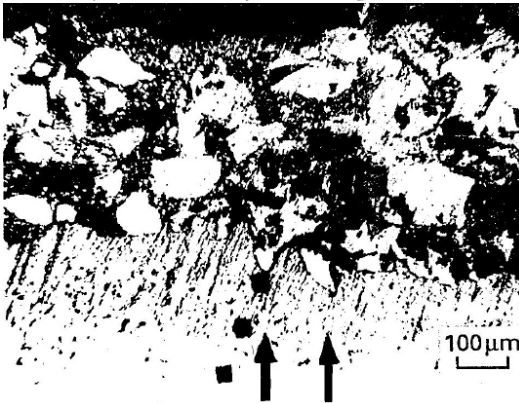


Fig. 2. Microstructure of cross-section of steel microsection after combined strengthening of LSH and SHS. A light arrow shows the direction along which the wells from the meter of the microhardness are located. The etching was carried out by nital



The substitution of a part of iron in the SHS-mixture by ferrochrome increases greatly corrosion resistance of carbidosteel 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. The same effect is obtained also with the substitution in another field of hot machining of metals namely the using of SHS-reactions for in moulding process (modification within of the form) in casting manufacturing.

The substitution of carbon in SHS-mixtures by the powder of boron is also perspective. In such a case it is possible to reach the liquidus-solidus interval of 1500 K that in other technologies it is practically impossible to meet. Thus, with the above mentioned method on the one hand high refractory diborides TiB_2 and CrB_2 (with high hardness) are formed and, on the other hand, very easily melted complex eutectics are formed.

CONCLUSIONS

1. 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 carbidosteels and hard alloys on metal surface.
2. Evolution of inner chemical heat in SHS-mixtures allows to decrease the power of laser radiation.
3. New complex technological process allows to build up wearied surfaces of parts of machines and devices to the hight of 0,5 mm.

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