RENOVATION OF HIGH SPEED STEEL BY PTA HARDFACING

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Abstract

Failure and wear of tools made of high speed steel (HSS) is a common cause of production slowdowns or interruptions. Renovation of structures made of high-speed tool steel can significantly reduce production costs and time needed for resumption of production. The Tool steel of HSS 23 type (M3/2, PMHS6-5-3C) was cladded on substrate of the same type of steel and heat-treated. The influence of hardfacing parameters on both macro- and microstructures was studied by light and electron microscopy. Development of hardness from substrate to deposit was measured by Vickers method. Metallurgical bond between parent material and deposit was created. The deposits are free of cracks

Keywords: Pulsed PTA, PTA hardfacing, High Speed Steel, Microhardness, renovation

1. INTRODUCTION

Hardfacing by PTA is a widely used technique of new material layer deposition on the surface of wear-resistant parts. It is one of the welding assisted hardfacing technologies where the plasma stream is used to melt both filler and parent material. After crystallization the new metallurgical bond is established between the deposit and parent material. The thickness of deposited layer varied between 0.5-10.0 mm [1] and the dilution is from 3 to 10 % for the majority of the PTA applications [2], [3]. PTA hardfacing is used for both new production and reparation of parts in valve-, glass-, oil- and other industrial fields [4], [5], [6], [7].

High speed steels are the alloys of iron and approximately 20% of alloying elements, namely carbon, vanadium, molybdenum, tungsten etc. The microstructure of a typical tool steel consists of a matrix of tempered martensite containing various dispersions of iron and alloy carbides [8].

In some previous studies it was reported that high speed steel can be deposited on mild carbon steel [9]. However there is no information in literature found about PTA hardfacing of high speed steel on the same grade parent material. The main aims of present research are to study the possibility of reparation of tools made from high speed steel by PTA hardfacing.

2. EXPERIMENTAL

High speed steel of AISI M3:2 type (Vanadis 23, Uddeholm) was used a parent material. Plates of 19mm thickness were prepared by powder metallurgy. One part of samples were quenched and tempered on to hardness of 61HRc and the other parts of plates were soft annealed (basic state). HSS 23 (Deutsche Edelstahlwerke, Germany) is molybdenum based high speed steel corresponding to AISI M3:2 with a good abrasive wear resistance and cutting edge retention with good toughness. It is suitable for demanding cold work applications like blanking of harder materials such as carbon steel or cold rolled strip steel and for cutting tools [10]. Powder of the same grade as parent material was used as the filler material for PTA hardfacing - AISI M3:2 (HSS23, DEW). Chemical composition of HSS23 powder is noted in **Table 1** and particle distribution were 63-180 µm.

Table 1 Chemical composition of powder (HSS23, DEW), (wt%)

	C	Si	Mn	Cr	Mo	V	W	Fe
HSS23 No25584	1.30	0.36	0.20	4.05	5.19	3.18	6.07	bal.

PTA hardfacing process was done by commercially available plasma surfacing automate PPC 250 R6 (KSK, s.r.o., Czech Rep), (**Figure 1**). This apparatus is suitable for hardfacing of rotary and non-rotary parts, on the circumference, on the top. Feed range of torch, realized by digital servo motors is 260-260-490 mm with tilting of the torch in range 40°. It is possible to use oscillation, up to 200 mm in X as well as in Y axe. Ar 4.8 was used as shielding, plasma and carrier gas.

Table 2 Samples, heat treatment of parent material and deposits

Sample	Plasma current	Heat treatment of PM	Heat treatment of deposit
1	100Hz	Quenched, tempered	Cooled in furnace
2	Cont.	Quenched, tempered	Cooled in furnace
3	100Hz	Annealed	Cooled in furnace
4	Cont.	Annealed	Cooled in furnace
1HT	100Hz	Quenched, tempered	Cooled in furnace and tempered
2HT	Cont.	Quenched, tempered	Cooled in furnace and tempered
3HT	100Hz	Annealed	Cooled in furnace and tempered
4HT	Cont.	Annealed	Cooled in furnace and tempered

Figure 1 PTA hardfacing on plasma surfacing automate PPC 250 R6 (KSK, s.r.o., Czech Rep.)

Properties of deposits were studied by metallography and both optical microscopy (Zeiss, Germany) and SEM (Jeol, Japan). Microhardness measurement was performed on microhardness tester IndentaMet (Buehler, Germany).

The single beads were deposited on to preheated parent material (250 °C) and cooled down in electrical furnace. All the samples were cut by metallographic saw and one part of the samples were tempered on temperatures 550-550-560 °C/1h on each temperature. Temperature of samples was measured by thermocouples and during deposition increased on 550°C approximately. Two samples were deposited by pulsed plasma current (170/80 A, 100Hz) and the others two samples by continuous current (155A) with oscillation wide of 13mm. Torch speed was 3mm·s-1 and oscillation speed was 9mm·s-1 (**Table 2**)

3. RESULTS AND DISCUSSION

The samples present regular appearance of deposited bead due to the same trajectory of torch. Deposited layer smoothly passes in to the parent material (**Figure 2**). Due to preheating, the deposits are larger and thinner in comparison with those in the previous work [11], [12]. There are no cracks neither pores on the surface of the deposits after hardfacing on soft annealed substrates. However deposition on quenched and tempered parent material results in cracking in both deposit and heat affected zone respectively as can be seen on the cross section (**Figure 3**). Cracking was detected also in heat affected zone of the sample 3HT after tempering. Sample No. 4 have no crack both before and after tempering. Based on previous studies [9], [13], hardfacing by pulsed-PTA caused decreasing of heat input in to the parent material and, consequently, higher cooling rates after crystallization. When high speed steel is used as filler material, the higher cooling rate results in higher hardness and lower ductility. This is the probable reason of cracking of sample 3 after tempering. Samples 1 and 2 present cracking in as welded state, the reason is the most likely quenched and tempered structure of parent material and too low temperature of preheating and interpass during hardfacing.

Figure 2 Deposit of high speed steel on the same grade parent material - pulsed plasma current - 100Hz

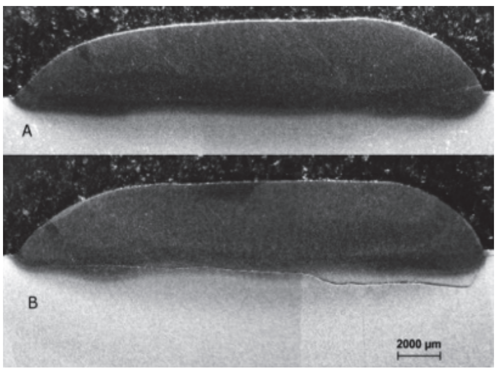

Figure 3 Sample 3 (A) and 3HT (B) - high speed steel deposit before (A), and after (B) teempering. Crack in HAZ of sample B

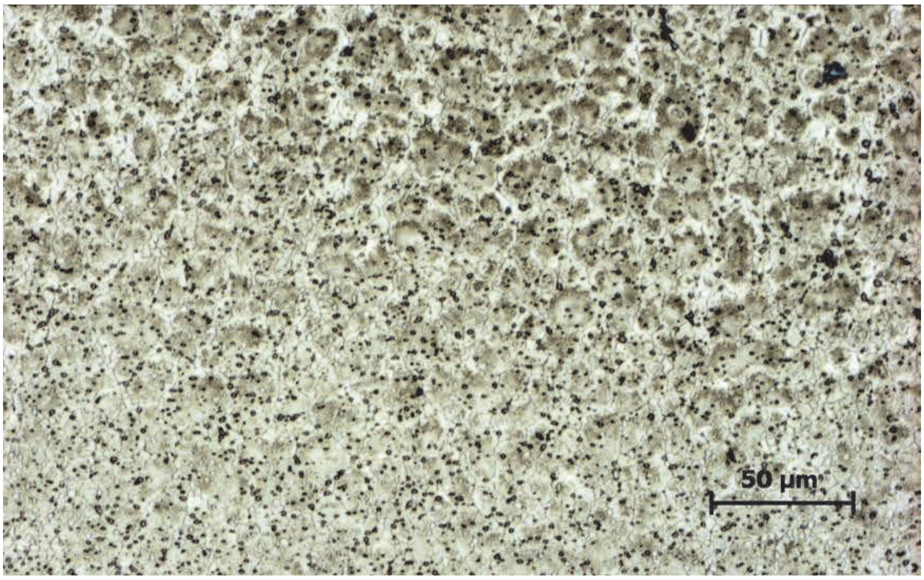

Figure 4 Sample 2 - transition area between parent material and deposited layer, 100x

Microstructure of PTA deposits (**Figure 4** - 4-D) is very similar to casted microstructure studied in [1], [14] and [15]. When the parent material, boundary region and deposit is compared (**Figure 4**) one can see that the carbides with high content of vanad are very similar shape and dimensions both in deposit and parent material respectively.They do not content mostly any iron while the content of carbon is higher than in carbides of molybdenum and tungsten. Iron is not present in any carbides of vanad, tungsten, neither molybdenum while chrom is dissolute in matrix with some slightly higher content in carbides region. Carbides of molybden and tungsten have different shape than in parent material. They form eutectic-like structure on the boundaries of grains. Smooth region in matrix on first images of (**Figure 4** - 4-D) belongs to retained austenite while rough parts represent bainite/martensite mix. These regions are completely removed by tempering as it shown on **Figure 5**. Parent material keep its structure and appear as the same as before tempering. Transition area between parent material and deposited layer is characterized by gradual change of carbides form and shape (**Figure 4**). Bright areas on the top of micrograph belong to retained austenite while dark regions present martensite.

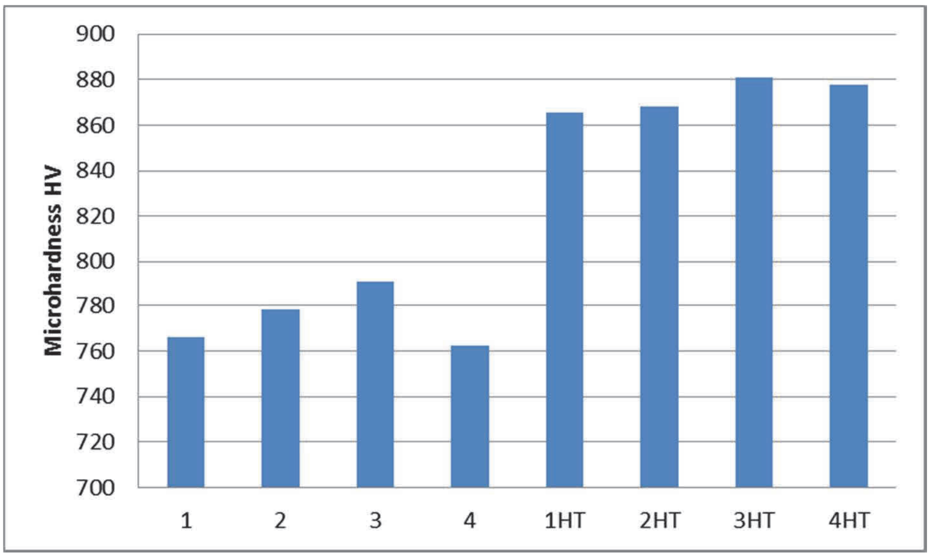

Figure 5 Microhardness of deposits - 2 mm under free surface

Microhardness measurement of deposits 1 mm under free surface revealed that tempering by three steps on 550°C increase microhardness of all four samples. Final microhardness of deposits on annealed parent material after tempering is slightly higher than microhardness of deposits on quenched and tempered material. The lowest microhardness was measured on sample deposited on annealed substrate by continuous plasma current.

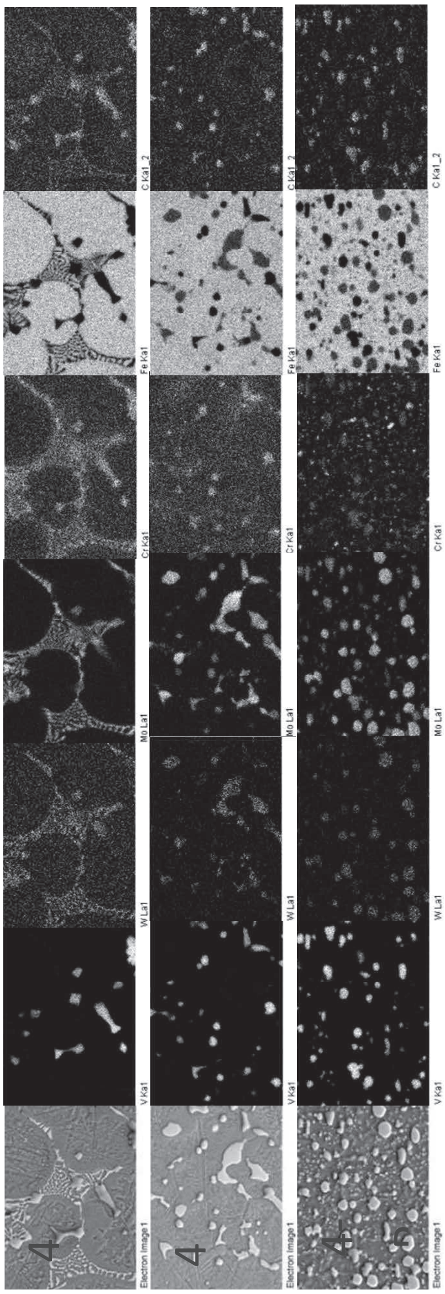

Figure 6 SEM micrographs of sample 4. 4-D - deposit, 4-J - deposit/parent material boundary, 4-PM - parent material

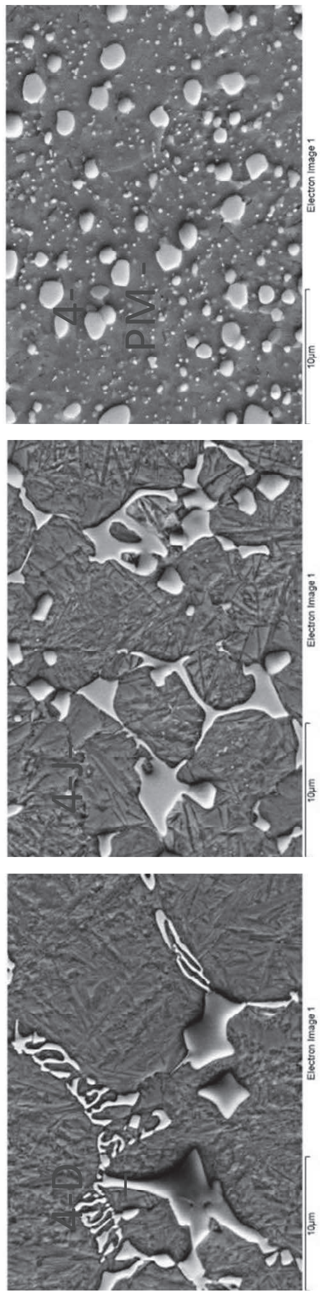

Figure 7 SEM micrographs of sample 4-HT. 4-D-T - deposit, 4-J-T - deposit/parent material boundary, 4-PM-T - parent material4000x

4. CONCLUSION

It is possible to successfully clad the high speed steel on annealed parent material of similar chemical composition, however, hardfacing on quenched and tempered parent material results in cracks formation in HAZ.

Microstructure of deposits is content relatively small vandad/carbon-rich particles (carbides) and eutectic-like molybden/tungsten carbides. Matrix is formed by retained austenite and martensite. Retained austenite is completely transformed by tempering in to martensite. Chrom is dissolute in matrix but some residual content can be seen In tungsten carbides too. Microhardness of all deposits increased after tempering three times on 550°C.

It is possible to repair large part of tool made from HSS but the piece has to be annealed, however some another change of parameters such as increasing of frequency of plasma current or increasing torch velocity can be promising in repair of quenched and tempered tools.

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