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# AN ANALYSIS OF STRUCTURES OCCURRING IN WELD DEPOSIT OF STEEL S235JR+N WITH TUNGSTEN CARBIDE PARTICLES AND MARTENSITIC MATRIX

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Protective layers include special weld deposits, utilizing e.g. ferrous, nickel or cobalt matrices in combination with tungsten carbide particles, which according to their properties belong among so-called composite materials, and which have slowly replaced conventional components produced from tool steels. A weld deposit with an iron-based matrix (Megafil A864M) was used, with tungsten carbide particles on steel S235JR+N. The high-level hardness of tungsten carbides together with a tough matrix allows achieving high resistance to different types of wear. This resistance significantly increases the lifetime of machine components and thus it reduces the costs of companies needed for repairs or the replacements of machine parts.

*Key words:* steel S235JR+N, weld deposit, abrasion, tungsten carbide, martensitic matrix

## INTRODUCTION

The most common cause of component discarding is surface breakage damage due to its wear. This type of damage occurs in up to 90 % of cases. When renovating such parts, up to 70 % of the cost can be saved, compared to new ones price. The amount of savings depends mainly on the price and availability of the new component, the extent of damage and the price of additional materials for welding [1, 2].

Prior to the renovation, it is necessary to deal with the determination of the type of wear and the possible influences of the working conditions. The result is the selection of a suitable technology for welding and suitable additional material for the weld deposit. Welding technology is not the only one that can be used for material surface treatment. Flame spraying and laser cladding can be used as well [3, 4].

One of the progressive materials used for weld deposits on knives and teeth for mining and building machines is tungsten carbide. Tungsten carbide is characterized by its high-level hardness and corrosion resistance [5, 6]. These properties predetermine it to be used for components designed to process different materials. Due to its fragility, it must be combined with a suitable matrix, to prevent the premature destruction of the tool by cracking or dropping out of the tungsten carbide particles [7, 8].

During welding, the basic material is thermally influenced, which may affect the mechanical properties of the layers below the melting line in the parent material in the heat-affected zone (HAZ). By welding it on a substrate with different chemical composition of the two components and after their final blending, a heterogeneous joint is created [9].

## MATERIALS AND METHODS

In the experimental part, the additional material Megafil A864M was used in the form of a filled electrode with a diameter of 1,6 mm (for chemical composition see Table 1). This material is used in common practice to weld layers on products, exposed to different types of wear in extractive and mining industries. This welding metal has a martensitic structure. The samples were welded in a protective atmosphere of 82 % Ar and 18 % $CO_2$. Steel S235JR+N was used as the base material (for the chemical composition, see Table 2).

The WC16 sample was deposited without tungsten carbide particles. In the WC19 sample, tungsten carbide particles with dimensions of approx. 1 - 2 mm was added to the melted pool during the welding process in

Table 1 **Chemical composition of Megafil A864M / mas. %**

| C | Si | Mn | P | S |
|---|---|---|---|---|
| 0,426 | 0,27 | 1,05 | 0,025 | 0,025 |
| Cr | Ni | B | Fe | |
| 0,27 | 1,57 | 4,62 | rest | |

Table 2 **Chemical composition of S235JR+N / mas. %**

| C | Si | Mn | P | S |
|---|---|---|---|---|
| 0,14 | 0,20 | 0,67 | 0,01 | 0,02 |
| Cr | Ni | Cu | Al | Fe |
| 0,02 | 0,01 | 0,01 | 0,05 | rest |

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amount of 40 g. 100 mm$^{-1}$. Welding parameters are provided in Table 3.

## X-ray diffraction (XRD) analysis

A XRD analysis in weld deposits was done using the instrument PANalytical Empyrean. This way, the phase analyses were done, for phases occurring during welding in each sample of the weld.

Table 3 **Welding parameters**

| | WC16 | WC19 |
|---|---|---|
| Current / A | 260 | 250 |
| Voltage / V | 33 | 27 |
| Speed / mm.s$^{-1}$ | 5 - 6 | 4 - 5 |

## Chemical analysis of weld deposits

A chemical analysis was performed using the electron microscope TESCAN 5130SB. A liner chemical analysis was done on selected areas between the weld deposit and the substrate. The surface chemical analysis was always done within the area of the weld matrix, 0,5 mm from the weld surface, 0,5 mm above the weld deposit interface and further 0,5 mm below the weld deposit interface of the basic material.

## Abrasive wear test

To measure abrasive wear, a Dry Sand/Rubber Wheel Abrasion Testing Device was used, which corresponds to the standard ASTM G 65. The measurement was made on samples with the grinded surface of the weld. The rotation speed corresponded to 60 rpm using 5 kg weights to create a contact force thanks to a leverage transfer 23 N, perpendicular to the surface of the wheel with a rubber surface. An abrasive (Sand of grit 0,1 - 0,6 mm) was dosed in the quantity of 27 - 32 g. min$^{-1}$. The measurement was divided into 5 periods of 12 minutes each. At the end of each period, the weight loss of the sample was measured, see Table 4.

## RESULTS AND DISCUSSION

## XRD analysis

In the WC16 sample (see Figue 1) alpha iron phases occur, together with the iron borides FeB and $Fe_2B$, and probably also residual gamma iron and iron boride $Fe_3B$.

In the weld sample WC19 (see Figure 2), there are phases of the alpha iron present, and also both forms of tungsten carbide WC and $W_2C$, iron boride FeB and a mixed substance of tungsten and iron carbide $Fe_3W_3C$.

## Chemical analysis of weld deposits

In the sample WC16, the content of manganese, chromium and nickel was gradually decreasing towards the base material (see Figure 3) in the measured section. It can, therefore, be stated that during welding there was a partial diffusion of Cr into the heat affected zone (HAZ) of the base material.

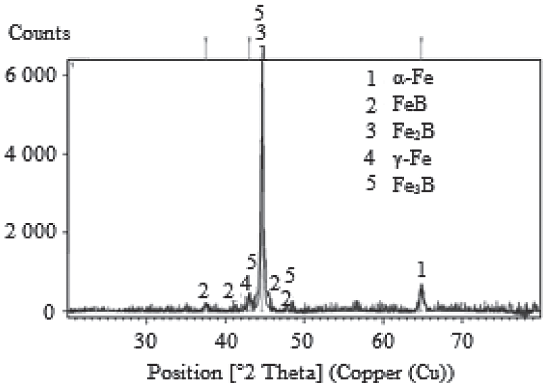

**Figure 1** XRD analysis of the WC16

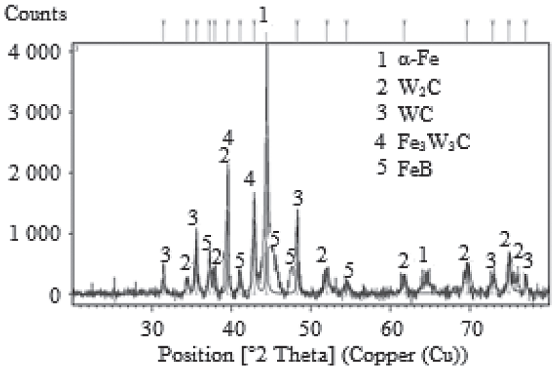

**Figure 2** XRD analysis of the WC19

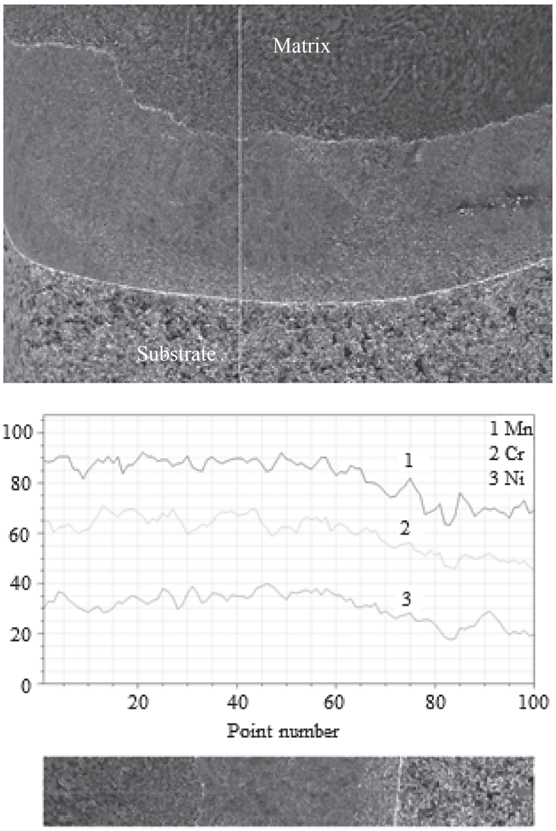

**Figure 3** Course of the chemical composition of WC16 (mag. 36 x)

From the chemical composition of the sample WC19, a perceptible decrease in the tungsten content can be observed, decreasing from the tungsten carbide particle into the weld matrix (see Figure 4). At the same time, there is an increase of iron on the melting boundary of the tungsten carbide particle and, furthermore, a gradual increase in the weld matrix and in the heat affected zone of the base material. In addition, there was a slight shift of chromium and nickel (in small scale) into the base material.

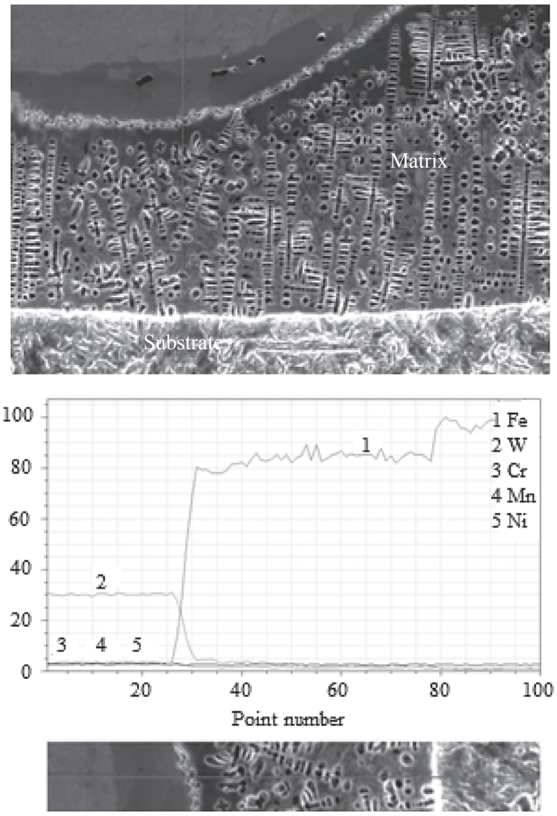

**Figure 4** Course of the chemical composition of WC19 (mag. 250 x)

## Abrasive wear test

The study of the weld surface after the wear test was performed, using an electron microscope.The weld deposit on the WC16 sample does not contain any particles of tungsten carbide. In this sample, due to the effect of abrasives, cutting of material occurred all over the weld deposit surface in the direction of the abrasives movement (see Figure 5). Results of test can be seen in Table 4.

Scratches occur on the surface, arising from the abrasive particles reflected from the surface of the weld. These scratches lead to further loss of material.

Table 4 **Weight loss of the weld deposits / g**

| | 0 min | 12 min | 24 min | |
|---|---|---|---|---|
| WC16 | 172,909 | 172,7 | 172,506 | |
| WC19 | 187,131 | 186,989 | 186,921 | |
| | 36 min | 48 min | 60 min | Tot. |
| WC16 | 172,322 | 172,128 | 172,01 | 0,9 |
| WC19 | 186,873 | 186,797 | 186,774 | 0,4 |

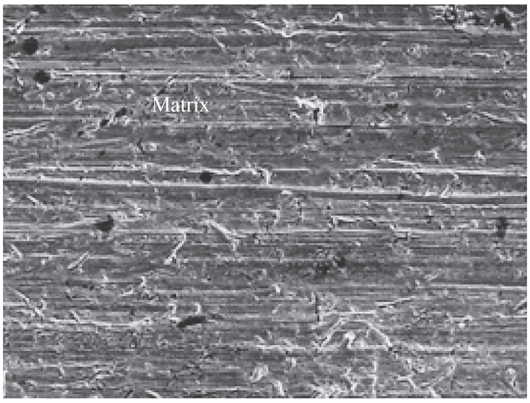

**Figure 5** The surface of worn weld deposit WC16 (mag. 240 x)

In the WC19 sample, it can be seen that tungsten carbide particles form a kind of barrier, preventing abrasive particles from moving further on the surface of the weld deposit and bounce them away (see Figure 6). This contributes to reducing the material loss due to its cutting. All traces end on the interface of weld matrix and tungsten carbide particles, where they no longer move. The tungsten carbide particle surface is, due to its higher hardness, only slightly affected by the action of abrasives.

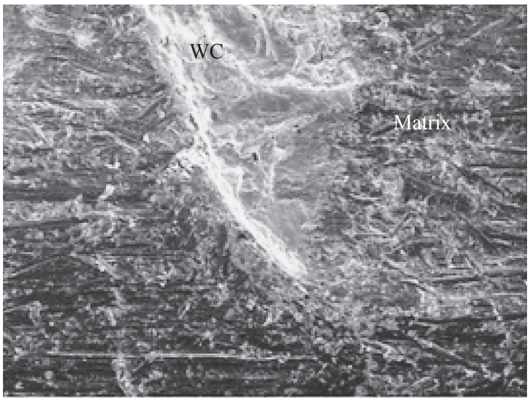

**Figure 6** The surface of worn weld deposit WC19 (mag. 240 x)

## CONCLUSION

The XRD analysis of WC16 and WC19 samples proved the formation of a whole series of phases. The WC16 sample contains mainly iron borides in the form of FeB and $Fe_2B$, and probably also $Fe_3B$. In the case of the XRD analysis of WC19 samples, both forms of tungsten carbide WC and $W_2C$ occur, as well as for iron boride FeB and the mixed tungsten and iron carbide $Fe_3W_3C$. For the WC19 sample, we can, therefore, observe the formation of mixed secondary carbides of iron with tungsten. These occur after the melting of tungsten carbide particles during welding.

This study of the worn surface of these samples shows that all abrasive wear mechanisms can be found here, in particular, the cutting of the material from the weld matrix, but also to a lesser extent, from a tungsten carbide particle surface in the case of the sample WC19.

This is the result of high-level hardness of tungsten carbide particles compared to the weld matrix.

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