APPLICATION OF WC GRAINS BY DEPOSITION BRAZING

MARIAN SIGMUND, JOSEF IZAK

FSI VUT Brno, Faculty of Mechanical Engineering, Institute of Welding and Surface Treatment, Brno, Czech Republic

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sigmund@fme.vutbr.cz

The article describes problems of hard depositional brazing of wolfram-carbide grains in various matrixes. Especially iron and nickel base matrix on base material from constructional carbon steel. The experimental part was brazed by oxyacetylene flame (method 912 according to EN ISO 4063). The major goals of the experiment were to describe the technological procedure of hard depositional brazing of this specific part. Consequently, were proved wolfram-carbide deposit on two test coupons. These test coupons were metallographically and qualitatively evaluated. The advantage of wolfram-carbide depositional brazing is a service life of deposit, that could be multiple higher, than standard weld deposit with carbon, chromium and vanadium filler material. The advantage is also costly because this kind of braze is cheaper than hard surfacing filler material. This specific application of the wolfram-carbide layer is one of the hardest coatings that could be by flame brazing technology performed. Usage of this application is for example in the mining, woodcutting industry, where it is necessary to improve abrasion and resistance, service life, and guaranteed durability or hardness for cutting tools.

KEYWORDS

WC - wolfram-carbide, WC grain – wolfram-carbide grain, hard deposition brazing, flame brazing, barking knife.

1 INTRODUCTION

This article specifies technological procedure and evaluation of brazed deposit on the hard depositional brazing barking knife. On the ground of hard and abrasion resistance of barking knife is braze containing WC grains deposited on a base material. Brazing with WC grains non-increase only hardness, but also multiple increases service life of barking knives. Used technology for hard depositional brazing of WC grains is the oxygen-acetylene flame. The experiment will examine two deposit layers with different chemical compositions. At first will examine the iron base layer with WC grains. In the second will examine nickel base layer with WC grains. For quality evaluation and metallurgical cleanness of deposited layers were established micro hardness measurement and evaluation of macrostructure and microstructure, including SEM (Scanning Electron Microscopy) and EDS (Energy Dispersive X-Ray Spectroscopy) analyses. In conclusion were verified possibilities brazer and brazing process qualification according to appropriate standards, appearance to given single part of a barking knife.

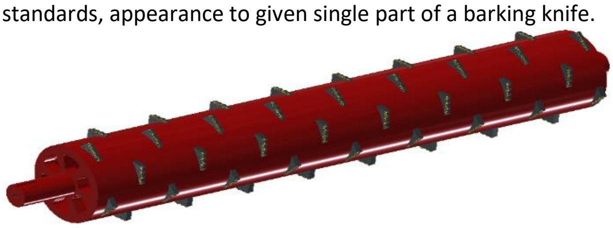


Figure 1. Barking knife roll with single knives

2 THE BRAZED PART

Machine, where are used these barking knife rolls is named barking machine. The purpose of the barking machine is to get off trees from barks. These barks could be used for example for the production of wood particle boards. A barking knife roll with single knives is displayed in Figure 1. The subject of this experiment is a barking knife (Figure 2). The base material of the barking knife is constructional carbon steel S355JR0. A barking knife is produced as burnout from a steel plate with addition for machining. On this machined burnout is by manual hard depositional brazing brazed WC grains with powder. A deposit filler material is in practice powder braze, especially two kinds of brazes either DURIT CS and DURIT Ni A. The general conditions of both brazes are mentioned in Tables 1 and 2. [WIRPO 2019]

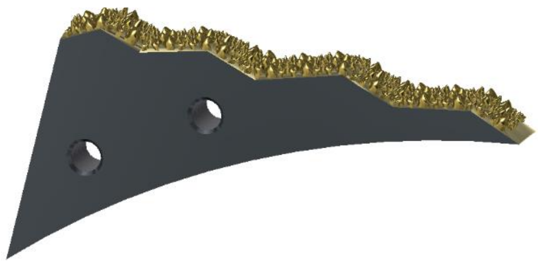


Figure 2. Barking knife with brazed WC grains

DURIT CS	Grain	Matrix
Composition	WC - W_2C	CuNiZn
Hardness [HV]	2600	~ 74
A portion [%]	60	40
Grain shape	Sintered WC	-

Table 1. General conditions of braze DURIT CS

DURIT NI A	Grain	Matrix
Composition	WC - W_2C	NiCrBSi
Hardness [HV]	2360	~ 485
A portion [%]	65	35
Grain shape	Fused Tungsten	-

Table 2. General conditions of braze DURIT Ni A

3 THE EXPERIMENT

A deposited filler material is double kind, in the specific brazes with trademark DURIT CS and DURIT Ni A. Braze DURIT CS is delivered as a welding rod compound from brass alloy matrix and milled sintered WC grains sized amount 6.4 mm. Braze DURIT Ni A is delivered as a flux-covered electrode compound from fused tungsten carbide powder in a nickel alloy matrix filled in tubular wire diameter 2.4 mm. Braze DURIT Ni A due to melting point 900–1000°C have very good braze and solder ability. Braze DURIT Ni A compared to braze DURIT CS have an advantage, that have excellent resistance to acids and corrosion. Braze DURIT Ni A we could use also in extreme conditions, where's huge wear and at the same time acid and corroding medium. [WIRPO 2019]

3.1 The brazing process with braze DURIT CS

The working part of a barking knife was brushed and cleaned from rust and fat. Consequently, were knife preheating by resistance on a heating elements to temperature 350°C. Preheating temperatures were monitor by joined thermocouples. For brazing were on flame torch set reducing as far as neutral flame. Brazing technique shall enable move WC grains in molten braze. Brazing's working temperature was 920°C. During brazing, solidification shall WC grains stay on turned on high vertically by edge up. After completing brazing were barking knives cooled in the wrap. This sample was stamped No. 1. [WIRPO 2019]

3.2 The brazing process with braze DURIT Ni A

The working part of a barking knife was brushed and cleaned from rust and fat. Consequently, were knife preheating by resistance on a heating elements to temperature 350°C. Preheating temperatures were monitor by joined thermocouples. For brazing were on flame torch set reducing as far as neutral flame. Brazing technique shall enable move WC grains in molten braze. The brazing working temperature was 1020°C. During brazing, solidification shall WC grains stay on turned on high vertically by edge up. After completing brazing were barking knives cooled in the wrap. This sample was stamped No. 2. [WIRPO 2019]

3.3 The brazer and brazing procedure qualification

The brazer qualification is possible according to standard EN ISO 13585 – Brazing – Examination of brazers. The brazing procedure qualification is also possible according to standard EN 13134 – Brazing – Examination of the brazing process. I'm afraid that qualify this special deposit brazing process according to standards EN 13134 was not possible. Standard isn't sufficient for qualification this specific type of depositional brazing of WC grains. To be sure a brazer qualification according to standards EN ISO 13585 is possible.

The basic variables and range of qualifications are:

- Brazing method – (method 912) flame brazing by the manual burner.
- Make of a product – metal plate (P).
- Is visible
- Group No. of Base Material 1 (carbon steel).
- Filler material and method braze deposition – beforehand deposited (PP).
- Dimensions – test piece t > 10mm.
- Deposition filler material direction – vertical deposition nose - up (VU), all directions deposition.
- Rate of mechanization – manual (range of qualification – manual and mechanized).

With braze DURIT CS could be written brazer qualification acc. EN ISO 13585 – 912 P B 1 DURIT CS PP t25 VU.
With braze DURIT Ni A could be written brazer qualification acc. EN ISO 13585 – 912 P B 1 DURIT Ni A PP t25 VU.

To qualify brazer to be necessary satisfy next examinations: visual testing, metallographic verification (macroscopic examination) and hardness measurement on a brazed deposit. Currency of European certificate is three years providing, that the brazer will not interrupt his activity on more than six months. If brazer succeeded is for him issued a EU certificate, that the successfully fetched qualification test. [SIGMUND, M 2019]

4 THE EXPERIMENT EVALUATION

After production of both types brazed barking knives was performed a non - destructive testing. A non-destructive testing has to find out imperfection in a brazed deposit. Above all find and sorts types of rents, leeks, and occlusions. After it was performed some metallographic destructive testing to check macro and microstructure and phasic analysis on test coupons from brazed deposits.

4.1 The visual and penetrant testing

Test pieces were visually tested according to standards EN ISO 5817 in qualities class C. After visual testing were brazed piece penetrant tested according to standard EN ISO 23277 in qualities class 2x. Results from testing are written in Table 3. Results are also documented by protocols and photo documentation. Since acts about brazed deposit wasn't effected any other NDT testing.

	Sample No. 1	**Sample No. 2**
Visual Testing	Acceptable.	Acceptable.
Penetrant Testing	Without indication.	Without indication.

Table 3 Results from visual and penetrant testing

4.2 The metallographic macrostructure evaluation

In Figure 3 is shown sample No. 1. In this picture is marked a place, where were evaluated macrostructure. In Figure 4 is shown a macrostructure of brazing and base material. On wolfram – carbide and braze boundary is visible black - eye gas hole. This defect could arise due to the reaction of hydrogen to zinc. Hydrogen arises a porosity. This could be caused by non-performance brazing procedures for example correct flame (using oxidizing flame) etc. Crack on WC could arise during WC production or heating processes after production. This crack could be arising also during cutting and force - into the pill for metallographic examination.

Figure 3. Place of macroscopic evaluation on sample No.1

Figure 4. Sample No. 1 macrostructure (40x zoom)

In Figure 5 is shown sample No. 2. In this picture is marked a place, where were evaluated macrostructure. In Figure 6 is shown a macrostructure of brazing with WC grains and base material. In the middle of the picture is shown inside the WC cluster of black dots. These dots are air checks that cause short molding during WC production.

Figure 5. Place of macroscopic evaluation on sample No.2

Figure 6 Sample No. 2 macrostructure (40x zoom)

4.3 *The metallographic microstructure evaluation*

Both specimens for microstructure evaluation were cut on a metallographic saw from one's barking knife (Figure 7). Braze DURIT CS were deposit from one side of the barking knife and braze DURIT Ni A on the opposite side. This procedure was set up on the ground with the same preheating temperature (on heating elements) and the same base material. Braze DURIT CS has a brass matrix (zinc and copper + next alloy elements). Brass is shown in Figure 8, because has in microstructure clear „ white" color grains. The grains that are colored more to the red (detail A), so contain more copper, and the grains that are more to the yellowy (detail B), are richer about zinc. On a brass, grain boundary segregates during brazing nickel and silicon (dark black line). In Figure 6 top is displayed braze DURIT Ni A microstructure that has nickel matrix with others alloy elements. Inside the nickel matrix is joined WC grains. Around WC grain is braze, that is light white color in form of nickel with outcast of silicon. Darker black formations form hard phases of chromium and boron. [Science Direct 2019]

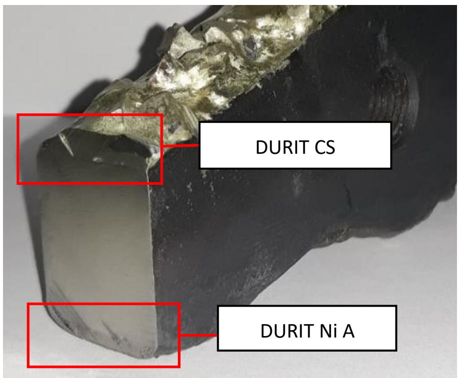


Figure 7 Places of microstructure evaluation on samples No.1 and No. 2

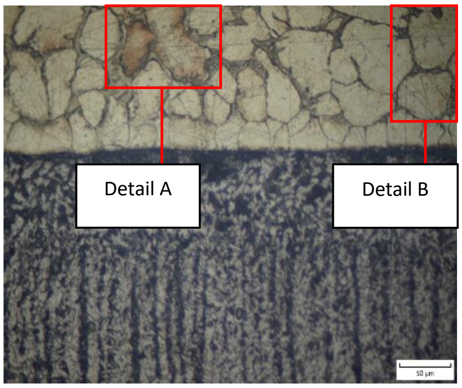


Figure 8 Sample No. 1 microstructure (400x zoom)

4.4 *The SEM and microanalysis evaluation*

First were evaluate photos from an electron microscope and consequently were all microstructures well-founded by chemical microanalysis. The inspected area from both types of brazing are interfaces between WC and braze and base material. Were evaluate three types of microanalysis namely surface, line, and point microanalysis. Braze DURIT CS is evaluated in Figure 9. In this picture is shown two huge black formations. Detail C refers to the pores cluster that is shown also zoomed on Figure 10. In this place on Figure 11 were by the help of point analysis marked two points (points 7 and 8), where were examine chemical composition. Point 8 display nothing special. Point 7 (Figure 12) display a high quantity of oxygen (gas-air or oxygen is cut-off inside), which results in huge porosity. By this evaluation was confirmed according to Figure 10, that acts about the bubble. On the finding pores cluster in the base material and form these black spots acts likely about air bubbles. [Science Direct 2019]

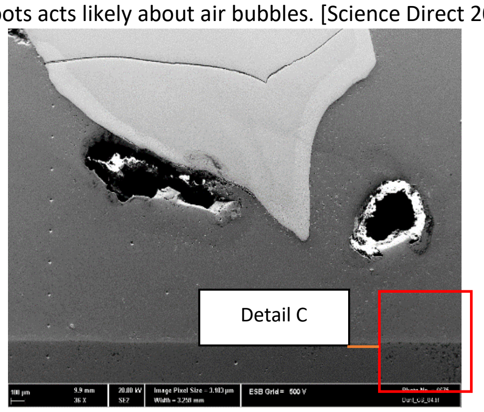


Figure 9 SEM microanalysis sample No. 1 (36x zoom)

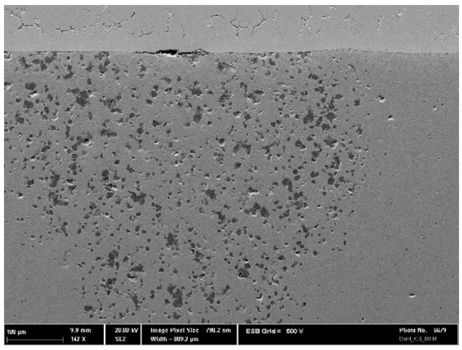


Figure 10 SEM microanalysis detail C, pores cluster in sample No.1 (142x zoom)

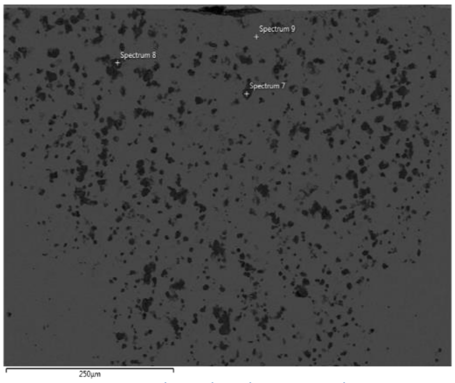


Figure 11 SEM microanalysis detail C, pores cluster in sample No.1 (250x zoom)

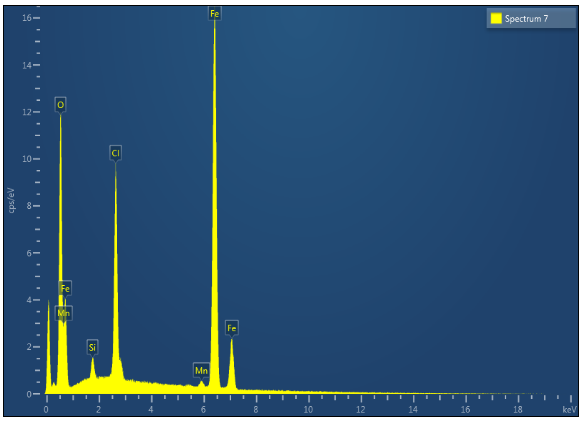


Figure 12 Point microanalysis of braze Durit CS (Point 7)

Further were performed on interface braze Durit CS and base material line microanalysis, which is displayed in Figure 13.

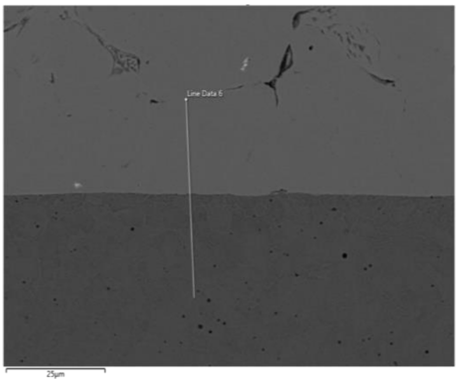
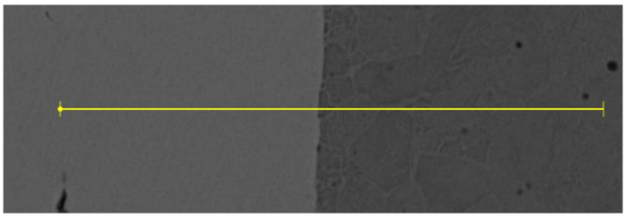


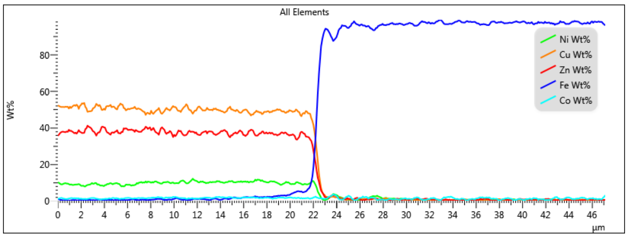
Figure 13 Line microanalysis of interface braze Durit CS and base material

Interest that is displayed in Figure 14 is that no exclude any alloy elements from base material to braze Durit CS or only very little. About alloy elements nickel, zinc, and cobalt of sorts, that according to findings (Figure 15). The content of alloying elements on line things are at least partial diffusion around grain boundary to the base material.

Line



Percent of substitution alloying element depending on the line



Chemical composition

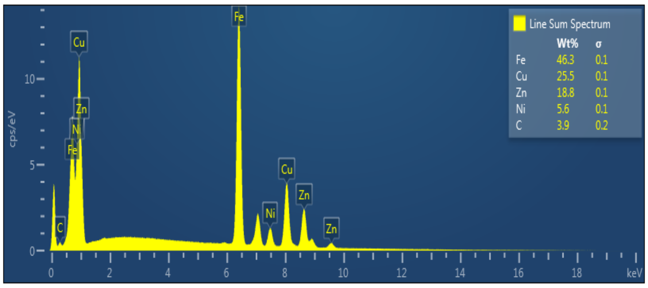


Figure 14 Line microanalysis of Braze Durit CS and base material interface

The first microanalysis that was performed on a sample with braze DURIT Ni A was the evaluation of microstructure (Figure 15) by surface analysis. From material datasheet results that the braze includes Ni, Cr, B, Si, but at least the approximate content of these alloying elements here wasn't detected.

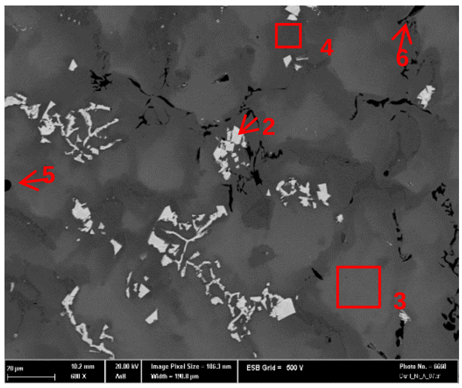


Figure 15 Microstructure of braze DURIT Ni A (600x zoom)

Approximate content of alloying elements finds in surface microanalysis (Figure 16), where nickel has the biggest substitution.

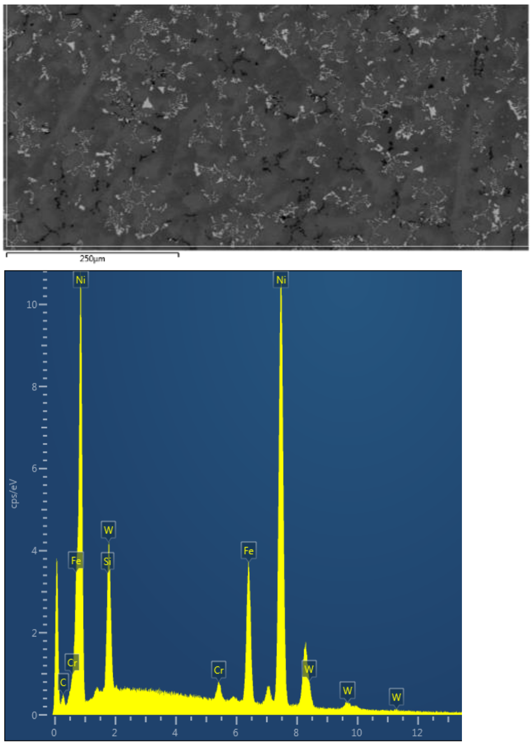


Figure 16 Surface microanalysis of braze Durit Ni A (250x zoom)

In Figure 17 is shown microstructure by surface microanalysis of WC and braze Durit Ni A. Better is microstructure shown in line analysis (Figure 18), as though carbon diffuse to braze from WC grains.

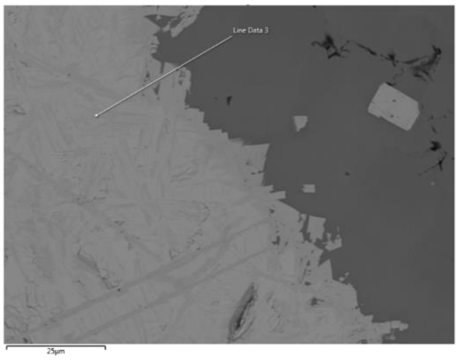
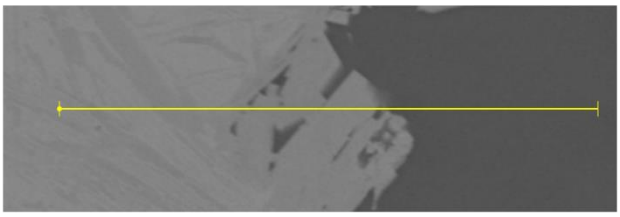
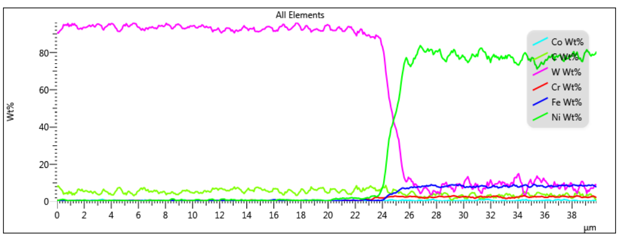


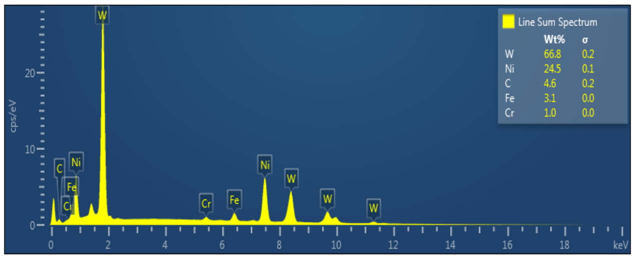
Figure 17 Line microanalysis of interface WC and braze Durit Ni A



Line



Percent of substitution alloying element depending on the line



Chemical composition

Figure 18 Line microanalysis of interface WC and braze Durit Ni A

Microstructure of surface microanalysis brazes Durit Ni A and base material is shown in Figure 19. In Figure 20 is shown iron diffusion from base material to braze Durit Ni A. In distance 15 mm is displayed passage through over WC, where percent nickel decline and percent wolfram grew up.

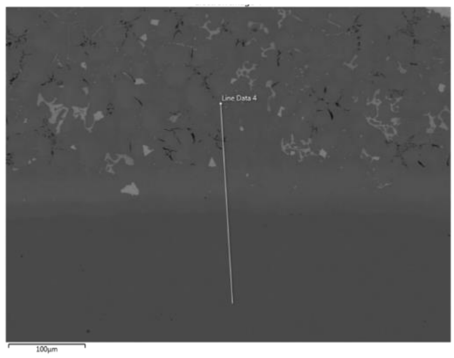
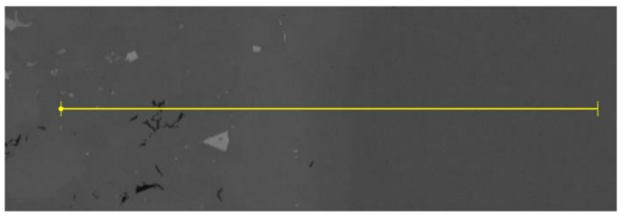
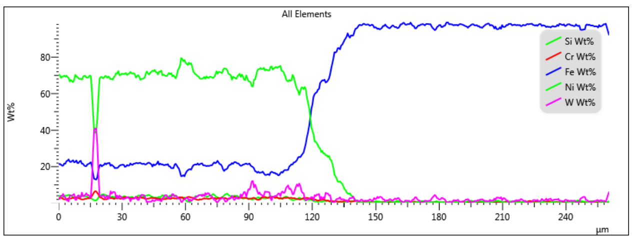


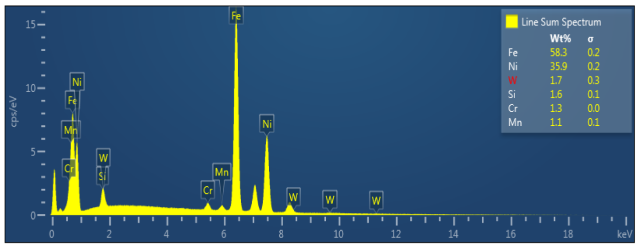
Figure 19 Line microanalysis of interface braze Durit Ni A and base material



Line



Percent of substitution alloying element depending on the line



Chemical composition

Figure 20 Line microanalysis of interface braze Durit Ni A and base material

4.5 The micro hardness evaluation

Were measured micro hardness HV 0.2 in line according to Figure 21. Measurement were performed from WC over brazing Durit CS, heat affected zone, and base material. All measured values of the micro harness are documented in Graph 1.

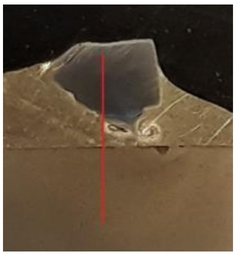
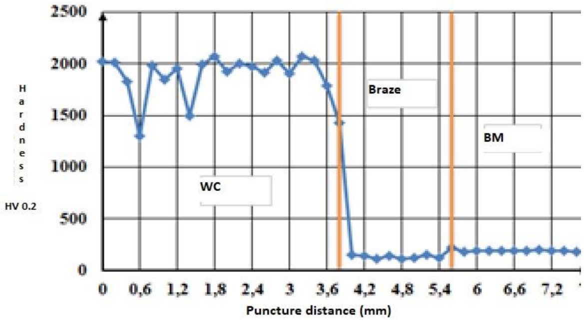


Figure 21 Micro harness measurement (line) of sample No. 1



Graph 1 Micro hardness evaluation of sample No. 1

Were measured micro hardness HV 0.2 in line according to Figure 22. Measurement were performed from WC over brazing Durit Ni A, heat affected zone, and base material. All measured values of the micro harness are documented in Graph 2.

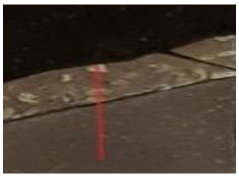
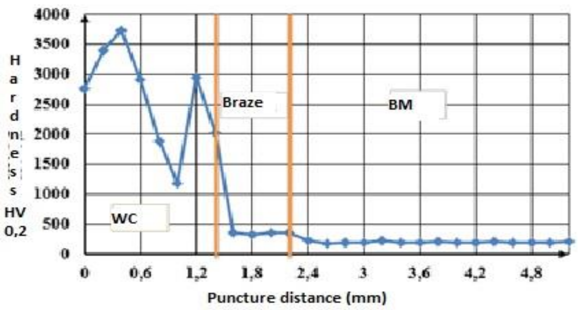


Figure 22 Micro harness measurement (line) of sample No. 2



Graph 2 Micro hardness evaluation of sample No. 2

5 THE CONCLUSIONS

This article describes the experiment and evaluation of hard depositional brazing of WC grains. First in metallographic study the brass-iron matrix (braze Durit CS) and second in metallographic study the nickel matrix (braze Durit Ni A).

WC grains are brazed on barking knives partly during the production of new knives and largely during the renovation of old knives. WC grains are during service crumble that is the main reason, why be necessary knives renovate. Iron matrix braze is concerning lower price select with dry abrasion conditions. On the other hand, nickel matrix braze is select rather with wet abrasion conditions. Which type of braze will be selected depends on the decision and request of the designer for the whole arrangement. Proposal of examinations described in experiment gets in reference with evaluation unusual microstructures and structural phases. Were performed acceptable visual testing and penetrant testing without linear indication on both types of braze. Consequently, were performed a metallographic evaluation of both deposited braze with WC grains. Whatever heterogeneity was evaluated by phasic analysis (SEM, EDS). The next important examination that were performed is micro hardness evaluation according to Vickers. Measured hardness were evaluated to the graphs. In both, brazes were find to considerable defects in form bubbles and porosity. It was caused according to my opinion by non-performance correct depositional brazing technological process or by preheating of base material before brazing. Both types of braze, were practically and experimentally proved, are possible successfully used for brazing.

ACKNOWLEDGMENTS

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CONTACTS:

Ing. Marian Sigmund, Ph.D., IWE
FSI VUT Brno, Faculty of Mechanical Engineering, Institute of Welding and Surface Treatment Technology
Technicka 2896/2, Brno, 616 69, Czech Republic
+420541142611,sigmund@fme.vutbr.cz,
https://www.vutbr.cz/lide/marian-sigmund-173