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ISTRAŽIVANJE NAVARA OD HROM BIJELOG GVOŽDJA OTPORNONG NA ABRAZIVNO HABANJE

INVESTIGATION OF CHROMIUM WHITE IRON WELD DEPOSITS RESISTANT TO ABRASIVE WEAR

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Rezime: Abrazija je dominantan mehanizam koji utice sa 50% habanja industrijskih komponenti. Navarivanje i reparacije su našle svoje mjesto u procesu obnavljanja pohabanih komponenti sa širokim spektrom zavarivačkih process od ručnih elektroda, zavarivanja pod praškom, punjene žice, MIG/MAG, elekto-šljake, plazma lučnog navarivanja, uključijuci procese od manualnih, poluautomatskih do robotizovanih. Ovo istraživanje je obuhvatilo legure koje pripadaju Hrom Bijelim Gvoždjima uključujući, Martenzitna Gvoždja, Austenitna Hrom Carbidna Gvoždja, Kompleksna Hrom Karbidna Gvoždja i Martenzitna hrom karbidna gvoždja. Analizirano je preko 90 navara, uključujuci tvrdoću, kvalitativnu i kvantitativnu mikrostrukturnu analizu i gubitke habanja prema ASTM G65 metodi. Definisan je Abrazivni Ugljenicni Ekvivalent (CEAbr) i uspostavljene su zavisnosti izmedju CEAbr i gubitaka habanja, gubitaka habanja i % nadeutektoidnih karbida, gubitaka habanja i tvrdoće, tvrdoće i % nadeutektoidnih kardbida, tvrdoće i CEAbr.

Ključne riječi: Abrazivno Habanje, Zavarivanje, Hrom Bijelim Gvoždja, Mikrostruktura

Abstract: Abrasion is the dominant wear mechanism impacting over 50% of industrial components deterioration. Weld deposits have found its application in refurbishing industrial components with wide spectrum of processes from Stick Electrodes, Submerged Arc, Flux Cored (gas, self shielded), GMAW, Electroslag, Plasma Arc Transfer, Oxy-fuel etc. including manual, semiautomatic to fully robotic automated processes. This investigation is focused on alloys belonging to Chromium White Iron weld deposits including Martensitic Iron, Austenitic Chromium Carbide Iron, Complex Chromium Carbide Iron, Martensitic chromium carbide iron. Over 90 weld deposits were investigated with reference to hardness, microstructure and abrasive wear loss (WL) to ASTM G65 method. Abrasive Resistant Carbon Equivalent (CEAbr) was established with numerous established relationships between CEAbr and WL, WL and % hypoeutectic carbides, WL and Hardness, hardness and % hypoeutectic carbides, hardness and CEAbr.

Keywords: Abrasive Wear, Weld Deposits, Chromium White Irons, Microstructure

1. INTRODUCTION

Commonly recognised wear categories [1] are:

Abrasive wear, Metal to metal wear, Impact wear, and Corrosive wear.

This research is focused on layer additions weld overlays to increase service life and/or restore components subjected to abrasive wear. Table 1 lists engineering methods of surface treatment of industrial components. Table 2. Lists available alloys to combat different wear mechanisms.

Table 1. Engineering methods for surface treatment of industrial components [1]

LAYER ADDITIONS	SUBSTRATE TREATMENT
HARDSURFACING	DIFFUSION PROCESS
Fusion hardfacing (welded overlays) Thermal spray (nonfusion bonded overlay)	Carburising; Nitriding; Carbonitriding Nitrocarburising; Boriding Titanium-carbon diffusion Toyota diffusion process
COATINGS	SELECTIVE HARDENING METHODS
Electrochemical plating Chemical vapour deposition Thin films (physical vapour deposition) Ion mixing	Flame hardening; Induction hardening Laser hardening; Electron beam hardening Ion implantation Selective carburising and nitriding

Table 2. Different alloys suitable for different wear applications.

ALLOYS/MATERIALS	WEAR APPLICATION
Pearlitic/Ferritic Steel	Metal to Metal
Austenitic Manganese Steel	Impact, Metal to Metal
Austenitic Stainless Steel	Impact, Corrosion, Heat Resistance
Low/High Carbon Martensitic, Tool Steel	Metal to Metal, Mild Abrasion; Impact
Martensitic Stainless Steel	Metal to Metal, Corrosion
Chromium White Irons	Abrasion/Moderate Impact
Tungsten Carbide Weld Deposits/Composites	Severe Abrasion
Cobalt/Nickel Alloys	Impact, Cavitation, High Temperature, Abrasion
Phosphorus/Aluminum/Nickel Bronze	Metal to Metal, Corrosion, Impact

Table 3. List of available fusion weld deposits and their characteristics.

Process		Form of Consumable	Dilution	Deposit Thickness	Deposition kg/h
MMAW	Manual	Coated electrodes rods and tubes	10-30 %	2 mm	1-3
SAW	Automatic Open Arc	Bare wire, tubular wire or strip	10-40%	3 mm	4-15
FCAW	Semi-automatic and automatic	Tubular wire, alloy wire or strip	10-35%	3 mm	2-10
GMAW	Semi-automatic and automatic	Alloy wire	10-25%	2 mm	2-10
Plasma Transf. Arc	Semi-automatic and automatic	Powder, bare wire or tubular wire	5-20%	0.5 mm	0.5-7
Laser surfacing/ clad	Automatic	Powder	5-20%	0.2 mm	0.3-6

2. EXPERIMENT

Large family [4] of chromium white irons weld deposits applied by MMAW, SAW, FCAW and Automated Open Arc composite welding processes was evaluated in regard to: microstructure qualitative and quantitative analysis, chemical composition, hardness, and wear

loss according to the ASTM G65 test method. White chromium alloys investigated are listed in Table 4. Figure 2. illustrated Cr-C diagram showing

Table 4. An overview of Chromium White Iron alloys used for abrasive wear applications [2].

Type	Alloy	%C	%Cr	%Ni	% Mo+Nb+Ti+V+W	% B	[3]
21	Austenitic Iron	2-2.7	15-27	12 max.	-		Fe-PAE
22	Martensitic Iron	2-2.7	15-27	-	-	Max. 2	-
23	Austenitic Cr-Carbide Iron	3.5-7.5	18-35	-	-	-	Fe-PKE
24	Complex Cr-Carbide Iron	3.5-7.5	18-35	-	5-14	-	Fe-KKA
25	Martensitic Cr-carbide iron	3.5-7.5	18-35	-	-	Max. 2	-

Measure variables included:

- Wear loss (g) ASTM G65;
- Chemical analysis;
- Carbon Equivalent Abrasive wear resistance:
  CEq ABR = C + f(C){Si/24 + Mn/6 + Cu/15 + Ni/60 + (Cr+Mo+Nb+V+W)/6+5B}
  where, f(C) = 0.75 + 0.25tanh{20(C - 0.12)}
- Hardness;
- Microstructure;
- Volume fraction of microstructure constituent secondary particle quantitative stereometric measurement and prediction/calculation per following formulae:
  VF%=1/8[301/3*[e/12-Nb/92.21-Ti/47.9-Zr/91.22]x12+91/24*Cr+57/10*Mo+95/10*W-485/4]+Nb+Ti+V+Zr
  Establishing: hypereutectic carbides; eutectic carbides; overall carbides; Fe-C-Cr matrix;

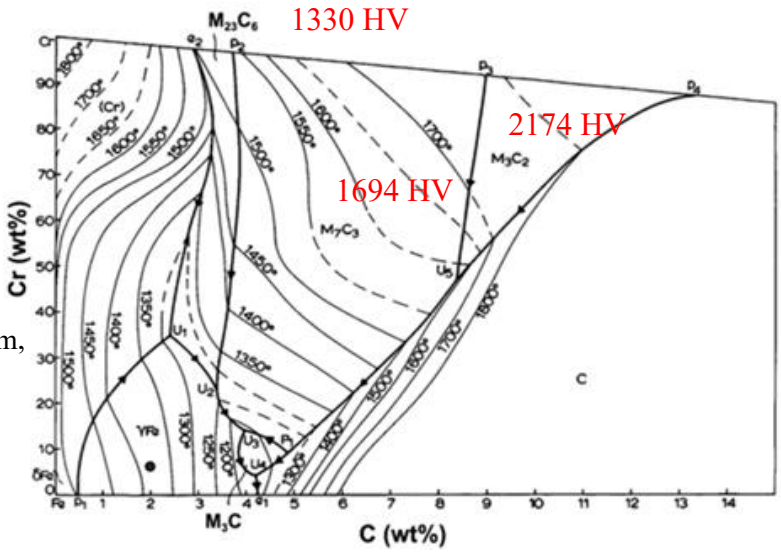


Figure 1. Fe-C-Cr ternary phase diagram, liquidus projections. [5].

3. RESULTS

Table 5 lists summarized properties of all types of Chromium White Alloy weld deposits. Figures 2-5 illustrate different relationships between microstructural characteristics and wear loss.

Table 5. Chromium White Iron weld deposits (Alloys 21,22,23,24,25) average characteristics.

CE Abr	Hardness HRC	% Hypereutectic carbides M7C3	ASTM G65 Weight Loss (g)	Cr7C3 Hardness
7.71	56.3	8.04	0.58	1100-1400 HV

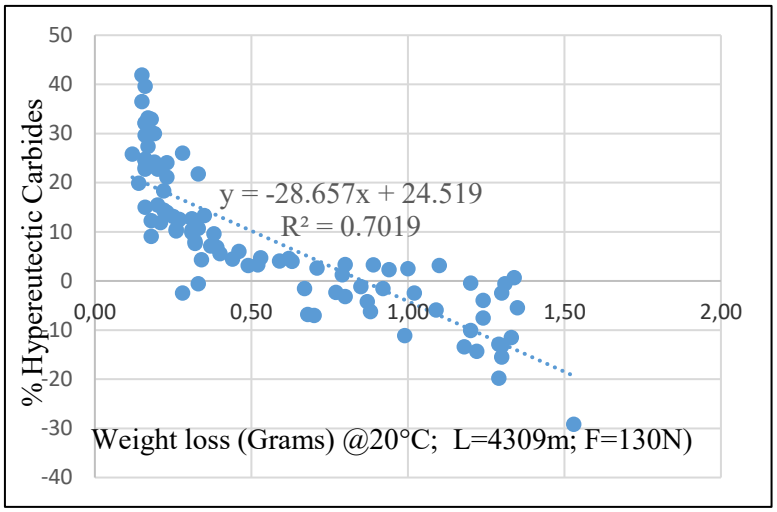


Figure 2. Wear vs %hypereutectic carbides of white chromium iron weld deposits (Alloys 21-25).

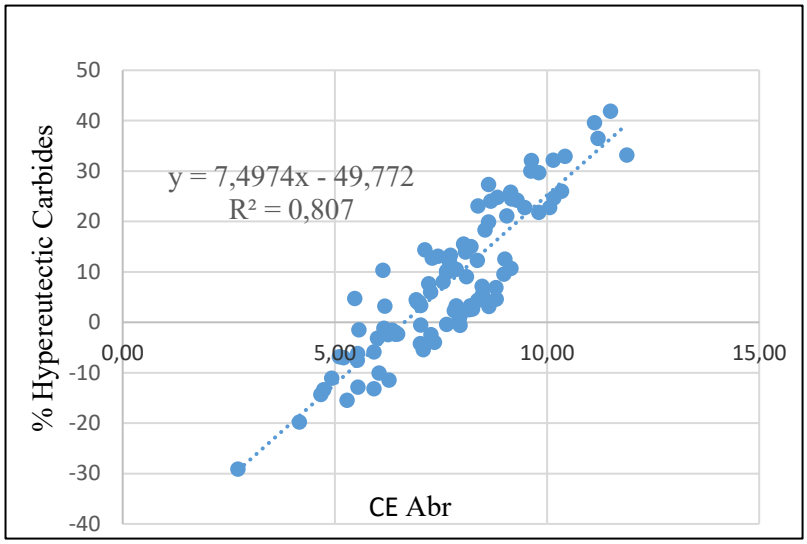


Figure 3. CEAbr vs %hypereutectic carbides of white chromium iron weld deposits (Alloys 21-25).

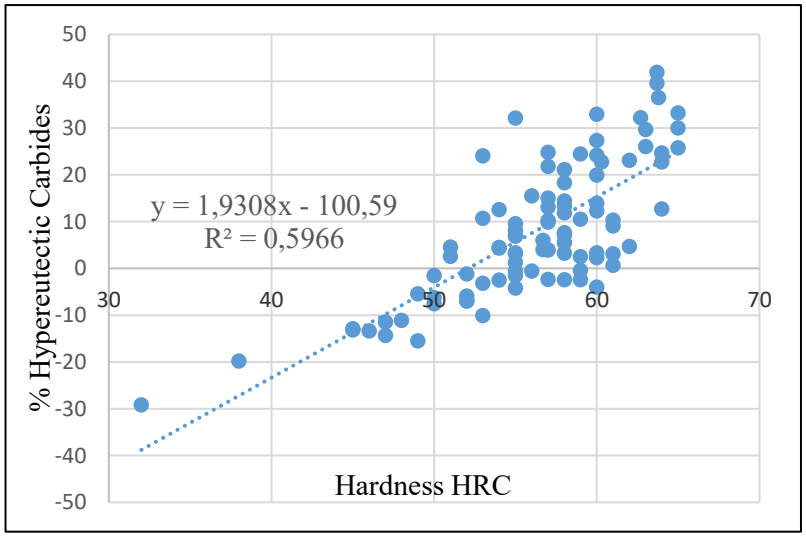


Figure 4. Hardness vs hypereutectic carbides white chromium iron weld deposits (Alloys 21-25).

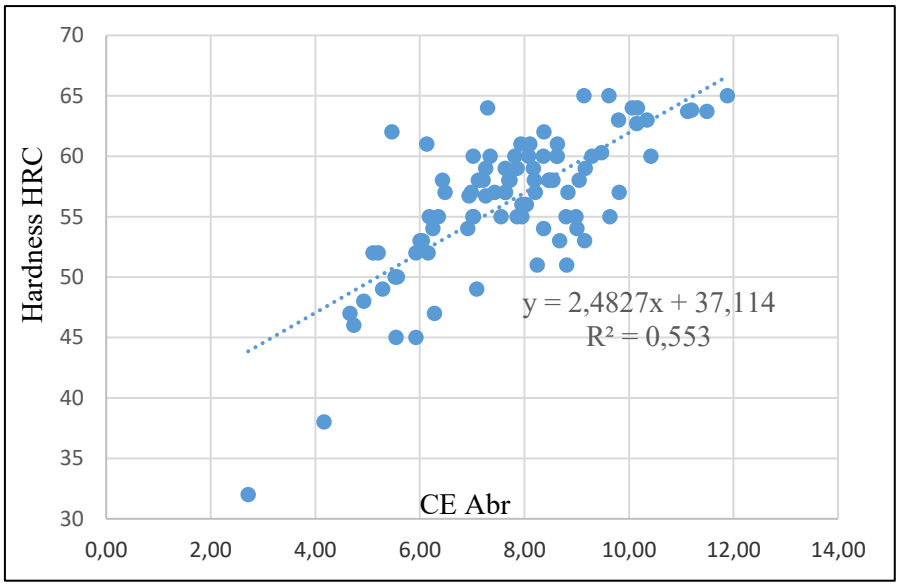


Figure 5. Hardness vs CEAbr white chromium iron weld deposits (Alloys 21,22,23,24,25).

3.1 AUSTENITIC IRON 21 TYPE ALLOY

Table 6 illustrates average properties and wear of Austenite Iron 21 type alloy.

Table 6. Austenitic Iron 21 Type alloy average characteristics.

CE Abr	Hardness HRC	% Hypereutectic carbides Cr_7C_3	ASTM G65 Weight Loss (g)
5.79	48.6	-10.2	1.22

Note negative % Hypereutectic carbides indicate absence of secondary Cr_7C_3 hypereutectic carbides.

Figure 6 illustrates typical microstructure of Austenitic Iron 21 type alloy.

Figure 7 illustrate the relationship between weight loss and volume fraction of hypereutectic carbides.

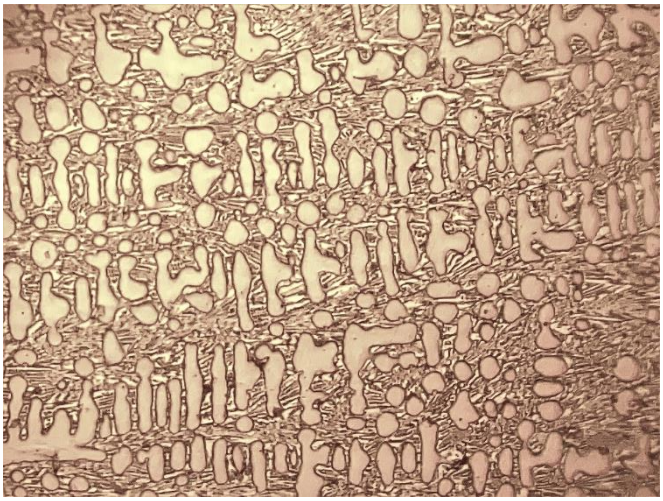


Figure 6. Typical microstructure of Austenitic Iron 21 type alloy. Austenite dendrites in a carbide-austenite eutectic matrix.

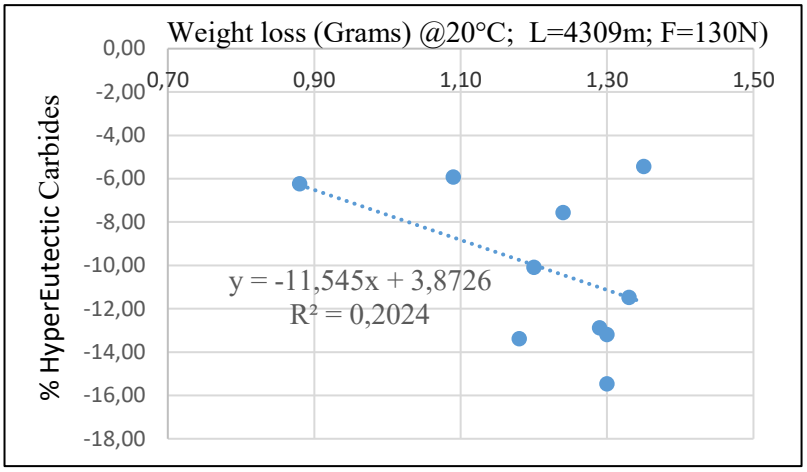


Figure 7. Wear vs % hypereutectic carbides Alloy 21. Negative presence indicates absence of M_7C_3 carbides.

3.2 AUSTENITIC CHROMIUM CARBIDE IRON 23 TYPE ALLOY AND COMPLEX CHROMIUM CARBIDE IRON 24XX ALLOY

Table 7. illustrates average properties and wear of Austenite Chromium Carbide Iron 23 type alloy.

Table 7. Austenite Chromium Carbide Iron 23 Type alloy average characteristics.

CE Abr	Hardness HRC	% Hypereutectic carbides Cr_7C_3	ASTM G65 Weight Loss (g)
8.6	58.4	14.7	0.4

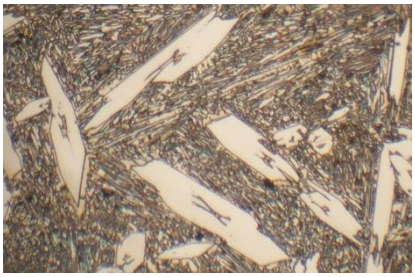


Figure 8. Typical microstructure of Austenite Chromium Carbide Iron 23 type alloy. Microstructure chromium-rich primary carbides Cr_7C_3 in a carbide austenite eutectic matrix

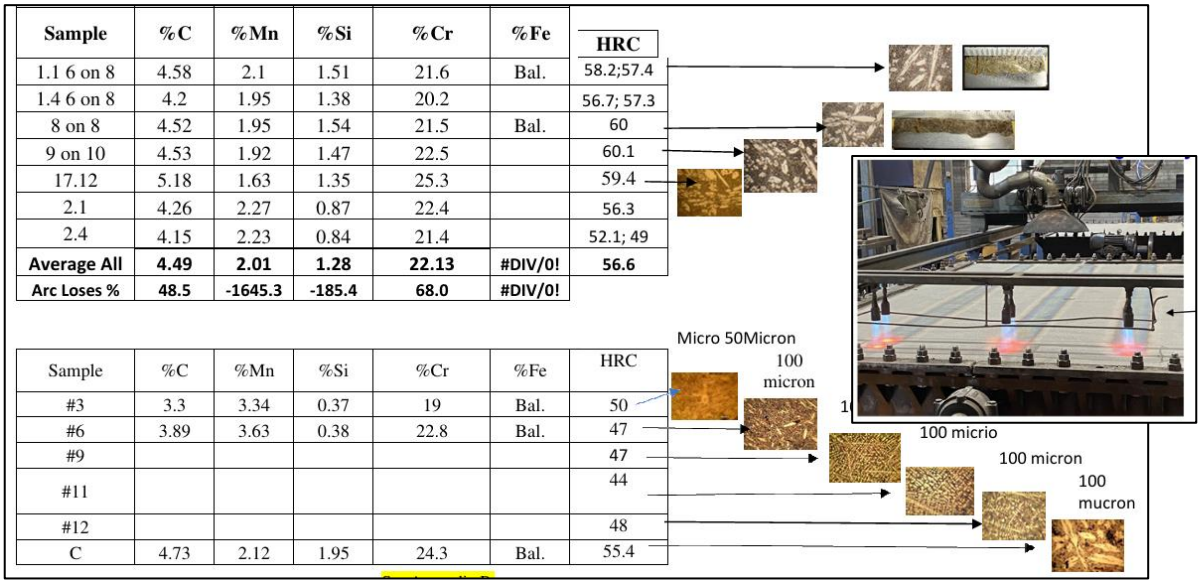


Figure 9. Some of the chemical composition and microstructures/hardnesses achieved in the process of automated bimetallic wear plate production [6].

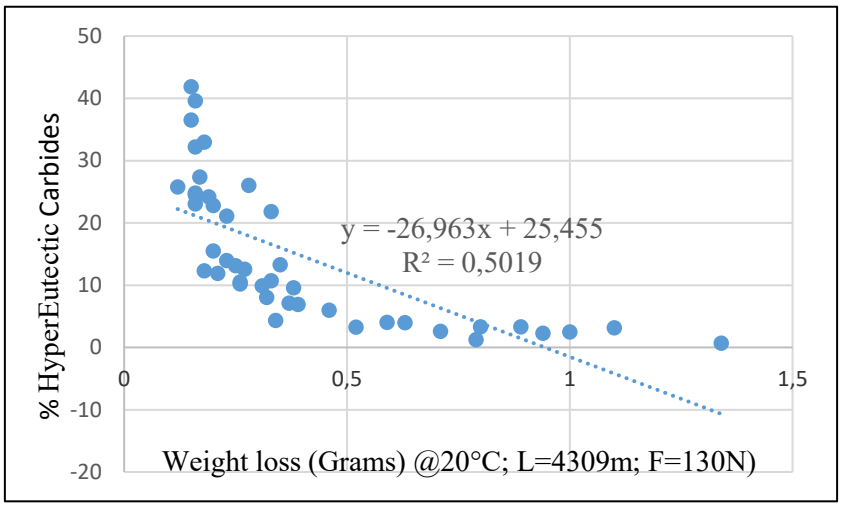


Figure 10. Wear vs % hypereutectic carbides Austenite Chromium Carbide Iron 23 type alloy.

Table 8. Complex Chromium Carbide Iron 24 Type alloy average characteristics.

CE Abr	Hardness HRC	% Hypereutectic carbides Cr_7C_3	ASTM G65 Weight Loss (g)
9.6	62.2	24.4	0.17

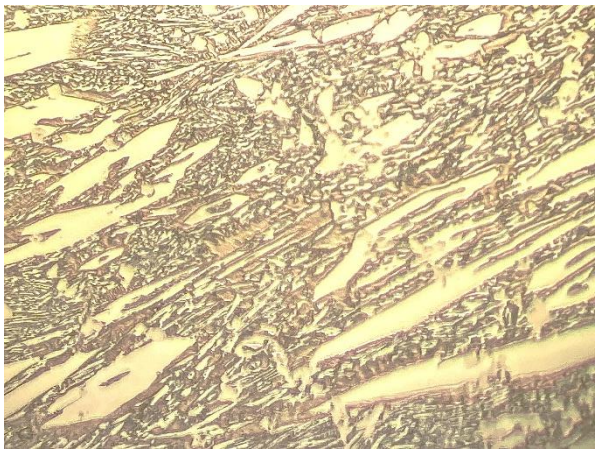


Figure 11. Typical microstructure of Complex Chromium Carbide Iron 24 type alloy. Microstructure chromium-rich primary carbides Cr_7C_3 and NbC in a complex carbide-austenite eutectic matrix. Base material stainless steel Crushing propeller/rotor single layer.



Figure 12. illustrates tungsten carbide weld deposits that are used for severe abrasion and are given for comparsion agains chromium white irons.

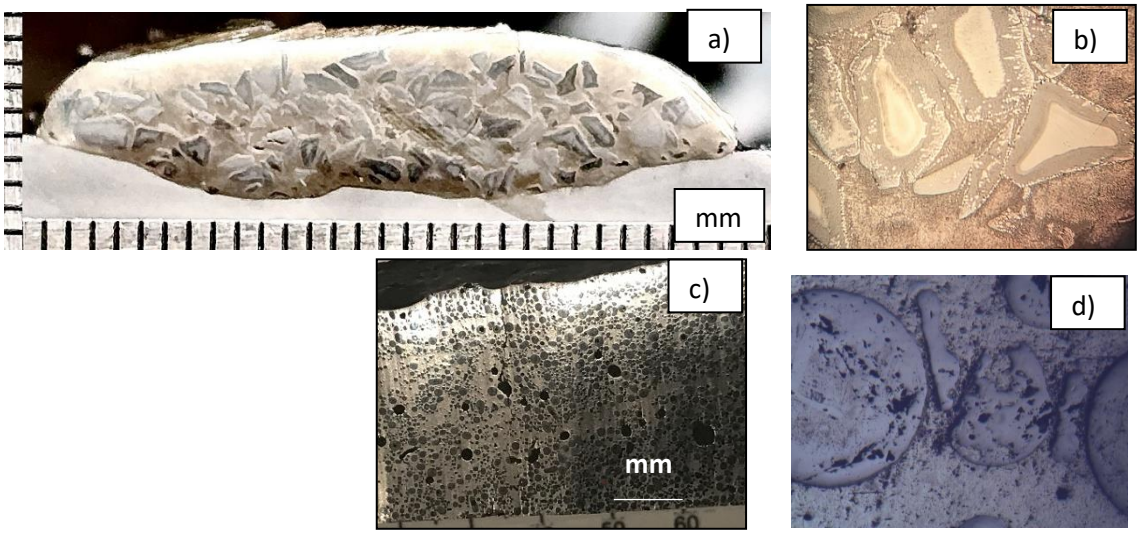


Figure 12. a) b) Tungsten Carbide granules in an iron-rich matrix. Matrix hardness 590HV; Tungsten Carbide granules size 10-30# hardness 1,650 HV; 32XX – W-FE grade. Spheroidal Tungsten Carbide particles (2,300 HV) in NiCrBSi (Hardness 580HV) matrix weld deposits, 36XX – W-Ni grade [6].

Table 9. Characteristics of tungsten carbide weld deposits

		Hardness Matrix	Hardness WC	% WC	ASTM G65 Weight Loss (g)
Bulk tungsten carbide composite; 32XX	W-Fe	590HV	1,650 HV	50	0.09
Spheroidal tungsten carbide in NiCrBSi matrix; 36XX	W-Ni	580 HV	2,300 HV	45	0.07

Table 10. Summary of Chromium White Irons characteristics.

	CE Abr	Hardness HRC	% Hypereutectic carbides Cr_7C_3	ASTM G65 Weight Loss (g)
Chromium white irons; Average	7.71	56.3	8.04	0.58
21xx 22xx	5.79	48.6	-10.2	1.22
23xx	8.6	58.4	14.7	0.4
24xx	9.6	62.0	24.4	0.17
25xx	9.1	63.0	20.5	0.13

CONCLUSIONS

Chromium White Iron weld deposits represent a significant part of engineering methods of maintenance and pre-conditioning of industrial components subjected to abrasive wear. They consist of a wide spectrum of alloying combinations providing cost effective solutions for different applications. Still their wear resistance is lower than tungsten carbide weld deposits however chromium white irons provide cost effective abrasive wear resistance solutions. Presence of hypereutectic carbides in chromium white irons plays an important role in the abrasive resistance therefore increasing their volume fraction in the matrix will improve weld deposits performance. Absence of hypereutectic carbides such as in 21 and 22 alloys will lower abrasive resistance however it will provide good impact – abrasive resistance combination. Additions of undercooling elements and their effect on matrix martensite transformation with matrix hardness increase by 65% [7] will in combination adequate volume fraction of hypereutectic carbides provide the best abrasive resistance of chromium white irons (alloy 25xx).

Number of relationships of the key chromium white irons characteristics have been established as an average indicator and also allocated to particular alloy grade.

WL (wear loss grams) =(9.3124-CEq ABR)/2.7851. (1)

Hardness (HCR)=2.4827*CEq ABR + 37.114. (2)

% Hypereutectic Carbides=7.4974*CEq ABR-49.772 (3)

Hardness (HRC)=(100.59-%Hypereutectic carbides)/1.9308 (4)

WL (weight loss grams)=-00475*HRC+3.2472 (5)

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