METALLURGICAL TESTING

Prepared For:

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Subject:

METALLURGICAL EXAMINATION OF ONE (1) WELD OVERLAY WEAR PLATE SAMPLE

Order No.	NA
Specimen Description:	9 on 10
Weld Overlay Material Specification:	NA
Testing Document:	NA

Executive Summary:

Parameter	Result							
Thickness (plate)	19 mm							
Thickness (overlay)	9 mm							
Vol. Frac. Carbides	44%							
Bulk Hardness	721 HV							
Eutectic Hardness	663 HV							
Primary Carbide Hardness	1501 HV							
Surface Roughness (R_a)	4.9 µm							
ASTM G65 – Mass loss	0.031 g							
ASTM G65 – Volume loss	4.2 mm^3							
Chemical Analysis (wt%)	Fe	C	Mn	Si	S	P	Ni	Cr
	Bal	3.80	1.10	1.03	0.01	0.05	0.19	29.5
	Mo	Cu	V	Nb	Ti	Al	W	B
	0.01	0.01	0.06	0.01	0.01	<0.01	-	0.15

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Introduction:

One (1) weld overlay wear plate sample was received for metallurgical testing.

Procedure and Results:

i. Elemental Composition:

Following suitable surface preparation, the elemental composition of the weld overlay was determined by Optical Emission Spectroscopy (QP018-OES), ICP-AES and Leco Combustion method. The results are summarised in Table 1.

Table 1: Chemical analysis results

Sample	Element, wt%										
	Fe	**C**	**Mn**	**Si**	**S**	**P**	**Ni**	**Cr**	**Mo**	**Cu**	**V**
9 on 10	Bal	3.80	1.10	1.03	0.01	0.05	0.19	29.5	0.01	0.01	0.06
Sample	**Element, wt%**										
	Nb	Ti	Al	W	B						
9 on 10	0.01	0.01	<0.01	-	0.15						

ii. Macroscopic Examination:

The wear plate cross section was evaluated following silicon carbide grinding to a P1200 surface finish using standard metallographic techniques, then etching with acid ferric chloride to draw out the macrostructure.

The sample exhibited satisfactory fusion with the substrate and absence of fusion defects. No stress relief cracks were evident through to the thickness of the weld overlay (Figure 1). Table 2 shows the plate total thickness, weld overlay thickness and number of hard facing weld layers.

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Table 2: Wear plate dimensions

Total Section Thickness	Nominal Weld Overlay Thickness	No. of Weld Overlay Layers
19 mm	9 mm	1

iii. Microstructural Examination:

The metallographically prepared specimen was diamond polished to a 1 µm finish and etched with acid ferric chloride to reveal the microstructure, which was then evaluated using an optical metallurgical microscope.

The microstructure of the weld overlay was seen to consist of primary carbides distributed throughout a matrix of eutectic carbides and austenite (Figures 2 - 3).

iv. Volume Fraction of Carbides:

The polished and etched specimen was used to measure the total volume fraction of carbides (primary + eutectic) in the weld overlay in accordance with ASTM E1245-03(2016) [1][1]. The results are shown in Table 3.

Table 3: Total volume fraction of carbides (%)

Sample	Measurement					Average
	1	2	3	4	5	
9 on 10	44%	43%	42%	47%	45%	44 ± 2%

v. Bulk Hardness Testing:

The bulk hardness of the weld overlay was determined on the polished and etched specimen using the Vickers method in accordance with AS 1817.1-2003 [2]. The results are shown in Table 4.

Table 4: Bulk hardness test results (HV30)

Sample	Measurement			Average
	1	2	3	
9 on 10	691 HV	739 HV	734 HV	721 ± 26 HV

[1] The numbers in square brackets refer to texts or documents listed in the Reference section of this report.

vi. Microhardness Testing:

A low load Vickers hardness tester was used to measure the primary carbide and eutectic matrix hardness of the weld overlay. Testing was performed in accordance with ASTM E384-22 [3]. The results are summarised in Table 5.

Table 5: Microhardness test results (HV0.3)

Sample		Measurement			Average
		1	2	3	
9 on 10	Eutectic Matrix	698 HV	663 HV	627 HV	663 ± 35 HV
	Primary Carbides	1545 HV	1457 HV	1501 HV	1501 ± 44 HV

vii. Surface Roughness Testing:

The surface roughness was determined on the as received weld overlay surface using a SRT 6210 surface roughness meter. Three tests were conducted on as received weld overlay surface. The results are summarised in Table 6.

Table 6: Surface roughness (R_a) results

Sample	Reading 1	Reading 2	Reading 3	Average
9 on 10	5.5 µm	4.5 µm	4.6 µm	4.9 ± 0.5 µm

viii. Abrasion Resistance Testing:

Dry Sand Rubber Wheel abrasion testing was performed on the three (3) specimens in accordance with ASTM G65-16(2021) Method A [4], following appropriate surface preparation. Figure 4 and Figure 5 show the samples before and after the test. The results are summarised in Table 7.

Table 7: Abrasion resistance material loss results

Sample		Specimen			Average
		1	2	3	
9 on 10	Mass loss	0.035 g	0.029 g	0.030 g	0.031 ± 0.003 g
	Volume loss	4.7 mm^3	3.9 mm^3	4.0 mm^3	4.2 ± 0.4 mm^3

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Conclusions:

Results are for information only.

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References:

1. ASTM E1245-03(2016), 'Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis', ASTM International, Pennsylvania USA.

2. Australian Standard AS 1817.1-2003, 'Metallic materials – Vickers hardness test Method 1: Test method (ISO 6507-1:1997, MOD)', Standards Australia, Sydney, NSW.

3. ASTM E384-22, 'Standard Test Method for Microindentation Hardness of Materials', ASTM International, Pennsylvania USA.

4. ASTM G65-16(2021), 'Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus', ASTM International, Pennsylvania USA.

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Figure 1. Macrograph of the specimen cross-section showing sound fusion to the substrate along the weld overlay (scale in mm).

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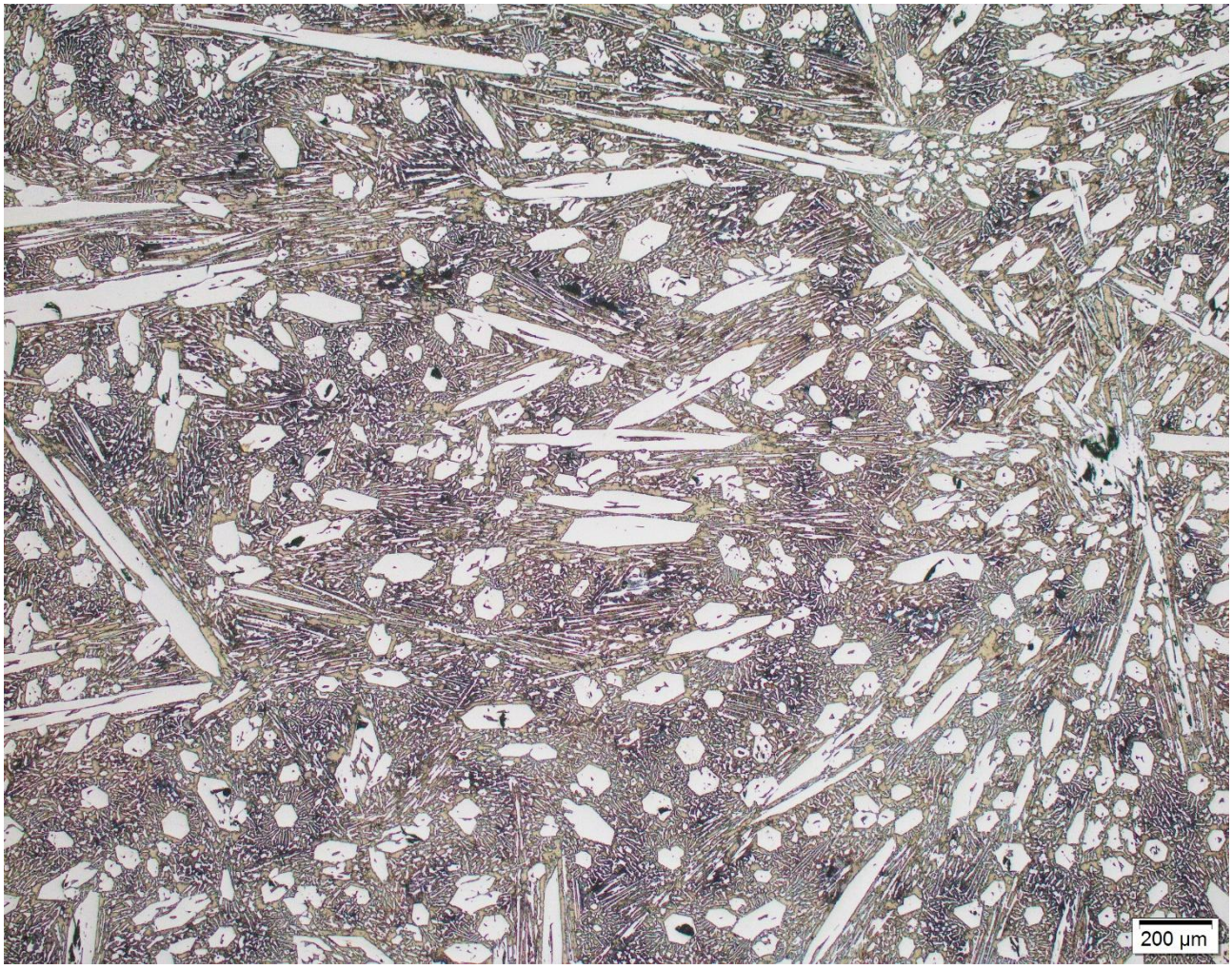

Figure 2. Typical weld overlay microstructure consisting of primary carbides in a matrix of austenite & eutectic carbides (low magnification).

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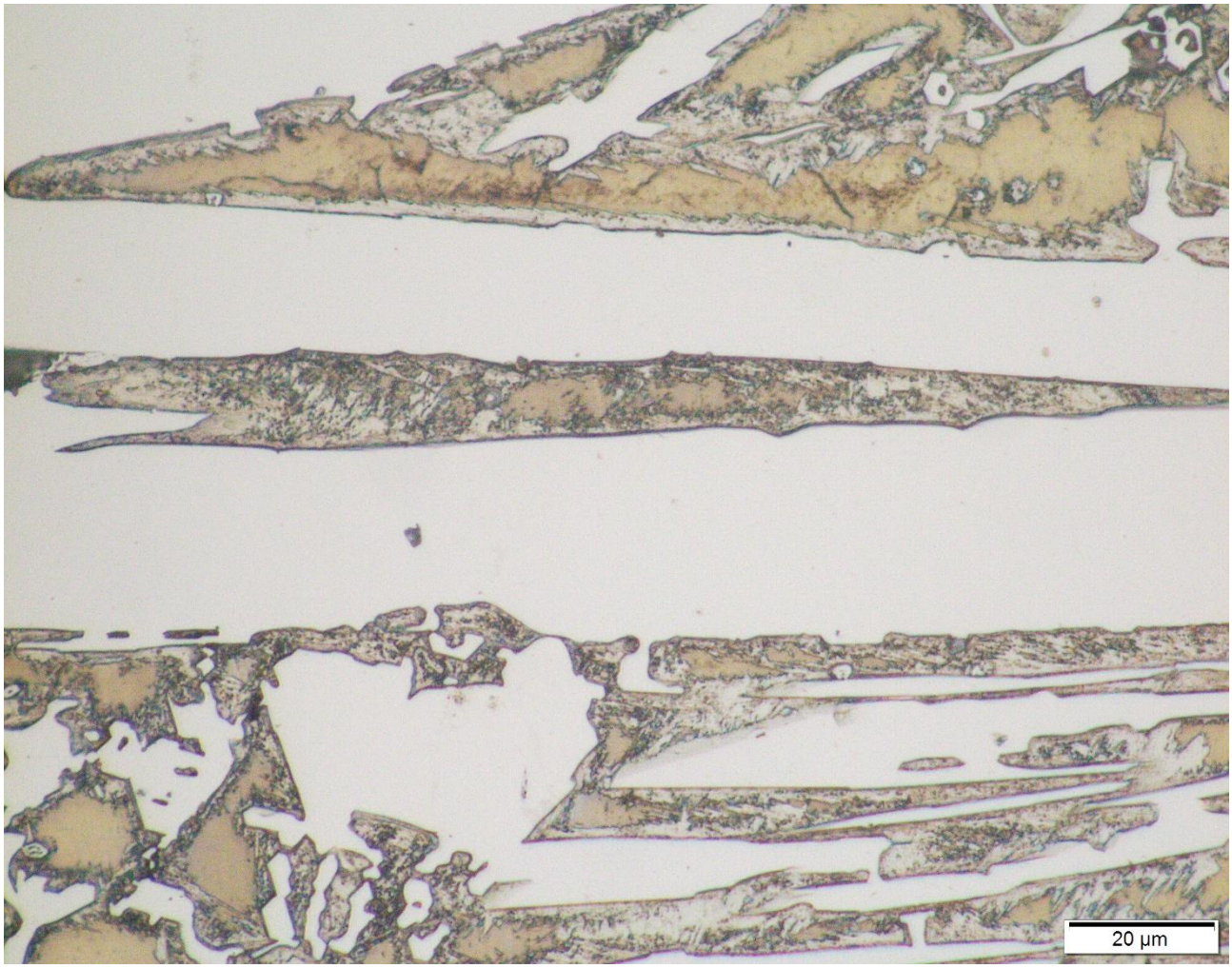

Figure 3. Microstructure at higher magnification.

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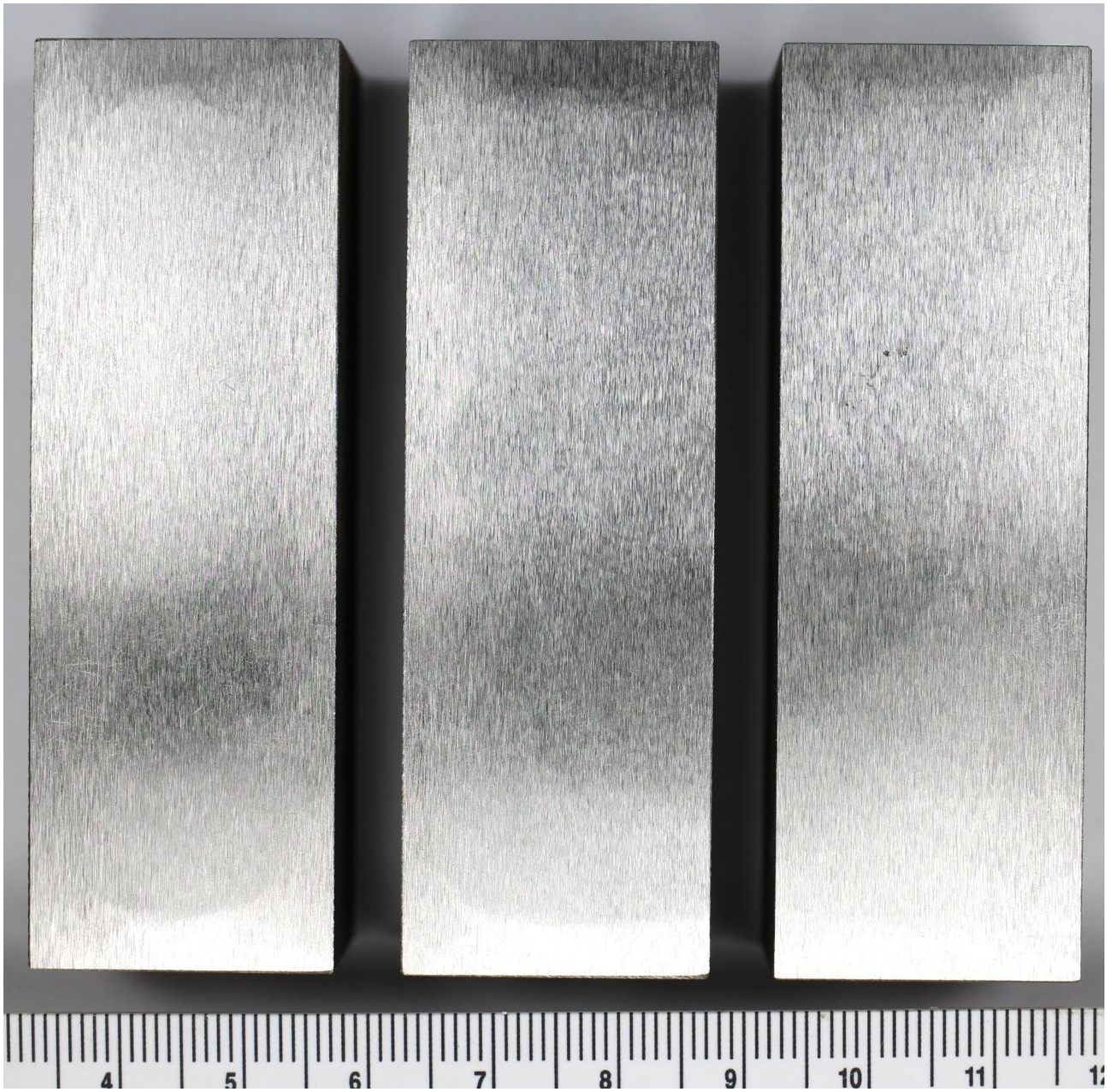

Figure 4. ASTM G65 specimens prior to testing (scale in cm).

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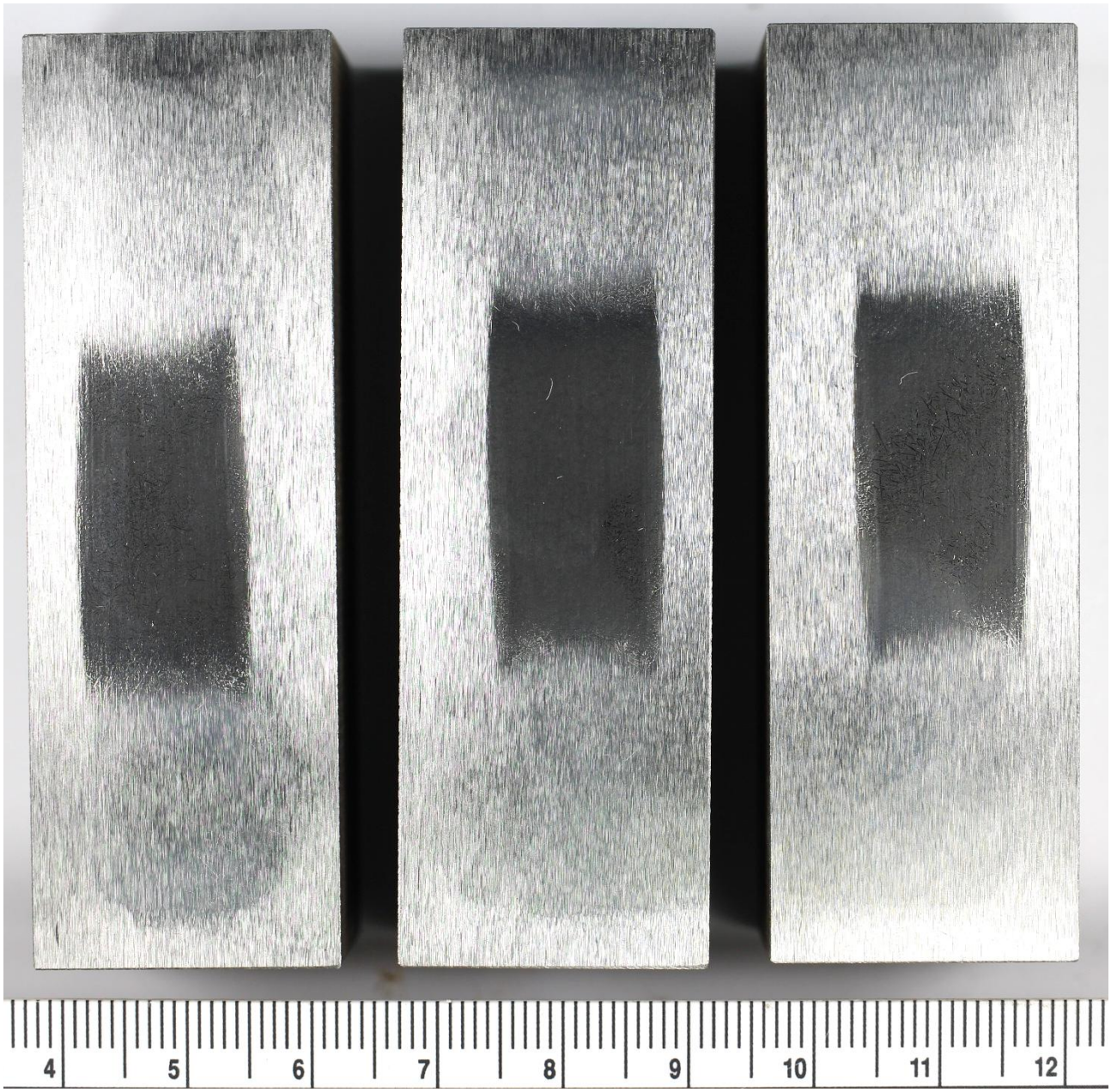

Figure 5. ASTM G65 specimen wear scars after testing (scale in cm).

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