1.2562

Increased toughness based on very fine austenite grainsize combined with almost no grain boundary carbides

accomplished and reported by

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1 Introduction

My name is Marco Guldimann, I am 34 years old and a patron of knifesteelnerds.com.

I am a trained chef and thanks to my job I got in to kitchen knives. Since 2007 I started making knives for myself as a hobbyist. In 2012 I sold the first kitchen knife and since then I continuously increased spending time in my Workshop. I worked for 50% as a Bladesmith for several years. Since first of January 2020 I happily work as a full time Bladesmith. The metallurgy and its importance on performance has always been my main target. I got in contact with Roman Landes who wrote a book on very important parameters concerning knives. (Messerklingen und Stahl, Roman Landes, ISBN: 978-3-938711-04-0)

To make sure the quality of my work is constantly good, I get periodically tested by my friend metallurgist who did run a lab for metallurgy and is specialized in failure analysis. He now works as a Teacher for metallurgy and as a freelancer specialized in failure analysis.

The following report was motivated by the very important work of Larrin Thomas published on knifesteelnerds.com. I am always impressed by the huge amount of qualified output he realizes in short period of time. The preparing of those samples was very time consuming. With this report I would like to support Larrin and the knifesteelnerds community.

I will show the importance of fine austenite grain sizes combined with very low appearance of carbide segregation on austenite grain boundaries. I hope this work will give another piece of the mosaic for understanding the properties of 1.2562 Steel.

I am sure, the carbide sizes and the austenite grainsize could be produced even finer, what would lead to better toughness then showed in this work. Please note; the showed micrographs are taken from the worst areas; it is from them we learn not from the good ones😊.

The same way I produced this testing of 1.2562 I although produce high performance kitchen knives with precision, knowledge and passion.

2 Forging

Since we know that the increasing amount of reduction has a huge impact on its homogeneity, I try to optimize it by following procedure. By the way this is the way I produce knives but with more amount of reduction! I started with a package of 3 layers all in all measuring 40mm x 30mm x 60mm. All Surfaces were ground flat and parallel. The package was sealed by TIG welding all around. Forge welding and forging temperature range was between 900°C and 750°C. This thermomechanical treatment was done by the help of my automatic and unusual fast spindle press with approximately 50 to of force and my small forging mill with approximately 2.5kN of torque. (I wished I had a stronger one😊)

As soon as the forged steel bar was getting a little long, I did cut it in to 4 pieces to mill it down in one heat from 7mm down to end shape of 3.3mm. After that reduction and cutting off the first few centimetres of each side, the 4 bars measured 18mm x 3.3mm x 270-290mm.

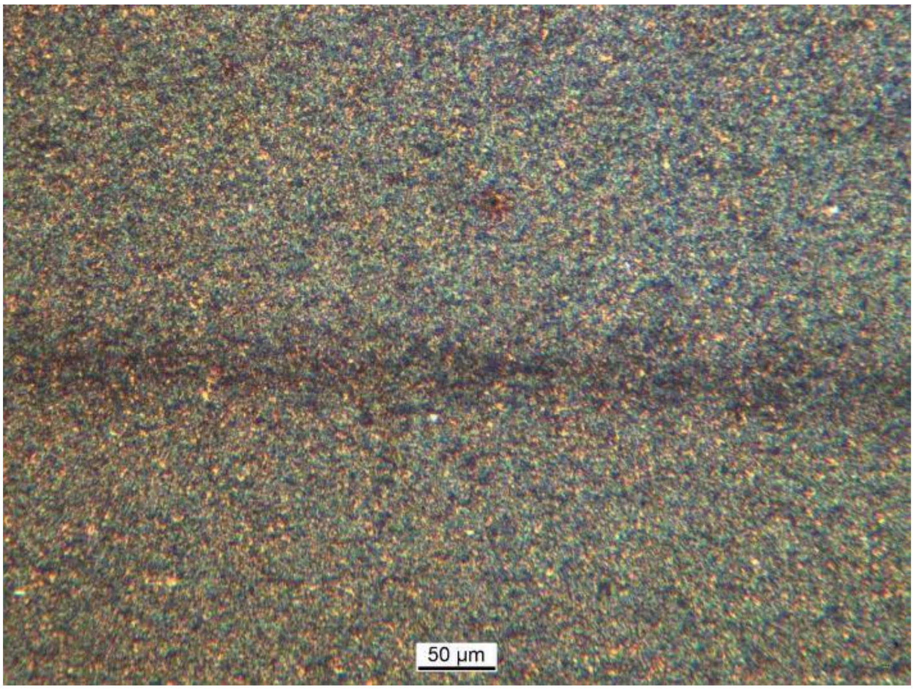

Figure 1 1.2562 as forged 200x

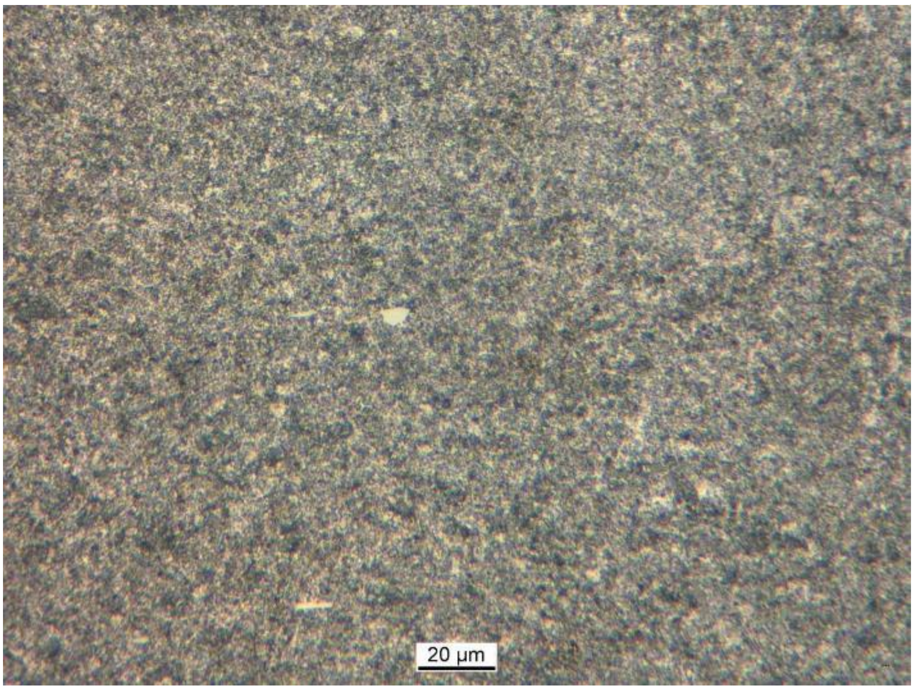

Figure 2 1.2562 as forged 500x

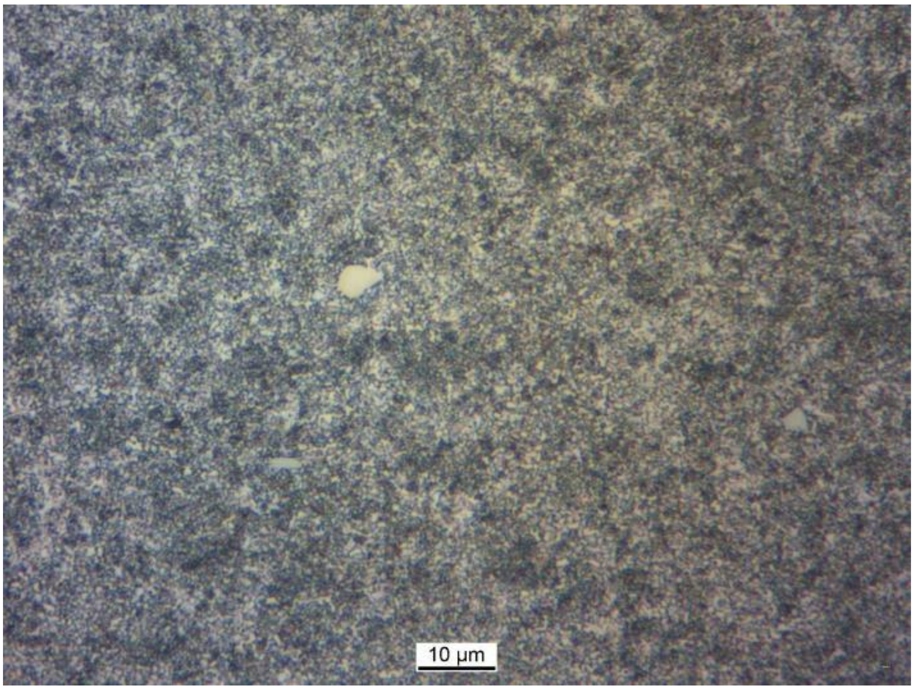

Figure 3 1.2562 as forged 1000x


Figure 4 Forged steelbar

3 Temper annealing

The 4 steel bars where austenitized at 770°C with a 10-minute hold. They were quenched in molten salt at 190°C, quickly equalized for 15 seconds combined with actively moving the samples, followed by air cooling to room temperature. Afterwards slowly heated up to 690°C with 30 min hold and furnace cooling.

4 Pregrinding and precutting

The temper annealed samples were preground to 12mm width. The 4 bars were cut in to 170mm long samples. The excess was used for sample number 5. The thickness was not ground at this moment to keep enough not decarburized material.

5 Final austenitizing

The hardening of each sample was done separately for avoiding confusion. After every completed heat treatment, the samples were put in a previously marked bag. They were quenched in molten salt, quickly equalized for 10 seconds combined with actively moving the samples, followed by air cooling to body temperature. Followed by annealing. The annealing was done in molten salt with extremely low hysteresis.

Sample number	Austenitizing temperature	Holding time	Annealing Temperature	Holding time and repetition
1	780°C	12	200°C	2 x 60 minutes
2	815°C	12	165°C	2 x 60 minutes
3	830°C	12	150°C	2 x 60 minutes
4	800°C	12	150°C	2 x 60 minutes
5	830°C	12	180°C	2 x 60 minutes

6 Final cutting and final grinding

All samples were cut separately and water cooled combined with slow cutting speed in to 58mm long samples. The length was water ground down to 55mm, tolerance +/- 0.1mm.

Afterwards they were ground down to a thickness of 2.5mm, tolerance +/- 0.02mm, on my water-cooled rotary surface grinder with CBN abrasive. Having all ground to the same thickness the width was ground down to 10mm, tolerance +/- 0.02mm.

7 Charpy testing

The samples were charpy tested in the metallurgical lab at room temperature.

Sample number	**Joule (1)**	**Joule (2)**	**Joule (3)**	**Average Joule**	**Average Ft-lbs**
1	10	13	11	11.33	8.4
2	11	10	16	12.33	9.1
3	5	9	8	7.33	5.4
4	11	9	9	9.66	7.1
5	11	13	10	11.33	8.4

8 Hardness

Hardness was tested from two different sources. The first table on 8.1 shows the results from the testing at the metallurgical lab by calibrated Vickers method and with 10kg of test load. The second table 8.2 shows the hardness tested by myself by UCI method **(Ultrasonic Contact Impedance).** The calibration of that tool (Krautkramer Branson Microdur) was done by a reference plate with 66 HRC and the measured difference was -0.2 HRC (Average of 10 measurements). Table 8.3 shows the average of both measurement systems.

8.1 Vickers HV10

Sample number	**HV10 (1)**	**HV10 (2)**	**HV10 (3)**	**Average HV10**	**Converted HRC**
1	699	669	705	691	59.7
2	841	822	833	832	65.1
3	852	844	855	850.33	65.6
4	751	744	767	754	62
5	828	825	822	825	64.8

8.2 Rockwell UCI

Every sample was tested on every side twice except where it broke and across of it.

Sample number	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Average
1	62	61	59	57	57	58	60	59	59.1
2	67	65	65	67	66	67	66	66	66.1
3	66	68	66	68	66	67	66	67	66.7
4	63	62	61	60	63	58	59	60	60.7
5	64	63	62	65	64	65	65	64	64

9 Hardness and toughness

Sample number	Average of HV10	Average of UCI	Average over all	Average of Ft-lbs	Average of Joule
1	59.7	59.1	**59.4**	8.4	11.33
2	65.1	66.1	**65.60**	**9.1**	**12.33**
3	65.6	66.7	**66.15**	5.4	7.33
4	62	60.7	**61.35**	7.1	9.66
5	64.8	64	**64.4**	8.4	11.33

10 Micrographs

Following micrographs were taken from the worst areas in the metallographic sample with big carbides, carbide alignment or other inhomogeneous structure.

10.1 Sample 1

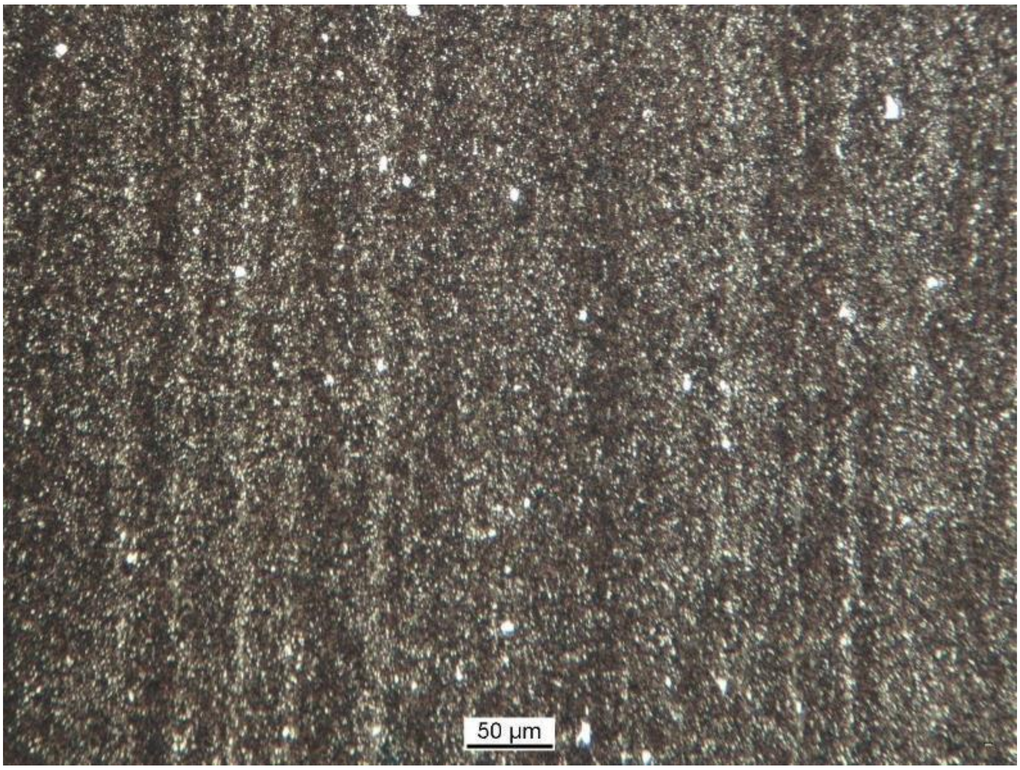

Figure 6 Sample 1 hardened 200x

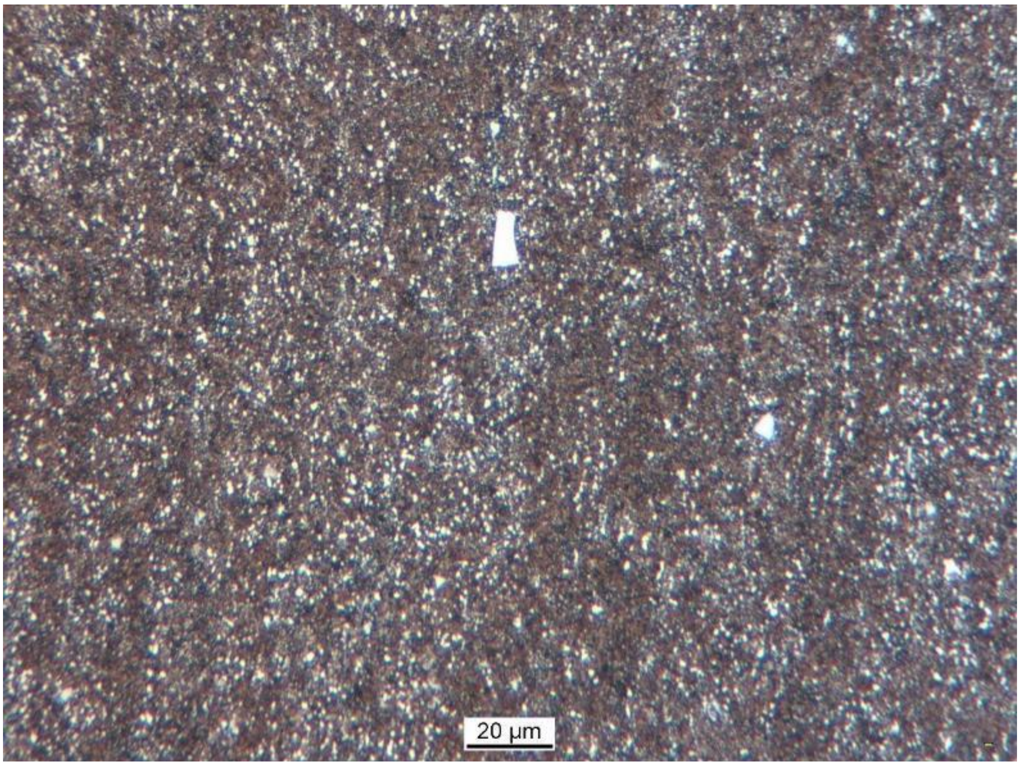

Figure 5 Sample 1 hardened 500x

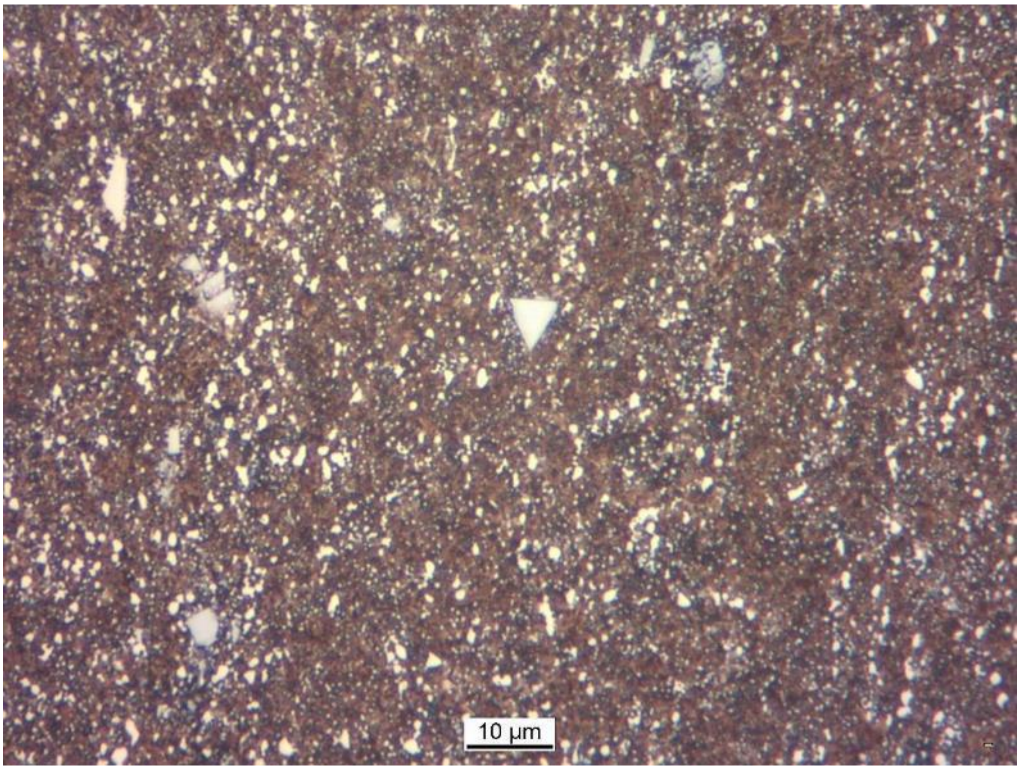

Figure 7 Sample 1 hardened 1000x

10.2 Sample 2

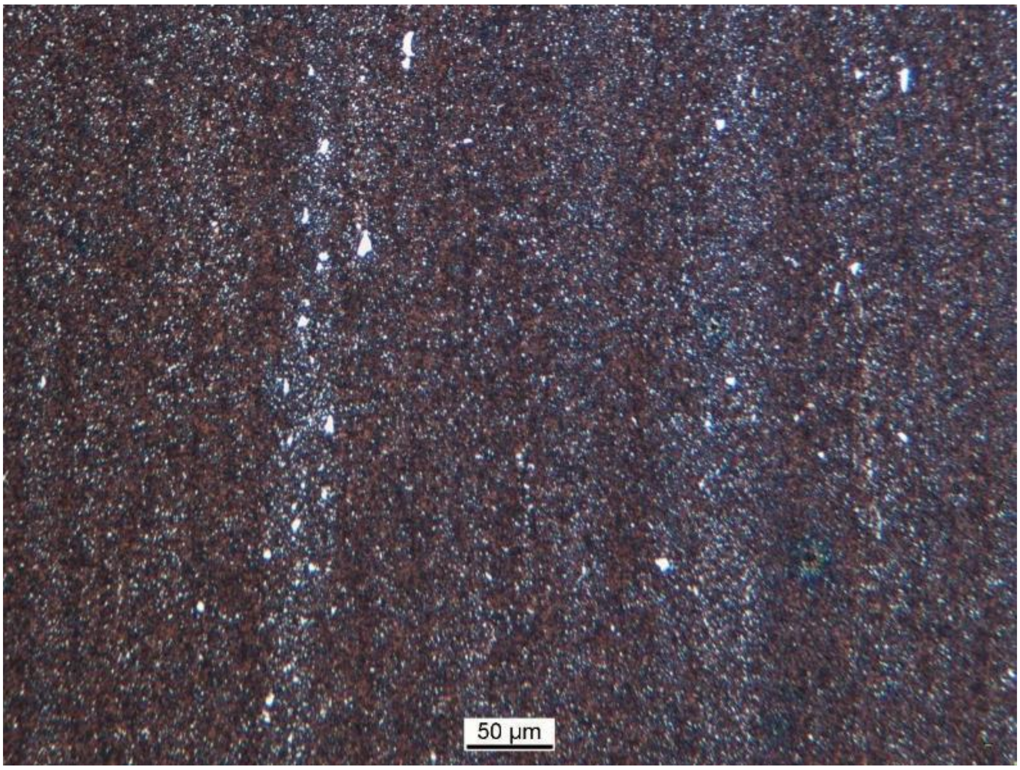

Figure 8 Sample 2 hardened 200x

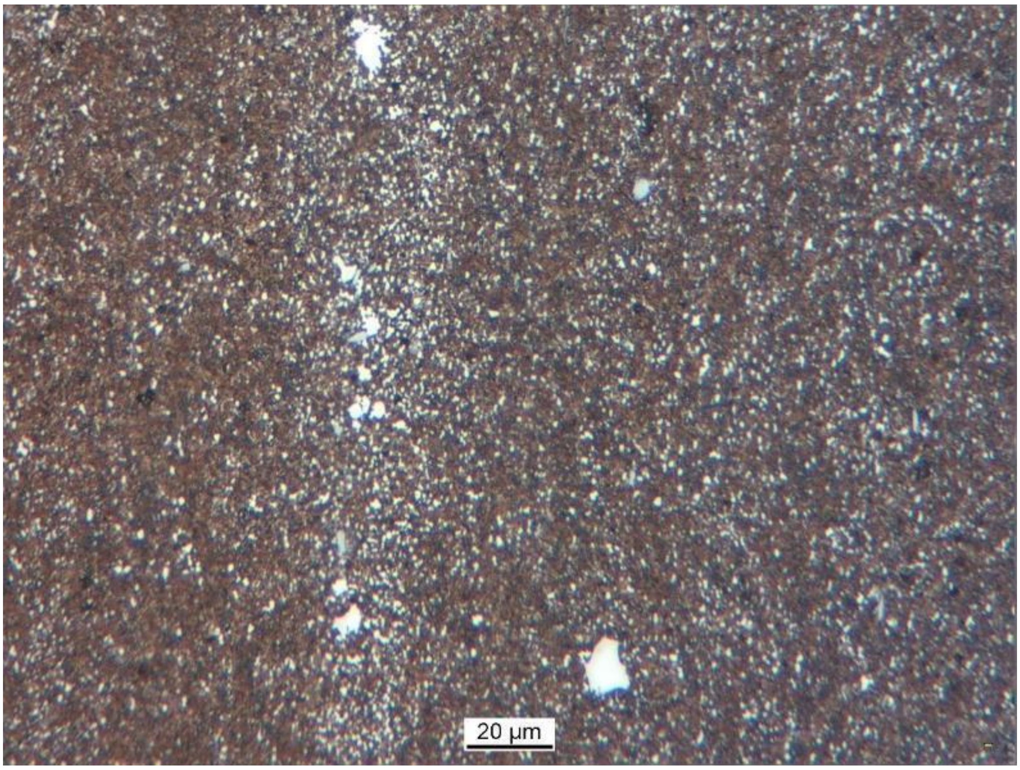

Figure 9 Sample 2 hardened 500x

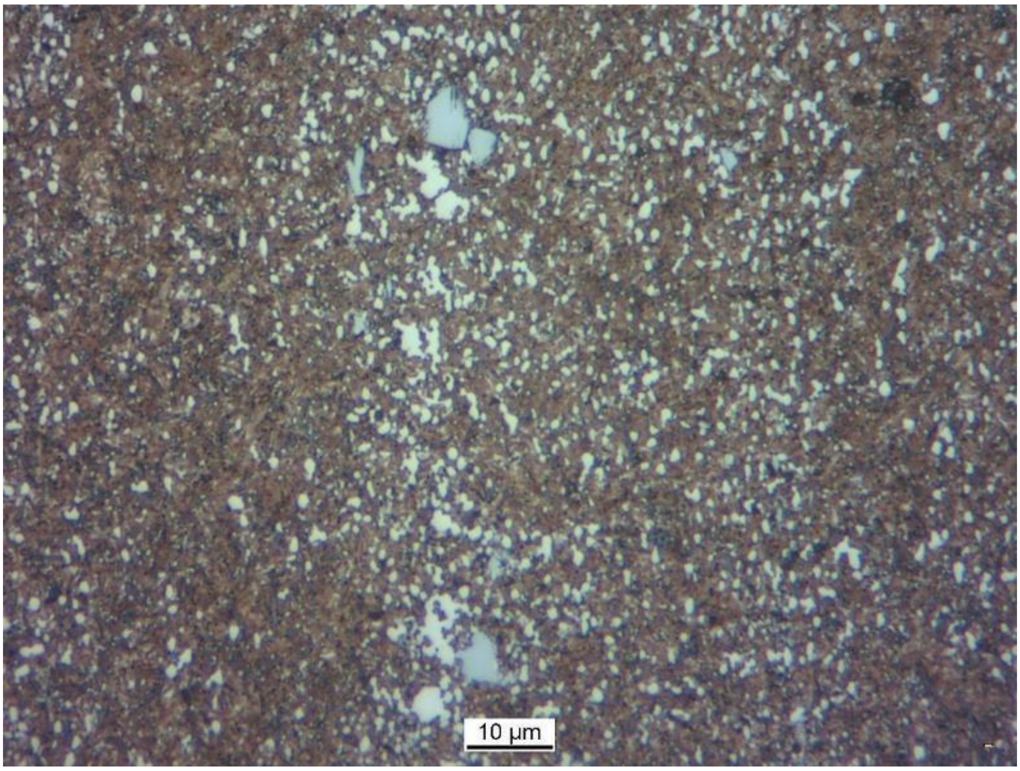

Figure 10 Sample 2 hardened 1000x

10.3 Sample 3

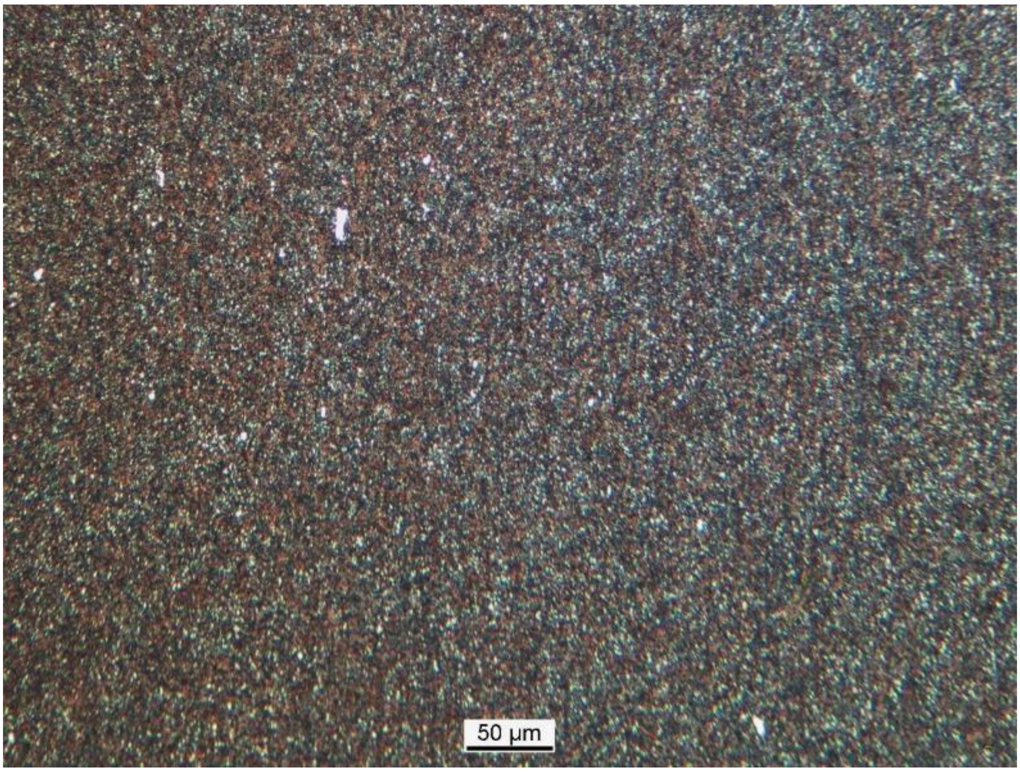

Figure 11 Sample 3 hardened 200x

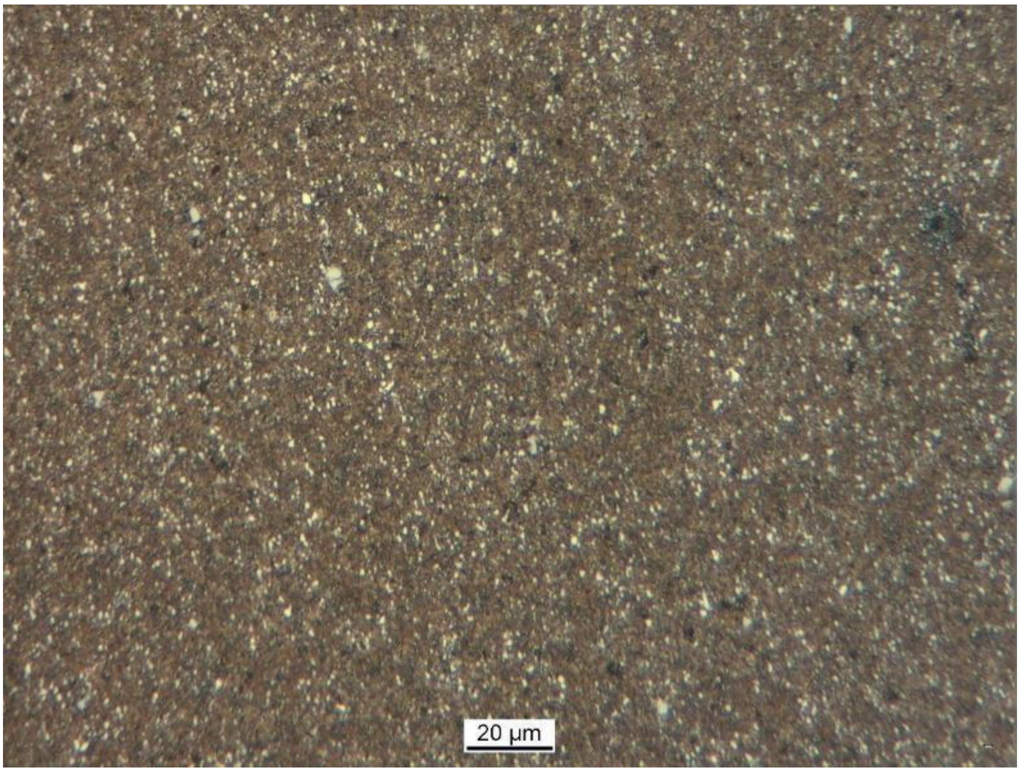

Figure 12 Sample 3 hardened 500x

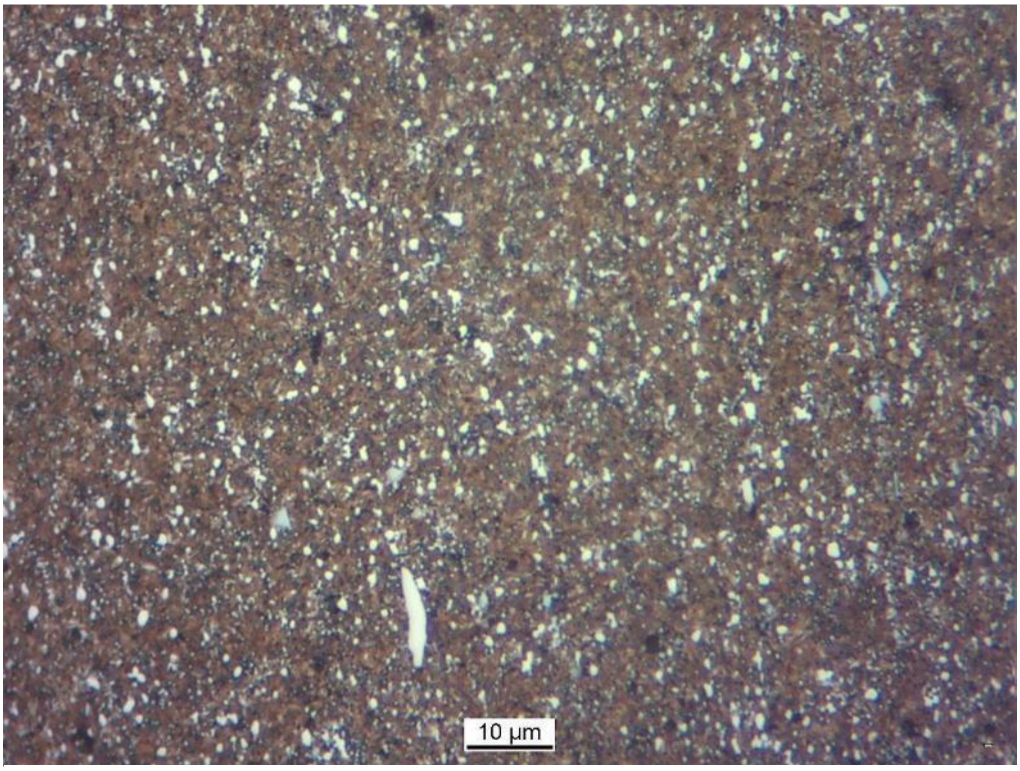

Figure 13 Sample 3 hardened 1000x

10.4 Sample 4

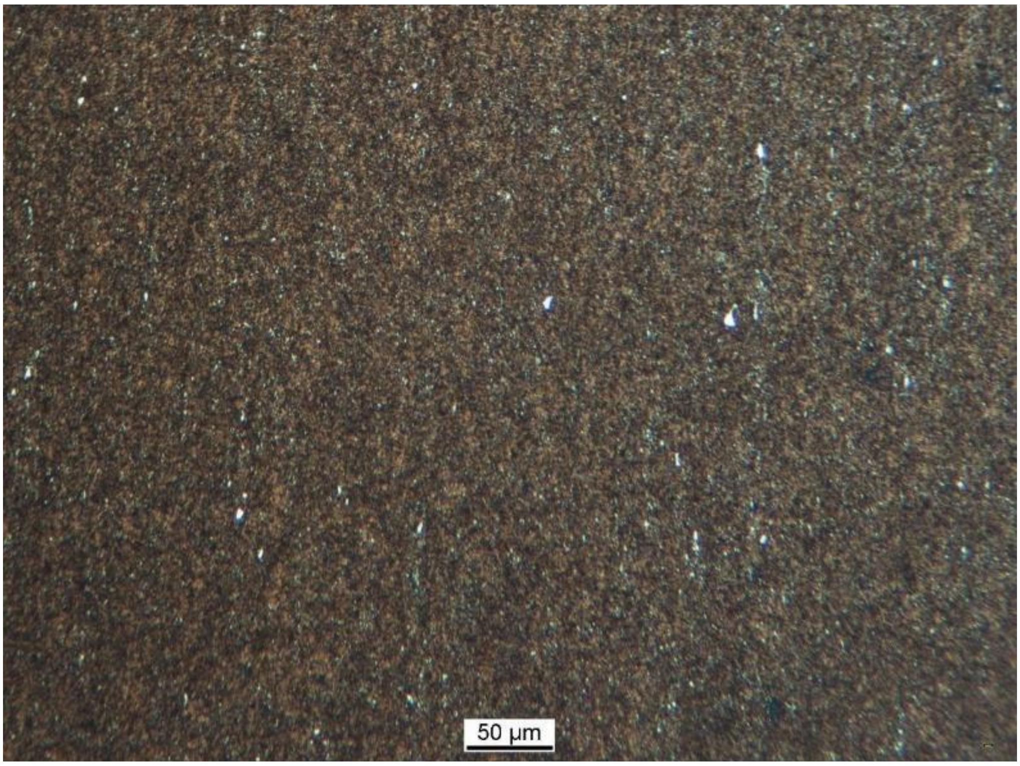

Figure 14 Sample 4 hardened 200x

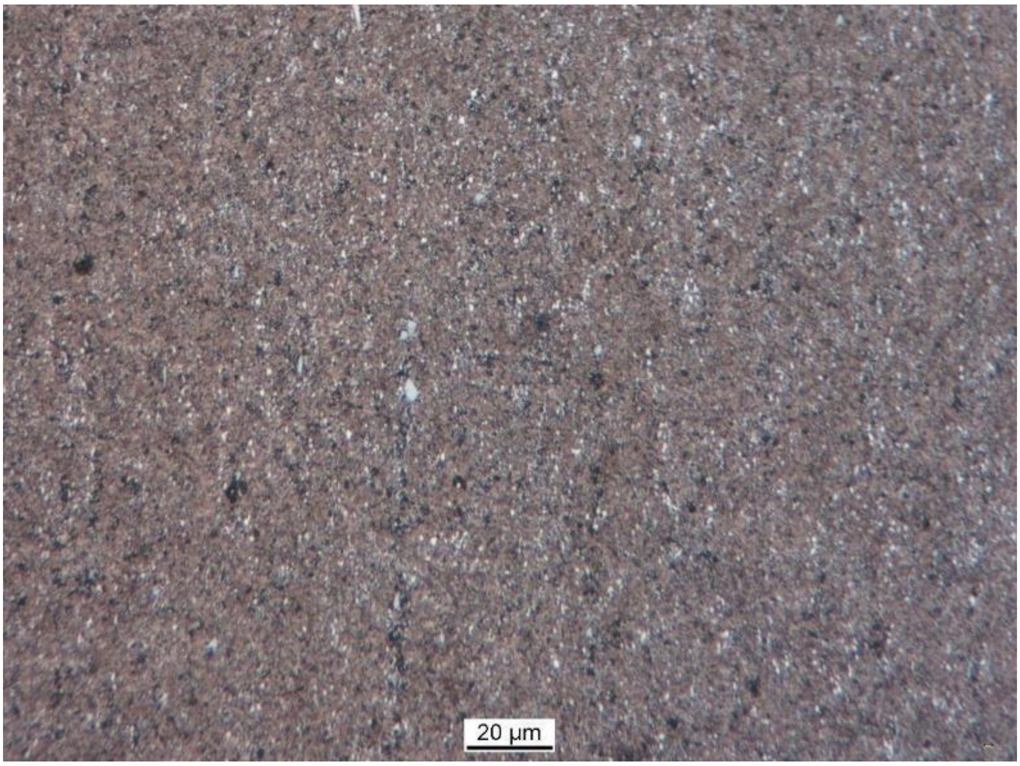

Figure 15 Sample 4 hardened 500x

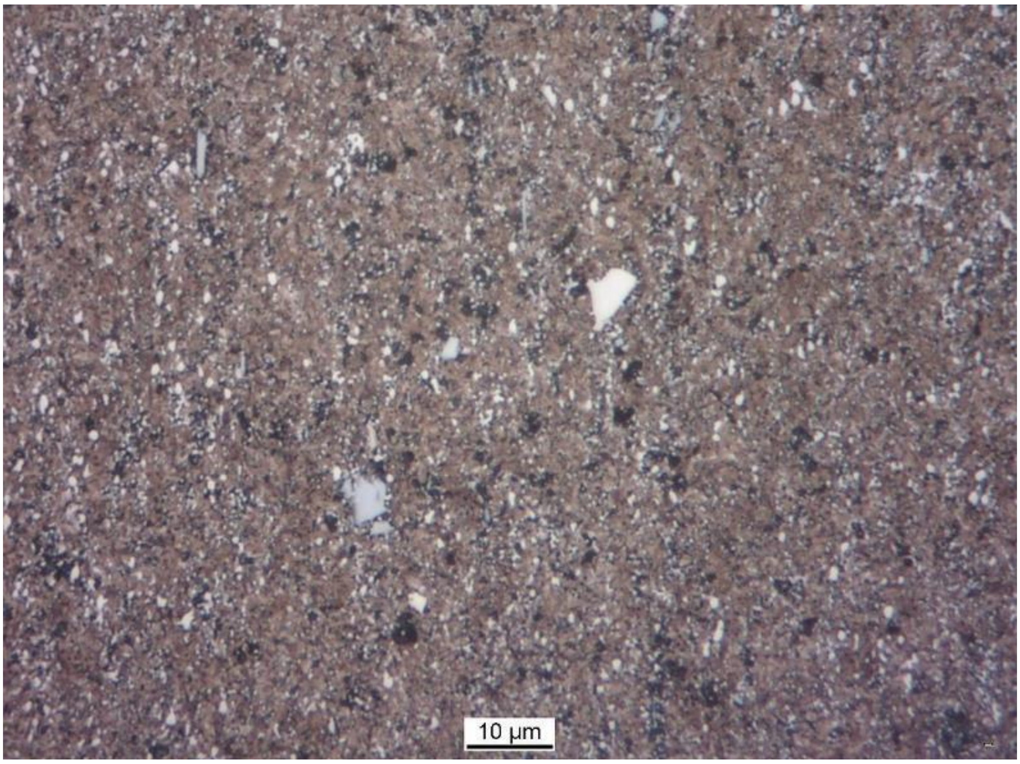

Figure 16 Sample 4 hardened 500x

10.5 Sample 5

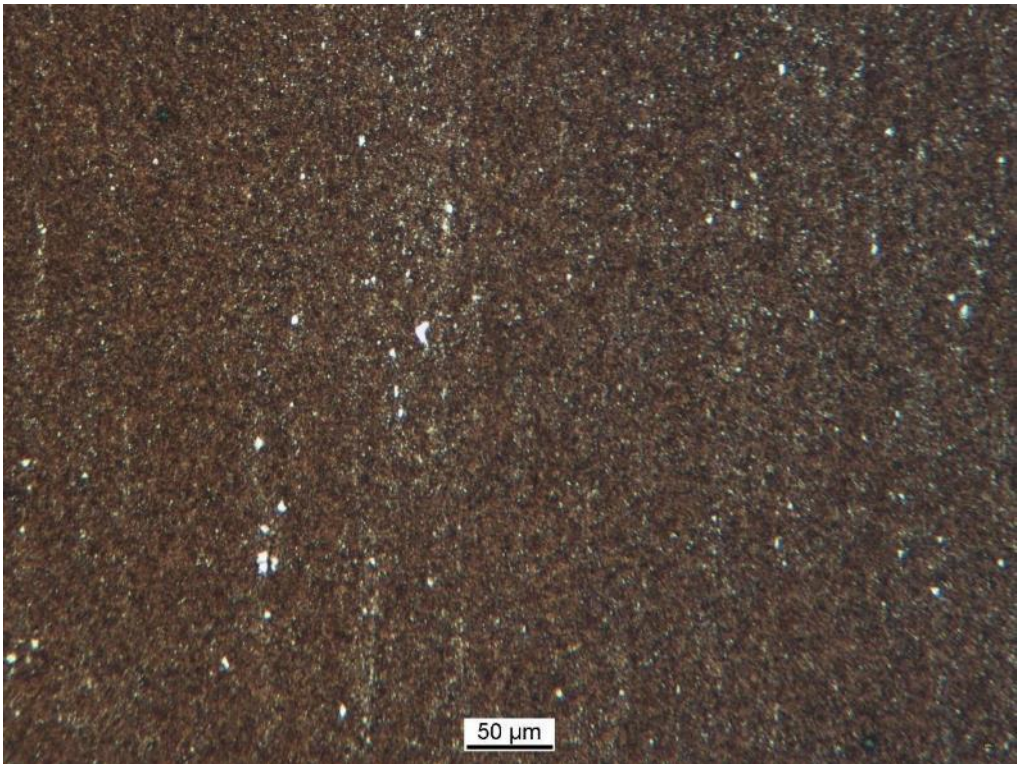

Figure 17 Sample 5 hardened 200x

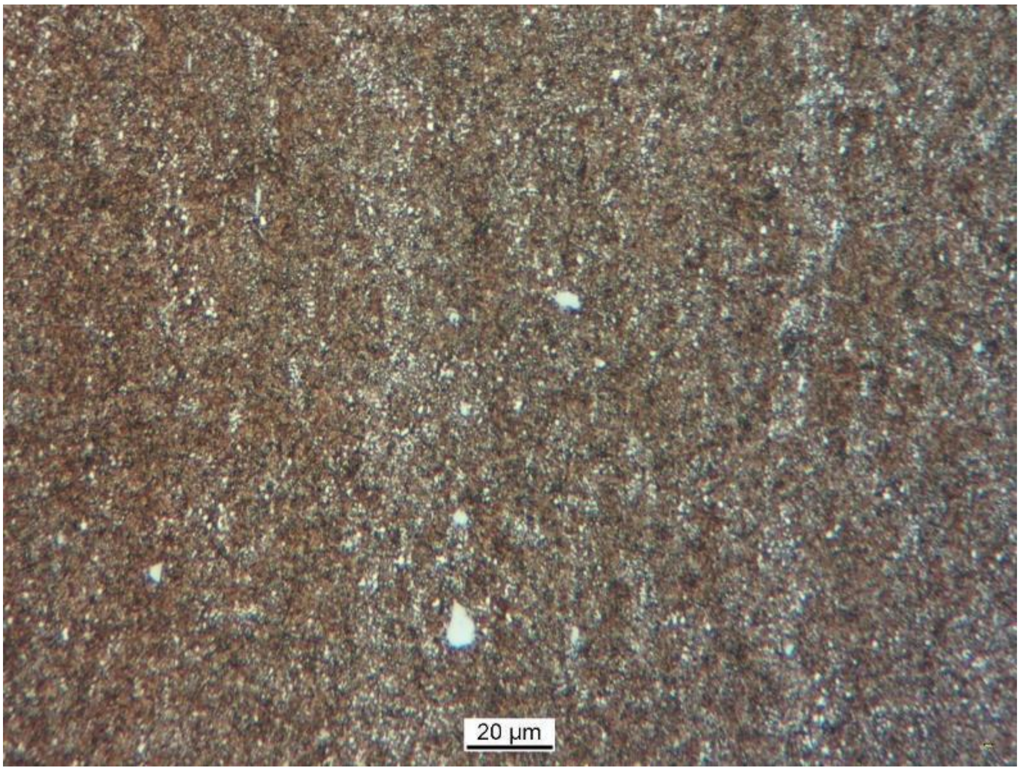

Figure 18 Sample 5 hardened 500x

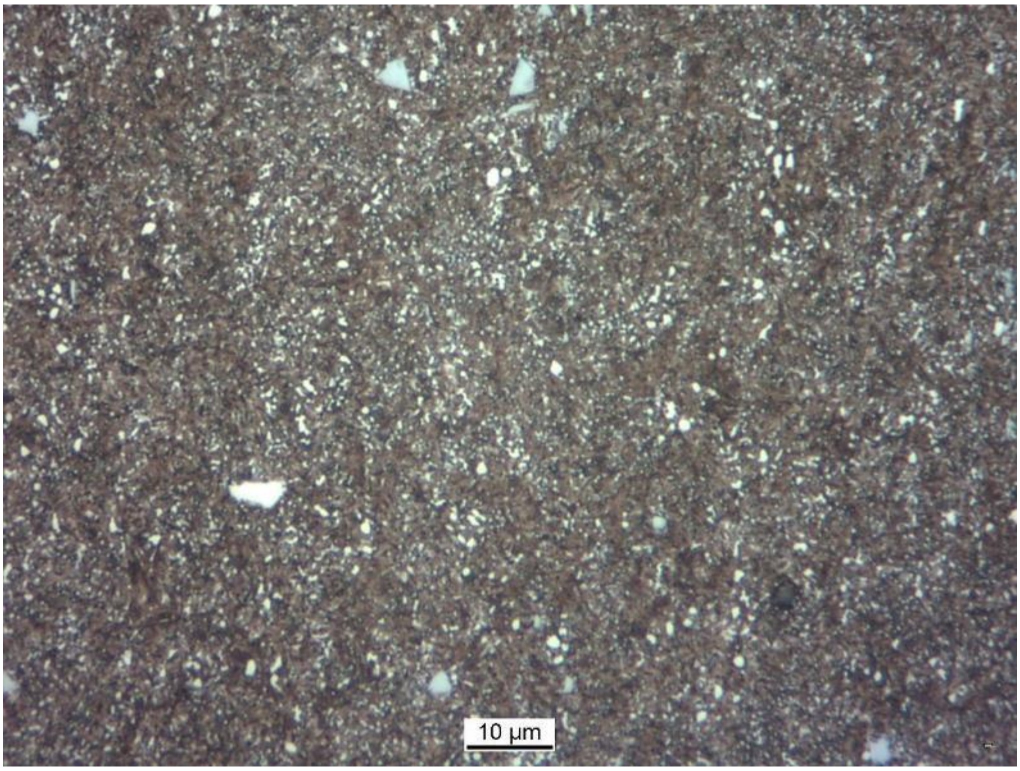

Figure 19 Sample 5 hardened 1000x

11 Measuring of austenite grainsize

The grainsize was measured from the laboratory on several samples by a specific etching technique followed by counting and measuring the average diameter. It was demanding to detect those grains because of its uniform structure and their small sizes. The detectable austenite grains were between **11.5** and **13** some of it even finer than **13**. Unfortunately, the photographs are always less informative than looking directly through the microscope.

11.1 Grain size ASTM E112 table

E112 – 13

TABLE 4 Grain Size Relationships Computed for Uniform, Randomly Oriented, Equiaxed Grains

Grain Size No. G	$\bar{N}_A$ Grains/Unit Area		$\bar{A}$ Average Grain Area		$\bar{d}$ Average Diameter		$\bar{\ell}$ Mean Intercept		$\bar{N}_L$
	No./in.² at 100X	No./mm² at 1X	mm²	µm²	mm	µm	mm	µm	No./mm
00	0.25	3.88	0.2581	258064	0.5080	508.0	0.4525	452.5	2.21
0	0.50	7.75	0.1290	129032	0.3592	359.2	0.3200	320.0	3.12
0.5	0.71	10.96	0.0912	91239	0.3021	302.1	0.2691	269.1	3.72
1.0	1.00	15.50	0.0645	64516	0.2540	254.0	0.2263	226.3	4.42
1.5	1.41	21.92	0.0456	45620	0.2136	213.6	0.1903	190.3	5.26
2.0	2.00	31.00	0.0323	32258	0.1796	179.6	0.1600	160.0	6.25
2.5	2.83	43.84	0.0228	22810	0.1510	151.0	0.1345	134.5	7.43
3.0	4.00	62.00	0.0161	16129	0.1270	127.0	0.1131	113.1	8.84
3.5	5.66	87.68	0.0114	11405	0.1068	106.8	0.0951	95.1	10.51
4.0	8.00	124.00	0.00806	8065	0.0898	89.8	0.0800	80.0	12.50
4.5	11.31	175.36	0.00570	5703	0.0755	75.5	0.0673	67.3	14.87
5.0	16.00	248.00	0.00403	4032	0.0635	63.5	0.0566	56.6	17.68
5.5	22.63	350.73	0.00285	2851	0.0534	53.4	0.0476	47.6	21.02
6.0	32.00	496.00	0.00202	2016	0.0449	44.9	0.0400	40.0	25.00
6.5	45.25	701.45	0.00143	1426	0.0378	37.8	0.0336	33.6	29.73
7.0	64.00	992.00	0.00101	1008	0.0318	31.8	0.0283	28.3	35.36
7.5	90.51	1402.9	0.00071	713	0.0267	26.7	0.0238	23.8	42.04
8.0	128.00	1984.0	0.00050	504	0.0225	22.5	0.0200	20.0	50.00
8.5	181.02	2805.8	0.00036	356	0.0189	18.9	0.0168	16.8	59.46
9.0	256.00	3968.0	0.00025	252	0.0159	15.9	0.0141	14.1	70.71
9.5	362.04	5611.6	0.00018	178	0.0133	13.3	0.0119	11.9	84.09
10.0	512.00	7936.0	0.00013	126	0.0112	11.2	0.0100	10.0	100.0
10.5	724.08	11223.2	0.000089	89.1	0.0094	9.4	0.0084	8.4	118.9
11.0	1024.00	15872.0	0.000063	63.0	0.0079	7.9	0.0071	7.1	141.4
11.5	1448.15	22446.4	0.000045	44.6	0.0067	6.7	0.0060	5.9	168.2
12.0	2048.00	31744.1	0.000032	31.5	0.0056	5.6	0.0050	5.0	200.0
12.5	2896.31	44892.9	0.000022	22.3	0.0047	4.7	0.0042	4.2	237.8
13.0	4096.00	63488.1	0.000016	15.8	0.0040	4.0	0.0035	3.5	282.8
13.5	5792.62	89785.8	0.000011	11.1	0.0033	3.3	0.0030	3.0	336.4
14.0	8192.00	126976.3	0.000008	7.9	0.0028	2.8	0.0025	2.5	400.0

Figure 20 ASTM E112

11.2 Austenite grain size sample 3

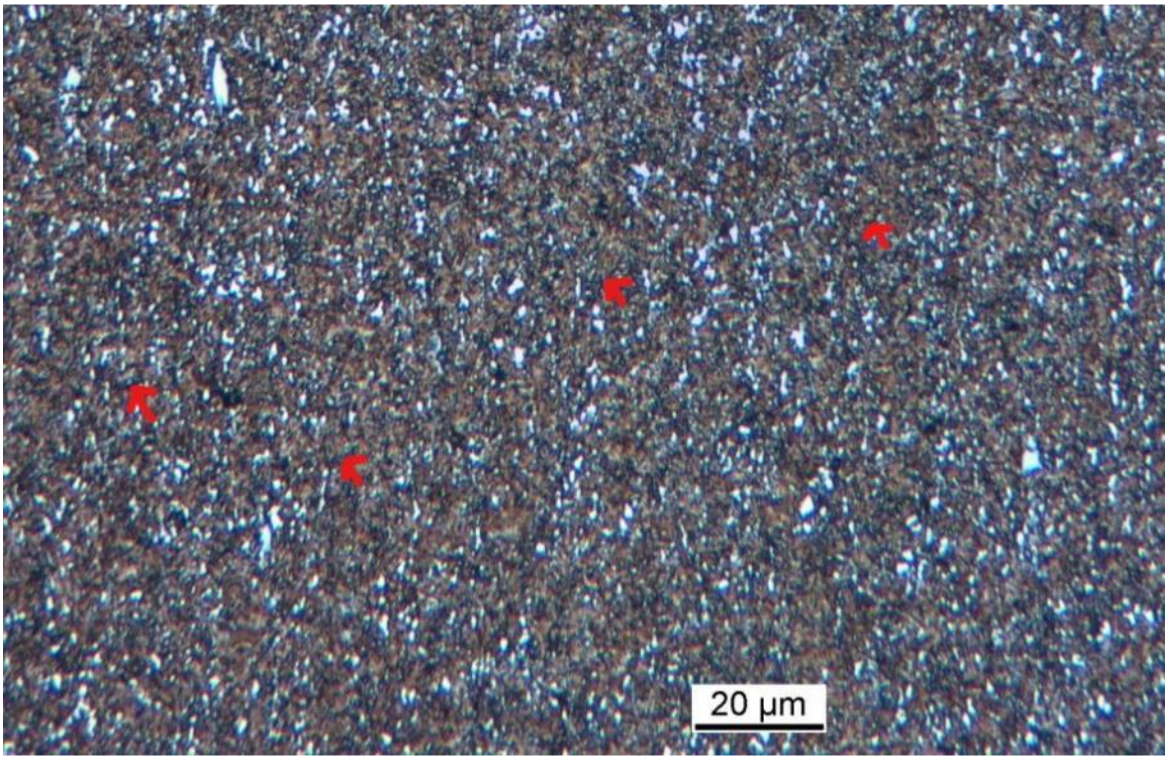

Figure 21 Over etched sample

12 Conclusion

I am 100% sure that the toughness can still be increased!

My work shows very fine austenite grain sizes (<11.5) and almost none of grain boundary carbides leading to interesting toughness-hardness relations. In my eye a good basis for long lasting cutting performance!

The as forged state is very fine, finer than the hardened state. I guess that the temper anneal and the hardening were slightly over timed. While this processing the carbides and the austenite grainsize were having enough time to grow a little bit. I would suggest to decrease austenizing time from 12 minutes down to 7 minutes. It might be worth a try to replace temper annealing by DET. Additionally I would temper it only 2 times 30 minutes in the salt bath, in that molten salt the heat is transferred extremely quick. This could slightly increase the average hardness.

On figures 11- 13 you can see a very beautiful structure, homogenous, almost no carbide alignment and very few bigger carbides. This state would be very nice but if heat treated not at its very best, no improvement in toughness. This state should be heat treated as same as sample 2 with the suggested improvements above; (DET) then hardening at 815°C 7 minutes hold, tempered at 165°C for 2 times 30 minutes.

I think the best relation between hardness and toughness showed the heat treatment number 2.

The toughness of sample number 2 is 9.1 foot-pound, it is approximately more than double times the result from knifesteelnerds.com.

My suggestion for all stock removal knifemakers trying on 1.2562: Know the state of your steel and if there are carbides on the austenite grain boundaries, you probably get poor toughness results. Toughness can be increased by specific forging or special heat treatments with high temperature molten salts. Know what you do, verify it and you will get performance…

Thank you very much!