26. The effect of a single quenching double tempering process on themechanical properties of NiCrMo alloyed steel casting

by Rendi Reynaldi

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1	Pronoun use	
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3	Comma misuse within clauses	
3	Improper formatting	
6	Punctuation in compound/complex sentences	
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8	Determiner use (a/an/the/this, etc.)	
1	Incorrect verb forms	
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31	**Engagement**	
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ISMEE 2019

IOP Publishing

IOP Conf. Series: Materials Science and Engineering 850 (2020) 012040

doi:10.1088/1757-899X/850/1/012040

The effect of a single quenching double tempering process on the mechanical properties of NiCrMo alloyed steel casting

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Abstract. This research aimed to improve the mechanical properties of NiCrMo alloyed steel casting, especially in terms of toughness.[1] Toughness is a combination of tensile strength, yield strength, and elongation. The method used was a multi-heat treatment process involves[2] normalizing, tempering, double tempering, and an additional intermediate process of quenching. The results obtained through the normalizing process followed by single quenching on oil media and double tempering (single quenching double tempering) produced the best-combined result of tensile strength, yield strength, and elongation. The modulus of toughness increased by up to 745 % compared to the as-cast condition from 20 N.mm/mm3 to 149 N.mm/mm3. The best mechanical properties were obtained[3] from tempered martensite microstructure. It is free from rest martensite and secondary carbide.

Introduction

There are several[4] known microstructures of steel, such as ferrite, pearlite, bainite, martensite, and austenite. Each structure has different mechanical properties [1,2]. It is possible to get a higher strength from one of these structures. In general, quenching and tempering are effective ways to increase steel strength, which can be achieved mainly through precipitation of fine dispersion of alloy carbides during tempering [3]. The technique is well known to produce the highest level of strength in steel. Martensitic structures are rarely used[5] without undergoing a tempering process because a[6] large amount of internal stress is created[7] due to the transformation process that causes the material to become more brittle [4]. Tempering at low temperatures is enough to reduce this stress significantly without fundamentally changing the basic characteristics of martensite structures. The effect of microstructure on the mechanical properties of low alloy steels has been actively studied by physical metallurgical researchers [5]. The coarse microstructure formed in the ferritic/pearlitic steel hot roll process developed conventionally results in increased ductility, toughness, and strength, which is good. The development of new steel with a better combination of strength, ductility, and toughness has led to the emergence of new types of multi-phase or ultra-fine grained high strength low alloy steel [6].

Applications in the transportation industry demand more economical high-strength steel with good ductility and impact toughness to lighten structural parts [7,8]. Mechanical properties of low alloy steel can be improved by improving austenite grains. Refinement of microstructure on martensitic steels resulting from quenching and tempering can increase steel strength and toughness. The martensitic lath structure is usually stronger, and increasing the toughness of lath martensite low alloy steel is important, especially for industrial applications used at low temperatures. To get a higher combination of strength

2

and toughness in low alloy steel, achieved through hardening and tempering, can be done by refining austenite grains by microalloying in addition to cyclic heating, initial microstructure, austenitization temperature and holding time at austenitizing temperatures. These factors are related to each other during the heat treatment process, and the overall effect can be determined by the measurement of austenitic prior to grain size. Besides microalloying and cyclic thermal treatment, the formation of austenite grains from various initial microstructure also becomes an interesting technique adopted in the industry for microstructure refining [9].

Sarikaya et al. found that very high impact energy values could be achieved with double heat treatment, but the strength was slightly lower because of the increase in the amount of austenite held through the double quenching treatment (DQ) followed by low temperature tempering on the base structural steel Fe-Cr-C [10]. Chang et al. studied the effect of double austenitization (DA) treatment on the toughness of Ni-Cr-Mo-V steel with the same strength and found that the increase in toughness of steel treated with DA could be mainly attributed to the lower aspect ratio of carbide [11]. Therefore, steels that are processed with double quenching and subsequent double tempering (DQT) treatments can produce different properties due to different microstructure and morphology as well as the distribution of secondary carbides in steel, the main factors, which improve different mechanical properties.

This research is a continuation of previous research, proposed the use of a single quenching double tempering (SQDT) process [12,13]. The effect of double

tempering on the mechanical properties after the normalizing process has been studied[42] on Ni-Cr-Mo alloy cast steel or equivalent to AISI 4340. It was done[43] to improve material toughness through modification of the heat treatment processes. In as-cast conditions, steel casting material has very brittle properties where elongation is only 4%, and impact value is 15 J/cm2. Previously the heat treatment process was carried out[44] by normalizing followed by double tempering at a temperature of 650 °C.[45] It was found[46] that steel casting
139 elongation increased up to 20%, and the toughness increased to 142 J/cm2 [12,13]. The objective of this research is to study the effects of the additional[47] process of hardening or quenching after normalizing, then followed by a double tempering process on microstructure and mechanical properties of cast steel, primarily with increasing material toughness.[48]

Experimental procedure

Material

The research involved the following steps: For experimental samples, raw materials alloy steel was made[49] of CrNiMo cast, with the composition of the AISI 4340 standard. Steel was cast[50] in the shape of the Y- block sample. Y-block was then cut[51] in a 15x15x12 mm square form. Square samples[52] were used[53] for metallographic examination and Rockwell hardness tests in accordance with[54] ASTM E 18 standards. In addition[55], the cylindrical sample[56] was also made for tensile tests observing ASTM E 8M standards. Castings were tested[57] for chemical composition using OES (optical emission spectroscopy). The chemical composition obtained is as per Table 1.

140 Table 1. Chemical composition (%).

C Si Mn P S Cr Ni Mo

0,34 0,22 0,70 0,02 0,01 0,87 1,82 0,34

The raw material, NiCrMo alloy steel, in as-cast condition[58] has a microstructure with the majority of widmanstaten[59] ferrite, which appears like sharp needles. The other structure is the presence of small amounts of fine pearlite. This steel as-cast NiCrMo has a hardness of 25.4 HRC and a very[60] low elongation of only 4%. Figure 1 shows the microstructure of NiCrMo alloy steel as-cast material.[61]

Figure 1. As-Cast microstructure.

The shortage of elongation makes the steel very brittle. The brittleness comes from the existence of a sharp needle widmanstaten[62] structure.

Heat treatment

The heat treatment process was carried out by implementing a variety of[63] processes,[64] as shown in Table 2.

Table 2. Heat treatment scheme.

No

Sample

Heat Treatment Process

1

AC

As-cast

2

N

Normalizing 900°C

NST Normalizing 900°C - Tempering

650°C

NDT Normalizing 900°C - Tempering

650°C - Tempering 705°C

Normalizing 900°C - Quenching

NSQDT 845° - Tempering 650°C –

Tempering 705°C

The process for N[65] sample (Normalizing) was done by heating at 900 °C for 2 hours, followed by air cooling.[66] The NST sample (Normalizing Single Tempering) was done by heating at 900 °C for 2 hours, followed by air cooling, then tempered at 650 °C for 2 hours, followed by air-cooled. The NDT sample (Normalizing Double Tempering) was carried out by heating at 900 °C for 2 hours, followed by air cooling, then tempered twice at 650 °C and 705 °C for 2 hours and then air-cooled. The NSQDT sample (Normalizing Single Quench Double Tempering) was carried out[67] by adding a single quench process before the double tempering process as done in the NDT sample. Single[68,69] quench was done by heating the sample at 845 °C for 2 hours, followed by quench[70] on oil media.

Mechanical testing and metallographic examination

Mechanical testing, namely tensile testing, was carried out according to E 8M standard, and Rockwell hardness testing followed E18[71] standard. The metallographic analysis was performed[72] using an optical microscope; the samples etched[73] using 3% Nital. The entire[74] test results were analyzed[75] for effects of the quenching process followed by double tempering treatment compared to other methods according to the various parameters determined prior to[76] the experimental.

Result and discussion

Microstructures

Figure 2 shows the microstructure observation results. Figure 2 (a) N,[77] shows the microstructure of the sample resulting from the normalizing process. There was no widmanstaten[78] ferrite needle in the microstructure. Instead, the structure was mostly fine pearlite with higher ductility. Figure 2 (b) NST,[79] shows a microstructure resulting from the normalizing process followed by single tempering. White ferrite structures appeared in clusters with higher ductility but lower in strength compared to the N sample. Figure 2 (c) NDT,[80] shows the microstructure of normalized results followed by double tempering. The microstructure had finer[81] grains, whilst[82] the prior austenite grain boundary that appeared on the NST sample was not found[83], and the ferrite structure was no longer clustered[84] but more dispersed. This[85] makes the sample's ductility higher. Figure 2 (d) NSQDT,[86] shows a normal[87] microstructure followed by a single quench then continued by double tempering. The microstructure appeared as tempered martensite, which was evenly distributed[88] and smooth. There was no longer the presence of ferrite, which made the sample stronger than the NDT sample. However, ductility may have increased because the form of temper martensite had finer[89] grains.

(a)

(b)

(c)

(d)

Figure 2. Microstructures (a) N (b) NST (c) NDT (d) NSQDT.

Mechanical properties

Figure 3. Hardness.

Figure 3 shows the hardness of the samples. The differences in terms of the value of hardness were insignificant. The highest value resulted from the N (Normalizing) process, with a value of 27.2 HRC, and the lowest value [90] came from the NDT (Normalizing-Double-Tempering) process [91] with a value [92] of 22.1 HRC. The hardness value is ascertained based on a combination of the microstructure formed. The N sample had a microstructure of mostly fine pearlite, which was harder, [93] whilst [94] the presence of ferrite in the NDT sample made it softer. [95]

Figure 4. Tensile test.

Figure 5. Elongation.

Figures 4 and 5 show the results of tensile testing data. Tensile strength in as-cast conditions was 786 MPa, with 4% elongation increasing after normalizing to 1051 MPa with elongation [96] up to 8.8%. The result shows that the normalizing process can significantly improve the mechanical properties of cast steel by transforming the widmanstaten [97] ferrite structure to fine pearlite [14]. [98] This [99] increases both elongation and strength simultaneously.

The various multiple heat treatment processes after normalizing, namely single tempering, double tempering, and quench double tempering, increase ductility for each sample. [100] The double tempering process produced a finer [101] grain structure [15-18]. In the double tempering process, the first tempering process reduced the hardness by transforming martensite to tempered martensite but can produce brittle secondary carbide from the steel alloy. [102] First, tempering produced[103] martensite from the rest austenite, resulting from the quenching process [14]. The second tempering process tempered the martensite, reducing brittleness and at[104] the same time, producing the fine grain. The NSQDT process increased elongation up to 19.8%.

Figure 6. Tensile test curve.

Figure 6 shows the tensile test curve. The original curve[105] from the test machine was incorrect because there was an error when recording the elongation associated with the slip in the sample gripping.[106] Figure 6 shows the correction done. From the curve, the modulus of toughness can be calculated.[107] This value measures the ability of the material[108] to absorb energy, which is represented by the area under the curve. The formula to calculate the modulus of toughness is as per (1) below [19]:

$U = so+su\ e$

□(1)

T 2[109] f

UT Modulus of toughness (J/m3) or (N.mm/mm3) So Yield strength (MPa)
Su Ultimate tensile strength (MPa) ef[110] Elongation at fracture

Figure 7. Modulus of toughness and tensile test curve.

Figure 7 shows the results of the calculation for the modulus of toughness for all the samples. The highest value was produced by the NSQDT sample. The NSQDT process produced CrNiMo alloy steel materials with the highest modulus of the toughness of 149 N.mm/mm3. The toughness is a combination of the tensile strength, yield strength, and elongation. The high value was the result of the quenching process, followed by double tempering. The process formed a microstructure of tempered martensite with fine grains, free from residual "brittle" martensite and free "brittle" secondary carbide at the prior austenite grain boundary.

Conclusion

The results of this study showed the NSQDT (Normalizing Single Quenching Double Tempering) process had the best combination of mechanical properties with good strength, yield strength, and elongation. It contributed to the toughness of NiCrMo steel. The modulus of toughness increased by up to 745 % compared to the as-cast condition from 20 N.mm/mm3 to 149 N.mm/mm3. The NSQDT process formed a microstructure of tempered martensite with fine grains, with high tensile strength and good mechanical properties. The second tempering process eliminated the martensite, after the first tempering process that made it tougher.

Acknowledgments

We would like to show our gratitude to the Kemenristekdikti and POLMAN Bandung, which have supported the research.

References

Chai H F and Laird C 1987 Mechanisms of cyclic softening and cyclic creep in low carbon steel

Mater. Sci. Eng. 93 159–74

Callister W D[123] and Rethwisch D G 2011 Materials science and engineering vol 5 (John Wiley & Sons NY)

Huang D H and Thomas G 1971 Structure and mechanical properties of tempered martensite and lower bainite in Fe-Ni-Mn-C steels Metall. Trans. 2 1587–98

Kwon H, Cha J C and Kim C H 1988 The effect of grain size on fracture behaviour in tempered martensite embrittlement for AISI 4340 steel Mater. Sci. Eng. 100 121–8

142 Meysami A H, Ghasemzadeh R, Seyedein S H and Aboutalebi M R 2010 An investigation on the microstructure and mechanical properties of direct-quenched and tempered AISI 4140 steel Mater. Des. 31 1570–5

Maropoulos[125] S, Ridley N, Kechagias J and[126] Karagiannis S 2004 Fracture toughness evaluation of a HSLA[127] steel Eng. Fract. Mech. 71 1695–704

Tomita Y 2000 Development of fracture toughness of ultrahigh strength, medium carbon, low alloy steels for aerospace applications Int. Mater. Rev. 45 27–37

Weng Y 2009 Ultra-fine grained steels[128] (Springer Science & Business Media)

143 Sanij[129] M H K, Banadkouki S S G,[130] Mashreghi A R and Moshrefifar M 2012 The effect of single and double quenching and tempering heat treatments on the microstructure and[131] mechanical properties of AISI 4140 steel Mater. Des. 42 339–46

Sarikaya M, Steinberg B G[132] and Thomas G 1982 Optimization of Fe/Cr/C base structural steels for improved strength and toughness Metall. Trans. A 13 2227–37

Chang E, Chang C Y and Liu C D 1994 The effects of double austenitization on the mechanical properties of a 0.34 C containing low-alloy Ni-Cr-Mo-V steel Metall. Mater. Trans. A 25 545– 55

Bandanadjaja B and Achyarsyah M 2014 Perbaikan Ketangguhan Material Baja Cor Paduan Ni- Cr-Mo Melalui Proses Tempering Ganda Seminar Nasional Teknologi Manufaktur (STEMAN) pp 1–4

Bandanadjaja B and Idamayanti D 2017 Pengaruh Proses Tempering Ganda Terhadap Sifat Mekanik Material Baja Cor Paduan Ni-Cr-Mo Metalurgi 1 29–36

Thelning K-E 2013 Steel and its heat treatment (Butterworth-heinemann)

144 Zhang C, Wang Q, Ren J, Li R, Wang M, Zhang F and Yan Z 2012 Effect of microstructure on the strength of 25CrMo48V martensitic steel tempered at different temperature and time Mater. Des. 36 220–6

145 Liu Y, Ye D, Yong Q, Su J, Zhao K and Jiang W 2011 Effect of heat treatment on microstructure and property of Cr13 super martensitic stainless steel J. iron steel Res. Int. 18 60–6

Kaijalainen[133] A J, Suikkanen P P, Limnell[134] T J, Karjalainen L P,[135] Kömi J I and Porter D A 2013 Effect of austenite grain structure on the strength and toughness of direct-quenched martensite

J. Alloys Compd. 577 S642–8

Wang Q, Zhang C, Li R, Gao J, Wang M and Zhang F 2013 Characterization of the microstructures and mechanical properties of 25CrMo48V martensitic steel tempered at[136] different times Mater. Sci. Eng. A 559 130–4

Davis J R 2004 Tensile testing .[137] ASM International Ohio, USA

1.		Intricate text	Clarity
2.	that involves	Pronoun use	Correctness
3.	*The best mechanical properties were obtained*	Passive voice misuse	Clarity
4.	~~There are several~~ → Several	Wordy sentences	Clarity
5.	*are rarely used*	Passive voice misuse	Clarity
6.	~~because a~~ → . A	Hard-to-read text	Clarity
7.	*is created*	Passive voice misuse	Clarity
8.	~~basic~~ → essential	Word choice	Engagement
9.		Intricate text	Clarity
10.	*been actively studied*	Passive voice misuse	Clarity
11.		Intricate text	Clarity
12.	*The coarse microstructure formed in the ferritic/pearlitic steel hot roll process developed conventionally results in increased ductility, toughness, and strength, which is good.*	Hard-to-read text	Clarity
13.	~~strength~~ → power	Word choice	Engagement
14.	*Mechanical properties of low alloy steel can be improved*	Passive voice misuse	Clarity
15.	*Refinement of microstructure on martensitic steels resulting from quenching and tempering can increase steel strength and toughness.*	Hard-to-read text	Clarity
16.	~~stronger~~ →	Word choice	Engagement

	more robust, more substantial, more muscular, more vital		
17.	~~important~~ → essential	Word choice	Engagement
18.	*The martensitic lath structure is usually stronger, and increasing the toughness of lath martensite low alloy steel is important, especially for industrial applications used at low temperatures.*	Hard-to-read text	Clarity
19.	strength.	Closing punctuation	Correctness
20.	*Content from this work may be used*	Passive voice misuse	Clarity
21.	~~licence~~ → license	Mixed dialects of English	Correctness
22.	~~title of the work~~ → work title	Wordy sentences	Clarity
23.	~~work~~ → book	Word choice	Engagement
24.	, and	Comma misuse within clauses	Correctness
25.	~~licence~~ → license	Mixed dialects of English	Correctness
26.	~~and~~ → And	Improper formatting	Correctness
27.	, and	Comma misuse within clauses	Correctness
28.	*and toughness in low alloy steel, achieved through hardening and tempering, can be done by refining austenite grains by microalloying in addition to cyclic heating, initial microstructure, austenitization temperature and holding time at austenitizing temperatures.*	Hard-to-read text	Clarity
29.	~~prior to~~ → before	Wordy sentences	Clarity
30.		Passive voice misuse	Clarity

31.	~~interesting~~ → exciting	Word choice	Engagement
32.	*Besides microalloying and cyclic thermal treatment, the formation of austenite grains from various initial microstructure also becomes an interesting technique adopted in the industry for microstructure refining [9].*	Hard-to-read text	Clarity
33.	*very high impact energy values could be achieved*	Passive voice misuse	Clarity
34.	~~, but the~~ → . Still, the	Hard-to-read text	Clarity
35.	~~double~~ → dual	Word choice	Engagement
36.	~~and found~~ → . They found	Hard-to-read text	Clarity
37.	*the increase in toughness of steel treated with DA could be mainly attributed*	Passive voice misuse	Clarity
38.	*are processed*	Passive voice misuse	Clarity
39.	~~as well as~~ → and	Wordy sentences	Clarity
40.	~~different~~ → other	Word choice	Engagement
41.	~~the use of~~ → using	Wordy sentences	Clarity
42.	*been studied*	Passive voice misuse	Clarity
43.	*was done*	Passive voice misuse	Clarity
44.	*the heat treatment process was carried out*	Passive voice misuse	Clarity
45.		Intricate text	Clarity
46.	*It was found*	Passive voice misuse	Clarity
47.	~~additional~~ → different	Word choice	Engagement

48.		Intricate text	Clarity
49.	*was made*	Passive voice misuse	Clarity
50.	*Steel was cast*	Passive voice misuse	Clarity
51.	*Y-block was then cut*	Passive voice misuse	Clarity
52.	~~samples~~ → pieces, models	Word choice	Engagement
53.	*Square samples were used*	Passive voice misuse	Clarity
54.	~~in accordance with~~ → by, following, per, under	Wordy sentences	Clarity
55.	~~In addition~~ → Also, Besides	Wordy sentences	Clarity
56.	~~sample~~ → selection, piece, model	Word choice	Engagement
57.	*Castings were tested*	Passive voice misuse	Clarity
58.	condition,	Punctuation in compound/complex sentences	Correctness
59.	*widmanstaten*	Unknown words	Correctness
60.	~~a~~ very	Determiner use (a/an/the/this, etc.)	Correctness
61.	*The other structure is the presence of small amounts of fine pearlite. This steel as-cast NiCrMo has a hardness of 25.4 HRC and a very low elongation of only 4%. Figure 1 shows the microstructure of NiCrMo alloy steel as-cast material.*	Monotonous sentences	Engagement
62.	*widmanstaten*	Unknown words	Correctness
63.	~~a variety of~~ → various	Wordy sentences	Clarity
64.	~~processes~~ →	Word choice	Engagement

	methods, techniques, functions, approaches		
65.	the N	Determiner use (a/an/the/this, etc.)	Correctness
66.		Intricate text	Clarity
67.	*The NSQDT sample (Normalizing Single Quench Double Tempering) was carried out*	Passive voice misuse	Clarity
68.	~~Single~~ → Available	Word choice	Engagement
69.	A single	Determiner use (a/an/the/this, etc.)	Correctness
70.	a quench	Determiner use (a/an/the/this, etc.)	Correctness
71.	the E18	Determiner use (a/an/the/this, etc.)	Correctness
72.	*was performed*	Passive voice misuse	Clarity
73.	were etched	Incorrect verb forms	Correctness
74.	~~entire~~ → complete, full	Word choice	Engagement
75.	*The entire test results were analyzed*	Passive voice misuse	Clarity
76.	~~prior to~~ → before	Wordy sentences	Clarity
77.	N,	Punctuation in compound/complex sentences	Correctness
78.	*widmanstaten*	Unknown words	Correctness
79.	NST,	Punctuation in compound/complex sentences	Correctness
80.	NDT,	Punctuation in compound/complex sentences	Correctness

81.	~~finer~~ → more refined	Word choice	Engagement
82.	~~whilst~~ → while	Outdated language	Clarity
83.	*the prior austenite grain boundary that appeared on the NST sample was not found*	Passive voice misuse	Clarity
84.	*the ferrite structure was no longer clustered*	Passive voice misuse	Clarity
85.	*This*	Intricate text	Clarity
86.	NSQDT,	Punctuation in compound/complex sentences	Correctness
87.	~~a normal~~ → an expected, a regular, a typical	Word choice	Engagement
88.	*was evenly distributed*	Passive voice misuse	Clarity
89.	~~finer~~ → more refined	Word choice	Engagement
90.	~~value~~ → cost	Word choice	Engagement
91.	~~process~~ → function, method, circle	Word choice	Engagement
92.	~~a value~~ → an amount	Word choice	Engagement
93.	~~harder~~ → more challenging, more problematic	Word choice	Engagement
94.	~~whilst~~ → while	Outdated language	Clarity
95.		Intricate text	Clarity
96.	~~elongation~~ → extension, stretching	Word choice	Engagement
97.	*widmanstaten*	Unknown words	Correctness
98.		Intricate text	Clarity

99.	*This*	Intricate text	Clarity
100.		Intricate text	Clarity
101.	~~finer~~ → more refined, more acceptable, more adequate, more sufficient	Word choice	Engagement
102.	*In the double tempering process, the first tempering process reduced the hardness by transforming martensite to tempered martensite but can produce brittle secondary carbide from the steel alloy.*	Hard-to-read text	Clarity
103.	~~produced~~ → made, had	Word choice	Engagement
104.	, at	Punctuation in compound/complex sentences	Correctness
105.	~~curve~~ → angle, turn	Word choice	Engagement
106.		Intricate text	Clarity
107.	*the modulus of toughness can be calculated*	Passive voice misuse	Clarity
108.	material's ability	Wordy sentences	Clarity
109.	~~2~~ → two	Improper formatting	Correctness
110.	~~of~~ → of	Confused words	Correctness
111.		Passive voice misuse	Clarity
112.	~~produced~~ → made, had	Word choice	Engagement
113.	~~the~~ toughness	Determiner use (a/an/the/this, etc.)	Correctness
114.	~~the~~ tensile	Determiner use (a/an/the/this, etc.)	Correctness

115.	*The highest value was produced by the NSQDT sample. The NSQDT process produced CrNiMo alloy steel materials with the highest modulus of the toughness of 149 N.mm/mm3. The toughness is a combination of the tensile strength, yield strength, and elongation.*	Monotonous sentences	Engagement
116.	~~fine~~ → refined	Word choice	Engagement
117.	*The process formed a microstructure of tempered martensite with fine grains, free from residual "brittle" martensite and free "brittle" secondary carbide at the prior austenite grain boundary.*	Hard-to-read text	Clarity
118.	tempered martensite microstructure	Wordy sentences	Clarity
119.	~~fine~~ → refined	Word choice	Engagement
120.	~~tougher~~ → more challenging, more rigid	Word choice	Engagement
121.	~~would like~~ → want	Tone issues	Delivery
122.	~~POLMAN~~ → Polman	Confused words	Correctness
123.	~~W.D~~ → WD	Confused words	Correctness
124.	~~behaviour~~ → behavior	Mixed dialects of English	Correctness
125.	~~Maropoulos~~ → Metropoulos	Misspelled words	Correctness
126.	, and	Comma misuse within clauses	Correctness
127.	~~a HSLA~~ → an HSLA	Determiner use (a/an/the/this, etc.)	Correctness
128.	~~steels~~ → sheets of steel, plates of steel	Incorrect noun number	Correctness
129.	~~Sanij~~ → Sanji, Sani	Misspelled words	Correctness

130.	~~S G~~ → SG	Confused words	Correctness
131.	~~and~~	Wordy sentences	Clarity
132.	~~B G~~ → BG	Confused words	Correctness
133.	~~Kaijalainen~~ → Karjalainen	Misspelled words	Correctness
134.	~~Limnell~~ → Linnell	Misspelled words	Correctness
135.	~~L P~~ → LP	Confused words	Correctness
136.	~~at~~	Wordy sentences	Clarity
137.	testing .	Improper formatting	Correctness
138.	*Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1*	IOP Conference Series: Materials Science and Engineering ... https://iopscience.iop.org/article/10.1088/1757-899X/103/1/012012/pdf	Originality
139.	*The objective of this research is to study the*	THE OBJECTIVE OF THIS RESEARCH IS TO STUDY THE FEASIBILITY ... https://www.sbir.gov/sbirsearch/detail/131520	Originality
140.	*Chemical composition (%). C Si Mn P S Cr Ni Mo 0,*	Cr-Ni-Mo AUSTENITIC STAINLESS STEEL ACX 240 http://www.acerinox.com/opencms803/export/sites/acerinox/.content/galerias/galeria-descargas/galeria-documentos-producto/ACX240-low.pdf	Originality
141.	*Acknowledgments We would like to show our gratitude to*	Driving Sustainability-Oriented Innovation https://sloanreview.mit.edu/article/driving-sustainability-oriented-innovation/	Originality

142.	*An investigation on the microstructure and mechanical properties of direct-quenched and tempered AISI 4140 steel*	An investigation on the microstructure and mechanical ... https://www.sciencedirect.com/science/article/pii/S0261306909005251	Originality
143.	*The effect of single and double quenching and tempering heat treatments on the microstructure and mechanical properties of AISI 4140 steel*	The effect of single and double quenching and tempering ... https://www.sciencedirect.com/science/article/pii/S0261306912003901	Originality
144.	*Effect of microstructure on the strength of 25CrMo48V martensitic steel tempered at different temperature and time*	Effect of microstructure on the strength of 25CrMo48V ... https://www.sciencedirect.com/science/article/pii/S0261306911007862	Originality
145.	*Effect of heat treatment on microstructure and property of Cr13 super martensitic stainless steel*	Effect of Heat Treatment on Microstructure and Property of ... https://www.sciencedirect.com/science/article/pii/S1006706X11601180	Originality