Research on Wear Behavior of Wheel Steel

H. Wang, D. Zuo, R. Pilon

Research on Wear Behavior of Wheel Steel

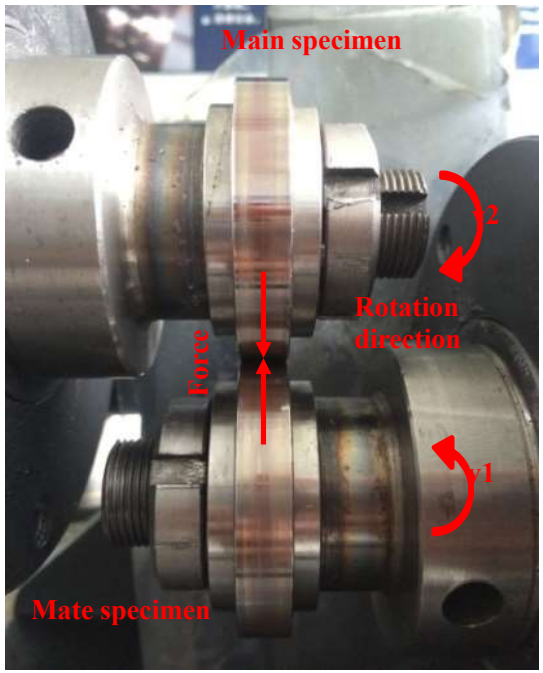
Overview

1. **Introduction**
2. **Test Program**
3. **Results**
4. **Discussion**
5. **Conclusions**

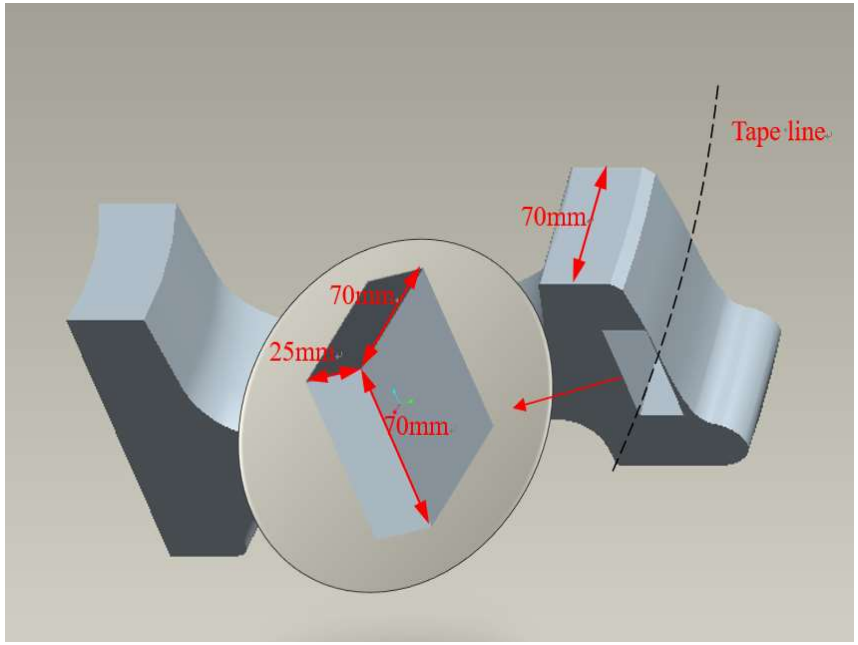
Introduction

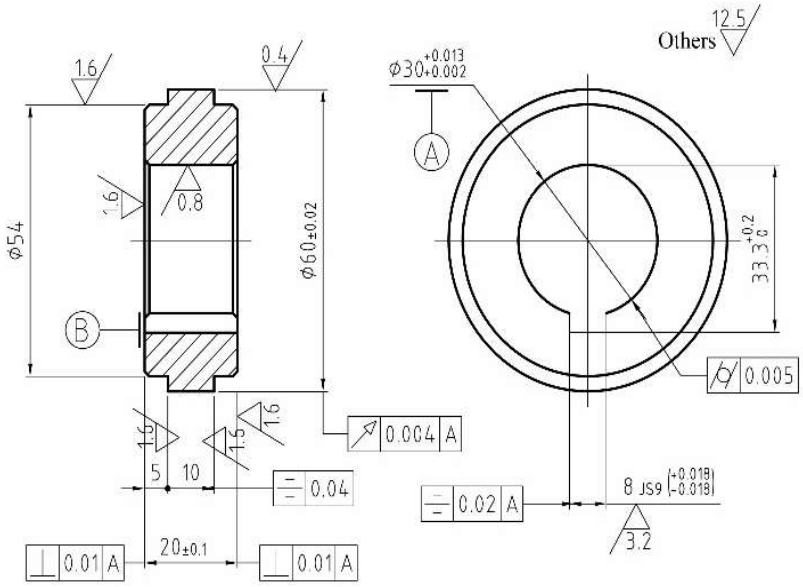
1. Amsted Rail used a GPM-30 Wear and Rolling Contact Fatigue test machine.
2. Weight loss as a measure of wear resistance.
3. AAR M107/208 Appendix C used as reference.
4. Chemistry, hardness, microstructure, and deformation zone hardness considered to be factors affecting wear resistance.

Test Program



Test Program





Test Program

1. Main specimen from various cast wheel steels.
2. Mate specimen from 1 class C wheel for all tests.
3. 673 Mpa stress, 0.75% slip
4. 250k, 500k, 750k cycles, each specimen cleaned and weighed.
5. 6 AAR class C wheels, 3 each from 2 facilities, and 4 of which had various micro-alloying elements added.

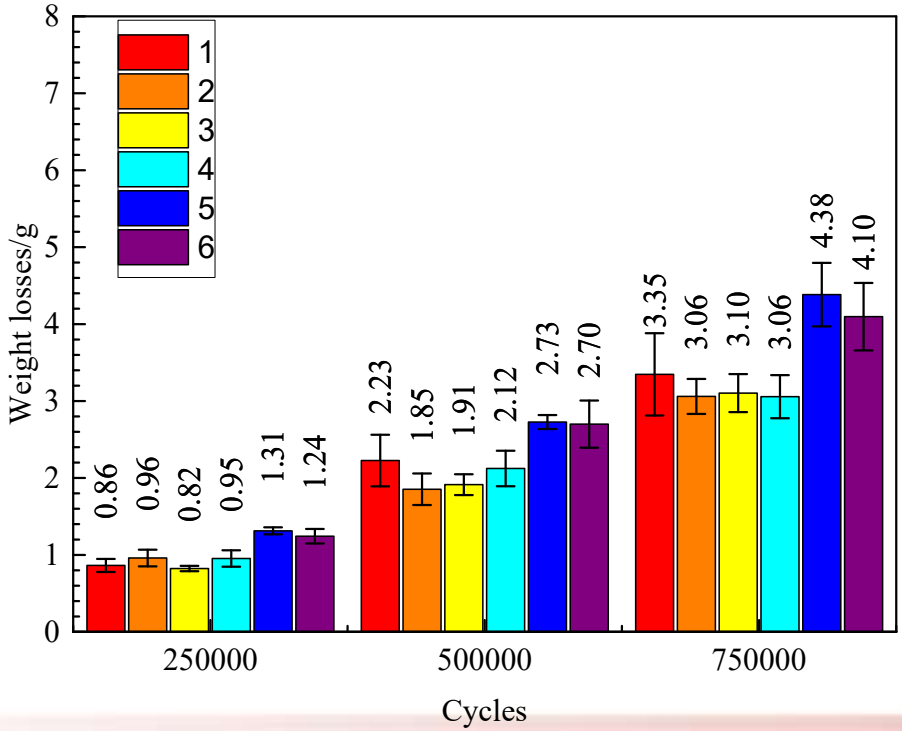
Test Program

Steel No	Chemistry							Mean hardness / HRC	Facility
	C%	Si%	Mn%	Cr%	Mo%	V%	Ce%		
AAR-C standard	0.67~0.77	0.15~1.00	0.60~0.90	≤0.25	≤0.10	≤0.040		30.0~42.0	
1	0.73	0.58	0.78	0.080	0.02	0.005	0.984	35.4	A
2	0.74	0.78	0.81	0.210	0.080	0.005	1.069	37.5	A
3	0.72	0.48	0.83	0.090	0.01	0.128	0.989	35.0	A
4	0.76	0.86	0.81	0.100	0.03	0.003	1.068	37.4	B
5	0.69	0.98	0.90	0.300	0.130	0.184	1.131	36.9	B
6	0.75	0.65	0.75	0.210	0.090	0.001	1.050	35.8	B
7	0.73	0.50	0.81	0.090	0.010	0.007	0.975	34.5	A

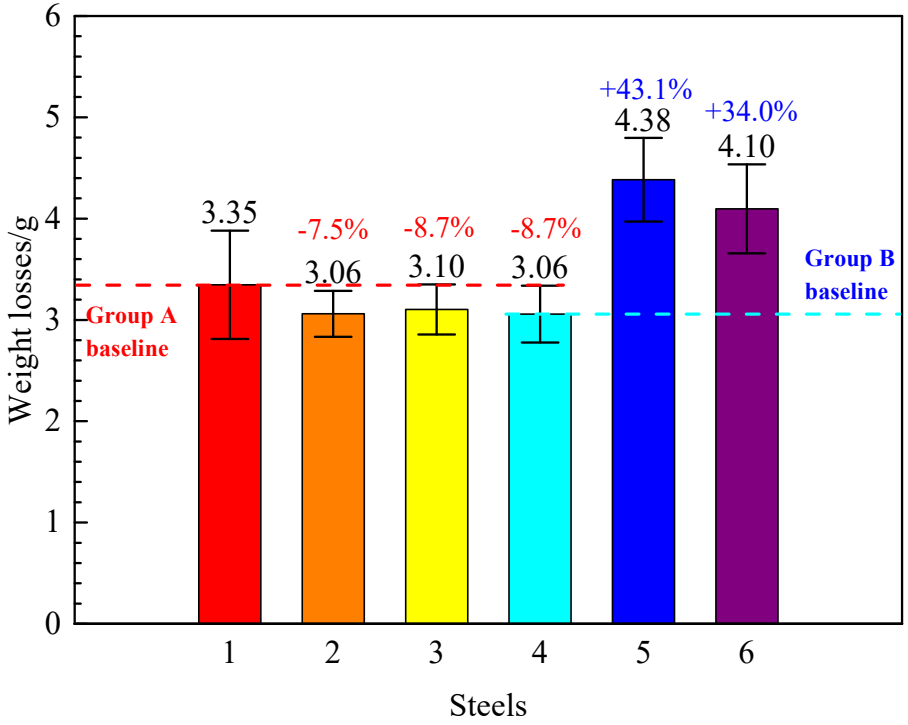
Results

1. **Observations during testing:**
    1. First 25k cycles break-in surface from fine finish to rough finish on wear surface.
    2. 25k to 600k cycles stable wear and low noise.
    3. 600k to 750k cycles vibration and noise increased, with a few specimens becoming corrugated and OOR.

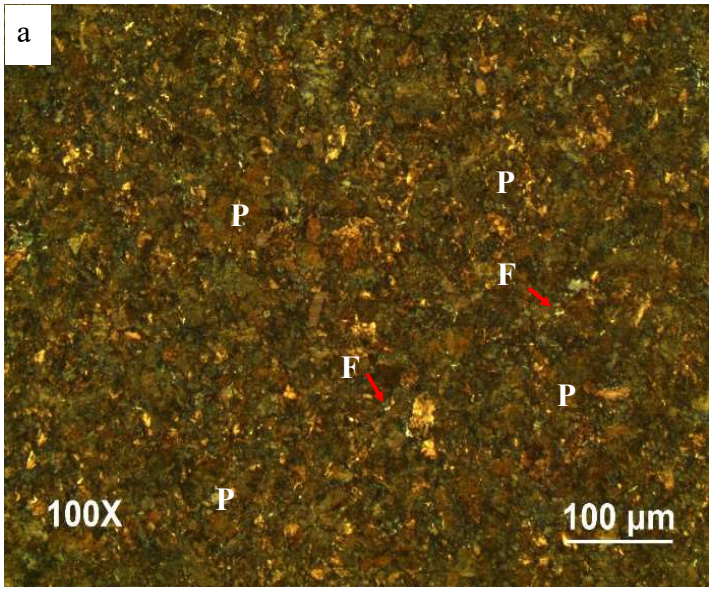
Results

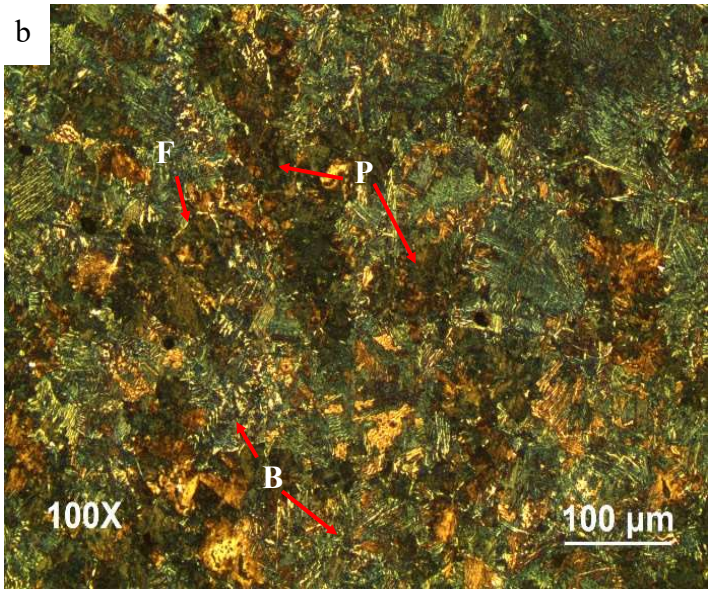

Weight losses/g
Cycles
250000
500000
750000
1
2
3
4
5
6
0.86
0.96
0.82
0.95
1.31
1.24
2.23
1.85
1.91
2.12
2.73
2.70
3.35
3.06
3.10
3.06
4.38
4.10

Results


Weight losses/g
Steels
0
1
2
3
4
5
6
1
2
3
4
5
6
3.35
3.06
3.10
3.06
4.38
4.10
-7.5%
-8.7%
-8.7%
+43.1%
+34.0%
Group A baseline
Group B baseline

Results

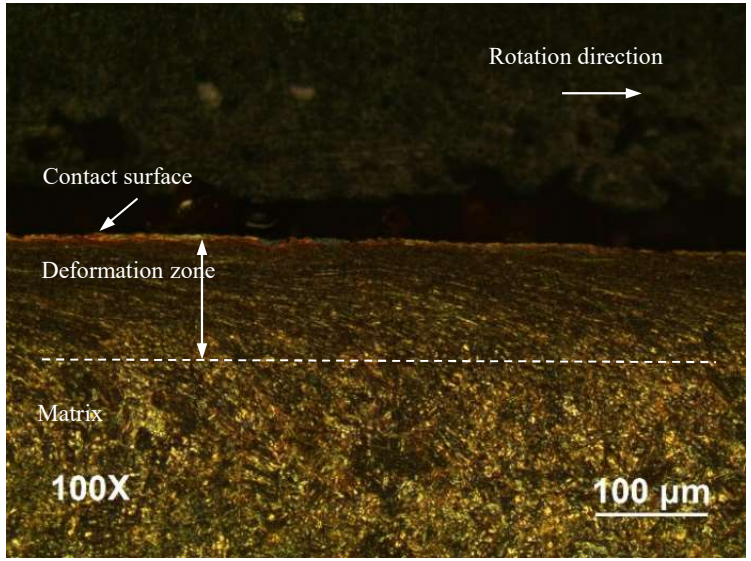


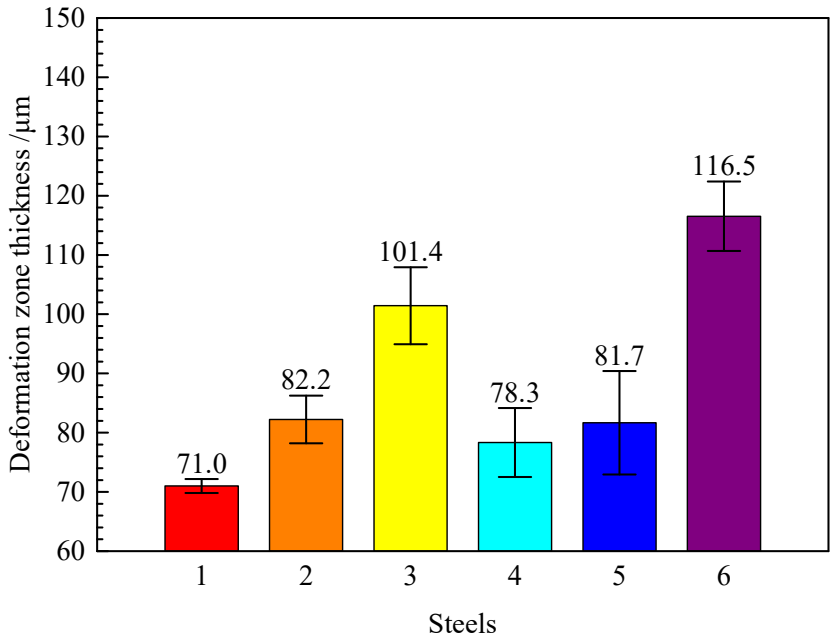


Results

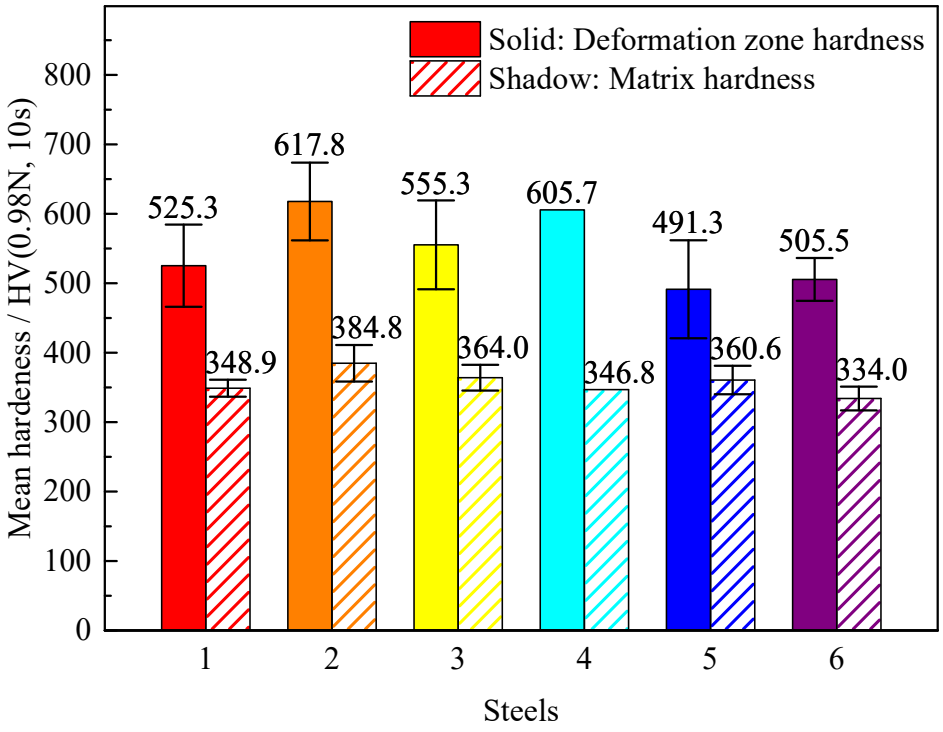
Steel No	F%	B%	P%	Grain grade
1	0.15	0.00	99.85	9.0
2	0.33	10.97	88.70	9.0
3	0.17	0.00	99.83	8.5
4	0.61	11.40	87.99	8.0
5	1.68	78.58	19.73	8.5
6	0.26	56.59	43.16	8.0

Results


Rotation direction
Contact surface
Deformation zone
Matrix
100X
100 μm


Deformation zone thickness /μm
150
140
130
120
110
100
90
80
70
60
71.0
82.2
101.4
78.3
81.7
116.5
1
2
3
4
5
6
Steels

Results

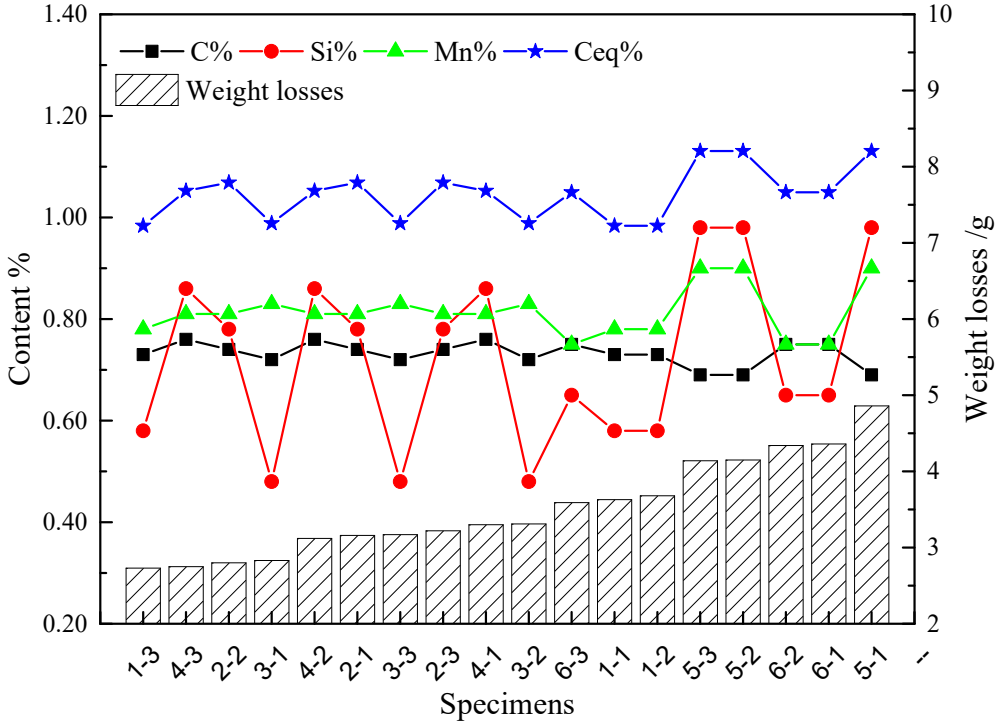

Solid: Deformation zone hardness
Shadow: Matrix hardness
Mean hardeness / HV(0.98N, 10s)
0
100
200
300
400
500
600
700
800
525.3
348.9
617.8
384.8
555.3
364.0
605.7
346.8
491.3
360.6
505.5
334.0
1
2
3
4
5
6
Steels

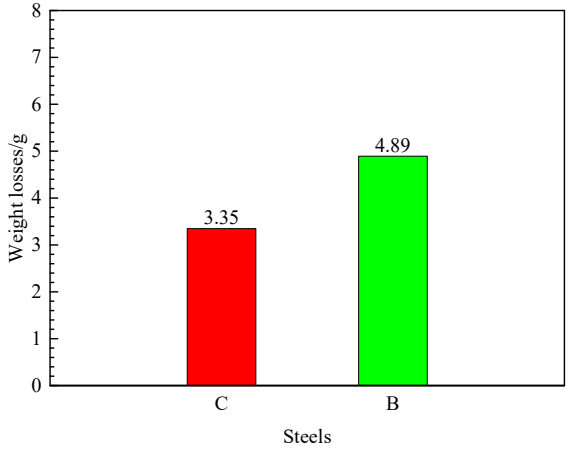
Discussion

1. Minitab® used to determine basic correlation between weight loss and other factors.
2. P value < 0.05 for correlation with 95% confidence.
3. To increase sample size, all 3 specimens from each steel were included as individual data point.

Factors	P	Correlation	Effect	Figure
C%	0.064	-0.445	NONE	11
Si%	0.161	+0.345	NONE	11
Mn%	0.348	+0.235	NONE	11
Ceq%	0.025	+0.525	POSITIVE	11
Hardness of main disc /HRC	0.927	+0.023	NONE	13
Hardness difference (Mate - Main) /HRC	0.284	-0.267	NONE	13
F%	0.011	+0.584	POSITIVE	14
B%	0.000	+0.825	POSITIVE	14
P%	0.000	-0.826	NEGATIVE	14
Grain grade	0.434	-0.197	NONE	15
Deformation zone thickness	0.195	+0.320	NONE	16
Deformation zone hardness /HV	0.038	-0.491	NEGATIVE	17
Hardness Differential (DZT- M) /HV	0.058	-0.455	NONE	17

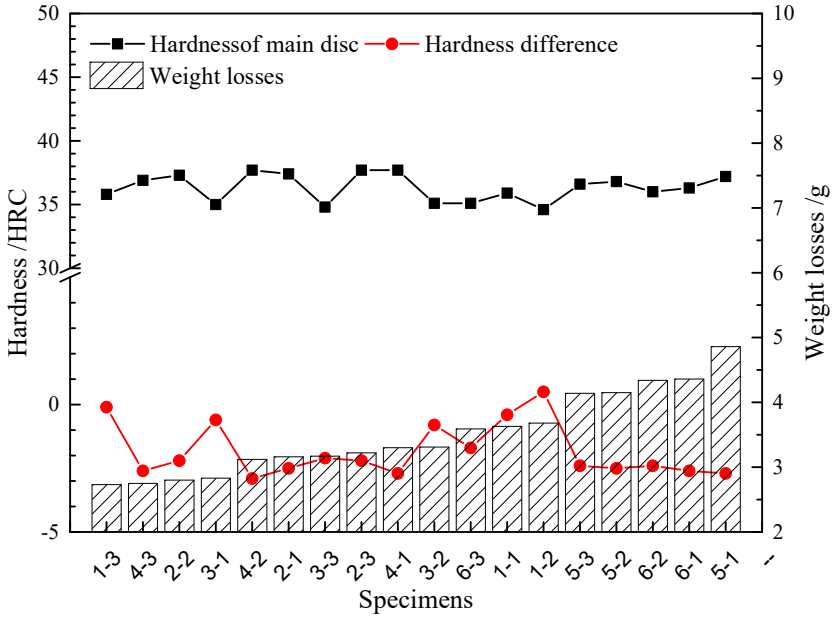
Discussion

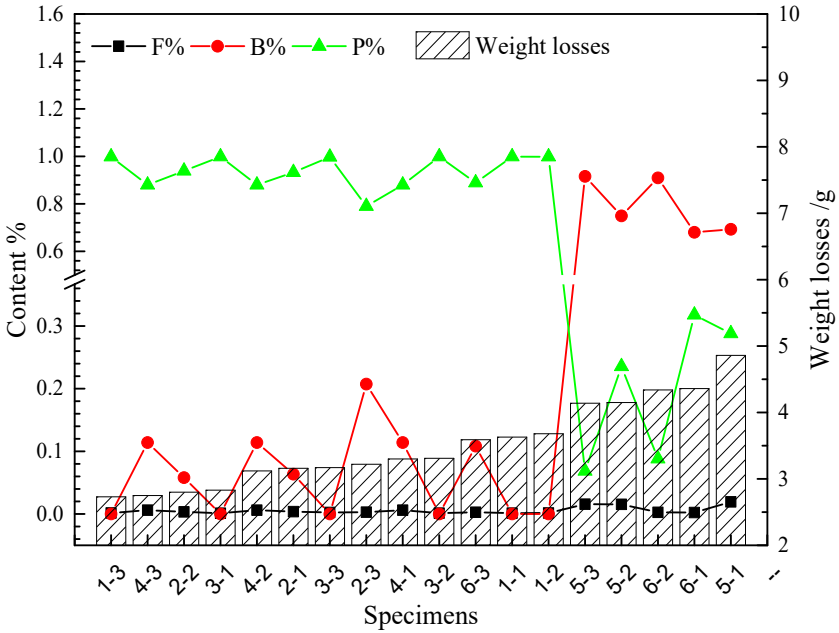




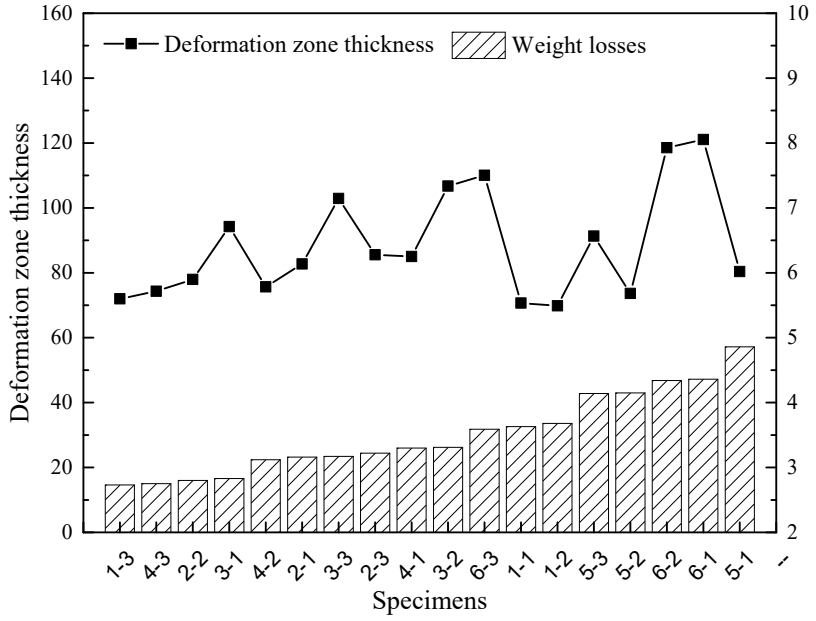
C steel has 30% better wear resistance than B steel

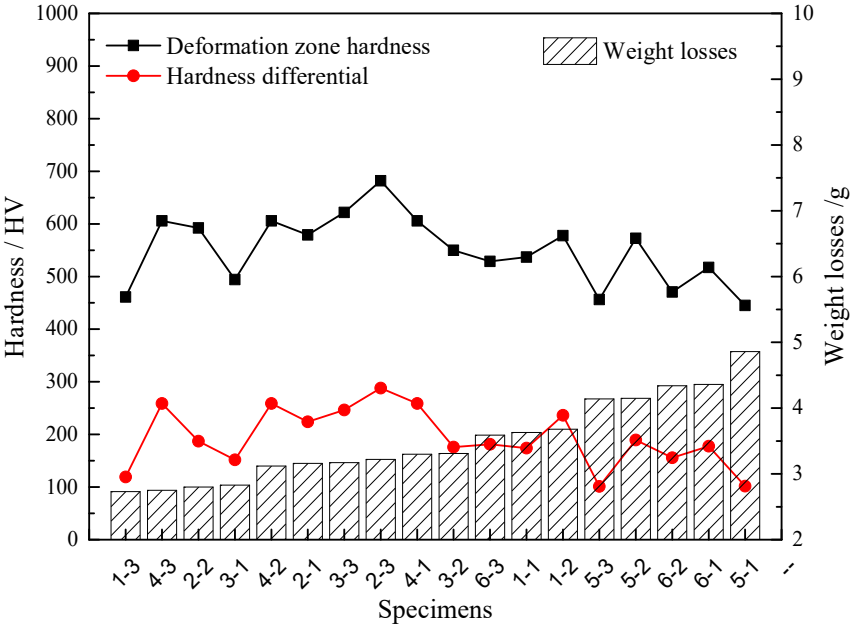
Discussion


Hardnessof main disc
Hardness difference
Weight losses
Hardness /HRC
Weight losses /g
Specimens
1-3
4-3
2-2
3-1
4-2
2-1
3-3
2-3
4-1
3-2
6-3
1-1
1-2
5-3
5-2
6-2
6-1
5-1


F%
B%
P%
Weight losses
Content %
Weight losses /g
Specimens
1-3
4-3
2-2
3-1
4-2
2-1
3-3
2-3
4-1
3-2
6-3
1-1
1-2
5-3
5-2
6-2
6-1
5-1

Discussion


Deformation zone thickness
Weight losses
Deformation zone thickness
Weight losses /g
Specimens
1-3 4-3 2-2 3-1 4-2 2-1 3-3 2-3 4-1 3-2 6-3 1-1 1-2 5-3 5-2 6-2 6-1 5-1


Deformation zone hardness
Hardness differential
Weight losses
Hardness / HV
Weight losses /g
Specimens
1-3 4-3 2-2 3-1 4-2 2-1 3-3 2-3 4-1 3-2 6-3 1-1 1-2 5-3 5-2 6-2 6-1 5-1

Conclusions

1. Use of micro-alloy elements, with proper processing, can increase the wear resistance of class C steel wheels.
2. Resulting microstructure from micro-alloying can be indicative of improved wear resistance.
3. Deformation zone properties, such as higher hardness, can correlate to increased wear resistance.

Future Work

1. Additional physical property testing of wheel samples.
2. Investigation of microstructure and strain hardening.
3. Additional wheel steels, facilities, and processes will be studied.

Thank You