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CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 59-27

EXAMINATION OF COLD HEADING STEEL STOCK

by

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PHYSICAL METALLURGY DIVISION

COPY NO. 16

MARCH 4, 1959

Mines Branch Investigation IR 59-27

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SUMMARY

Samples of steel from Canadian and U.S. suppliers were examined to determine the metallurgical factors affecting their cold heading properties. The Canadian steels were found to have higher carbon and manganese contents than the U.S. steels. This was the major factor which made the U.S. steels more amenable to the cold heading process. Examination of samples of the satisfactory steels and of one of the Canadian steels taken from the final stage of the process preceding cold heading, indicated that the degree of carbide spheroidization was considerably better in useable steels.

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INTRODUCTION

An enquiry, dated July 17, 1958, concerning difficulties experienced with cold-heading screw stock was forwarded to the Mines Branch by the P.L. Robertson Manufacturing Company, Ltd., Milton, Ontario. Little difficulty had been encountered with C 1012-capped and C 1015-capped stock, but, due to a trend towards higher carbon contents for fastener materials, an attempt was made to use C 1018-capped, C 1022-capped, and C 1022-killed steels. Material ordered from Canadian sources proved to be unsuitable for the cold heading operation. Steels ordered to the same analysis from the United States were found to be useable. It was decided that the Mines Branch should attempt to find the reason for the difference in properties so that Canadian produced materials could be used.

PROCESS

The method used for the processing of one size of stock is cited as an example. Number 5 rod is given an initial pickle in a 10% sulphuric acid solution, and is rinsed in cold water. The material is then coated with an aluminum stearate - pulverized lime mixture and baked to relieve hydrogen embrittlement and to bind the coating to the rod. The coated rod is passed through carbide dies and reduced from 0.218" to 0.187" on the first pass, to 0.162" on the second pass, and to 0.140" on the third pass. Following this 36% reduction the rod is annealed (spheroidized) at 1340 to 1360°F for a period of 3 hours under a protective atmosphere. The load is cooled to 900°F in the furnace after the removal of the heating coils. Then the protective atmosphere seal is broken and the material is allowed to cool to a convenient handling temperature. A short pickling,rinsing, lime coating and baking operation precedes the final draw to the required 0.131" diameter.

MATERIALS

Samples of rod from Canadian and U.S. sources were forwarded to the Mines Branch. Canadian stock was referred to as "A" type, and U.S. stock as "B", "C", and "D" types. Code numbers 1, 2, 3 and 4 referred to:

(1) as-received #5 rod

(2) 0.140" wire before annealing

(3) 0.140" wire after annealing

(4) 0.131" finished wire

The samples which were forwarded were as in Table 1.

TABLE 1

List of Samples Supplied

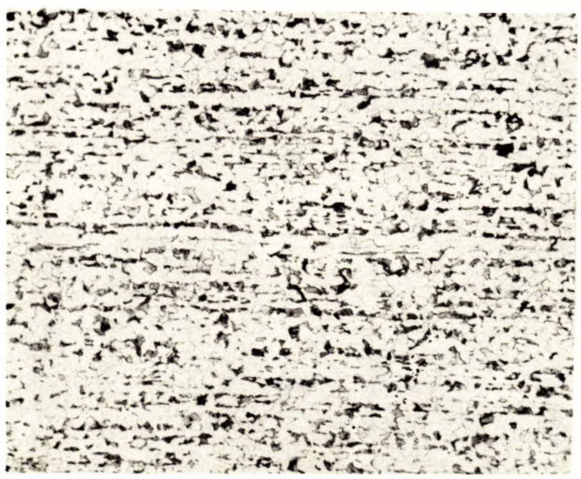
Material	Condition
A-1018-capped-141028-20	1
A-1018-capped-141199-20	1
A-1022-capped-111211-19	1, 2, 3, 4
A-1022-capped-97232-18	1
A-1022-killed-102123-20	1
A-10-35 *	4
B-10-15-1348	1, 2, 3, 4
C **	4
D-10-15	1, 2, 3, 4

* Sample was 0.118" diameter finished wire.
** Sample was stock that was ordered in the finished condition, i.e. ready for cold-heading.

INVESTIGATION

Representative samples were taken from the required rods for semi-quantitative spectrographic analysis, chemical analysis and tensile testing. Specimens were prepared for microscopic examination and hardness testing. The results of the chemical and spectrographic analyses are given in Table 2, the hardness test results in Table 3, the tensile test results in Table 4, and photomicrographs of the various structures observed are shown in Figures 1 to 15.

Examination of microspecimens in the as-polished condition revealed no significant differences in the amount or types of non-metallic inclusions. The microstructures of all the as-received #5 rods were essentially similar to that shown in Figure 1, with more or less pearlite (dark areas) depending on whether the carbon content was higher or lower than the sample shown.



(X100 - 2% Nital)

Figure 1. - A-1022-C-111211-19(1)
Structure of as-received rod.
0.21% C - 147 D.P.H.

TABLE 2

Results of Chemical and Semi-Quantitative Spectrographic Analyses

Identification	Percent Analyses													SAE Type Indicated By Analysis
	C	Mn	Si	S	P	N_2	Ni'	Cu'	Cr'	Mo'	Sn'	Co'	Al'	
A-1018-C-141028-20(1)	.23	.74	.01	.030	.014	.004	.1	.15	.04	.03"	.007	.004	N.D.	C 1022
A-1018-C-141199-20(1)	.20	.74	.01	.019	.007	.004	.1	.15	.04	.01"	.004"	.003	N.D.	C 1022
A-1022-C-97232-18(1)	.21	.86	.04	.032	.008	.003	.07	.1	.04	.02"	.004"	.003	N.D.	C 1022
A-1022-C-111211-19(1)	.21	.89	.04	.033	.013	.004	.2	.15	.03	.01"	.006	.003	N.D.	C 1022
A-1022-C-111211-19(2)	.21	1.01	.05	.034	.010	.002	.05	.15	.04	N.D.	<.02	<.002	<.02	C 1022
A-1022-K-102123-20(1)	.23	.79	.21	.027	.011	.004	.1	.1	.04	.01"	.004"	.002	.02	C 1022
A-10-35 (4)	.29	.78	.23	.019	.010	.002	.06	.15	.05	N.D.	<.02	<.002	.04	C 1030
B (1)	.17	.68	.02	.027	.010	.002	.09	.15	.03	N.D.	.004"	.002	.005	C 1019
B (2)	.18	.59	.03	.038	.026	.002	.04	.1	.05	N.D.	<.02	<.002	<.02	C 1018
C (4)	.19	.73	.01	.027	.008	.006	.15	.2	.04	.02"	.006"	.003	.009	C 1019
D (1)	.15	.54	.02	.029	.013	.004	.09	.2	.04	N.D.	.007	.004	.003"	C 1017
D (4)	.16	.46	.02	.030	.012	.003	.09	.2	.04	N.D.	.007	.003	.002"	C 1017
D (2)	.16	.43	.01	.028	.028	.002	.07	.2	.04	<.02	<.02	<.002	<.02	C 1017

' - Semi-Quantitative Spectrographic Analysis
" - Identification not certain
N.D. - Not determinable

TABLE 3

Diamond Pyramid Hardness Results Obtained on Transverse Samples Using the Vickers Hardness Tester with a 10 Kg. Load

Identification	Diamond Pyramid Hardness	Identification	Diamond Pyramid Hardness
A-1018-C-141028-20(1)	159	B (1)	120
A-1018-C-141199-20(1)	134	B (2)	267' 214"
A-1022-C-97232-18(1)	147	B (3)	126' 90"
A-1022-C-111211-19(1)	147		
A-1022-C-111211-19(2)	279	B (4)	216' 152"
A-1022-C-111211-19(3)	135' 98"	C (4)	169
A-1022-C-111211-19(4)	159' 121"	D (1)	130
		D (1) #	140' 105"
A-1022-K-102123-20(1)	161		
A-10-35(4)	203	D (2)	232
		D (3)	121' 106"
		D (4)	146

\# - Only one bar of this lot had a rim

' - Hardness of core

" - Hardness of rim (impression often as wide as rim)

TABLE 4

Results of Tensile Testing of Wire Samples

Sample Identification	Ultimate Tensile Strength kpsi	Yield Strength 0.2% Offset kpsi	% Elongation in 2 in.	% Reduction in Area
A-1018-C-141028-20(1)'	67.9	43.1	30.5	67.8
A-1018-C-141199-20(1)'	65.9	42.7	30.5	72.6
A-1022-C-97232-18(1)"	67.7	43.4	27.5	67.0
A-1022-C-111211-19(1)"	67.3	44.0	33.5	68.6
A-1022-C-111211-19(2)"	120.0	108.0	6.0	50.0
A-1022-C-111211-19(3)'	63.2	41.4	31.0	78.6
A-1022-C-111211-19(4)'	70.6	70.2	13.5	77.0
A-1022-C-102123-20(1)'	75.4	48.4	29.8	70.8
A-10-35(4)'	83.5	70.1	8.0	70.0
B(1)'	57.9	35.6	31.5	71.0
B(2)"	110.0	106.0	4.0	42.8
B(3)'	57.9	36.8	34.8	78.6
B(4)"	89.2	89.0	4.0	54.3
C(4)'	76.1	73.6	7.5	61.1
D(1)'	55.0	34.3	35.3	71.5
D(2)"	98.6	93.6	4.5	50.0
D(3)'	50.0	29.7	33.0	74.0
D(4)"	60.5	54.1	19.9	76.4

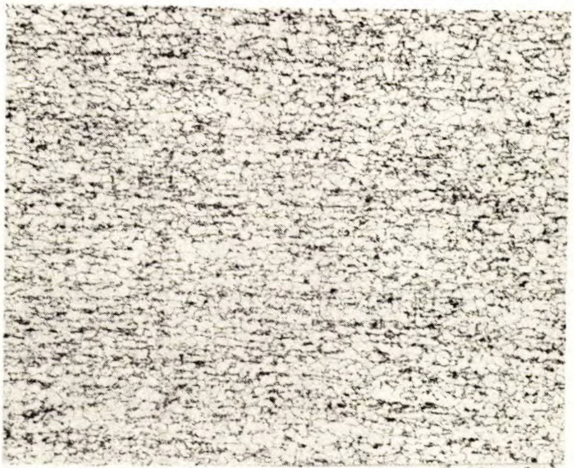
' - Average for 2 or more samples

" - Value for single sample

Figures 2, 3 and 4 are photomicrographs taken at the centre of steel A-1022-C-111211-19 samples after various stages of the process. At this magnification (X100) all such series of samples appeared similar except for the presence of more or less carbide. Figure 5 shows the extent of the low-carbon rim of the finished-wire samples of the A-1022-C-111211-19 series.

(X100 - 2% Nital)

<u>Figure 2</u>. - A-1022-C-111211-19(2)
0.140" wire before anneal.
279 D.P.H.



(X100 - 2% Nital)

<u>Figure 3</u>. - A-1022-C-111211-19(3)
0.140" wire after anneal.
135 D.P.H.

(X100 - 2% Nital)

<u>Figure 4</u>. - A-1022-C-111211-19(4)
Centre of finished wire.
182 D.P.H.

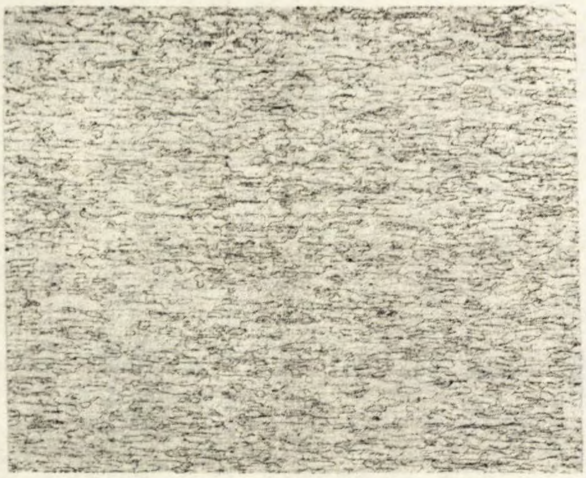
(X100 - 2% Nital)

<u>Figure 5</u>. - A-1022-C-111211-19(4)
Edge of finished wire.
131 D.P.H.

Figure 6 shows a view of the finished-wire sample of A-1022-C-111211-19 at a higher magnification. Photomicrographs of other finished-wire samples are shown in Figures 7 to 15.

(X1000 - 2% Nital)

Figure 6. - A-1022-C-111211-19(4) Same as Figure 4 but at higher magnification. Illustrates incomplete spheroidization in finished-wire sample.

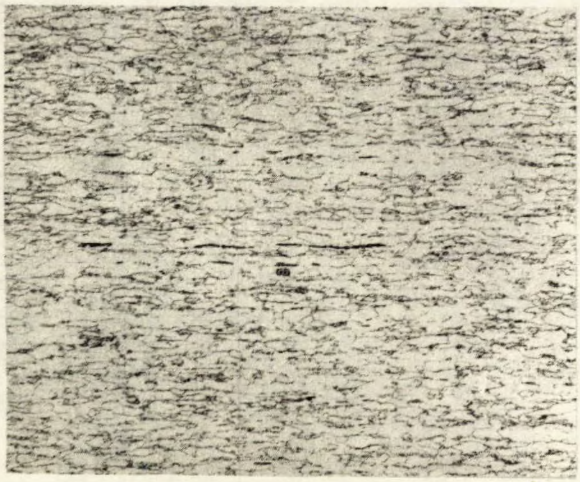


(X100 - 2% Nital)

Figure 7. - A-10-35(4) - 0.29% C (killed steel). Centre of finished-wire sample. 217 D.P.H.

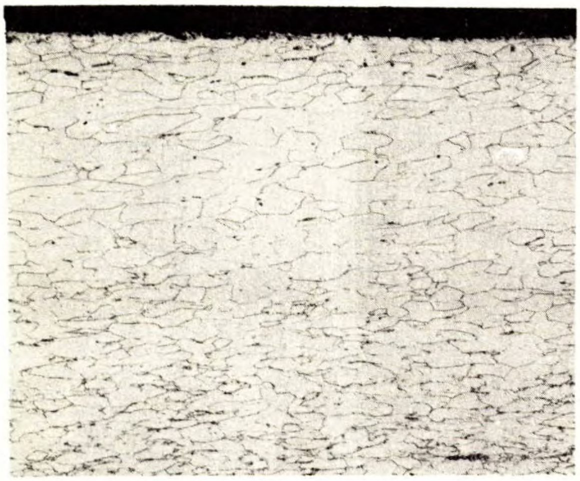
(X1000 - 2% Nital)

Figure 8. - A-10-35(4). Same as Figure 7 but at higher magnification. Note that the carbides are well spheroidized.



(X100 - 2% Nital)

Figure 9. - B(4) - 0.17% C. Centre of finished-wire sample. 235 D.P.H.

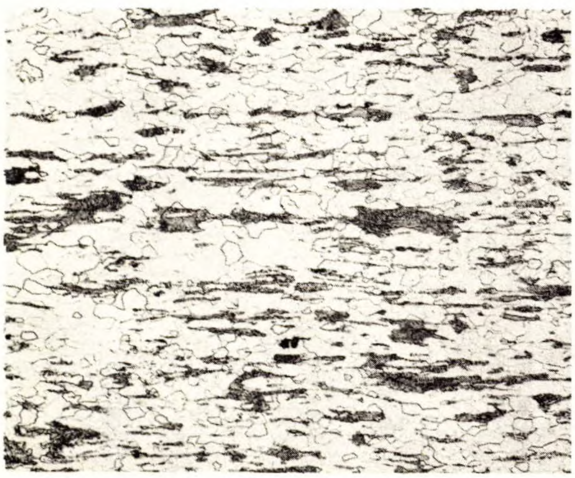


(X100 - 2% Nital)

Figure 10. - B(4). Edge of finished-wire sample. 201 D.P.H.

(X1000 - 2% Nital)

Figure 11. - B(4). Same as Figure 9 but at higher magnfication. Carbides are well spheroidized.

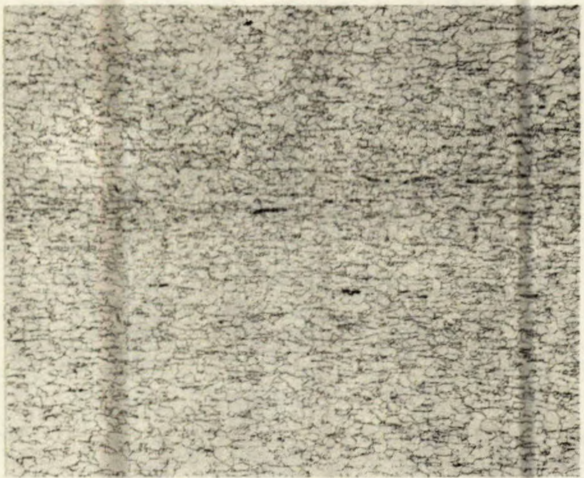


(X100 - 2% Nital)

Figure 12. - C(4) - 0.19% C. Centre of finished-wire. No rim was present. 183 D.P.H.

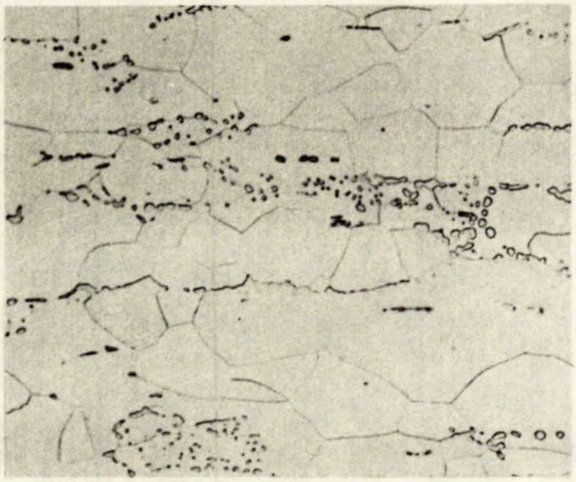
(X1000 - 2% Nital)

Figure 13. - C(4). Same as Figure 12 but at a higher magnification. Note the presence of spheroidized carbides.



(X100 - 2% Nital)

Figure 14. - D(4) - 0.16% C. Centre of finished wire. No rim was noticeable in this sample, but there were rims on other samples in this series. 162 D.P.H.



(X1000 - 2% Nital)

Figure 15. - D(4). Same as Figure 14 but at a higher magnification. Note the small quantity and spheroidal nature of the carbide.

DISCUSSION OF RESULTS

Chemical analysis revealed a noticeable difference between the Canadian and U.S. steels. With the exception of the A-10-35 sample, all the Canadian steels were within the analysis limits for SAE C1022, whereas the American steels were lower carbon grades ranging from C1017 to C1019. The higher carbon and manganese contents of the Canadian steels probably constitute the major reason for their resistance to cold heading. No other chemical difference could be noted which could be related to cold heading problems.

Hardness tests revealed nothing which could fully explain the differences in cold heading properties. No single standard test property is a good index of cold heading properties(1). The tensile property values found for the wire samples revealed no consistent differences between the useable and unsatisfactory steels. The cold heading properties of steel B were reported to be inferior to those of steel C, and both were inferior to D. The superiority of steel D was apparently due to its low carbon and manganese contents (and hence, low strength). It would be expected that, on the basis of the reported analyses, the cold heading properties of B would be slightly better than those of C. However, examination of the properties of the annealed and finished-wire samples of B revealed that it had the greatest increase in strength and hardness and the greatest decrease in ductility of any of the series samples available. That is, the final pass through the dies had a greater affect on steel B than on the other steels. While the annealed sample of C was not available, it is possible that it too was affected to a lesser degree by the final draw than was steel B, and thus had better cold heading properties in spite of the higher carbon content (as was reported).

No significant difference could be noticed in the amount or type of non-metallic inclusions in the steels. A greater number of the U.S. samples showed rims, but this probably had little bearing on the problem since some of the unsatisfactory Canadian samples showed rims as well. Comparison of the structures at a magnification of 1000 diameters revealed that all satisfactory finished-wire samples supplied had a spheroidal carbide structure, whereas the A-1022-C-111211-19 sample which could not be cold headed had some lamellar carbides, that is, a considerably less spheroidized structure. The annealing temperature might have been over the lower critical temperature in the case of the less spheroidized steel. It is possible that a slightly lower furnace temperature and longer holding periods would give a more suitable product for cold heading.

It should be noted that the A-10-35 steel (0.30% C), which was reported as being satisfactory in spite of the higher carbon content, had a well spheroidized structure. The strength-ductility properties of this steel appear better in relation to cold heading than those of steel B (comparing finished-wire samples). It is probable that this steel was affected less than was steel B by the final pass through the dies.

CONCLUSIONS

(1) The Canadian steels had higher carbon and manganese contents than the American steels. Analyses showed the Canadian steels (except A-10-35) to be SAE 1022, while the U.S. steels were SAE C1017, 1018 and 1019.

(2) On the basis of the samples forwarded it appears that all the useable steels were well spheroidized before the final draw through the dies. The one unsatisfactory finished-wire sample was definitely less spheroidized. Slightly lower annealing temperatures and a longer holding time might be beneficial.

REFERENCES

(1) P. O'Keefe, Cold Headed Parts, Materials & Methods, 34, 85-100, (Nov. 1951)

(2) H.E. Linsley, Fundamentals of Cold Heading, Machinist, 92, 99-110, (April 8, 1948)

RFK/RB