THESIS

CASE HARDENING
OF
COLD ROLLED STEEL

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1912

This thesis was sent to us by Mr. W. L. Nies when he contributed his copy. In hunting for his he discovered that he had this copy by "F. L. Barrows and G. M. O'Dell" in his possession. As Mr. Nies was a member of 1913, he evidently borrowed this thesis and did not return it to the owner or the college.

Feb. 18, 1918.

T H E S I S

EFFECT OF CASE HARDENING
ON
TENSILE STRENGTH OF COLD ROLLED STEEL.

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East Lansing, Mich. 1912.

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Preface.

The subject of this thesis was selected because of the prominent place case hardening and heat treatment of steels is now occupying in the manufacturing world particularly in the manufacture of automobiles where lightness is required without the sacrifice of strength.

It was evidently impossible to cover the entire field including the heat treatment of special steels owing, not only to the shortness of time but also to the difficulty of obtaining the necessary materials, so we finally decided to limit our investigations to the relation of case hardening to tensile strength.

As preliminary reading matter we referred principally to "Metallurgy of Iron and Steel" by Bradley Stoughton and a thesis entitled "Tool Steel" by E. J. Kunze. We also received many practical suggestions from Mr. Frank Sallows who has charge of the heat-treating department of the Reo Motor Car Company, from a booklet "Heat Treating of Steels" by the Tate, Jones Company of Pittsburgh, Pa., and a series of bulletins published by the Hoskins Manufacturing Company of Detroit, Michigan, manufacturers of pyrometers.

APPARATUS

The apparatus used consisted of a "Stuart Combination Gas Furnace" manufactured by the Chicago Flexible Shaft Company of Chicago, Illinois. (See photo.) The fuel used was illuminating gas supplied by a main of the Lansing City Gas Company.

The carbonizing material was a mixture consisting principally of charred leather and known commercially as "Blaich Modern Carbonizer"(#1 & #3 mixed) made by Alfred O. Blaich of Chicago, Illinois.

The pyrometer used was kindly loaned us by the Chemistry Department and was of the portable type of the Hoskins Thermo-electric pyrometer made by the Hoskins Manufacturing Company of Detroit, Michigan.

The pyrometer was calibrated and compared with the stationary pyrometer in the lecture room of the chemical laboratory.

PRELIMINARY WORK.

The preliminary work consisted of turning up a number of standard specimens from cold rolled steel of the size shown in fig. 1. Holding the diameter of the test length within .002 of .5 inch. In addition it became necessary to make patterns and have cast, iron boxes in which to pack the specimens. These boxes were 15" in length by 9" wide and 4 1/2" deep and approximately 3/16" thick, this being

Apparatus.

Fig. 1.

the largest size which could be used in the furnace. We would recommend smaller sizes than this for similar work because of the greater ease with which they might be handled and what is more important, that if made of the correct proportions as many as three might be placed in the furnace at one time. In this case when heating for different lengths of time they could be drawn as required without disturbing the rest, heating would be continuous and the time and gas required to bring the furnace up to the proper temperature for each run would be saved.

A series of chemical tests by the colorimetric method were run on samples of the steel to determine approximately the carbon content which was found to average about .25 percent.

PACKING.

The packing was done by first placing a layer of the carbonizing material in the bottom of the box to a depth of about one inch then the specimens were placed on this layer and at least one inch from the sides of the box and one half inch apart, another layer of the carbonizing material was added, a layer of specimens then more of the material and so on until the box was filled. The iron cover was then set in place and sealed with fire clay. The cover had a 5/16 " hole drilled in it so that a 1/4" test wire could be inserted and drawn from time to time in order to determine when the box had been heated through.

HEATING.

After sealing, the boxes were placed in the combustion chamber of the muffle furnace and brought up to the desired temperature. (This required from one half to three quarters of an hour.) The tests were run for a definite length of time and the beginning of this period was taken when the test wire was drawn and indicated that the box was heated through. The period through which the heating was continued at the desired temperature was called the "time of carbonisation". Some difficulty was encountered in maintaining a constant temperature due to the varying quality of the gas and our inexperience as to the proper amount of air to supply. This latter difficulty was overcome as we became more efficient in the handling of the furnace though we were unable to get as high temperatures as we wished due to the inferior quality of the gas. The highest temperature attainable varying as much as 100° F. on different days.

We found a wide variation in the temperature of carbonisation used and recommended by different authorities (1200° F. - 1832° F.) and it was our aim to try to determine which of these temperatures will give the best results.

REHEATING.

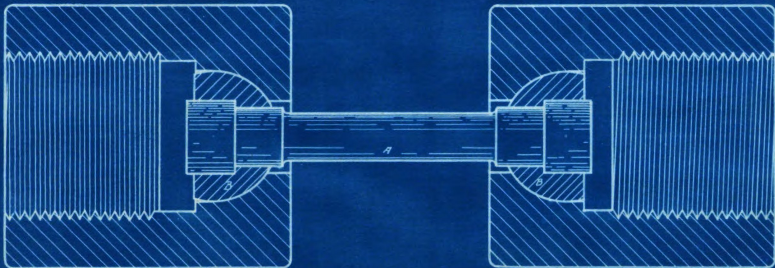
After carbonizing the specimens were allowed to cool in the carbonizing material, then removed and slowly heated in the furnace, each specimen of each set being heated to a different temperature than the rest, for here also we found disagreement as to the proper temperature.

QUENCHING.

After reaching the proper temperature the specimens were quickly removed from the furnace and dipped in linseed oil. Oil being used because it gives a tougher structure than when brine is used as the quenching medium. It might be well to mention here some rules for hardening:+

1. Heat slowly.
2. Heat uniformly throughout the piece.
3. Do not heat too hot.
4. Do not let the piece soak after it has been heated evenly and thoroughly. Remove from the furnace.
5. Avoid drafts of air and contact of any cold metal before or just after dipping into the cooling agent.
6. Dip the piece vertically to avoid warping.
7. Avoid quick moving of the piece in the cooling agent to avoid warping.

+From "Tool Steel" by E. J. Kunze.



TEST SPECIMEN IN GRIPS
— FOR —
100,000# RIEHLE TESTING MACHINE
SCALE - FULL SIZE
A - TEST SPECIMEN
B - SPLIT SPHERICAL BUSHINGS

There was a certain amount of oxidization in the reheating process, an objection common to all gas furnaces which would be serious should the piece be a finished part but with our specimens the oxidization was so slight that we disregarded it.

TESTING.

The testing was done in the 100,000# Riehle Testing Machine in the engineering laboratory. Special grips were designed to hold the test bars (Fig. 2). The important feature of these grips is the "ball and socket joint" effect procured by the spherical bushings. The object being to eliminate any bending of the hardened piece and insure failure by tension.

No extensometers were available so the elastic limit could be determined only approximately by the action of the machine. However, it is certain that the elastic ratio is high for the case-hardened pieces. Following are the tabulated results of the test and a set of curves showing the relation of the strength to the time of carbonization. These curves are plotted from the results obtained from the specimens carbonized at 1300°F. for different lengths of time and reheated to different temperatures.

PRELIMINARY TEST.

+Carbonized at 1562°F. For 2 hours.

Specimen No.	Reheat Temp.	Max. Load (# sq. In.)
A_5	1100°F.	73800
A_4	1200	78400
A_3	1300	80100
A_2	1455	70180
A_1	1455	68450

+This temperature was not held for the entire two hours but was reached during the latter part of the period.

TEST No. 1.

Carbonized at 1300°F. For 3 hours.

Specimen No.	Reheat Temp.	Max. Load (# sq. in.)
B_4	Not reheated.	59800
A_6	1300°F.	74500
A_7	1400	73650
B_1	1450	71750
B_5	1500	72250

TEST No. 2.

Carbonized at 1300°F. For 4 hours.

Specimen No.	Reheat Temp.	Max. Load (# sq. in.)
B_2	1300°F.	73600
B_3	1400	71900
B_6	1450	78050
B_7	1500	74450
B_8	1500	76300

TEST No. 3.

Carbonized at 1300°F. For 5 hours.

Specimen No.	Reheat Temp.	Max. Load (#sq. in.)
B_9	1300°F.	81600
C_1	1350	81000
C_2	1400	71500
C_3	1450	79750
C_4	1500	87500
C_5	1500	83950

TEST No. 4.

Carbonized at 1300°F. For 6 hours.

Specimen No.	Reheat Temp.	Max. Load (# sq. in.)
C_6	1300°F.	69500
C_7	1350	70400
C_8	1400	67450
C_9	1450	69800
D	1500	70800
D_1	1500	75000

TEST No. 5.

Carbonized at 1400°F. For 2 hours.

Specimen No.	Reheated Temp.	Max. Load (# sq. in.)
D_2	1300°F.	71750
D_3	1350	77600
D_4	1400	84450
D_5	1450	91400
D_7	1500	85900
D_8	1500	85000

TEST No. 6.

Carbonized at 1500°F. For 2 hours.

Specimen No.	Reheat Temp.	Max. Load (#sq. in.)
D_6	1300°F.	73550
D_9	1350	72500
E	1400	71900
E_1	1450	70850
E_2	1500	81200
E_3	1500	78900

The curves represent the following conditions:

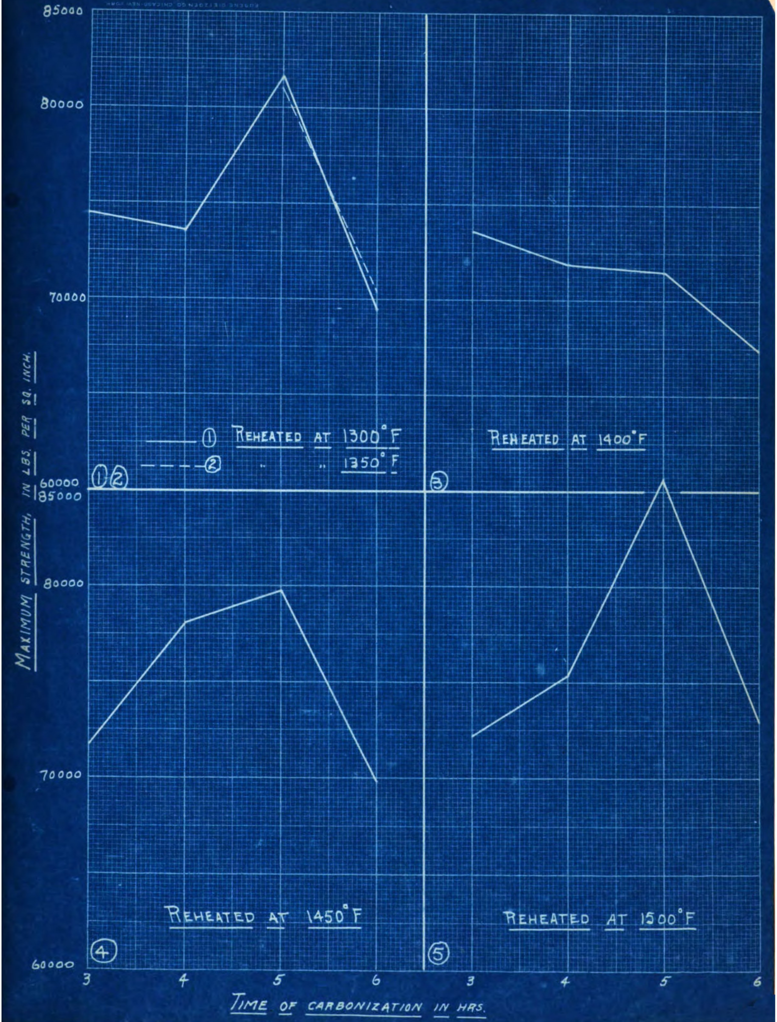
Curve 1. Carbonized at 1300°F. from 3 to 6 hours and reheated to 1300°F.

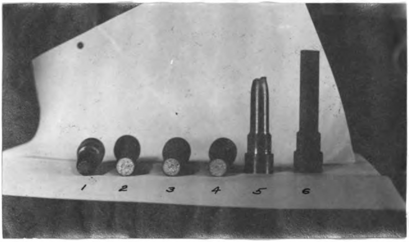
Curve 2. Carbonized at 1300°F. from 5 to 6 hours and reheated to 1350°F.

Curve 3. Carbonized at 1300°F. from 3 to 6 hours and reheated to 1400°F.

Curve 4. Carbonized at 1300°F. from 3 to 6 hours and reheated to 1450°F.

Curve 5. Carbonized at 1300°F. from 3 to 6 hours and reheated to 1500°F.


85000
80000
70000
60000
85000
80000
70000
60000
MAXIMUM STRENGTH, IN LBS. PER SQ. INCH.
① REHEATED AT 1300°F
② " " 1350°F
①②
REHEATED AT 1400°F
③
REHEATED AT 1450°F
④
REHEATED AT 1500°F
⑤
3
4
5
6
3
4
5
6
TIME OF CARBONIZATION IN HRS.



Broken Specimens.

Explanation:

Specimens no's. 1 and 5 show the crystal texture, and reduction of area due to the load.

No's. 2 and 3 show the coarse porous cyrstal of specimens which were not properly reheated. No. 3 also shows the case.

No. 4 shows a properly reheated specimen.

No. 6 shows the way in which a treated specimen breaks, there being no reduction of area.

CONCLUSION.

EFFECT OF TIME ON TENSILE STRENGTH.

A study of the curves shows that the tensile strength increases (except in specimens reheated to 1400°F.) with the time of carbonization up to and including five hours but when the carbonizing was continued for six hours the specimens without exception showed the same or less strength than those carbonized for three hours. It would be interesting and instructive to continue the heating for a longer time than six hours and determine whether the continued heating is detrimental. If so, it would seem that the "soaking" effect is the same as occurs when tempering or hardening tool steel.

PROPER CARBONIZING TEMPERATURES.

From a commercial standpoint the results show that long continued carbonizing at a low temperature is not nearly so effective as carbonizing for a short time at a high temperature, for the results show that those pieces (Test No. 5) carbonized at 1400°F. are uniformly stronger than those heated at 1300°F. for five hours (The strongest specimens carbonized at 1300°F.) and furthermore there would be a saving in time and fuel if the higher temperature were used. Some authorities recommend as high a carbonizing temperature as

1832°F. but our investigations do not seem to confirm their opinions. Probably different steels would give best results at different temperatures but for cold rolled steel we would recommend 1400°F. as the proper carbonizing temperature.

EFFECT OF REHEATING
CORRECT REHEATING TEMPERATURE.

A further study of the results and curves shows that reheating is almost a necessity if the strength of the steel is to be retained. Specimen No. B_4 was not reheated after carbonising but was dipped immediately upon the removal of the box from the furnace. It showed a tensile strength almost 10,000# per sq. in. lower than the weakest reheated specimen. This shows the value of the reheat.

Our strongest specimens in almost every case were those heated from 1400°F. to 1500°F. Here we agree with other experimenters who recommend 1472°F. as the proper reheat temperature.

EFFECT OF CASE-HARDENING ON TENSILE STRENGTH.

The results show that as a rule the case-hardened steel will be weaker than the original though in one or two cases the case-hardened piece showed greater strength. To be on the safe side we would recommend a greater factor of safety for a case-hardened part than that which would be allowed for the same part if used without case-hardening, particularly if the piece is to be in tension.

ROOM USE ONLY

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