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OTTAWA January 25, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1780.

Preliminary Longitudinal Testing of Welds.

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(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Introduction:

On December 1, 1944, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, requested that an investigation be undertaken with a view to devising a method of testing the heat-affected zones of welds made with ferritic electrodes in armour plate. It was suggested that welds be tested longitudinally in tension and in bending. It was proposed that the test pieces be under constant examination during testing and that the end-point be taken as at the first appearance of a crack.

It was postulated that in the tensile test piece the heat-affected zone would have a higher yield point than either the unaffected armour or the weld metal; that, consequently, as the load was applied these latter materials

(Introduction, cont'd) -

would deform plastically; and that when the heat-affected zone cracked the elongation of the specimen would be the elongation of the heat-affected zone.

Before launching into a full-scale investigation it was decided that some preliminary tests would be advisable to permit tentative assessment of the validity of this approach to the problem.

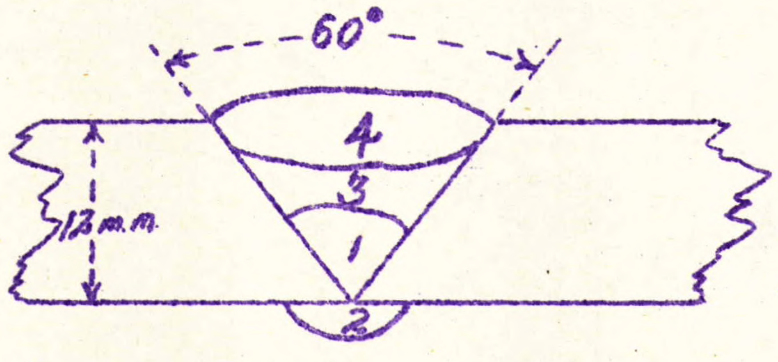
Object of Investigation:

To conduct some preliminary longitudinal tests of welds, in order to observe the reaction of the heat-affected zone to the method of testing.

Procedure:

(1) Two test pieces were made up, using 12-mm. bulletproof plate, ferritic electrodes, and the following welding technique:

Figure 1.



ZERO ROOT GAP.

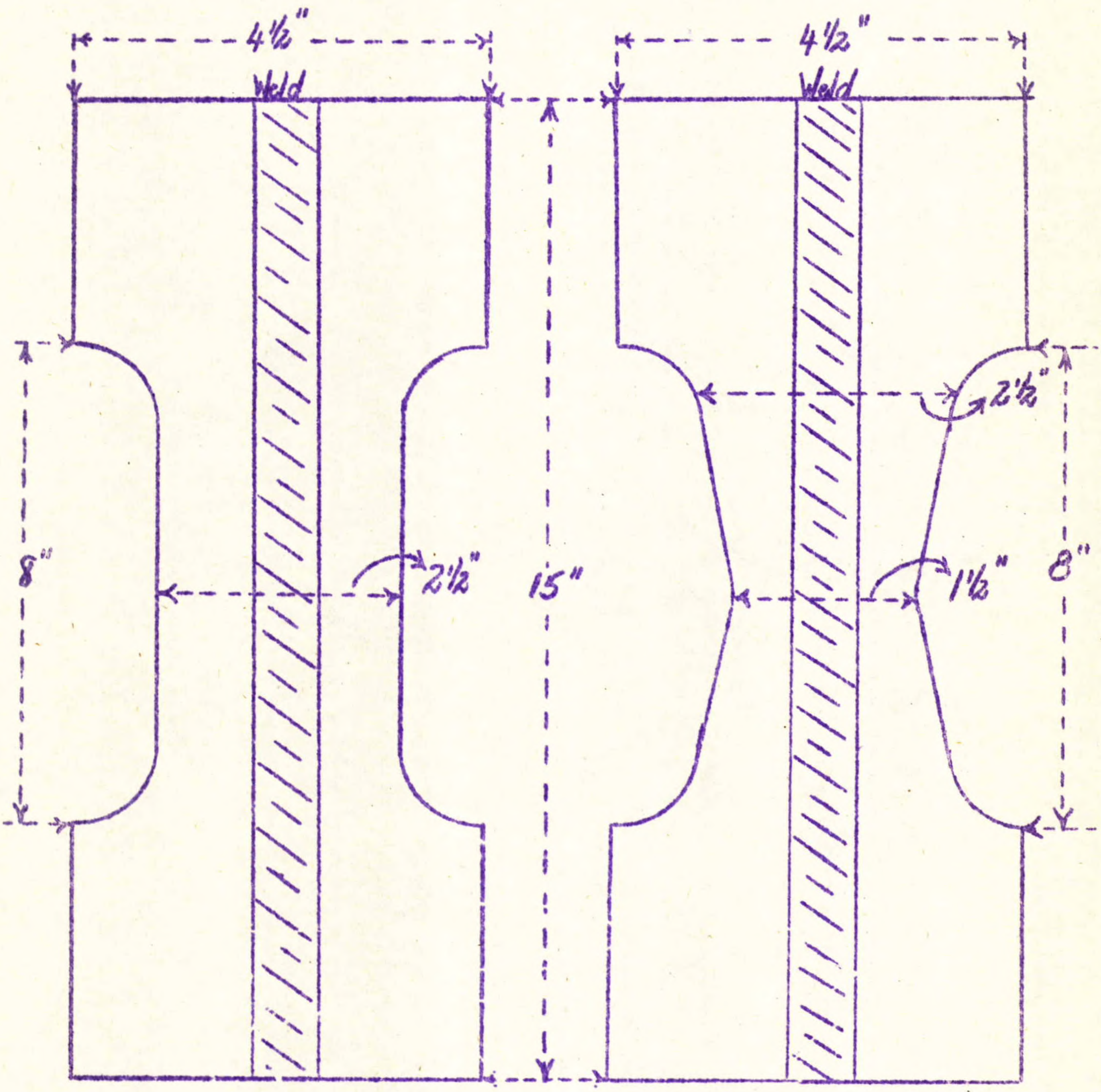
1. 1/8" Murex Vertex electrode - 100 amps. - 24 volts.
2. 1/8" " " " - 100 " - 24 " .
3. 3/16" Wilson No. 98 - 150 amps. - 26 volts.
4. 3/16" " " 98 - 150 " - 26 " .

(Continued on next page)

(Procedure, cont'd) -

After welding, the test pieces were machined to give tensile test pieces as shown in the sketches below:

Figure 2. Figure 3.



TEST PIECE NO. 1. TEST PIECE NO. 2.

Prior to testing, both sides of the test pieces were pop-marked at one-inch intervals along the 8-inch gauge length. In addition, both test pieces were magnetized longitudinally and given a generous coating of magnaflux powder in the gauge length.

Tension was applied in increments of 10,000 pounds, the specimen was examined for cracking after each increment, and dividers were used to determine when plastic flow began. The following table lists the results obtained:

Test No.	Ultimate tensile strength, p.s.i.	Elongation in 8 inches, per cent
1	140,600	3
2	140,200	4

No cracking was detected prior to complete failure. Plastic flow, as detected by the dividers method, began just prior to failure. Test Piece No. 2 broke in the area of smallest cross-section.

(2) After tensile testing, both test pieces were radiographed at the National Research Council, Ottawa. No cracks were found in either specimen. As an additional check, both pieces were ground flush along the gauge length on a wet grinder, deep-etched, and examined under a microscope. No cracks were found in either specimen.

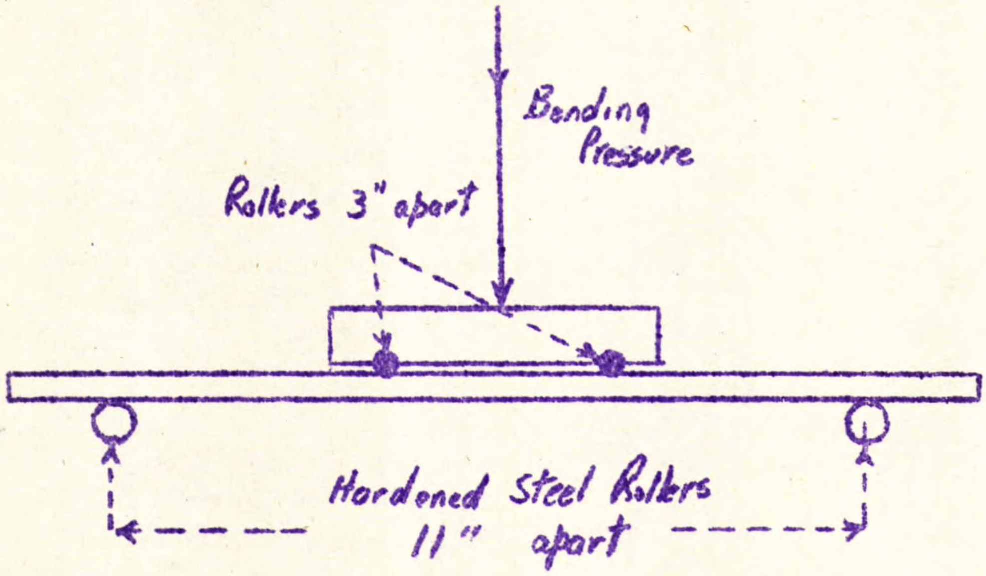
(3) An attempt was made to obtain some idea of the impact strength of the heat-affected zone by the following method: Unnotched specimens ¼-inch square were machined from the ends of the tensile test pieces which had been in the grips of the tensile machine. In these test pieces the welds were transverse to the length of the specimen. All test pieces were lightly etched to reveal the location of the heat-affected zone. Specimens tested by the Charpy method failed to fracture, since sufficient bending took place in the ductile weld metal to permit the specimens to slip out of the jaws of the machine. Similarly, specimens tested in the Izod method bent in the same area to permit the hammer to ride over the top of the specimen.

(4) Using the original plate and the same welding

(Procedure, cont'd) -

procedure, a bend specimen 2 inches wide and 15 inches in length was prepared, the weld running along the centre of the 2-inch width. This specimen was face-bent in the following manner:

Figure 4.



This specimen could not be observed during the test, due to the danger of sudden failure and consequent flying pieces. An attempt was made to detect cracking audibly during the course of the test, without success. The test was stopped prior to failure several times, the load removed, and the test piece examined for cracking. No cracking was detected before failure occurred. Failure occurred when a load of 8,800 pounds had been applied. The total deflection was found to be 2-1/8 inches. No cracks were detected along the length of the specimen.

Discussion:

From the results of the tensile tests, it would appear that the following sequence of events takes place: As the strain is continuously increased the yield points of the parent metal and the weld metal are eventually reached and plastic flow begins. The heat-affected zone, having a higher yield strength, does not deform until a higher stress

(Discussion, cont'd) -

value is reached. The plastic deformation of the more ductile materials throws a higher unit stress on the heat-affected zone, with the result that its yield point is rapidly reached and soon thereafter its ultimate strength. Consequently, failure occurs by cracking in the heat-affected zone and due to the notch effect this crack immediately propagates and brings about complete failure of the joint. The failure to detect any cracks in the specimens lends support to the contention that the first crack in the heat-affected zone leads to complete failure of the specimen.

From the above it would seem reasonable that the elongation measured in the tensile specimens is a comparatively accurate measure of the elongation of the heat-affected zone and as such might prove to be of value. It should be recognized, however, that the low order of magnitude of the elongation requires accurate measurement. The use of such a test as a criterion of acceptability of a welding procedure would first require extensive testing to determine the limits between good and bad welding as reflected by elongation measurements. The possibility exists that these differences in elongation might be of a very small order of magnitude and would consequently require a high degree of accuracy of measurement.

Attempts to secure some idea of the impact strength of the heat-affected zone failed because of the high ductility of the weld metal and the narrow width of the heat-affected zone. Failure could have been forced to occur in this zone by notching, but this would have provided a measure of the notch sensitivity of the material in this zone, which was not the object of the test.

The bend test seems to indicate a chain of events

(Discussion, cont'd) -

similar to that occurring in the tensile testing. It should be pointed out that the method of bending with pressure applied by rollers was employed to secure a constant bending moment and to avoid severe stress concentrations as would be inevitable under a single pressure point. It is significant that failure of this test piece occurred at the notch caused by one of the upper rollers. The deflection value of 2-1/8 inches is surprisingly high, and the possibility exists that a bend test employing deflection as a measure of acceptability might be of some value.

CONCLUSIONS:

On the basis of rough preliminary testing, it would appear that:

1. The tensile test provides a means of measuring the elongation of the heat-affected zone of welds in hardenable steels.
2. The bend test may be of value if deflection is taken as a measure of the ductility of the heat-affected zone.
3. Both bend and tensile tests apparently fail as a result of the formation of the first crack in the heat-affected zone.

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