



A Field Weldability Test for Pipeline Steels

Simple test indicates susceptibility to hydrogen-induced cracking and shows the effect of time lapse between root pass and hot pass on cracking

BY R. D. STOUT, R. VASUDEVAN AND A. W. PENSE

ABSTRACT. This is a report of an investigation requested and supported by the American Petroleum Institute to develop a simple weldability test for pipeline steels that could be conducted in the field as a measure of their susceptibility to hydrogen-induced cracking. The goal was a quantitative and reproducible test that could be prepared and evaluated with a hammer, vise and power saws.

A 150×200 mm specimen cut from formed pipe with a central sawed slot in the girth direction and welded with a cellulosic electrode at welding conditions matching those used in the field was found to develop hydrogen-induced cracks. Easy measurement of the extent of cracking was accomplished by tempering and heat tinting any cracks formed and then cutting slits into the weld from one side of the specimen and hammering off one side of the plate to expose any part of the fracture previously heat tinted. The test was examined for sensitivity and reproducibility by testing a wide range of pipe steel compositions and thicknesses and was found to respond, as expected, to carbon, alloy content and gage.

The test was used to study the ex-

tent of cracking as a function of time lapse up to 20 min after welding. Not only was there a strong effect of time lapse, but some of the more sensitive steels developed cracks in less than 5 min. The effect of preheat on cracking was also clearly shown by the test. Thus the test appeared potentially useful for determining the time limit between the root pass and hot pass and the necessary preheat. It should have applicability to testing structural steels, generally, as well.

Foreword

The authors wish to express their appreciation to the American Petroleum Institute for sponsoring the investigation reported here and to the members of the Project Committee who contributed advice and arranged for the steel samples used for the tests.

Introduction

In the construction of pipe lines by the "stove pipe" technique, the production of girth welds is often accomplished under difficult conditions of weather and terrain. Further, the use of cellulosic electrodes and the trend toward higher strength steels have kept the possibility of hydrogen-induced cracking a matter of concern to the constructor. The American Petroleum Institute commissioned Lehigh University to pre-

pare a review report on the field weldability of pipeline steels, and accepted the recommendation for a project to develop a simple shop-type weldability test for susceptibility of pipe steels to hydrogen-induced cracking. This paper is a report on the outcome of the project.

The object of the investigation was to develop a test which is quantitative, reproducible, and amenable to use in the field without test equipment other than saws, a vise, and a hammer. These conditions barred the use of the laboratory tests that have become generally accepted for evaluating cracking susceptibility. The bead-on-plate test is simple to prepare and weld, but it offers problems in measuring the extent of cracking accurately with shop equipment. It was necessary therefore to explore other specimen designs.

Experimental Procedure

Materials

In order to develop and characterize candidate specimen designs, it was necessary to obtain a variety of compositions and thicknesses of pipe steels that would provide a range of responses to hydrogen-induced cracking. The compositions and gages of the steel pipes obtained are listed in Table 1. The steel grades ranging from 5LX-52 to arctic grades, included precipitation hardening

R. D. STOUT is Dean, Graduate School, R. VASUDEVAN is a doctoral candidate in the Dept. of Metallurgy, and A. W. PENSE is Professor of Metallurgy & Materials Science, Lehigh University, Bethlehem, PA 18015.

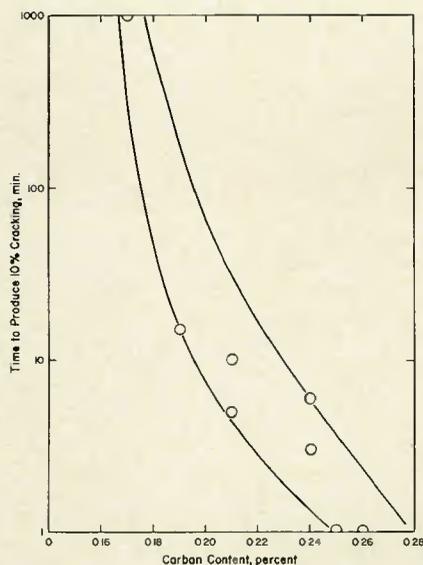


Fig. 6 — Relation of onset of cracking to carbon content

ceptible steels without resorting to preheating of the pipes to an appropriate temperature.

It can also be seen from the results that the time before start of the crack is shortest for high carbon steels and that the time increases with a lowering of the carbon content. Figure 6 shows the trend. These results confirm that the best way to avoid hydrogen-induced cracking in high strength steels is to use lower carbon contents.

Preheating

The results thus far available on the effect of plate preheating temperature are given in Table 4. As expected, preheating was effective in reducing or eliminating cracking, especially at temperatures approaching 100 C. The combined effect of preheating and time lapse after welding is still under study and will be reported subsequently.

Variable Constraint

It was found desirable to examine the specimen design for means of varying the restraint so that test results could be "tuned" to match field experience. The slot-weld test specimen provides a convenient way of varying the restraint which can be achieved simply by varying the position of the slot across the breadth of the sample. Heat No. 63843 which gave 50% cracking with the slot in the center was chosen for the test on variable restraint. Figure 7 shows the fracture surface together with the test plate design for three different restraint levels. It is interesting to note that the slot placed 25 mm from the edge (the least restraint) gave 0%

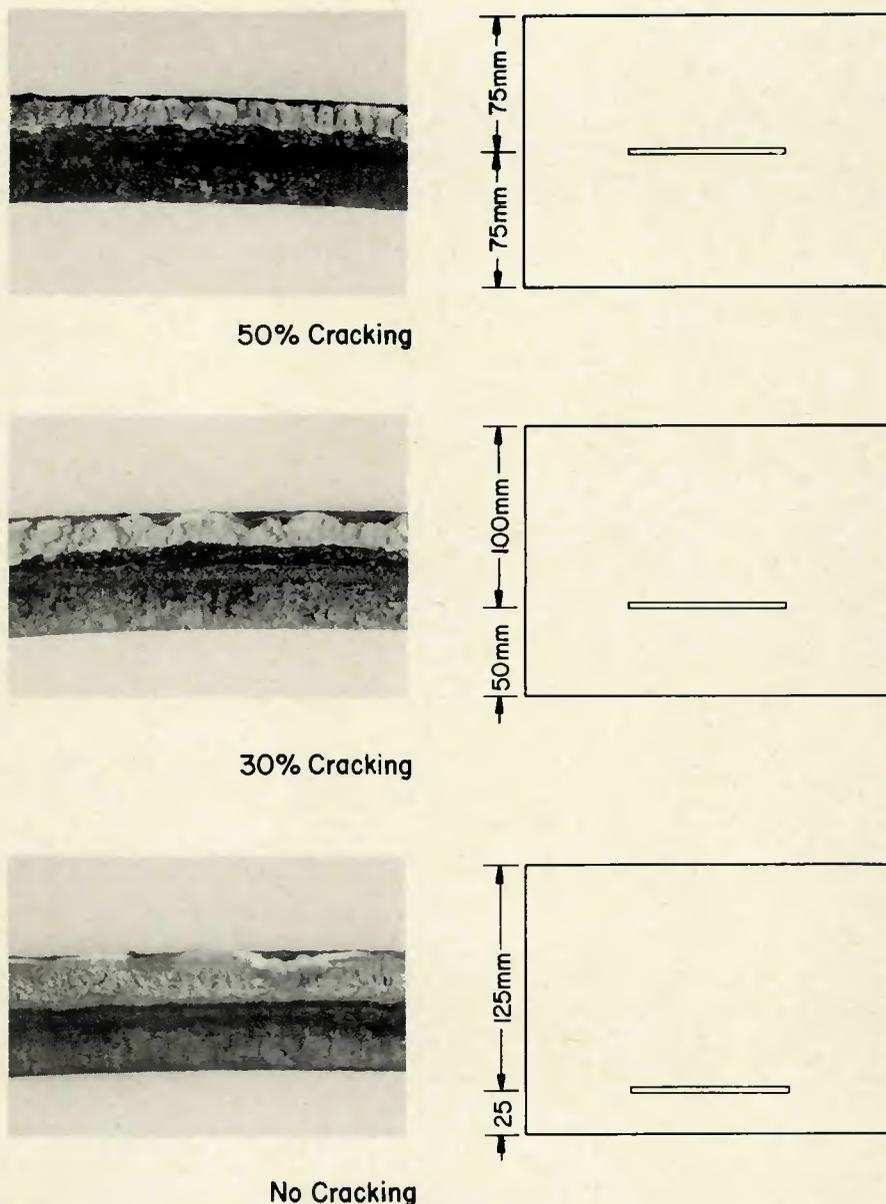


Fig. 7 — Variation of restraint in the slot specimen by moving the slot toward one side and its effect on hydrogen cracking in Heat 63843

Table 4 — Effect of Preheat on the Extent of HAZ Cracking

Heat	Percent Cracking with a Preheat of					
	20 C (R.T.)	52 C (125 F)	66 C (150 F)	80 C (175 F)	93 C (200 F)	120 C (250 F)
63843	50	50	40	35	30	1
B319	40	30-40	~15	~ 1	~ 1	Nil
98173	25	~ 5	5	3-5	1	Traces
88284	20	~13	10	~ 5	3-5	Traces
W3134	2	Nil	Nil			
H228	15	Nil	Nil			
A210	10	1 to 2	Nil			
A69-2	3	Nil	Nil			
492S1871	80	70	45	45	3-40	1
496S2211	2	Nil				
496S1871	1	<1				
490S2441	4 to 5	1 to 2				
490S2681	3	~ 1				
490S2391	2 to 3	2 to 5				
493S2791	1	Nil				

cracking and the specimen with the slot 2 in. (51 mm) from the edge, the intermediate restraint level, produced about 30% cracking. Thus a satisfactory method of controlling restraint has been devised, and the specimen can be adjusted to match constraints encountered in field welded girth joints.

Summary and Conclusions

The results of this investigation may be summarized as follows:

1. A satisfactory shop-type weldability test has been developed for measuring the field weldability of pipeline steels. It utilizes a 150 by 200 mm specimen removed from formed pipe, slotted centrally in the

direction of pipe curvature, and welded by depositing the weld bead over the slot and extending 25 mm beyond each end of the slot. The welding conditions are chosen to match field practice.

2. Quantitative measurement of the extent of cracking is obtained with shop tools by aging the specimen up to 24 h, reheating to about 500 C with a gas torch to arrest cracking and to heat tint any hydrogen-induced cracking, and hammering off one side of the weld to reveal the oxidized surface of the hydrogen-induced crack which can then be measured.

3. The test was shown to discriminate among various compositions of pipeline steels and to correlate approximately with carbon equivalent values.

4. The test method was used to show the rate at which cracking takes place over intervals of time following welding. Some of the more crack-sensitive steels exhibited partial cracking within one minute of completion of the weld. Cracking occurred sooner in steels of higher carbon content.

5. The benefit of moderate preheating in preventing hydrogen-induced cracking was demonstrated by the slot specimen.

6. Variable constraint is readily obtained by moving the slot off center toward one side of the specimen.

7. The slot specimen appears suitable for measuring the weldability of structural steels generally, and more conveniently than the tests requiring laboratory facilities.

AWS D10.10-75

Local Heat Treatment of Welds in Piping and Tubing

In the manufacture of welded articles or structures in the shop or in the field, it may be desirable, for a variety of reasons, to heat the weld regions before welding (preheating), between passes (interpass heating), or after welding (postheating). This document presents in detail the various means commercially available for heating pipe welds locally, either before or after welding, or between passes. The relative advantages and disadvantages of each method are also discussed. Although the document is oriented principally toward the heating of welds in piping and tubing, the discussion of the various heating methods is applicable to any type of welded fabrication.

Topics covered include the following:

- Measurement of Temperature
- Induction Heating
- Electric Resistance Heating
- Flame Heating
- Exothermic Heating
- Gas-Flame Generated Infrared Heating
- Radiant Heating by Quartz Lamps.

The price of AWS D10.10-75, Local Heat Treatment of Welds in Piping and Tubing, is \$3.50. Discounts: 25% to A and B members; 20% to bookstores, public libraries and schools; 15% to C and D members. Send your orders to the American Welding Society, 2501 N.W. 7th Street, Miami, FL 33125. Florida residents add 4% sales tax.