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POTENTIAL ULTRAWELDABLE STEELS FOR TRUCK CASTINGS

SUMMARY

Tests were performed to determine the ultraweldability (i.e., improved steel material which does not require preheating or post-heating during manufacturing or during reconditioning) of five steels that were identified during previous Federal Railroad Administration (FRA) research conducted by Transportation Technology Center, Inc. (TTCI). Five steels were selected for evaluation for this work: HSLA 65, HSLA 100, HY-80, LCC, and LC3. Testing was performed at the Transportation Technology Center (TTC) in Pueblo, CO, and Ohio State University from July 2016 to late 2017.

Two of the high-strength low alloy (HSLA) steels investigated met the ultraweldability requirements.

The rapid, dramatic temperature changes that occur during welding can form brittle phases or cracking in some steels. The welding parameters and chemical composition of the steel determines whether these phases will form.

The weld has three areas of differing structure: the weld, the heat affected zone, and the parent metal. The maximum hardness occurs in the heat affected zone and is the limiting factor in determining weldability steels can be evaluated with respect to their weldability by comparing the chemical composition and susceptibility to cracking. This method was used to evaluate many potentially ultraweldable steels.

To evaluate the ultraweldability of these steels, groove welds were made on the five candidate alloys, using gas tungsten arc welding (GTAW) and an E7018 electrode. These welds simulated repair welds. The welds were then sectioned and prepared for microstructural and microhardness evaluation.

Next, a heterogeneous spot weld was made on each material using an E7018 filler rod, a common filler used for steel. This simulated a spot repair weld. Microhardness traverses were made across the weld, heat affected zone, and parent metal.

Another test performed was an autogenous spot weld. An autogenous spot weld is one in which the welding arc melts only a part of the parent material, not using a filler rod or wire. The welds were performed on either a sample block or a small cast button and simulated a spot repair weld. As in the heterogeneous spot welds, hardness traverses were made across the three zones.

To prevent hydrogen-induced cracking and the formation of brittle phases, the maximum hardness in the heat affected zone should be approximately 40 on the Rockwell C hardness scale.

The LCC, LC3, and HY-80 steels formed brittle phases during most of the tests, with maximum hardness between 47 and 52 on the Rockwell C hardness scale. This indicates these materials are not ultraweldable, as they form hard brittle phases when they do not undergo a post weld heat treatment. They would also be susceptible to hydrogen-induced cracking.

The HSLA 65 and HSLA 100 steels meet the requirements for ultraweldability. These steels can be welded without preheat or post weld heat treatment. They will also have a very low occurrence of hydrogen-induced cracking.

BACKGROUND

When truck casting components are welded, the initial rapid temperature increase and subsequent rapid decrease can cause brittle phases to form in some steels. The castings then need to be post weld heat treated to relieve stress and to reduce the effects of the brittle phases.

The chemical composition, primarily the carbon content, of the welded steel controls whether these brittle phases will form. Decreasing or controlling the carbon, chromium, and vanadium content will minimize them. Hydrogen-induced cracking can also occur in harder steels.

The weld has three areas of differing structure: the weld, the heat affected zone, and the parent metal. The maximum hardness, which occurs in the heat affected zone, determines the weldability of a steel. By comparing the chemical composition and susceptibility to hydrogen-induced cracking, steels can be evaluated with respect to their ultraweldability. This process was used to evaluate many steels, including the steel used in most truck castings, American Association of Railroads (AAR) Grade B+.

OBJECTIVES

The goal was to determine whether five previously selected steel grades met the guidelines for ultraweldability. These five steel grades were selected by research conducted under Phase I [1]. Three steel grades were HSLA: HSLA 65, HSLA 100, and HY-80. Two medium carbon steels, American Society for Testing and Materials (ASTM) A352 grades LCC and LC3, were also selected as potentially ultraweldable.

HSLA 65, HSLA 100, and HY-80 are typically produced only as wrought products.

METHODS

To evaluate the ultraweldability of these steels, groove welds were made on each of the five candidate alloys, using GTAW and an E7018 electrode. These welds simulated repair welds. These were then sectioned, mounted, polished, and etched for microstructural and microhardness evaluation. A typical view of one of the groove welds is shown in Figure 1. The red box shows the area where the microhardness readings were made. Three horizontal hardness traverses using seven measurements each were performed in this area. The size of the hardness indentation is directly related to the hardness; the larger the indentation, the softer the material. The maximum hardness in a weld was used as the main test for ultraweldability.

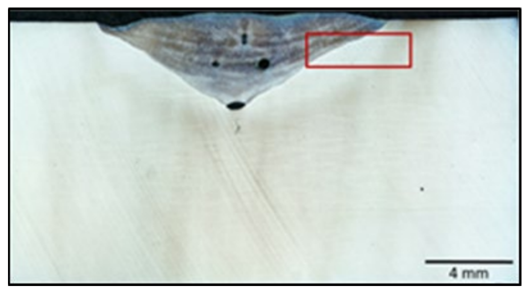

Figure 1. Typical cross-section of groove weld

Next, a heterogeneous spot weld was made on each material using an E7018 filler rod, a common filler used for steel. This simulated a spot repair weld. Microhardness traverses were made across the weld, heat affected zone, and parent metal, as shown in Figure 2 and Figure 3.

Microhardness indentations on a weld are shown in Figure 2. The hardness value is estimated from a formula that uses the length of the diagonals of the indentation and the load on the indenter.

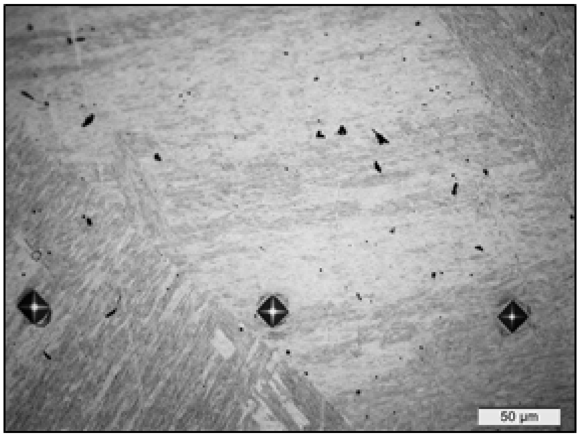

Figure 2. Microhardness indentations across a weld

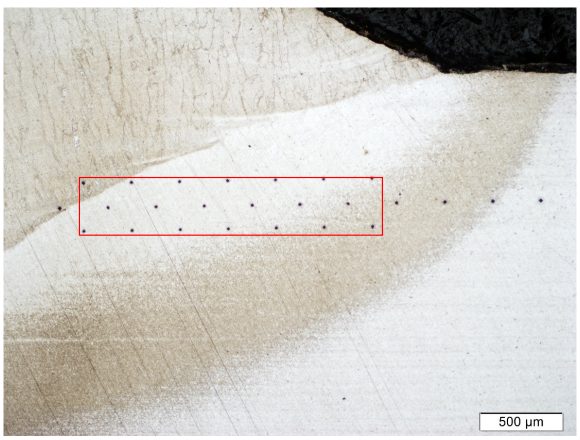

Figure 3. Hardness traverse of a spot weld

Another test performed was an autogenous spot weld. An autogenous spot weld is one in which the welding arc melts only a part of the parent material, not using a filler rod or wire. The welds were performed on either a sample block or a small cast button, and simulated a spot repair weld. As with the heterogeneous spot welds, hardness traverses were made across the weld, heat affected zone, and parent metal to find the maximum hardness value.

RESULTS

Heterogeneous Spot Welds

A typical hardness traverse for a spot weld is shown in Figure 3. The traverses included part of the weld, went across the heat affected zone, and into the parent metal.

The maximum hardness data for the spot welds for each of the steels is summarized in Table 1. For each material, the maximum hardness on the Rockwell C scale (HRC) occurred in the heat affected zone, which was expected.

Table 1. Maximum hardness values across the spot welds

Material	Maximum Hardness, Rockwell C
LCC	52.4
LC3	46.3
HY-80	47.8
HSLA 65	41.5
HSLA 100	37.8
Target	≤ 40

A commonly used upper hardness limit for steels to be resistant to hydrogen-induced cracking is approximately 40 HRC. The hardness of the LCC, LC3, and HY-80 steels during the spot weld test ranged from 47 to 52 HRC. These values are too high and indicate hard, brittle microstructure has formed. In addition, these steels are susceptible to hydrogen-induced cracking.

Chemical and mechanical testing was also performed on the five steels used in this research. Each material met its respective chemical and mechanical requirements.

CONCLUSIONS

Ultraweldability tests were performed on five previously identified steels. Three were HSLA steels, and two were medium carbon steels. The HSLA 65 and HSLA 100 steels met the requirements for ultraweldability. These steels can be welded without preheat or post weld heat treatment. They will also have a very low occurrence of hydrogen-induced cracking.

The LCC, LC3, and HY-80 steels formed brittle phases during most of the tests, with maximum hardness between 47 and 52 on the Rockwell C hardness scale. This indicates these materials are not ultraweldable, as they form hard brittle phases when they do not undergo a post weld heat treatment. They would also be susceptible to hydrogen-induced cracking.

FUTURE ACTION

A cost-benefit analysis will be performed to determine the feasibility of using these ultraweldable steels for truck castings. If that analysis is favorable, the next phase would include producing truck castings from these two materials. Since these HSLA steels are not generally used as castings, a slight chemistry modification, mainly increased silicon, may be needed. The castings would then undergo the same fatigue and mechanical testing that manufacturers must complete for new designs.

REFERENCE

[1] Federal Railroad Administration, "Ultraweldable and Low Temperature Steels for Truck Castings," U.S. Department of Transportation, Research Results No. 20/22. Washington, DC, 2020.

ACKNOWLEDGEMENTS

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