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ULTRAWELDABLE AND LOW TEMPERATURE STEELS FOR TRUCK CASTINGS

SUMMARY

From September 2016 to December 2017, the Federal Railroad Administration's (FRA) Office of Research, Development and Technology funded a research investigation by, conducted by Transportation Technology Center, Inc. (TTCI) to study two types of improved truck casting materials under this Phase I effort. The first type of improved material was designated as ultraweldable, which would not require preheating or postheating during manufacturing or reconditioning. The second type was for a specific application: finding materials that would retain their ductility at low temperature services. The ultraweldable steels and the low service temperature steels were separate, but parallel objectives of the investigation were not required to meet both sets of criteria.

Most truck components are manufactured from cast steel. Figure 1 shows an assembled freight car truck. Weld repairs are made during manufacturing, reconditioning, and even in the field. During welding, undesirable structures and hard spots can develop. These areas can serve as initiation sites of cracks and other defects that reduce component life and cause safety issues.

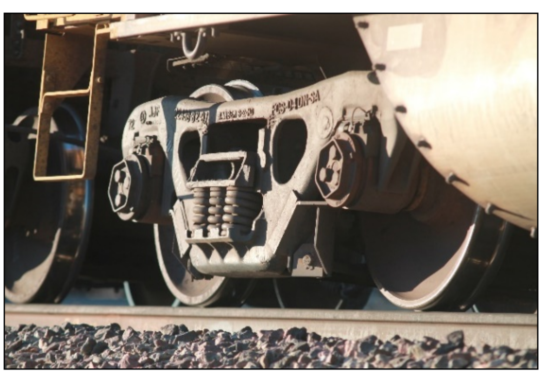

Figure 1. Freight car side frame and wheels

Carbon and other alloying elements have strong effects on the weldability of steel. As the amount of these elements increases, the more likely the steel will need to be preheated or postheated to prevent hard phases from forming. Steels designated as ultraweldable must not form these phases after welding, but they also need to possess mechanical properties similar to those of the Association of American Railroads' (AAR) Grade B+ castings.

At low temperatures, most steels experience a decrease in their ductility, or the amount that the material can deform before breaking; this is known as brittle fracture.

For purposes of this research, low service temperatures were defined as -40 °F or less. Steels that are less brittle at low temperature are less likely to exhibit sudden fracture during cold conditions. Bolsters and side frames made from these more ductile steels would reduce the number of failures and accidents.

Literature searches were conducted for both the ultraweldable steels and the steels that would retain ductility at low temperatures. References showing properties of steels were also used to find materials with the desired characteristics.

In the search for ultraweldable steels, many such grades exist, but not all have the required mechanical properties. Five grades were found that met strength and weldability requirements with little or no chemistry modification.

For the low service temperature steels, six grades were selected that met the requirements for this investigation. These, along with the five ultraweldable grades, are recommended for further evaluation in Phase II of this research.

BACKGROUND

When steels are welded, undesired phases and hard spots develop near the weld locations; cracks can also develop in these areas. Carbon and alloying elements such as chromium, molybdenum, and vanadium have strong effects on the weldability of steel. As the amount of these elements increase, the steel will likely need to be preheated or postheated to prevent hard phases or cracks from forming. Under the current AAR Manual of Standards and Recommended Practices Standard M-201, "Castings, Steel," weld repairs made on critical areas of Grade B+ castings must be fully re-heat treated [1].

At low temperatures, most steels exhibit brittle fracture, which occurs suddenly and shows few indications. AAR Standard M-201 covers the requirements for cast truck components and couplers. Class B+ components are required to meet average values of 15 ft-lb impact energy at +20 °F. Many parts of North America experience much lower temperatures during colder months. Using steels that maintain their ductility at low service temperatures would prevent incidents involving steel truck castings. An example of a broken side frame is shown in Figure 2.

OBJECTIVES

The primary objective of this research was to investigate cast steels that could be welded without the use of preheating or postheating.

The secondary objective was to investigate cast steels that would maintain ductility in low temperature service.

METHODS

A literature search was conducted for both the ultraweldable steels and for grades that would not exhibit brittle fracture at temperatures of 40 °F.

The search for ultraweldable steels was quite expansive. For low service temperature steels, technical papers and national standards were used as primary sources.

A Technical Advisory Group (TAG) was formed for this project, consisting of metallurgists from railroads, a truck casting supplier, a consulting company, a university, and from TTCI. The findings of the TAG led to the results in this report.

Figure 2. Broken side frame that led to derailment in winter

RESULTS

Multiple ultraweldable steels were found that had similar mechanical properties to those of Grade B+ [1]. Table 1 lists the typical tensile strength and the ultraweldability rating compared to the current material, Grade B+, which was given an ultraweldability rating of 6. In this ranking, a lower number is more weldable.

Table 1. Property comparison of potentially ultraweldable steels

Grade	Typical Tensile Strength, ksi	Relative Ultraweldability
AAR B+	70–80	6
HSLA65	80	1
LCC	70.0–95.0	3

Grade	**Typical Tensile Strength, ksi**	**Relative Ultraweldability**
LC3	70.0–95.0	4
HSLA100 [2]	120	2
HY-80 [2]	110	5

Two of these steels, HSLA65 and HSLA100, are produced as wrought products such as bar or plate, but can usually be poured as castings with only minor modifications. These, as well as the HY-80, use alloying elements such as chromium or molybdenum instead of carbon to achieve mechanical properties. Both the HSLA65 and HSLA100 steels could be welded without preheat if appropriate cooling rates were used.

Two other cast grades, LCC and LC3, were found that would meet the strength requirements, but lower carbon and additional alloying elements would be needed to make them ultraweldable.

Another important consideration is the weld filler selection. A filler material must not form undesired phases in the heat affected zone and must be compatible with the ultraweldable steel. A failed side frame is shown in Figure 3.

Several suitable steel grades were found that have similar mechanical properties to Grade B+ and are suitable for low temperature service. These are specified in the American Society for Testing and Materials (ASTM) A352, "Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low Temperature Service [3]." The nickel additions to the steel provide ductility at low temperatures, which reduces sudden, brittle fractures. The materials suggested for further investigation, along with their carbon and nickel contents, are listed in Table 2.

Table 2. Carbon and nickel content requirements for some low service temperature steels

Grade	**Carbon**	**Nickel**
LCC	0.25% max	0.50% max
LC2	0.25% max	2.00–3.00%
LC3	0.15% max	3.00–4.00%
LC4	0.15% max	4.00–5.00%
LC9	0.13% max	8.50–10.00%
CA6NM	0.06% max	3.5–4.5%

Figure 3. Fractured side frame

CONCLUSIONS

From September 2016 to December 2017, TTCI's research found the following five potentially ultraweldable steels with mechanical properties similar to those of Grade B+: HSLA65, LCC, LC3, HSLA100, AND HY-80. Grades HSLA65 and HSLA100 are not typically produced as castings.

A parallel investigation was performed for steels suited for low temperature service, using toughness or ductility at temperatures below -40 °F as the main selection criteria. Nickel containing steels have ductility higher than similar carbon steels, both at room temperature and at low temperatures. The ductility generally increases as the nickel content increases. Grade

LCC and nickel alloy steels LC2, LC3, LC4, LC9, and CA6NM meet the criteria for low temperature service and are recommended for further testing in Phase II.

FUTURE ACTION

Further testing of candidate materials is proposed for Phase II research. Testing potentially ultraweldable steels will involve welding at various parameters, thorough microstructural analyses and mechanical testing. Combinations of base materials and filler materials will also be tested.

Testing low service temperature steels will include a full range of chemical, mechanical, and metallurgical tests to further evaluate the applicability of candidate materials to low temperature service.

REFERENCES

1. Association of American Railroads. "Castings, Steel." 2020. *Manual of Standards and Recommended Practices, Section S*. Pueblo, CO.
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3. Standard A352, "Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low Temperature Service." *2015 Annual Book of Standards, Section 1*. 2015. ASTM International, West Conshohocken, PA.

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CONTACT

Monique Ferguson Stewart
Senior Program Manager/Mechanical Engineer
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue, SE
Mail Stop 20
Washington, DC 20590
(202) 493-6358
Monique.Stewart@dot.gov

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