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RESEARCH RESULTS

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DEVELOPING LOW SERVICE TEMPERATURE STEELS FOR RAILROAD TRUCK CASTINGS

SUMMARY

At low temperatures, plain carbon steels, such as the types used in truck castings, can fracture in a brittle manner, with no visible deformation. The ability of a material to deform without fracture is its toughness or ductility. Figure 1 shows a broken side frame. The addition of elements such as nickel can help steel maintain its toughness at low temperatures. Using steels with such additives in specific, low temperature applications could prevent brittle failures of truck castings.

The research performed for the Federal Railroad Administration (FRA) previously identified six grades of steel currently used in low temperature applications that could potentially be used as truck castings. These materials are specified under the American Society of Testing Materials (ASTM) A352, Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service. The grades are named LCC, LC2, LC3, LC4, LC9, and CA6NM, and their most common applications are for pump and valve bodies in low temperature service.

Transportation Technology Center, Inc. obtained specimens from each of the six materials and evaluated their tensile properties at room temperature and -60 °F. Charpy impact specimens were tested at temperatures ranging from -20 °F to -120 °F. The evaluations were performed at the Transportation Technology Center (TTC) in Pueblo, CO, and Ohio State University from June 7, 2016, to October 6, 2017.

The measured room temperature tensile properties of each of the six steels met or exceeded the requirements for grade B+, the steel currently used for truck castings.

Figure 1. Broken side frame in low temperature service

The Charpy impact energies (ductility) generally increase with nickel content. The LCC steel, which contains no nickel, had very low impact energies and would not be a good choice for further work.

The LC2, LC4, and CA6NM steels had higher impact energies, much higher than LCC over much of the temperature range. The LC3 and LC9 steels showed the consistently highest energies over the tested temperature range and would be the best candidates for future work in this area.

Future work would involve producing truck castings from one or more of these alloys, then testing them for fatigue performance.

BACKGROUND

At low temperatures, plain carbon steels, such as the types used in truck castings, can fracture in a brittle manner, with no visible deformation. The material property of deforming without fracture is toughness or ductility. The addition of elements such as nickel can help steel maintain its toughness at low temperatures. Using these materials in specific, low temperature applications could prevent brittle failures of truck castings.

The requirements for the grade B+ material used in the current truck castings are detailed in the Association of American Railroads' (AAR) Standard M-201. It is classified as a medium carbon steel.

OBJECTIVES

This research investigated the feasibility of using one or more of these six steels in truck castings. Little mechanical property data are available for these materials. To properly assess their suitability as truck casting materials, more information on the mechanical properties was needed.

METHODS

The investigation into the properties of each of these six steels consisted of mechanical and metallurgical analyses. The steels in this study contain differing amounts of alloying elements. Table 1 lists the nickel, chromium, and molybdenum contents of grade B+ and each material in this study.

Table 1. Alloying elements present in the six steels & B+

Material	Nickel (%)	Chromium (%)	Molybdenum (%)
Grade B+	Not specified	Not specified	Not specified
LCC	0.50 max	0.50 max	0.20 max
LC2	2.0–3.0	Not specified	Not specified
LC3	3.0–4.0	Not specified	Not specified
LC4	4.0–5.0	Not specified	Not specified
LC9	8.5–10.0	0.50 max	0.20 max
CA6NM	3.5–4.5	11.5–14.0	0.4–1.0

Nickel plays the most important role in maintaining ductility and provides significant strengthening. Chromium and molybdenum contribute to strengthening, and can reduce ductility, if not balanced by nickel.

Since most of these steels are uncommon, samples were obtained by purchasing keel blocks. Foundries frequently use these blocks to machine mechanical test samples from them. Tensile test samples and Charpy impact samples were obtained from the keel blocks. For each material, four tensile samples were tested: two at -60 °F and two at 73 °F (i.e., room temperature). Three Charpy samples of each material were tested at -20, -40, -60, -80, -100, and -120 °F.

RESULTS

Tensile Properties

The room temperature tensile property data for the six steels and the requirements for grade B+ are listed in Table 2.

Table 2. Room temperature tensile property data for the six steels and the grade B+ requirements

Material	Tensile Strength (ksi)	Yield Strength (ksi)	Elongation (%)	Reduct. of Area (%)
B+	80	50	24	36
LCC	82	57	31	68
LC2	98	86	24	70
LC3	83	68	28	75
LC4	102	88	22	67
LC9	114	101	20	61
CA6NM	135	100	14	41

The elongation is the change in length of the tensile sample during the test. Reduction of area is the change in cross-sectional area of the tensile sample. These properties give a rough measure of ductility.

The tensile test results at -60 °F are graphically shown at room temperature in Figure 2.

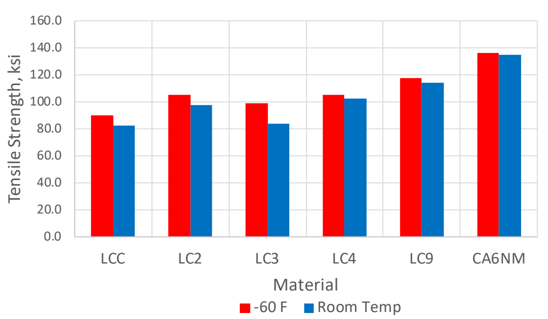

Figure 2. Ultimate tensile strength at -60 °F and at room temperature for the six steels

The yield strength of the steels at -60 °F are graphically shown at room temperature in Figure 3.

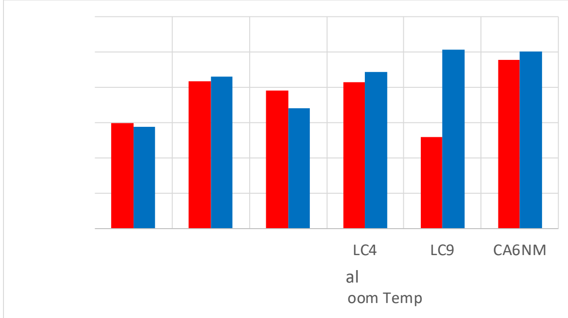

Figure 3. Yield strength at -60 °F and at room temperature for the six steels

The ultimate tensile strengths of the steels increased as the nickel content increased in the LCX steels, as expected. CA6NM, which is a stainless steel, had the highest tensile strength.

The LC9 material had the lowest yield strength at -60 °F of any of the steels. This was lower than expected; examination of the specimens revealed casting defects. The tested tensile properties for all these steels met or exceeded the requirements for truck castings.

Charpy Impact Energies

The Charpy impact energies are summarized in Figure 4. The LC3 material showed very high impact absorption at most temperatures, but at -100 °F, the average impact energy dropped to less than 6 ft-lb. The energies at -80 °F and -120 °F are significantly higher. The specimens were examined and found to have material defects.

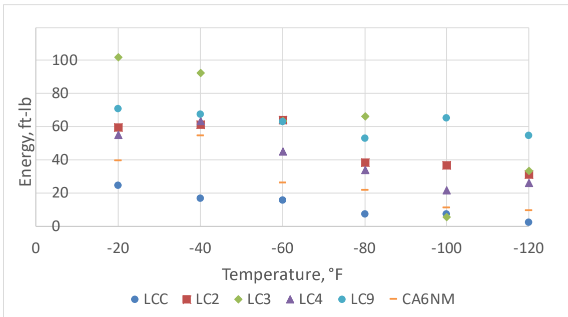

Figure 4. Charpy impact energies of the six steels

The LCC steel, which contains no nickel, had low impact energies and would not be a good choice for further work.

The LC2, LC4, and CA6NM steels had higher impact energies, much higher than LCC over much of the range.

The LC3 and LC9 steels showed consistently high energies over the tested temperature range, and would be the best replacement for B+ steel in low temperature service.

CONCLUSIONS

Through evaluations performed from June 7, 2016, to October 6, 2017, the results showed that the LC2, LC3, LC4, and LC9 steels would offer significantly improved low temperature performance in comparison with the standard grade B+ steel, which reduces the probability of brittle fracture in low temperature. The LC3 and LC9 steels would be the best materials to consider for future work in this area. Future work would involve producing truck castings from one or more of these alloys, then testing them for fatigue performance, preferably at low temperatures.

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