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SUMMARY OF CHARPY AND DYNAMIC TEAR TESTING OF BOLSTER SAMPLES

SUMMARY

The Federal Railroad Administration (FRA) collaborates with the Association of American Railroads' (AAR) Coupling System and Truck Castings Committee and Transportation Technology Center, Inc. to investigate possible solutions to early-life failures of railcar side frames and bolsters.

Side frame and bolster failures can be mostly attributed to either fatigue or brittle failure. Of the brittle failures, most can be attributed to marginal strength and poor impact resistance of the cast steel material. A brittle failure can occur instantaneously and under stresses that can be below the yield strength of the material.

The results of Charpy (fracture toughness) and dynamic tear (progressive fracture resistance) tests of samples from seven different foundries showed the probability of brittle failures may be higher than expected. Such was the case for cars operating in colder weather because of the increased brittleness of the material in lower temperatures.

The Charpy test results showed that most samples passed at the critical temperatures (Figure 1). The fracture surfaces could be examined for more information in the later phase of this research.

The dynamic tear tests show an upward sloping trend in Figure 2, which may indicate that the transition period from brittle to ductile failures was somewhere between 20 °F and 60 °F. The dynamic tear test samples also indicated larger discrepancies between individual samples and between foundries.

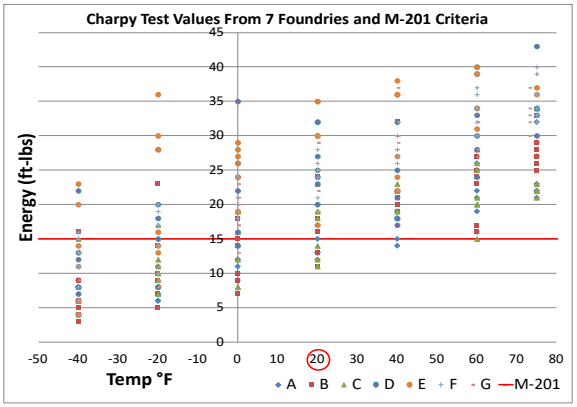

Figure 1: Charpy Test Values at 7 Temperatures

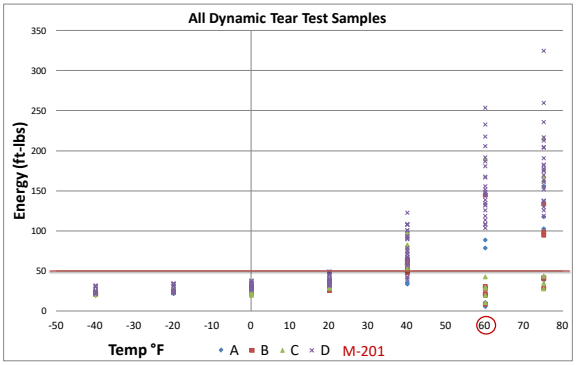

Figure 2: Dynamic Tear Test Values at 7 Temperatures

Final test results will be compiled and reviewed to recommend approaches to improve the castings. An iterative process with the foundries is expected to cost-effectively improve castings.

BACKGROUND

Side frame and bolster failures incurred by North American Railroads in recent years can be mostly attributed to either fatigue or brittle failure. Fatigue failures have most often resulted from less-than-desirable welding/casting

workmanship and casting solidity. Of the brittle failures, most can be attributed to marginal strength and poor impact resistance of the cast steel material. A brittle failure can occur instantaneously and under stresses that may be below the yield strength of the material.

The Coupling System and Truck Castings Committee and Transportation Technology Center, Inc. believe that manufacturing modifications are necessary to improve the performance and to reduce the occurrence of brittle failures of cast components. FRA collaborates with these groups to study possible solutions.

OBJECTIVES

This project focused on improving the chemistry, material quality, and life of grade B+ castings. To fully examine the mechanical properties of the casting, Charpy, dynamic tear, and tensile tests were conducted. This report presents the Charpy and dynamic tear testing results.

Results of these tests, which focused on critical areas of the castings, could be further studied to determine recommendations to improve the chemistry, quality, and life of grade B+ materials.

METHODS

Charpy testing is a way to measure a material's fracture toughness. Four samples were taken from the keel block, and 14 samples were taken from the critical areas from each bolster. Methods for testing were taken from ASTM International manuals. Test specifications from ASTM A370 and ASTM E23 were used, and the testing was conducted at a range of temperatures from -40 °F to 75 °F.

Dynamic tear testing was used to quantify the resistance to rapid, progressive fracturing. It measured similar properties as the Charpy test but was also performed because it is listed as an alternative test in the AAR M201 standard (1). These samples were taken from a similar area of the casting as the samples for the Charpy testing. The 14 dynamic tear samples were tested per ASTM E604, at the same 7 temperatures, as the Charpy tests. The temperature described in the AAR M201 standard corresponded with one of the seven temperatures from the ASTM E604 testing.

RESULTS

An early indication from the Charpy and dynamic tear testing was that the probability of brittle failures may have been more likely than previously expected.

According to AAR M201 standard, Charpy-V notch testing can be performed on coupons produced from keel blocks. For grade B+ materials, AAR M201 states that the average energy absorbed for three samples must be above 15 ft-lb when tested at 20 °F. One goal of this investigation was to test several temperatures, but only two samples were available for testing from each bolster at each temperature, rather than the three samples as specified in AAR M201. Figure 1 shows the energy absorption of six samples, two per bolster, at each temperature from seven different foundries; the criteria described by AAR M201 standard are shown in red. Ten total samples tested at 20 °F absorbed under 15 ft-lbs of energy. Three pairs of samples from the bolsters averaged less than 15 ft-lbs of energy when tested at 20 °F.

Figure 1 shows a positive correlation between the increasing temperatures and the mean value of energy absorption. This is a common phenomenon, because as temperature increases, the fractures become more ductile in nature. A more comprehensive fracture surface analysis is in *Technology Digest* TD-11-044 (2). Comprehensive analysis of the samples showed significant levels of porosity, chemical inclusions, and low resistance to impact at lower temperatures.

Figure 3 displays the Charpy test data for each bolster tested at 20 °F. The average, maximum, and minimum values of the two samples tested are shown. This plot is the most linear comparison to the AAR M201 standard, which specifies three test samples averaged. Three of

the averaged values did not meet the 15 ft-lb criteria, and two of the averages passed by less than 1 ft-lb. Two of the three samples came from foundry A and one from foundry B. The two other samples that passed by 1 ft-lb came from foundry A and foundry C.

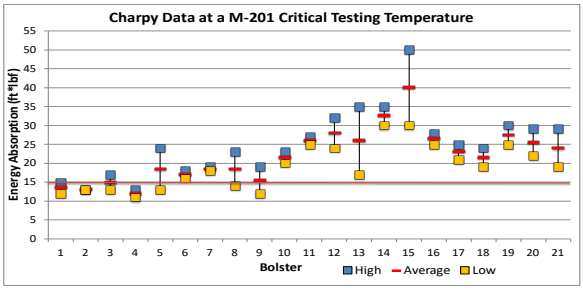

Figure 3: Charpy Test Values at 20 °F

Dynamic tear tests are used to determine the fracture resistance of a material. AAR M201 standard requires three samples have an average energy absorption above 50 ft-lbs at 60 °F. Figure 2 shows the dynamic tear values for the tested bolsters.

The majority of the samples tested at 60 °F passed the minimum amount of 50 ft-lbs of energy. Two foundries had samples that failed the 50 ft-lb requirement at 60 °F. Both foundries had samples that passed the minimum requirement. The upward slope of the average value indicates the beginning of the transition period from brittle to ductile fractures, which may be between 20 °F and 60 °F. To complete the analysis, samples below and above the AAR M201 standard requirement of 50 ft-lbs will need to be examined for surface defects and compared in order to understand the fracture mechanisms.

CONCLUSIONS

The Charpy and dynamic tear tests showed that the probability of brittle failures may have been higher than expected. This probably was the case for cars operating in colder weather because of the increased brittleness of the material in lower temperatures.

FUTURE ACTION

Final test results could be compiled and studied thoroughly to determine the best way to improve the castings. An iterative process with the foundries is expected to develop cost-effective improvements of B+ castings.

REFERENCES

1. Association of American Railroads. (2005). *Manual of Standards and Recommended Practices*. Section S, Casting Details Specification M-201. Washington, DC.
2. Sammon, D., Gonzales, K., Szablewski, D., and Carter, D. (November 2011). Fracture Surface Analysis of Grade B+ Material over a Range of Temperatures. *Technology Digest* TD-11-044. AAR, TTCI, Pueblo, CO.

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CONTACT

David Brabb
Federal Railroad Administration
Office of Research, Development, and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(719) 584-0507
david.brabb@dot.gov

KEYWORDS

Charpy, dynamic tear, bolster, side frame, brittle failure