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Recommended Nondestructive Inspection Guide for Side Frame, Bolster, and Knuckle Castings

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Summary

Casting inspection techniques developed by the Transportation Technology Center, Inc. (TTCI) have led to the creation of manual procedures that can potentially be used for the inspection of side frames, bolsters, and knuckles at the car shop, manufacturer, or other railroad environments. The Association of American Railroads (AAR) Coupling Systems and Truck Casting Committee will have these techniques available for consideration in developing requirements to improve the quality and increase safety of the castings used in revenue service.

TTCI performed manual field inspections to help in the creation of the inspection procedures, which resulted in the following:

- 25 bolsters inspected of which 56 percent had relevant indications. Indication relevance was determined by a comparison of the indication to the surface condition criteria set forth in M-210[1]. Of the bolsters that had relevant indications, 57 percent had indications located around the brake rod hole, 21 percent had indications located on the transition radius, and 21 percent had indications at both the brake rod hole and the transition radius.
- 26 side frames inspected of which 50 percent had relevant indications. Indication relevance was determined by a comparison of the indication to the surface condition criteria set forth in M-210.[1] Of the side frames with relevant indications, 59 percent had indications in only one location, and 41 percent had multiple indications in multiple locations.
- 169 knuckles inspected of which 72 percent had relevant indications. Knuckle indication relevance was determined by comparison with guidelines set forth by the Federal Railroad Administration. Of the knuckles that did have surface indications, 54 percent were removed from service.

Through the AAR's Strategic Research Initiatives Program, the Mechanical and Vehicle/Track Systems Committee requested TTCI to develop a reasonable nondestructive inspection (NDI) technique for inspection of critical stress areas of side frames, bolsters, and knuckles. The inspection of castings was used to identify an approach to nondestructively inspect side frames, bolsters, and knuckles using handheld portable inspection equipment. NDI was performed on unpainted side frames, bolsters, and knuckles using techniques developed in the laboratory by TTCI/NDI staff. The primary NDI method used to inspect side frames and knuckles was magnetic particle (MT), while a combination MT and liquid penetrant inspection was used to inspect the bolsters. The Union Pacific Railroad participated in the inspections of the side frame and bolster.

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INTRODUCTION

As part of an overall industry effort to improve the quality and reliability of large freight car castings, specifically side frames, bolsters and knuckles, TTCI initiated a research project in 2007 to identify applicable nondestructive testing techniques to inspect railroad castings in the manufacturing, car shop, or railroad environment. TTCI has developed manual inspection techniques and performed NDIs of side frame, bolster, and knuckle castings. The inspections were conducted in response to the Mechanical and Vehicle/Track Systems Committee request for TTCI to come up with a reasonable NDI approach to inspect critical stress areas of side frames, bolsters, and knuckles. TTCI and Union Pacific (UP) inspected the side frame and bolster. The UP provided TTCI with 50 newly manufactured, unpainted, side frames and bolsters for the inspections. A NDI of the side frames and bolsters was performed at the Cudahy Car Shop in Cudahy, Wisconsin, from June 5 to 7, 2007, followed by a NDI of the knuckles July 9 to 13, 2007, at the Transportation Technology Center, Pueblo, Colorado, on cars used for testing at the Facility for Accelerated Service Testing.

These inspections were completed to identify a manual approach to nondestructively inspect side frames, bolsters, and knuckles using handheld portable inspection equipment. A NDI was performed on unpainted side frames, bolsters, and knuckles using techniques developed in the laboratory by TTCI/NDI staff. The primary NDI method used to inspect side frames and knuckles was MT. A combination MT and liquid penetrant inspection was used to inspect the bolsters.

The critical areas of the castings are known as Zone 1 areas and are labeled as such due to the higher stresses that are seen at these locations compared with the rest of the casting. Zone 1 areas of side frames and bolsters are defined in AAR specification M-210.[1] The critical Zone 1 area of the knuckle casting is defined in AAR specification M-211.[2] The bolster Zone 1 areas can be seen as the black areas of the bolster in Figure 1. Figure 2 shows the Zone 1 areas of a side frame, and Figure 3 shows the knuckle Zone 1 areas.

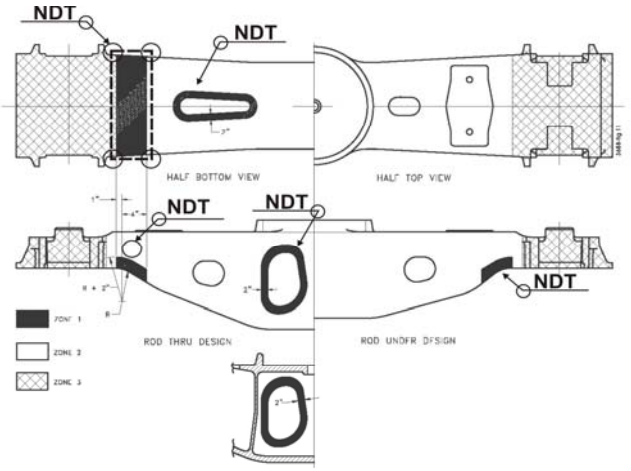

Figure 1. Bolster Critical Areas

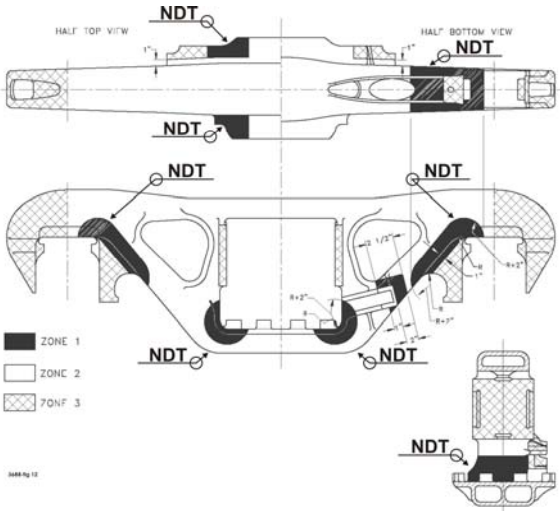

Figure 2. Side Frame Critical Areas

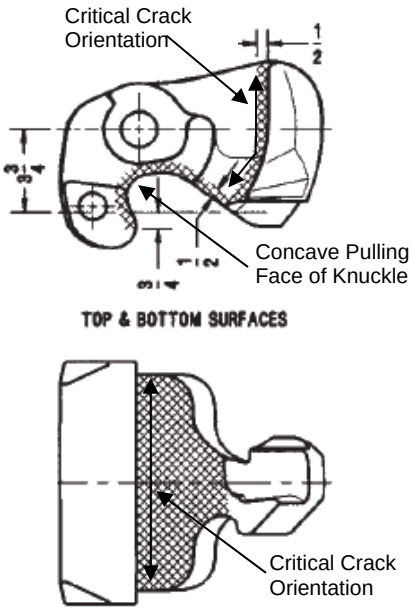

Figure 3. Knuckle Critical Areas

Side Frame and Bolster Inspections

The bolsters used for the inspection were placed upside down on the ground, as Figure 4 shows. Each bolster casting was inspected by a NDI technician who used a portable magnetic yoke, dry magnetic powder, remover, and developer to perform the MT portion of the inspection. Liquid penetrant inspection of the inside ribs was also performed by the same NDI technician using remover, visible red dye penetrant, and developer for the inspection.

Figure 4. Bolster Setup

The side frames used for the inspection were placed upside down on the ground. They were stabilized using wood wedges on either side of the side frame. Figure 5 shows the setup of the side frame and areas inspected in Zone 1. The NDI technician inspected each side-frame casting using a portable magnetic yoke and dry magnetic powder. The Zone 1 areas were sprayed with developer to increase the contrast between the casting surface and the magnetic powder.

Figure 5. Side Frame Setup

Knuckle Inspections

The knuckles were inspected attached to the cars, with the cars separated, and with the knuckles in the open position. Prior to performing MT inspection, a visual inspection was performed on the front and pulling faces of the knuckle. After the preliminary visual inspection, the MT inspection was then performed on the pulling face of the knuckle, using a portable yoke. Figure 6 shows an inspected knuckle.

Figure 6. Inspected Knuckle

RESULTS

All indications found from the inspection of the side frames and bolsters were compared with the Steel Castings Research and Trade Association references, as called out by the surface condition in critical areas set forth in M-210.[1] This comparison was used to determine the relevance of the indications found. The tears were considered relevant according to M-210 5.5.1.12, which states that a crack, hot tear, surface shrinkage is a condition on the castings that was formed during the manufacture or processing of the casting.[1] These foundry-related defects must be removed by either grinding or excavation and repair welding. The tears (cracks) are also labeled as a "cause for renewal" in the *Field Manual for the A.A.R Interchange Rules*, specifically Rule 47 concerning bolsters and Rule 48 concerning side frames.[3,4] A new AAR specification is being finalized by the CSTCC to include the indication relevancy used for the knuckle inspections. All cracks found were considered relevant according to the guidelines set forth by the Federal Railroad Administration Motive Power and Equipment Compliance Manual, specifically regulation §215.123 Defective Couplers.[5]

TTCI inspected 25 bolsters of which 56 percent had relevant indications, while 44 percent did not have any relevant indications. Of the bolsters that had relevant indications, 57 percent had indications located around the brake rod hole, 21 percent had indications located on the transition radius, and 21 percent had indications at both the brake rod hole and the transition radius. The longest indication found on the bolsters was 2 inches long, and the smallest indication was 1/16 inch long. The indications found on the bolster castings include porosity, inclusions, tears (cracks), and some scabs. Most of the ribs from the bolsters had a seam from the mold, and one had porosity. Figure 7 shows the porosity on one of the inside ribs. Figure 8 shows a tear on the transition radius. Inspection of the bolster using this technique takes 40 minutes using one technician.

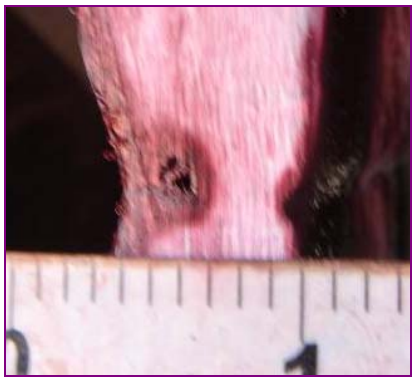

Figure 7. Porosity on Inside Rib

Figure 8. Tear on Transition Radius

TTCI inspected 26 side frames of which 50 percent had relevant indications; 50 percent did not have relevant indications. Of the 13 side frames with relevant indications, 59 percent had indications in only one location, and 41 percent had multiple indications in multiple locations.

On the 13 side frames, 24 indications were found. Of these, 25 percent were on the pedestal roof radius, 8 percent were located on the side of the casting near the pedestal radius, 8 percent were located near the pedestal leg radius with the tension member, 21 percent were located in the spring seat radius, 21 percent were located on the side of the casting near the spring seat radius, and 17 percent had indications near the unit bracket.

Figure 9 shows an average tear found in the spring seat radius. Figure 10 shows a scab located on the pedestal roof. The longest indication found during the side-frame inspection was 2 1/4 inches long and the smallest indication was 1/16 inch long. Indications found on the side-frame castings included porosity, tears (cracks), and some scabs. It takes a technician 30 minutes to inspect the side frame using this technique.

TTCI inspected 169 knuckles of which 28 percent did not have any surface indications, and 72 percent did have indications. Of the 72 percent of knuckles that did have surface indications, 54 percent were removed from service. Figure 11 shows a knuckle that was inspected and found to have tears and a gouge. The indications found during the inspection of the knuckles included tears (cracks), porosity, and gouges. It takes a technician 10 minutes to inspect a knuckle using this technique.

CONCLUSIONS

The casting inspections led to the creation of viable procedures that can be used for the inspection of areas in Zone 1 of side frames, bolsters, and knuckles at the car shop, manufacturer, or other railroad environments. These inspection techniques, created for the inspection of the side frame, bolster, and knuckle casting will improve the quality and increase safety of the castings used in revenue service.

Figure 9. Tear on Spring Seat Radius

Figure 10. Scab on Pedestal Radius

Figure 11. Tears and Gouge on Pulling Face

Future Work

Using the inspection technology from these inspections, TTCI is progressing toward the development of an automated inspection system.

References

1. Association of American Railroads. 2007. *Manual of Standards and Recommended Practices*, Section S, "Specification for Purchase and Acceptance of AAR Approved Side Frames and Bolsters Applicable to Interchange Freight Cars M-210."
2. Association of American Railroads. 2007. *Manual of Standards and Recommended Practices*, Section S, "Couplers and Yokes, AAR Approved – Purchase and Acceptance Specification M-211."
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5. Federal Railroad Administration. 2007. Motive Power and Equipment Compliance Manual, Chapter 4, Part 215.123, Railroad Freight Car Safety Standards, Washington, DC.