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Inspection Methods for Side Frame, Bolster, and Knuckle Castings

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Summary

In 2007, Transportation Technology Center, Inc. identified applicable nondestructive inspection (NDI) methods to inspect railroad castings in manufacturing facilities, car shops, and other railroad environments as part of the Association of American Railroads' Strategic Research Initiatives Program.

For comparison purposes, critical areas of castings were inspected using the following NDI methods: dry magnetic particle, wet fluorescent magnetic particle, liquid penetrant, alcohol wipe, visual, ultrasonic, ultrasonic phased array, and radiography.

The wet fluorescent method was the most dependable method for finding finer surface indications, followed by dry magnetic particle, liquid penetrant, alcohol wipe, and the visual method. Radiography was the better method for finding the finer internal indications, followed by ultrasonic phased array, and ultrasonic methods.

TTCI recommendations from the research results for the surface NDI methods of all critical areas of the various castings are as follows:

- Car shops and railroad environments
  - Inspection of bolster: a combination of two methods — dry magnetic particle and liquid penetrant
  - Inspection of side frames: dry magnetic particle method
  - Inspection of the pulling face of the knuckles: dry magnetic particle method
- Manufacturing environment
  - Inspection of bolster, side frame, and knuckle castings: wet fluorescent magnetic particle inspection

The following table shows the recommended application of each NDI method for inspecting different casting parts.

NDI Method	Casting (Inspection Time minutes)		
	Side Frame	Bolster	Knuckle
Dry Magnetic Particle	All (30)	Partial (40)	All (10)
Wet Fluorescent Magnetic Particle	All (15)	All (15)	All (5)
Liquid Penetrant	All (93)	All (62)	All (15)
Alcohol Wipe	All (32)	All (49)	All (10)
Visual	All (20)	All (20)	All (5)
Ultrasonic	Partial	Partial	Partial
Ultrasonic – Phased Array	None	Partial	Partial
Radiography	All	All	NA

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INTRODUCTION

In 2007, Transportation Technology Center, Inc. identified applicable nondestructive inspection (NDI) methods to inspect railroad castings in manufacturing facilities, car shops, and other railroad environments. This Strategic Research Initiative is part of an overall industry effort to improve the quality and reliability of large freight car castings, specifically side frames, bolsters, and knuckles.

Critical areas on castings were inspected using various NDI methods in order to identify reliable methods. The critical areas of the castings are labeled as Zone 1 areas due to the higher stresses that are found at these locations as compared with the rest of the casting.[1]

Each of the NDI methods was used to inspect several side frames, bolsters, and knuckles. The inspections were documented and timed for comparison purposes.

The NDI methods conducted on each casting were dry magnetic particle, wet fluorescent magnetic particle, liquid penetrant, alcohol wipe, visual, ultrasonic, ultrasonic phased array, and radiography.

DESCRIPTIONS OF NDI METHODS

The eight NDI methods used are described in detail:

- Dry magnetic particle inspection is performed using a magnetic yoke to produce a circular magnetic field and dry iron oxide powder; TTCI inspections used a non-aqueous developer on the casting for added contrast. During dry magnetic particle inspection, the developer is sprayed onto the casting and then the yoke is energized to create a magnetic field on the surface of the casting. While generating the magnetic field, iron oxide powder is lightly applied onto the surface of the casting. Wherever there is a defect, a flux leakage of the magnetic field occurs, drawing the iron oxide powder to that location.
- Wet fluorescent magnetic particle inspection can use the same magnetic yoke or a larger magnetic unit to produce the magnetic field. A wet fluorescent iron oxide is applied onto the surface of the casting while the magnetic field is applied. The fluorescent iron oxide particles are drawn to the defect. A black light is then used to inspect the casting; each defect or magnetic leakage point will fluoresce.
- Liquid penetrant inspection uses cleaner/remover, red dye penetrant, and developer. The casting is cleaned with the cleaner and the red dye penetrant is sprayed onto the casting. The penetrant is allowed to dwell for 5 to 15 minutes, and then the excess is wiped off. Next, the casting is sprayed with the developer, which is a white aerosol powder. The developer draws out any penetrant in a defect to the surface of the casting, and the casting can then be inspected for any defects.
- Alcohol wipe testing uses the same principles as the liquid penetrant inspection. Alcohol is applied onto the surface of the casting and allowed to dwell for 10 to 30 seconds, depending on the temperature of the casting. The excess is then wiped off, and if there is a defect the alcohol would be drawn to the surface of the casting. This effect can be visually seen on the surface of the casting.
- Visual inspection uses a trained inspector who visually looks for surface defects on the casting. The inspector will look at each critical area of the casting and determine if there are any defects.
- Ultrasonic inspection is performed using a piezo-electric transducer attached to a portable flaw detector. The transducer sends ultrasonic signals into the casting and defects inside the casting or the backwall will reflect a signal back to the transducer. The flaw detector is used to visualize the signals that the transducer sends and receives.
- Ultrasonic phased array inspection uses a phased array transducer attached to a portable flaw detector. The phased array transducer sends ultrasonic signals into the casting and defects inside the casting or the backwall will reflect a signal back to the transducer. The flaw detector is used to visualize the signals that the transducer sends and receives. The phased array system is able to look at multiple angles in the same plane from the transducer.
- Radiography uses film and a device that emits radiation in the form of x-rays. The film is placed behind or inside the casting depending on what area is being inspected. The x-ray device is turned on for a specified amount of time depending on the thickness of the casting and power of the device. The film is then developed and the casting can then be inspected from the film.

RESULTS OF SURFACE NDI METHODS

Results from the dry magnetic particle inspection method showed that the side frame and knuckle can be inspected in all critical areas. Using the dry magnetic particle method, the bolster was able to be inspected only on the outside critical areas, but not the ribs inside the brake rod holes. The inspection of the side frame took about 30 minutes, the bolster inspection took 40 minutes, and the knuckle inspection took 10 minutes to perform.[2] Figure 1 shows defects found using the dry magnetic particle inspection method.

Results from the wet fluorescent magnetic particle inspection method showed that the side frame, bolster, and knuckle could be inspected in all of the critical areas. The inspection of the side frame and bolster each took 15 minutes, whereas the knuckle inspection took 5 minutes to perform.[3] Figure 2 shows a defect found using the wet fluorescent magnetic particle inspection method.

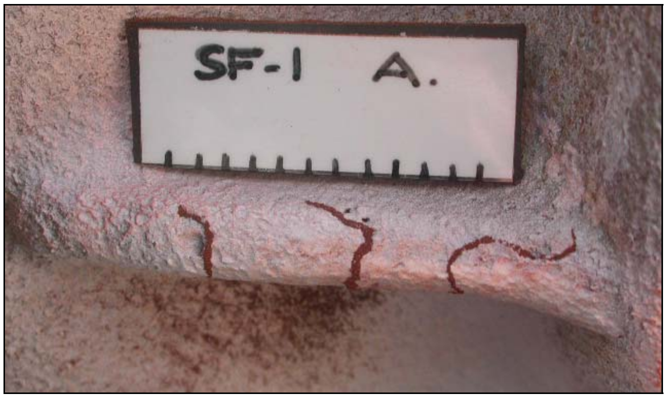

Figure 1. Defects Identified using Dry Magnetic Particle Inspection

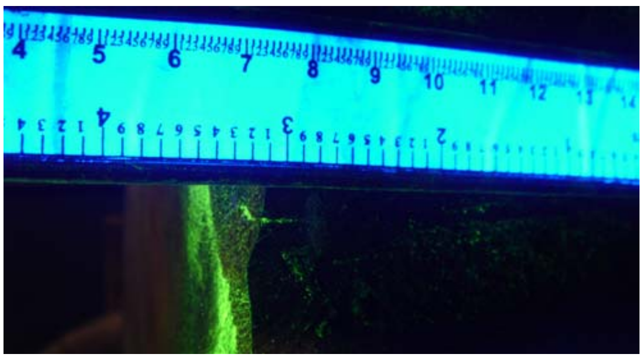

Figure 2. Defect Identified using Wet Fluorescent Magnetic Particle Inspection

Results from the liquid penetrant inspection method showed the side frame, bolster, and knuckle could be inspected in all critical areas. The side frame inspection took 93 minutes, the bolster inspection 62 minutes, and the knuckle inspection took 15 minutes to perform. Figure 3 shows porosity in a rib section of a bolster found using the liquid penetrant inspection method.

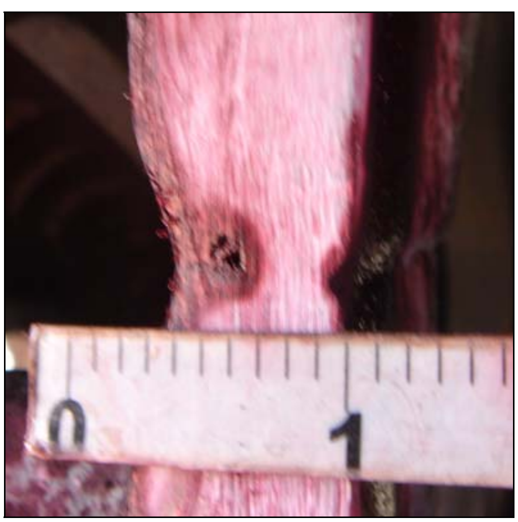

Figure 3. Porosity Defect Identified using Liquid Penetrant Inspection

Results for the alcohol wipe method showed that the side frame, bolster, and knuckle could be inspected in all of the critical areas. The results were similar to the liquid penetrant method, but took less time to perform. The side frame inspection took 32 minutes and the bolster inspection took 49 minutes to perform. Figure 4 shows a defect found using the alcohol wipe inspection method.

Figure 4. Defect Identified using Alcohol Wipe Inspection

All the critical areas of the castings could be inspected by the visual inspection method. The bolster and side frame inspections each took 20 minutes and the knuckle inspection took 5 minutes to perform.

RESULTS OF INTERNAL NDI METHODS

The ultrasonic inspection method could only partially inspect the critical areas of the side frame, bolster, and knuckle. The surfaces of the castings were very rough and did not provide for a good coupling between the transducer and the inspection surface. Successful inspection of the bolster using this method was limited to the transition radius from the diagonal tension member and the spring seat. Successful inspection of the side frame using this method was limited to the side of the pedestal radius. The knuckle could only be successfully inspected on the pulling face using this method. Figure 5 shows an ultrasonic A-scan that identified a casting defect.

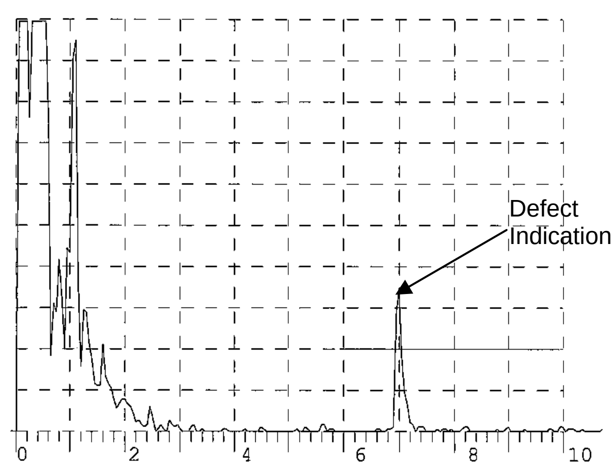

Figure 5. Ultrasonic Method A-scan showing a Casting Defect

The ultrasonic phased array method could only partially inspect the critical areas of the bolster and the knuckle. The ultrasonic phased array method had the same limitations as the ultrasonic method concerning the surface conditions of the castings. The bolster could only be successfully inspected along the transition radius from the diagonal tension member and along the spring seat using ultrasonic phased array. The knuckle could only be successfully inspected on the pulling face using ultrasonic phased array. Figure 6 shows multiple indications found using the ultrasonic phased array inspection method that can be seen in the C-scan.

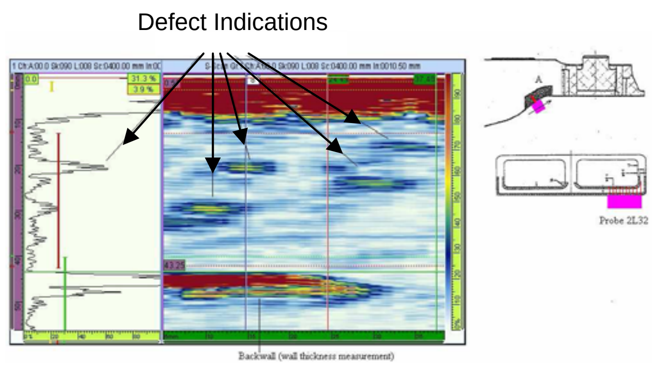

Figure 6. Ultrasonic Phased Array C-scan Showing Multiple Casting Defects

The radiography inspection method was able to evaluate all of the critical areas of the side frame and bolster casting. Two methods were tried: the first used film and the second used a digital method. The digital method proved to be a quicker inspection, although most of the inspection time was used during the positioning of the samples and the radiation source. Figure 7 shows a radiographic film example using digital radiography.

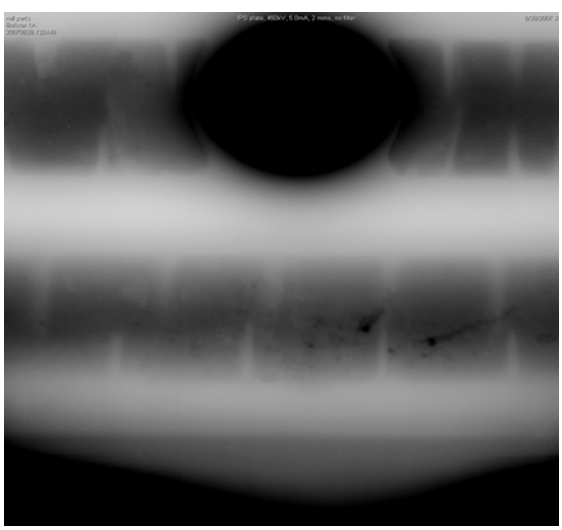

Figure 7. Radiography Method Digital Film

CONCLUSIONS

The wet fluorescent method was the most dependable NDI method for finding finer surface indications, followed by dry magnetic particle, liquid penetrant, alcohol wipe, and the visual method. Radiography was the better NDI method for finding the finer internal indications, followed by ultrasonic phased array, and ultrasonic methods.

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REFERENCES

1. Carter, Daniel. January 2008. “Recommended Nondestructive Inspection Guide for Side Frame, Bolster, and Knuckle Castings.” *Technology Digest*, TD-08-001, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

2. Carter, Daniel. May 2008. “Nondestructive Testing of Side Frame and Bolster Castings at the Cudahy Car Shop, Cudahy, Wisconsin.” Research Report, R-992, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

3. Carter, Daniel. October 2008. “Nondestructive Inspection of Side Frame and Bolster Castings at Gunderson.” Research Report, R-994, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.