TECHNOLOGY DIGEST
TD-10-033
©OCTOBER 2010
TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc.,
a wholly owned subsidiary of the Association of American Railroads.

Survey of Failed Couplers and Knuckles

Daniel Carter, MaryClara Jones, and Kari Gonzales

Summary

The Transportation Technology Center, Inc. (TTCI) conducted a survey of knuckles and couplers, as part of the Association of American Railroads (AAR) Strategic Research Initiatives Program, to determine the most common failure locations, validate critical stress areas found using finite element analysis, and determine the size and location of contact patches between the knuckle and coupler pulling lugs. The survey focused on couplers and knuckles removed from service due to being cracked or broken according to the *Field Manual of the AAR Interchange Rules*. All of the components examined during this survey were collected in 2010. TTCI engineering staff examined the removed components at three different railroad shops.

In March 2010, 53 couplers and 68 knuckles were examined during a three-day survey. Cracks were identified on the horn, shank, lugs, and pin holes of the couplers. The most common crack location identified for the couplers was on the horn. A majority of the couplers exhibited moderate to severe wear and deformation on the butt of the casting. The pulling face was the most common location for fatigue cracks in the 68 knuckles examined. Other knuckle defects were cracks on the lugs and in the flag hole. One knuckle was set out because of fitment problems. Although only one knuckle was identified in the survey as not fitting, shop personnel indicated that fitment issues are common with new components.

The contact areas between the knuckle and coupler were determined by identifying the locations with the most reduction of material. The coupler and knuckle lugs and the lock face of the knuckle showed the greatest amount of contact and wear. The area between the pulling lugs of the knuckle and coupler had the most fitment issues, resulting in the most reduction of material.

The survey conducted in 2010 is part of a larger program focused on improving the performance of knuckles and couplers. Results from the research conducted under this program will be used to determine acceptable tolerances for knuckles and couplers.

Please contact **Daniel Carter (719) 584-0577** with questions or concerns regarding this *Technology Digest.* E-mail: Daniel_carter@ttci.aar.com.

INTRODUCTION

TTCI completed a survey of couplers and knuckles removed from revenue service due to being either cracked or broken. The survey was completed under the AAR Strategic Research Initiatives Program to determine common crack and failure locations, validate critical stress areas in finite element models, and determine contact conditions between the coupler and knuckle pulling lugs.

BACKGROUND

Broken and cracked knuckles and couplers were observed at three car shop locations. The shops visited were the Burlington Northern Santa Fe (BNSF) Havelock shop in Lincoln, NE, the Watco shop in Council Bluffs, IA, and the Greenbrier shop in Omaha, NE. Each of the shops collected components before the survey was conducted.

The BNSF Havelock shop collected 15 couplers and 17 knuckles for the survey. During the inspections at Havelock, additional components were added from the scrap bins. After these components were added, the Havelock shop contributed 18 couplers and 56 knuckles to the survey. The Watco shop contributed 20 couplers and 1 knuckle, and the Greenbrier shop had 15 couplers and 11 knuckles available for the survey.

INSPECTIONS

The components considered for this failure survey included cracked and broken castings removed from service in accordance with AAR Interchange Rules 16, 17, and 18.[1] The shops had additional criteria to determine if a coupler or knuckle should be removed from revenue service. The survey took into account all components removed by each of the shops.

During the survey, TTCI worked with shop employees to determine the proper components to evaluate. The knuckles that were cracked had all been previously inspected using the magnetic particle technique found in AAR Specification M-220.[2] Figure 1 shows a crack on the pulling face of the knuckle that was identified using the magnetic particle technique.

Figure 1. Fatigue Crack on the Pulling Face of a Knuckle

Defects for each of the components were categorized by location on the part. Defect locations for couplers include the horn, shank, lugs, and pin hole. Figure 2 is a labeled coupler body diagram showing the common locations for defects. Also, the survey examined wear and deformation on the coupler shank.

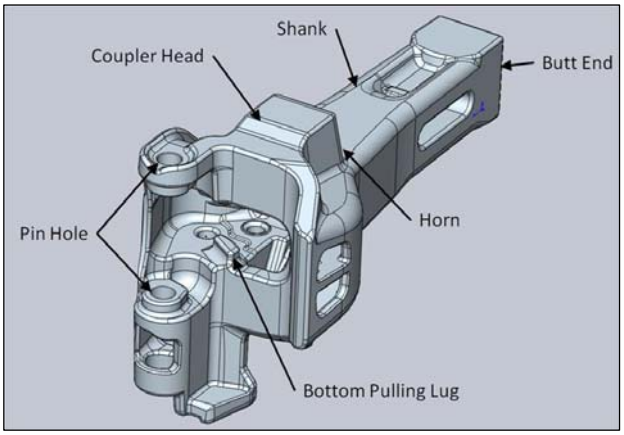

Figure 2. Coupler Diagram of Common Failure Locations

Defect locations for knuckles include the pulling face, flag hole, and pulling lugs. Figure 3 is a labeled diagram of the most common knuckle failure locations. Both knuckles and couplers were checked for fitment issues.

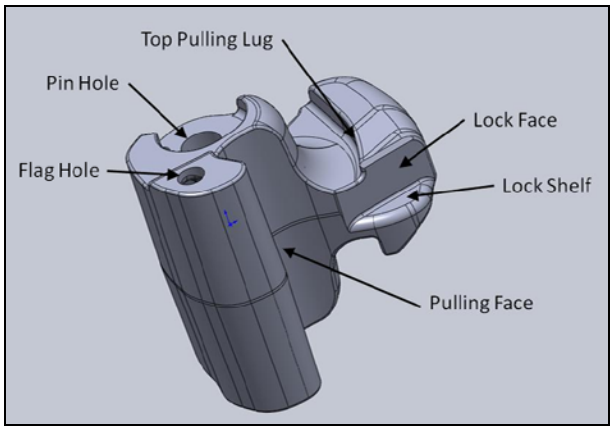

Figure 3. Knuckle Diagram of Common Failure Locations

SURVEY RESULTS SUMMARY

Butt wear and deformation was the most common defect observed on the coupler body. Figure 4 shows that of the 53 couplers examined, 16 exhibited coupler shank butt wear and deformation. Cracks on the lugs and in the pin hole were also frequently observed.

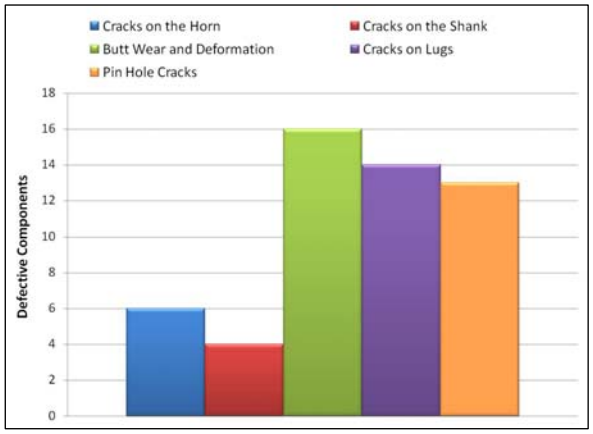

Figure 4. Survey Results for All Couplers Examined

The majority of the defects on the knuckles examined were located on the pulling face. Figure 5 shows that 64 of the 68 knuckles contained cracks on the pulling face. Cracking was also identified in the flag hole and on the lugs of the knuckle. Last, a classification for fitment was necessary due to one knuckle not fitting properly into the coupler body.

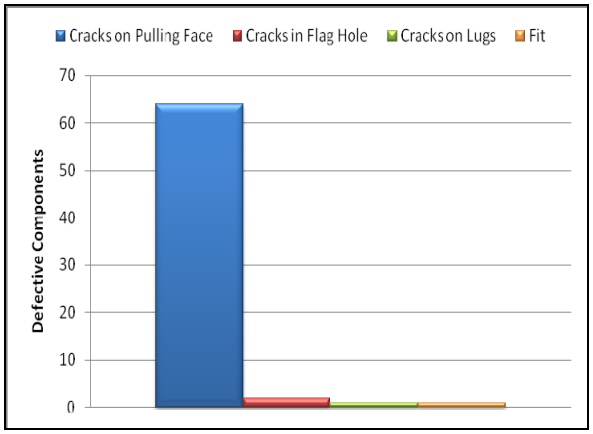

Figure 5. Survey Results for All Knuckles Examined

OBSERVED DEFECTS

Defects on several areas of the coupler body were observed during the survey. Coupler body defects consisted of cracks on the horn, shank, pin hole, and pulling lugs. Deformation and wear at the butt of the coupler shank was also a common observation. Figures 6 through 8 show typical defects found on the coupler body.

Figure 6. 3.5-inch Fatigue Crack on Coupler Horn

Figure 7. Coupler Pin Hole Defect

Figure 8. Fatigue Crack on Coupler Pulling Lug

The pulling face was the most common location for defects on knuckles. Cracks were also observed in the flag hole and on the pulling lugs. One knuckle was removed because it did not fit properly in the coupler body. This knuckle, which was new from the manufacturer, could only be removed by using a torch to cut the knuckle out of the coupler. Figures 9 and 10 are examples of defects in the flag hole and on the pulling lugs of the knuckle.

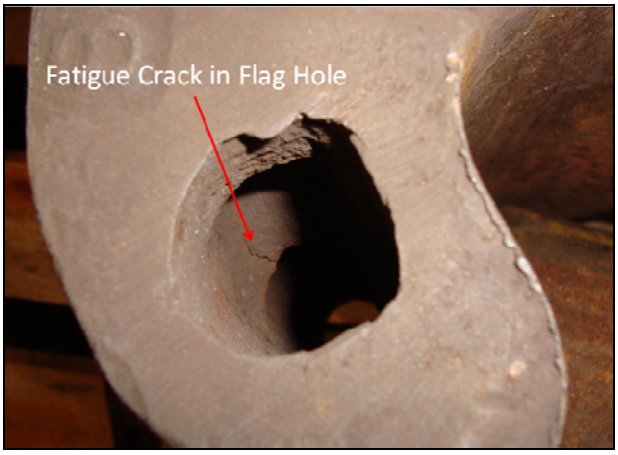

Figure 9. Fatigue Crack in Flag Hole of Knuckle

Figure 10. Fatigue Crack on Knuckle Pulling Lug

COMPARISON OF FINITE ELEMENT HIGH STRESS AREAS TO SURVEY RESULTS

High stress areas determined by finite element techniques in both the knuckle and coupler have been validated by the results of the shop survey. A comparison was made between the high stress areas identified using finite element analysis techniques and the defect locations observed for the knuckle and coupler. The data for each of these analyses shows there is a high correlation between the observed defect locations and the high stress areas of the finite element models. Figures 11 and 12 show the high stress areas found on the coupler and knuckle using finite element techniques; the red highlights show the high stress areas.

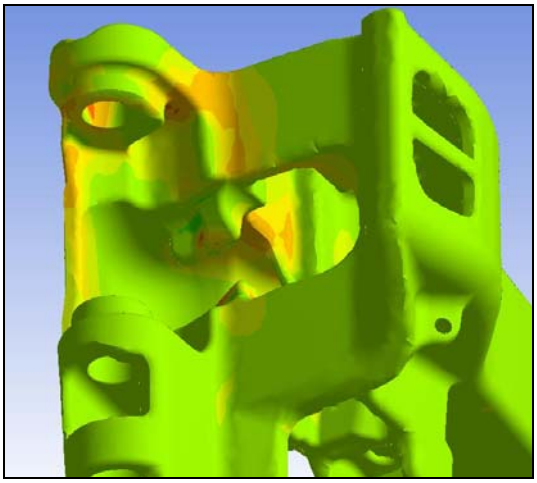

Figure 11. Coupler High Stress Areas

Comparing the finite element results to the survey results shows that the high stress areas predicted by the models are problem areas on the physical parts. Examples of the correlation include the pin hole and lug locations on the coupler body, the pulling face, and flag hole on the knuckle. In both castings, the areas exhibited high stress concentrations in the finite element model and contained a large number of defects in the survey results.

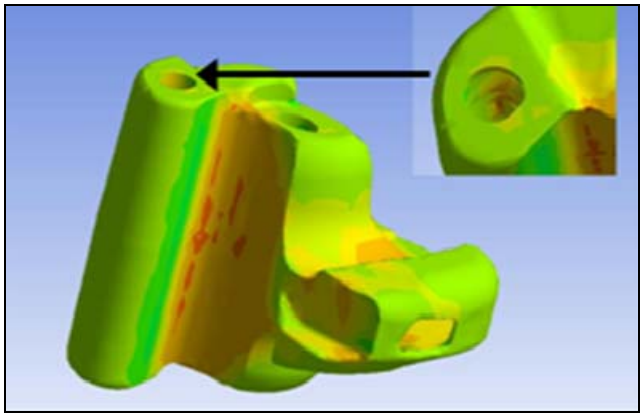

Figure 12. Knuckle High Stress Areas

CONTACT CONDITIONS AT LUG INTERFACE

The survey results indicated that the contact between the coupler and knuckle produced a high amount of wear on both castings. The lugs on the knuckles showed a 2.5 to 2.625 inch length where the two components contacted. The wear on the lugs of the couplers indicated that the contact was uniform across the contacting face of the lug. Wear was also observed on the top and front of the bottom coupler lugs. Although wear was not expected to occur here, it is highly likely that it was caused by the knuckle due to clearance problems, because the knuckle also showed wear in the corresponding area to the coupler lug.

CONCLUSIONS

The most common defects observed in the survey were butt wear and deformation in the shank of the coupler body and fatigue cracks in the pulling face of the knuckle. Comparing the results of the survey to the output of the finite element models developed by TTCI showed that the high stress locations identified in the model are valid. Observations of the contact wear areas between the coupler and knuckle indicate that fitment issues do occur. These issues can cause uneven loading and can increase stress in critical areas of the castings.

FUTURE WORK

TTCI will continue to investigate the causes and solutions for fitment problems between knuckles and couplers. Additionally, a more thorough finite element analysis of the coupling system is being completed to determine the fatigue life of the individual components with and without defects.

ACKNOWLEDGEMENT

TTCI thanks BNSF, Union Pacific Railroad, Watco, and Greenbrier for access to their facilities in order to conduct the failure survey.

REFERENCES

1. Association of American Railroads. 2007. *Field Manual of the AAR Interchange Rules*. Rules 16, 17, and 18.
2. Association of American Railroads. 2008. *Manual of Standards and Recommended Practices*, Section S, "Casting Details" Specification M-220, Washington, D.C.