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Coupler and Knuckle Assembly Interchangeability and Tolerance Investigation

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Summary

A coupler interchange was completed at the end of 2009 to better understand the fitment issues that railroads and repair shops are experiencing. New E60EE and F70DE coupler assemblies (coupler, knuckle, lock, thrower, and lock lift assemblies) from each of the major casting manufacturers were interchanged to determine if any of the components experienced fitment problems. Component manufacturers included Columbus Steel Castings (CSC), McConway & Torley (M&T), ASF-Keystone, Granite City, Illinois, (ASF-GC), ASF-Keystone, Sahagun, Mexico, (ASF-M), Bedloe Industries (Bedloe), and Workhorse Rail (Workhorse).

Results from the coupler interchange and the knuckle tolerance study indicate that a significant dimensional variability exists, and that variability often leads to inoperability of an assembly. To address the fitment and interchangeability problems observed during the interchange and tolerance studies, TTCI will continue studying the current state of knuckle and coupler component interactions and use the knowledge gained through this research to recommend improvements and updates for the current Association of American Railroads' *Manual of Standards and Recommended Practices*.

The coupler interchange tested components in lock, unlock, and lockset operations. Any unsuccessful operation was documented as a failure. Analysis of the data collected during the interchange showed that the failure rates for the lock, unlock, and lockset operations ranged from 13 to 28 percent for E-type assemblies and 0 to 17 percent for F-type assemblies. In several instances with the E-type assemblies, components manufactured by a single foundry failed the interchange test. The results from this test indicate that significant improvements can be made with the interchangeability of coupler assemblies.

In addition to the coupler interchange, Transportation Technology Center, Inc. (TTCI) began a study to produce tolerance distributions for critical dimensions in knuckles. Near the end of 2009, approximately 40 new knuckles from various manufacturers were scanned by a laser to collect dimensional data in critical areas. Data analysis shows that ranges of nearly 0.5 inch exist in critical dimensions of the casting. Further analysis of the tolerance spread must be completed to determine the impact of the range of values on component stress and fitment.

In 2010, TTCI plans to conduct another coupler interchange and also complete a more thorough tolerance distribution study of knuckles and couplers.

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INTRODUCTION

As part of an industry effort to improve the performance of coupling components, TTCI initiated a research effort to determine the current state of component tolerances and the influence of these tolerances on component stress and performance. The research summarized in this *Technology Digest* (TD) is part of the Train Condition Monitoring Strategic Research Initiative, SRI 6D: Improved Castings and Inspection Procedures.

BACKGROUND

The objective of SRI 6D is to improve the safety, quality, and performance of cast components by reducing the number of failures occurring in service. TTCI developed a program that focuses on three areas to achieve the project objectives:

- Component life
- Inspection and defect detection
- Interchangeability and tolerances

Each one of these areas encompasses many aspects of the design and quality of cast components. This TD details the analysis approach, results, and future work focused on defining and improving the interchangeability of cast coupling components. Additional TDs are available that summarize the activities and results relating to the two other focus areas of SRI 6D.[1,2]

Improved Interchangeability and Tolerances

The interchangeability of coupling components is of continual concern in the railroad industry because fitment problems between coupling system components result in costly train delays. In response to the fitment problems currently experienced in revenue service, TTCI has developed a methodology aimed at improving the interchangeability and tolerances of cast coupling components. The flowchart in Figure 1 details the approach that will be used to reduce the number of fitment related problems experienced in revenue service applications.

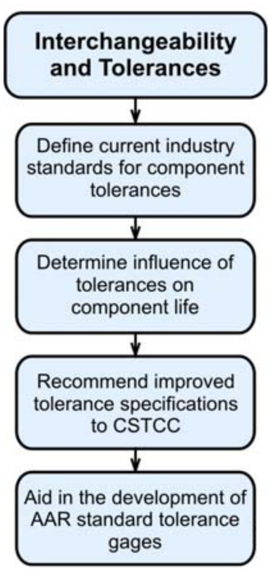

Figure 1. Interchangeability and Tolerances Flowchart

As shown in the flowchart, the first step in improving the performance of cast components is to define the problem size. In 2009, TTCI conducted a coupler interchange and a dimensional tolerance investigation to determine the current state of interchangeability of knuckles and couplers. The information in this TD details the testing and results of both the coupler interchange and the knuckle dimensional tolerance investigation.

Coupler Interchange Overview

The objective of the coupler interchange was to evaluate fitment between new coupler assemblies from each manufacturer. Although a similar interchange is conducted by members of the Mechanical Committee of Standard Coupler Manufacturers (MCSCM), an industry objective to develop a broader perspective on the interchangeability of knuckles and couplers led to the decision to conduct an independent interchange at Transportation Technology Center (TTC). The interchange testing was completed under the direction of the AAR Strategic Research Initiatives Program and the Coupling Systems and Truck Casting Committee (CSTCC).

Using an independent and neutral approach, the interchange conducted at TTC allowed for evaluation of components from manufacturing facilities that are not included in the interchange completed by the members of the MCSCM. By including all manufacturers in the evaluation, TTCI has developed a full understanding of the current state of interchangeability in revenue service. All manufacturers represented in the interchange were notified of the testing, but none were allowed to attend the event. Only TTCI staff and CSTCC members were in attendance during the interchange.

Coupler Interchange Description

The interchange testing was completed using new E60EE and F70DE coupler assemblies from each manufacturer. All testing was conducted in the Passenger-Rail Service Building at TTC. TTCI, in conjunction with the CSTCC, designed and constructed several test fixtures to enable safe interchange of all of the test components. Figure 2 shows the test table that was built to accommodate a total of six coupler assemblies.

Figure 2. Interchange Test Table

Table 1 lists the components that were randomly selected from stock and included in the interchange. Only components that are AAR approved (full or conditional) were tested. CSTCC members donated all components.

Table 1. Components Used in Coupler Interchange

Manufacturer	Coupler Body	Lock	Thrower	Knuckle
Columbus Steel Castings	E, F	E, F	E, F	E, F
McConway &Torley	E, F	E, F	E, F	E, F
ASF-Keystone Granite City	E, F	E, F	E, F	E, F
ASF-Keystone Sahgun, Mex.	E, F	E, F	E, F	E, F
Bedloe Industries	E	E	E	E
Workhorse Rail	-	-	-	E, F
Total E-Type	5	5	5	6
Total F-Type	4	4	4	5

Each of the component variations was tested under lock, lock set, and unlock conditions. Anticreep conditions were also monitored for each of the component variations, but are not included in final results.

The test matrix consisted of testing components in their original condition (all original parts of the assembly), then changing out one component (knuckle, lock, and thrower) at a time. For each variation, three opportunities for success or failure exist (lock, lockset, unlock). An additional check for knuckles was conducted because the lock dropped behind the knuckle in several instances, which also is reported as a failure in the summary statistics. Any unsuccessful operation was documented as a failure. Also, no field modifications (e.g., grinding) were allowed during testing. All reported results are for the component in its as-manufactured condition.

Coupler Interchange Results

Data collected during the interchange showed that the failure rates for the lock, unlock, and lockset operations by component ranged from 13 to 28 percent for E-type assemblies and 0 to 17 percent for F-type assemblies.

Table 2 summarizes the results of the interchange for E-type assemblies. The overall observed failure rate of the E-type testing was 20 percent. The largest failure rate, 28 percent, was observed in knuckles. The lock set operation was the main contributor to the high knuckle failure rate. The E-type assemblies also had fitment issues with original components. Two of the five original assemblies failed in one or more of the operations tested. Because one of the manufacturers failed in all three operations with its original components, only knuckles were varied so results from the remainder of the test would not be skewed. For this coupler body, one knuckle passed all three test operations and one knuckle passed all but the lock set operation. All other knuckles failed in all three operations with this coupler body. The other coupler body that failed with its own components showed high failure rates for all manufactures knuckles in the lock set operation. Only one of the six knuckles tested in this coupler body passed the lock set operation. A comparison of failure rates by manufacturer was also completed. Results by manufacturer shows observed failure rates ranging from 9 to 55 percent.

Observed failure rates were significantly lower for F-type assemblies than for E-type assemblies. The overall failure rate for F-type assemblies was 7 percent, as Table 3 shows.

Table 2. E-Type Assembly Interchange Data

E-type Assembly Summary Stats - By Component (Approved only)				
Component	**Thrower**	**Knuckle**	**Lock**	**Total**
Opportunities	63	120	63	246
Failures	8	33	8	49
Failure Rate	13%	28%	13%	20%

Table 3. F-Type Assembly Interchange Data

F-type Assembly Summary Stats - By Component				
Component	**Thrower**	**Knuckle**	**Lock**	**Total**
Opportunities	48	60	48	156
Failures	0	10	1	11
Failure Rate	0%	17%	2%	7%

Once again, knuckle fitment issues had the highest rate of failure for all components at 17 percent. The variation between manufacturers was also not as significant as the E-type assemblies. The observed failure rate by manufacturer ranged from 0 to 58 percent.

Results from the coupler interchange show that there is a significant likelihood of coupler inoperability due to poor fitment of new components between manufacturers. To further understand the problem size and its influence on the performance of coupling component performance, an investigation into the as-manufactured tolerances of knuckles was completed. The following sections detail the procedures and analysis used to serve as a preliminary review of current tolerance standards.

Tolerance Investigation Overview

In addition to the results of the coupler interchange reported above, static testing and finite element results reported in previous TDs indicate that the tolerances of knuckles and couplers play a key role in the working stresses of the components.[1,2] To evaluate the current state of as-manufactured tolerances of knuckles, TTCI selected a random sample of 31 new knuckles from four different manufacturers to measure critical dimensions and report on the tolerances for all of the components.

The external surfaces of new knuckles were scanned by a laser to collect dimensional data. The data was used to compare variance in dimensions from manufacturer to manufacturer and to compare dimensions of multiple knuckles from the same manufacturer.

DATA COLLECTION AND ANALYSIS

Dimensional data was collected in critical fitment areas for each of the 31 knuckles. Twelve critical dimensions and several other comparison points were measured. Figure 3a is a sample of the initial scan data collected using laser scanning techniques, and Figure 3b is an example of locations of measured dimensions.

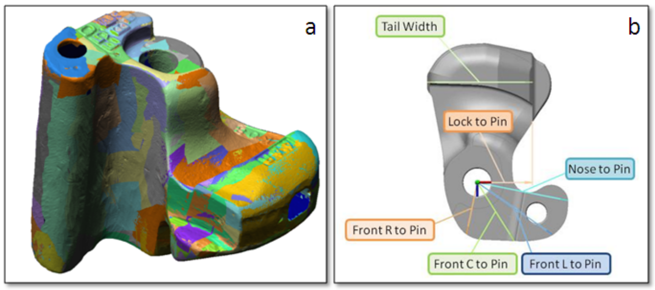

Figure 3. (a) Sample of Knuckle Laser Scan Data and (b) Measured Dimension Locations

The dimensional features measured from the model include:

- Pin hole diameter
- Distance between lock and pin hole
- Distance between nose and pin hole
- Distance between top lug and pin hole (3 locations)
- Hub, tail, and lock height
- Tail width
- Distance from tail to hub
- Distance between thrower and pin hole

Once scan data for all of the knuckles was collected, ranges were established for all of the specified dimensions. The ranges of dimensions measured varied from less than 0.05 inch to over 0.60 inch for all manufacturers. The tail height measurement had the largest variation, with a range of almost 0.65 inch. Figure 4 shows the range of several measured dimensions for all manufacturers.

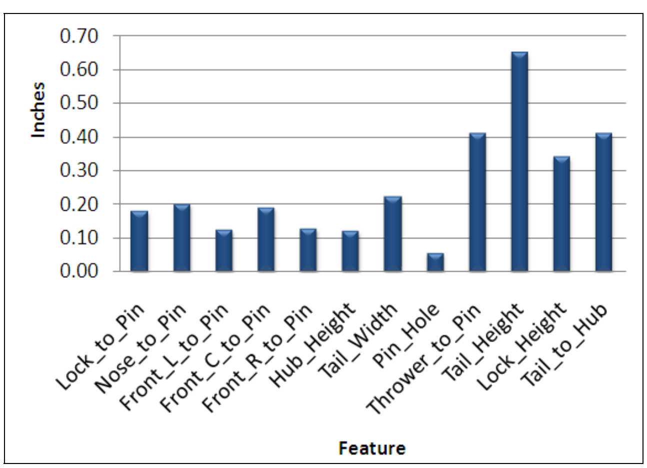

Figure 4. Range Comparison for All Manufacturers

Dimensional variability was also determined for each manufacturer. Figure 5 is a plot of measurement ranges by manufacturer. The data indicates that manufacturer 3 has more variation between parts than the other manufacturers. This is especially apparent in the bottom hub measurements, where the hub height is measured between the top and bottom hubs in three different locations.

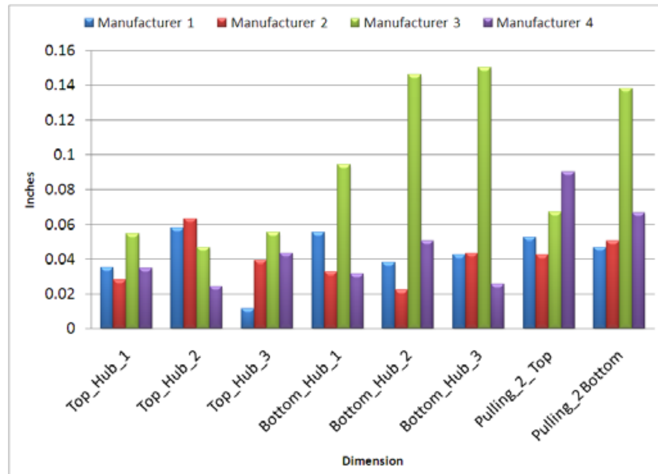

Figure 5. Range Comparison by Manufacturer

The results from this study show that current knuckle tolerances need to be thoroughly reviewed and changes are necessary to eliminate fitment problems of coupling components.

CONCLUSIONS AND FUTURE WORK

The coupler interchange and the knuckle tolerance study indicate that significant improvements can be made with the interchangeability of coupler assemblies.

To address the problems of fitment and interchangeability, TTCI will continue studying the current state of knuckle and coupler component interactions and use the knowledge gained through this research to improve and update the current AAR *Manual of Standards and Recommended Practices*. In 2010, TTCI plans to conduct another coupler interchange and also complete a more thorough tolerance distribution study of knuckles and couplers.

REFERENCES

1. Carter, Daniel and Kari Gonzales. September 2009. "Influence of Lug Contact Misalignment on Knuckle and Coupler Stress." *Technology Digest TD* 09-023. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Gonzales, Kari and Daniel Carter. May 2010. "Finite Element Analysis of a Knuckle and Coupler Assembly." *Technology* Digest TD-10-016. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.

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