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Summary Statistics of Broken or Cracked Cast Car Components

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Summary

As part of an ongoing effort to improve the safety of train operations and improve capacity through fewer train partings and in-service failures, Transportation Technology Center, Inc. (TTCI) is investigating the rate and types of broken or cracked cast car components that have occurred recently in revenue service. The work described in this *Technology Digest* (TD) has been completed under the Association of American Railroads' Strategic Research Initiatives Program.

An average of over 160,000 cast car components are removed from service each year because they are either cracked or broken. TTCI, in conjunction with several Class I railroads and representatives from the Coupling Systems and Truck Castings Committee, is addressing this problem by an ongoing effort to collect detailed failure data for cast components. This data may then be used to determine root causes of failures and may also help in the development of nondestructive inspection procedures, which have the potential to reduce the number of catastrophic failures occurring in service. Analyses to date show:

- On average, over 80,000 knuckles and over 56,000 couplers are found to be broken or cracked each year.
- The top four car types for knuckle removals are auto racks, equipped box cars, general service flat cars, and rotary dump gondolas.
- The pin protector and the pulling face are the two most common locations for crack formation or failure in couplers and knuckles.
- Common failure locations for bolsters include the brake rod holes and the transition radius between the end and tension member.
- The inner pedestal radius and the tension arm are two common failure locations for side frames.
- The necessary information to produce a reliable failure mode analysis is not available at this time due to the minimal amount of failure reports of cast components in-service.

This TD describes analyses focused on determining the number of broken components reported in the past 9 years for bolsters, side frames, knuckles, and couplers. Additionally, a detailed analysis to define common fracture locations and conditions of bolsters, side frames, couplers, and knuckles is included. Future reports will feature related efforts focused on determining component stress levels, fatigue life estimates, and nondestructive testing procedures.



INTRODUCTION

As part of an ongoing effort to improve the safety of train operations and improve capacity through fewer train partings and in-service failures, TTCI is investigating the rate and types of broken or cracked cast car components that have occurred recently in revenue service.

BACKGROUND

An increasing number of in-service fractures of side frames, bolsters, couplers, knuckles, and other drawgear components have been observed in recent years. Action was taken to define the failure rates, critical stress areas, and primary fracture types/locations for each of these components in response to the increasing number of broken components reported by railroads. This TD focuses on determining the number of broken components reported in the past 9 years for the cast components listed. Additionally, a detailed analysis is included to define common fracture locations and conditions of bolsters, side frames, couplers, and knuckles. Future reports will feature related efforts focused on determining component stress levels, fatigue life estimates, and nondestructive testing procedures.

Data Collection

Class I railroads were surveyed to determine the number of broken and cracked components that occurred between 2000 and 2008 on a variety of cast car components. Because the initial response was minimal and the survey results did not yield the amount of information necessary to complete a formal analysis, TTCI used the Car Repair Billing Data Exchange (CRBX) data to gain a better understanding of the current number of failures occurring in the railroad industry. This TD summarizes the results of the data collected from the CRBX, respondent surveys, and the failure matrix database developed by TTCI under the guidance of the Coupling Systems and Truck Castings Committee (CSTCC).¹

CRBX Analysis

Data was collected from the CRBX for broken/cracked bolsters, side frames, couplers, knuckles, draft gear, and yokes that occurred between 2000-2008. The analysis used only AAR Field Manual Why Made (WM) codes for broken and cracked components. WM codes 79 (cracked behind horn), 82 (cracked front face), 86 (cracked key slot), 87 (cracked pin protector), and 88 (cracked behind pulling lug) were also used for the coupler portion of this analysis.²

Figure 1 shows the results of the CRBX analysis. The removal year is on the horizontal axis and the number of removals per year is on the primary vertical axis of the chart. The secondary vertical axis (right side) shows the sum of all broken/cracked components per year and is represented by the green line.

As a group, cast components account for an average of over 160,000 removals every year. Figure 1 shows that knuckles (blue bar) and couplers (red bar) are the highest contributors to

the total number of removals of cast car components per year. On average, over 80,000 knuckles and over 56,000 couplers are found to be broken or cracked each year.

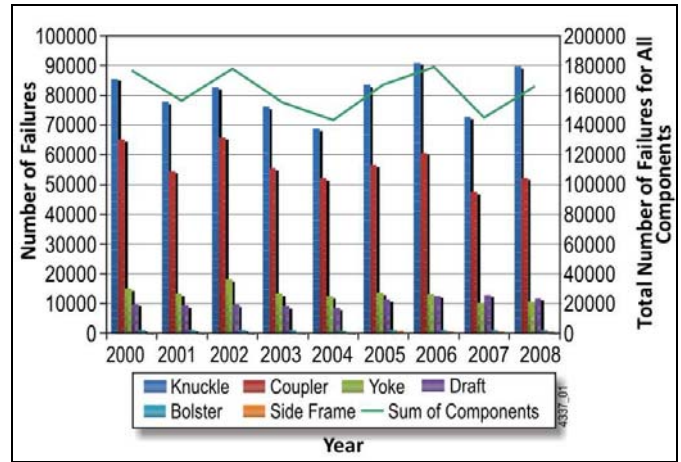


Figure 1. Casting Removals between 2000 and 2008

Several activities are ongoing as a result of the initial analysis of the CRBX data. Examples include an analysis of the costs incurred due to the broken or cracked components and more detailed analyses for root causes of failures. The next section provides preliminary analyses for root causes of failures for knuckles, bolsters, and side frames.

Removal Analysis of Knuckles

The CRBX was used to determine if removal trends for knuckles are observed based on car type and age. Similar analyses will be completed for other cast components in the future. Figure 2 shows the results produced from the CRBX data analysis for the total number of knuckle removals of broken or cracked components based on car type between 1963 and the present. The data is normalized for the number of cars in service. Table 1 is a legend for the car types shown in Figure 2.

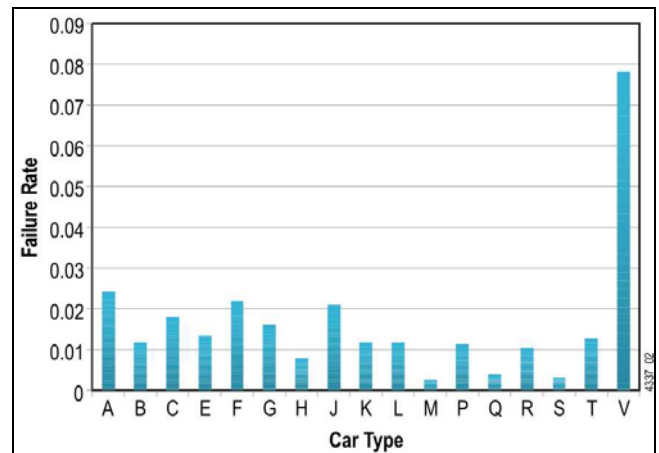


Figure 2. Summary of Removals Based on Car Type

Table 1. Car Type Legend for Figure 2

Graph Label	Car Type	Graph Label	Car Type
A	Equipped Box Car	L	Special
B	Plain Box Car	M	Maintenance of Way
C	Covered Hopper	P	Conventional Intermodal
E	Equipped Gondola	Q	Light Weight, Low Profile Intermodal
F	General Service Flat	R	Refrigerator
G	Plain Gondola	S	Double Stack
H	Plain Open Hopper	T	Tank
J	Rotary Dump Gondola	V	Auto Rack
K	Rapid Discharge Open Hopper		

The results shown in Figure 2 indicate that the top four car types for knuckle removals are auto racks (V), equipped box cars (A), general service flat cars (F), and rotary dump gondolas (J). Cushioned draft gear units used on auto racks are a possible source of the increased removals. More investigation into the performance of cushioned and noncushioned units under draft load conditions is necessary before conclusions can be drawn about the cause of increased removals in auto racks.

An additional analysis was conducted to determine if a particular series of car (car build year) was responsible for higher removal rates of knuckles from auto racks than the other cars studied in the analysis.

Figure 3 is a normalized plot of the knuckle removal rate by car build year. The maximum removal rate of 0.1226 occurred in 1992. For that car build year, a total of 353 knuckles were removed from 26,479 cars. Although there is a slight upward trend in removal rates, the variation for the past 44 years has not been significant.

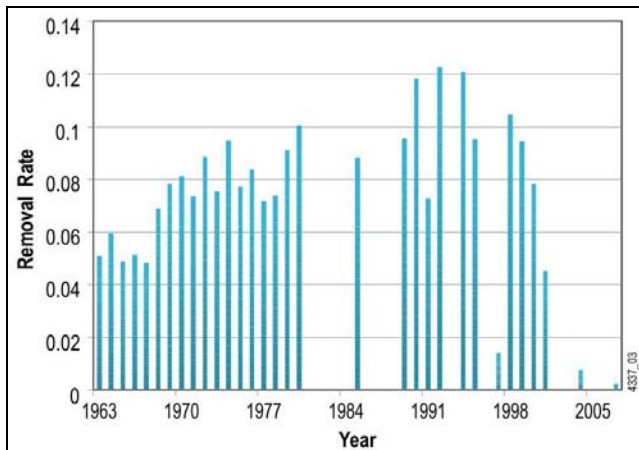


Figure 3. Auto Rack Knuckle Removal Rate by Car Build Year

Industry Failures of Cast Components

Another source of information on cracked or broken cast components is a failure matrix database under development by TTCI and the CSTCC. The database is a collection of industry reported failures of cast components. To date, the database is relatively small in comparison to the number of removals that occur every year. Figure 4 is a plot of the side frame, bolster, knuckle, and coupler failures available in the database for years 2000-2008.

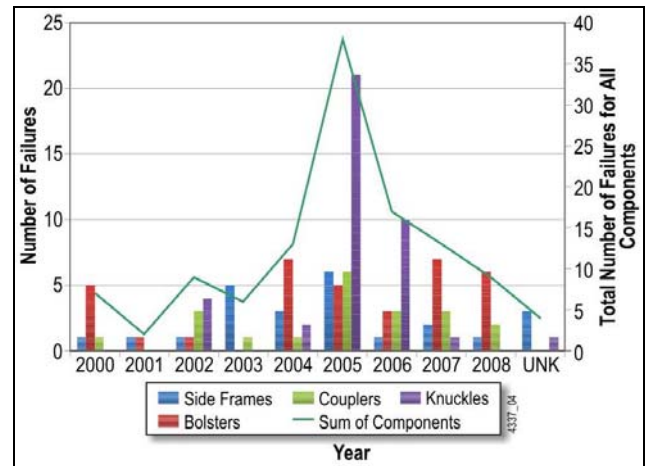


Figure 4. CSTCC Reported Failures for 2000-2008

In 2005, there were a total of 38 failures reported among side frames, bolsters, couplers, and knuckles compared to the 142,058 reported removals listed in the CRBX for the same subset of components over the same time period. Therefore, in order to conduct an accurate root cause of failure analysis, more data from the industry must be provided to add to the CRBX database.

Knuckle and Coupler Teardown Data

In early 2009, the results of the CRBX data analysis and industry reported failure analysis were presented to the railroad industry. In response to TTCI's efforts to obtain more detailed information on broken or cracked components, a western railway conducted a small inspection of knuckles and couplers at its maintenance shop. Table 2 shows the results of the teardowns.

Table 2. Knuckle and Coupler Teardown Summary Provided by a Western Railway

Component	Quantity Inspected	Percent Cracked	Percent Broken
"E" Couplers	2,410	3.9	0.41
"F" Couplers	1,818	10.2	0.28
Knuckles	4,228	35.5	0.14

Table 2 shows that over 21 percent of the 8,456 components inspected were either cracked or broken. A detailed inspection was also conducted for each of the broken/cracked components. Figure 5 shows the percentage of failures that occurred at each location for the inspected couplers (left side) and knuckles (right side).

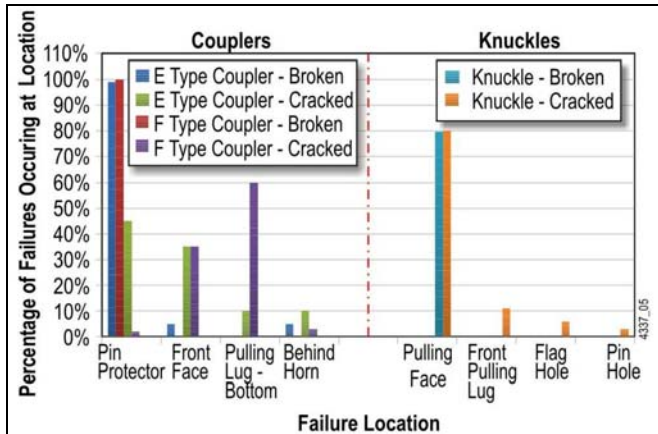


Figure 5. Coupler and Knuckle Failure Locations

The teardown results show that the pin protector and the pulling face are the two most common locations for crack formation or failure in couplers and knuckles. This data was compared to strain data collected during static testing conducted by TTCI in early 2009 to determine if any correlation existed between the high stress areas during static testing and the failure locations found in the teardowns.⁵ Static testing and teardown results indicate that the pulling face is a critical area of the knuckle. No strain gages were located at the pin protector of the coupler, so correlation could not be established.

Bolster and Side Frame Failure Locations

A detailed report is available for each of the components contained in the TTCI/CSTCC failed cast component database. Typically, the location (on the part) of the failure and possible causes for the failure are listed in the database. Figures 6 and 7 are examples of failure location data that has been extracted from the failure matrix database. The inset drawings in each of the figures show the failure locations (in bold) listed in the chart.

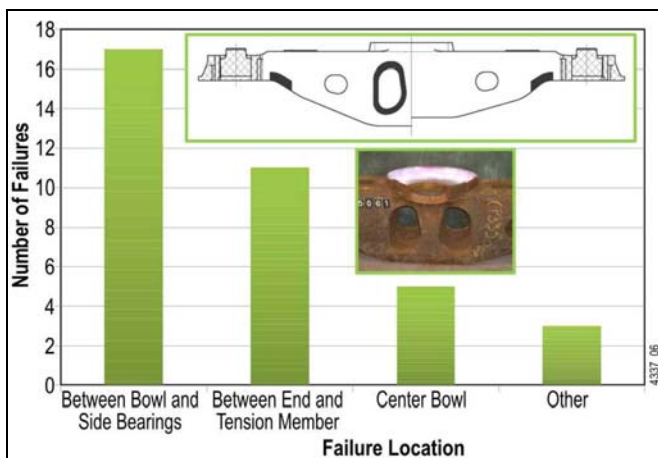


Figure 6. Bolster Failure Locations

The data in Figure 6 shows that the majority of the reported bolster failures occurred between the center bowl and the side bearing at the brake rod hole. A secondary area of common failures is in the transition area between the end and the tension member.

Figure 7 indicates that the pedestal radius generates the most failures for side frames reported in the database.

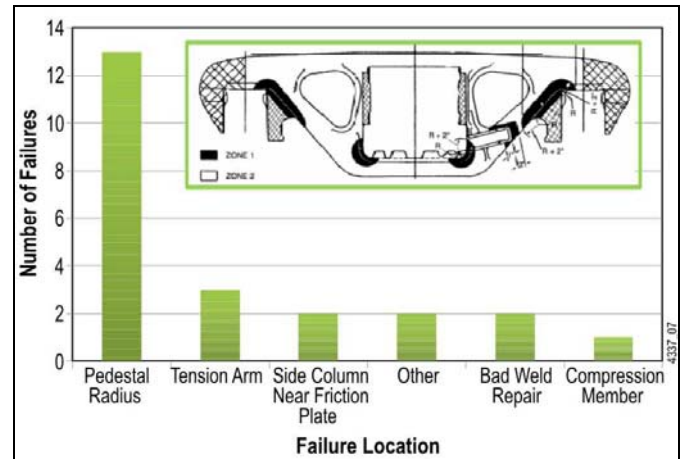


Figure 7. Side Frame Failure Locations

CONCLUSIONS

The railroad industry continues to experience in-service failures of cast car components. Although the necessary data to determine root causes of component failures is inaccessible at this time, it exists and should be used to assist in the development of higher quality castings and improved inspection techniques to detect cracked or broken components.

FUTURE WORK

TTCI will continue to compile data for the purpose of determining failure modes and patterns for cast car components. As more data becomes available, TTCI will report results in future TDs and Research Reports.

ACKNOWLEDGEMENT

TTCI thanks the members of the CSTCC for sharing their expertise and for their persistence in the development of the failure database. Also, a special thanks to Tom Guins for mining the CRBX for the data presented in this TD.

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