NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Norfolk Southern Railway general merchandise freight train 32N derailment with subsequent hazardous material release and fires, in East Palestine, Ohio, on February 3, 2023

GROUP	E
EXHIBIT	
2	

Agency / Organization

American Society of Metals

Title

Exhibit 2- Iwand, ASM 11A, 2021

accordance with the MSRP, corrosion pits are to be removed within the fillet area.

The fillet and dust-guard area (just inboard of the fillet) are coated with Tectyl (Ashland Consumer Markets) product (Ref 5). Tectyl dries to a waxy consistency that, when properly applied, forms a sealing surface between the backing ring and the axle. To protect the sliding surfaces during application of the bearing and to provide a seal on the inboard side of the bearing, one of several oil-based materials is applied to the fillet and journal. A breakdown of the wheelset components is shown in Fig. 12.

Since the adoption of the 286,000 lb gross rail load (GRL) freight cars, all wheelsets must be assembled with fitted backing rings on fitted axles. This means that the backing ring must have an interference press-fit onto the axle. Figure 13 compares a fitted backing ring with a nonfitted backing ring arrangement. This axle was found to have a fitted backing ring. (For non-286,000 lb GRL axles, it is possible that fitted backing rings could be applied to nonfitted axles. The backing ring would cover the dust guard of the axle; however, the axle dust guard would be too small in diameter to provide a press fit.)

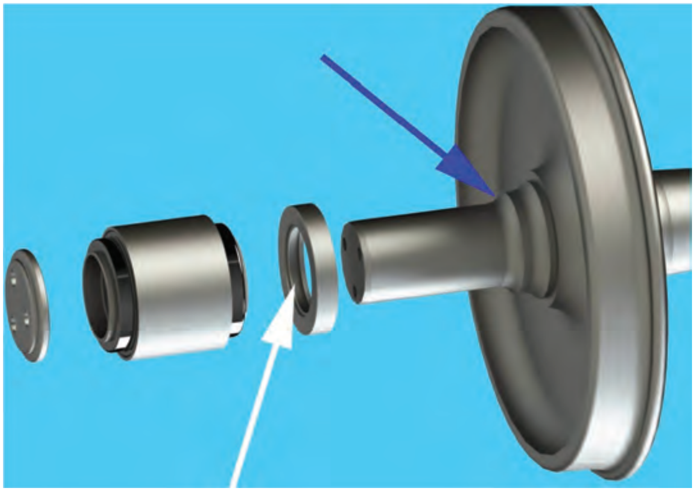

Fig. 12 One-half of wheelset showing journal fillet (blue arrow), backing ring blend radius (white arrow), cartridge bearing, and end cap (at left)

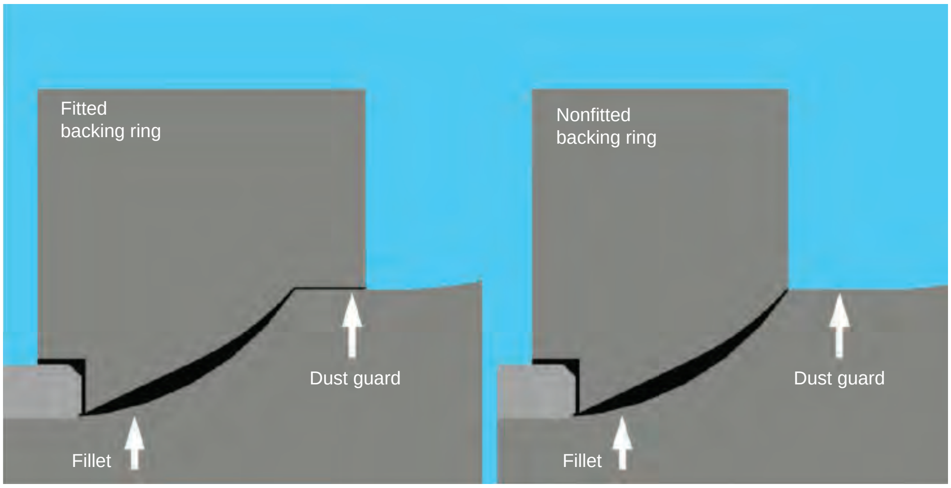

Fig. 13 Cross-sectional view of fitted backing ring on a fitted axle versus a nonfitted backing ring on a nonfitted axle

Background

There is no routine maintenance interval (mileage or time) for bearings, wheels, or axles on freight car wheelsets. Maintenance rules are outlined in the AAR *Field Manual of Interchange Rules*, which includes Why Made (WM) codes that dictate wheel, axle, and bearing conditions that, if met, are cause for the wheelset to be removed from operation. With the exception of overheated, leaking grease, and noisy bearings, all of the other WM codes are directed to the wheels and axle condition. When a wheelset is returned to a wheel shop, the bearings must be removed and reconditioned prior to reapplication of an axle. Similarly, axles do not have an aging-out rule; as long as the dimensions meet the requirements as outlined in AAR MSRP G and G-II, the axles can be reconditioned and placed back into service in an "as-new" condition indefinitely. The same can be said of wheels. However, because the treads of the wheels do wear, it is generally true that when wheels are pressed off an axle, they will no longer be remounted to an axle.

Analysis

Axle Inspection

The bearings were pressed off both journals using a hydraulic bearing puller. The axle identification stampings indicated that the axle was manufactured in August 1992. In addition, the markings indicated that the axle had been normalized and tempered in accordance with AAR grade F axles.

The fracture surfaces were cleaned with a nylon brush and soapy water to facilitate a more thorough inspection. Figures 14 and 15 show both halves of the fracture surfaces, with a singular fatigue-crack-initiation site along the outer surface. Beach marks present on the fracture surface confirmed that the crack grew much of the distance through the cross section of the axle prior to sudden rupture and complete separation of the journal. The fracture surface on the wheelset was mechanically damaged postfracture. The postfracture damage destroyed the initiation site of the fracture surface.

The mate journal after bearing removal is shown in Fig. 16 and 17. Pitting is present along the Tectyl application interface. Both journals were cleaned using a solvent to remove the Tectyl from the surface of the journals. Figures 18 and 19 depict the failed

Fig. 14 Fracture surface of subject journal, axle side (arrow indicates initiation location)

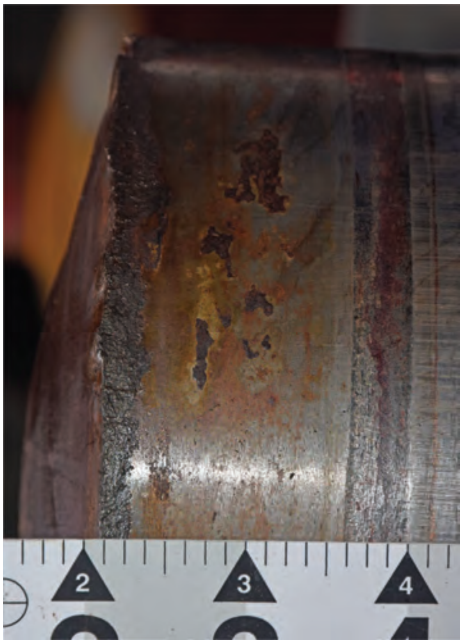

Fig. 35 Side view of axle stub, with fracture on left, showing heavy buildup and groove from seal wear ring

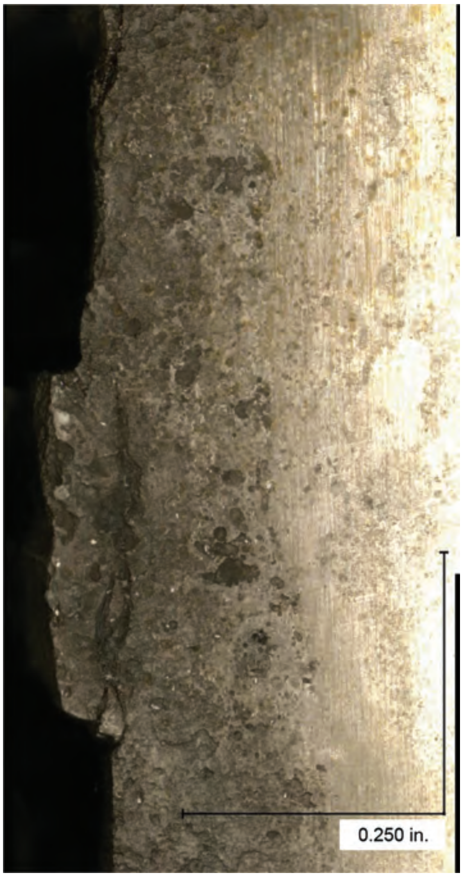

Fig. 36 Overall view of pitting near fracture surface

the pits (Fig. 38, 39). It is noteworthy that there are no abrasion marks present in the embedded debris. In reconditioned bearings, it has been observed that the embedded debris contains abrasion markings due to the abrasion that occurs during the reconditioning process. Of course, if properly reconditioned, there should be no pitting present in the filet area of the journal.

Greater magnification inspection around the circumference of the axle revealed additional fatigue cracks (secondary) near the fracture surface (Fig. 39).

Results and Discussion

Advanced pitting corrosion occurred between the fitted backing ring and the axle journal. The pitting acted as stress-concentration locations when the axle rotated under load. Fatigue cracks initiated in multiple locations around the circumference of the journal in the area of corrosion, leaving the distinctive ratchet marks observed on both fracture surfaces. The fatigue cracks then coalesced into a primary crack, which progressively propagated through the cross section of the axle and finally failing in bending overload, causing the derailment. In contrast, journals that have failed after reconditioning often do not exhibit multiple ratchet marks; rather, the fracture initiates from a singular location or area of the journal with minimal ratchet marks present.

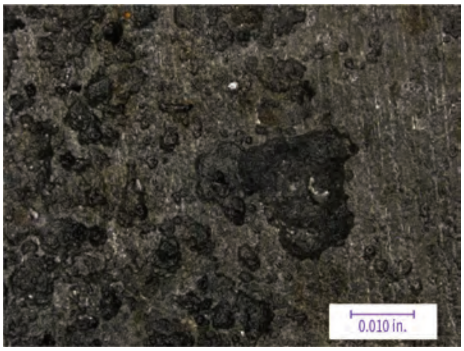

Fig. 37 General pitting present in the axle. Note parallel lathe tooling marks interrupted by corrosion pits

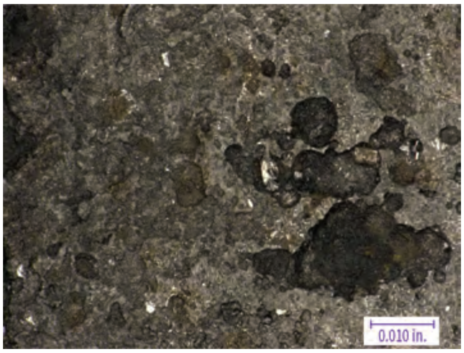

Fig. 38 Pronounced pitting present on journal surface. Note the corrosion material embedded in some of the pits

Notably, the mate axle journal had only minimal rust behind the backing ring, and the rust inhibitor applied to the axle journal fillet prior to bearing application appeared to be in good condition. No conclusive evidence was identified as to why there was a notable amount of corrosion present under one backing ring versus the other.

Conclusions

The axle journal failed due to the presence of corrosion pits around the circumference of the journal below the backing ring and seal wear ring. The corrosion pits raised the localized bending stress above the endurance limit and initiated multiple fatigue cracks on the circumference of the journal. The fracture surfaces were consistent with the morphology of rotating-bending fatigue.

The bearing was applied new to a new axle in December 1990; the installation was in operation for more than 30 years with no maintenance. The mate side of the axle still had intact rust inhibitor on the journal and a minimal amount of corrosion present on the end cap, whereas the subject side contained a notable amount of corrosion on the end cap and on the journal near the pitting and fracture area. No evidence was discovered to explain why one journal had corrosion on the journal fillet while the other journal was in a noncorroded condition.

Bearing Failures

When railroad components fail, the component often becomes substantially more damaged before the failure is detected. This especially holds true for overheated freight car bearings, because they generate sufficient heat to damage all components involved, including the axle journal, the location where the bearing is applied, causing what is known

Fig. 39 Secondary fatigue cracks present near primary fracture surface

as burnoff. A teardown of the mating bearing to inspect for damage is often performed to help infer the cause of failure of the burned-off bearing.

The general arrangement of the axle journal and bearing is shown in Fig. 40. Note that the double-taper roller bearing inner races as well as the seal wear rings are interference-fit to the axle journal. After pressing the bearing onto the axle journal, an end cap and three cap screws maintain the compressive load onto the bearing stack.

The aftermath of failed bearings can indicate the speed at which the failure occurred and the resulting location where the heat was applied. The majority of roller bearing failures occur on the most highly stressed part of the bearing, which is the inner cone, because the stresses are greatest closest to the wheel. When the inner cone fails, the heat generated causes rapid heating and failure of the journal. Because the inner race is the high-stress-concentration location, the axle fails quicker, and the remaining journal stub is typically shorter. When the outboard cone fails first, the entire journal is heated until the stresses at the point of highest stress (next to the wheel) cause the journal to fail. Because heating occurs from the outside in, the journal is eventually deformed and elongated, resulting in a long, tapered journal stub. Figures 41 and 42 show the differences in location when initial failure occurs at the inner race location versus the outer race location.

There are a few common causes of bearing failures in freight car service. Because railroad bearings are meant to last for many years with no maintenance, the more common failures that are not related to wear over time, such as lubrication breakdown, general spalling of components, or uneven loading of the bearing, are not covered. Three common types of bearing failures seen in rail service are loose components, water ingress, and failures due to high impacts, resulting in broken internal components.

Loose Components

When disassembling a bearing, it is important to examine the front hub and plate of the wheel, because it often can contain grease that escaped from the bearing, a sign that the grease seal was compromised. An indication of bearing component stack loss is that the cap screw torques holding the bearing end cap in place are low when compared to the installation torque. The normal bolt torques are in the range of 290 to 420 lb/ft, depending on the bearing size. If the torques are less than the specified values, the preload of the bearing cartridge assembly will result in poor lateral retention and end loading of rollers, which can lead to overheating. Tapered roller bearings are designed to operate on the crown, or center, or the roller. When the clamp load is lost and the bearing rollers are end loaded, the ends of the bearings will spall and fail (Fig. 43).

While the cap screws were likely installed with the proper torque, over time and usage the flexing of the axle journal will lead to fretting damage between the bearing cones and seal wear rings. When the components of the bearing begin to lose the lateral clamp load, movement of the components can exacerbate the issue by wearing further. Back face wear of the roller cones occurs when the cone interacts with the seal wear ring, wearing a step into the cone. The loss of material reduces the lateral preload. Figure 44 shows the step created from back face wear in the roller cone.

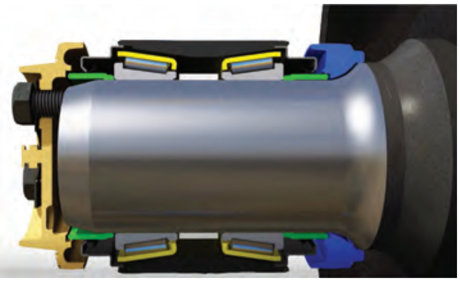

Fig. 40 Sectional view of the cartridge bearing and related components on the axle journal

Fig. 41 Burned-off journal stub. The short, rough stub indicates high heat over a short time period and is associated with an inner cone failure

Fig. 42 Burned-off journal stub. The long, thinned-out journal indicates that the bearing was hot over a long time period and is associated with an outer cone failure

Fig. 43 Tapered roller bearing fracture from end loading due to loss of lateral clamp force

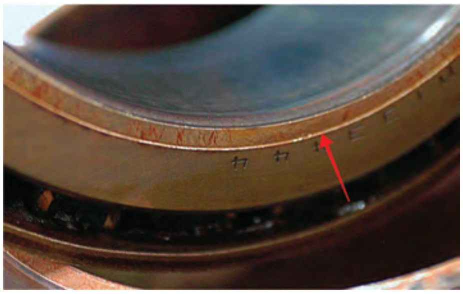

Fig. 44 Back face wear of a bearing cone. Arrow indicates the step present from wear against the seal wear ring

So-called spun cone failures occur when the cones fret into the axle journal and lose the interference fit due to fretting. The loss of radial clamp load may be from improper interference fit of the components. Spun cone failures generate heat, resulting in discoloration of the bearing components and fretting damage.

A wheelset with a failed bearing was inspected. It was found that the mate bearing to the failed side had a cone that showed fretting wear (Fig. 45) and discolored rollers. The failed-side bearing had fused together the inner bearing components (Fig. 46).

Water Ingress

Another common failure mode is water ingress into freight rail bearings, causing accelerated failure. The most prevalent sign of water ingress is free water during the bearing removal and disassembly process, followed by emulsified grease. Grease that has had water emulsified into it appears milky (Fig. 47) rather than the normal black or yellow. It should be noted that the aforementioned fretting damage stains the grease a red-rust color, but this coloring could also be due to rusting of components. Therefore, caution should be practiced to evaluate the seal condition for wear before concluding that the grease discoloration is due to water ingress. Water intrusion into the bearing results in lubrication breakdown. When teardowns of bearings are performed, the amount of grease present is measured by weight; if the amount of grease is over the specified amount, it can be assumed that at least that much water has been trapped. Water ingress often happens from worn-out seals, fit, or the cars were exposed to flood water.

Water entrainment in the grease leads to water etching of the rolling bearing components (Fig. 48). Water etching leads to spalling of the races and rollers. These spalled fragments that are now also entrained in the grease act as an abrasive, wearing rollers and cages. If the cage roller pockets wear sufficiently, the rollers skew in the pockets and slide rather than roll. Water etching can result in cracking of the internal components of the bearings if the condition is pronounced or if sufficient time has transpired to reach a critical point. Figure 49 shows microcracking present with water etching and rust on the cup of a bearing.

Fig. 45 Fretting wear on the inside diameter of a bearing with a spun cone

Fig. 46 Damage from a spun cone bearing failure. All internal components were fused together

Wheel Impacts

Often, the mate bearing does not provide reasons for the failed bearing. If end cap retaining bolt torques and bearing surface conditions do not cause concern, one could look to the wheel on the side of the failed bearing. Tread shelling or other wheel defects can cause elevated impact loading to the bearing due to an out-of-round wheel condition. Railroads employ wheel impact load detectors installed at various points throughout their networks to help identify wheelsets that need maintenance or replacement.

The impact loads can cause the bearing cage to fail in fatigue, resulting in skewed and seized rollers and an eventual failure. The cage pocket corners are the locations where the cracking occurs. Other signs of cage failure are wear marks present on the cage, due to misalignment of the rollers.

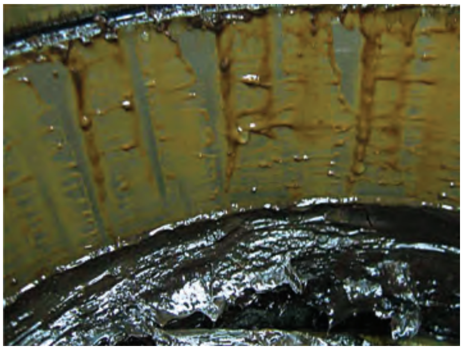

Fig. 47 Grease condition during bearing disassembly with water ingress. Free water was noted, and milky grease is present along the rolling-contact surfaces

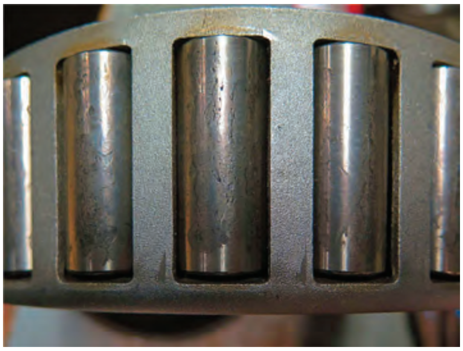

Fig. 48 Water etching present on rollers

Wheel Failure due to Corrosion

A failed wheel was found when a dragging equipment warning occurred. The train was stopped, and it was noted that a wheel was broken but riding on the rail on the hub. The failed wheel was a J33 design, forged from grade C steel and manufactured in September 1992. The locking plates on the bearings indicated that the bearings were rebuilt and installed in March 1994. Figures 50 and 51

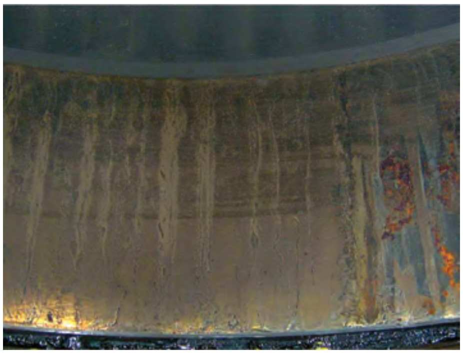

Fig. 49 Water etching with microcracking present on the cup of a bearing

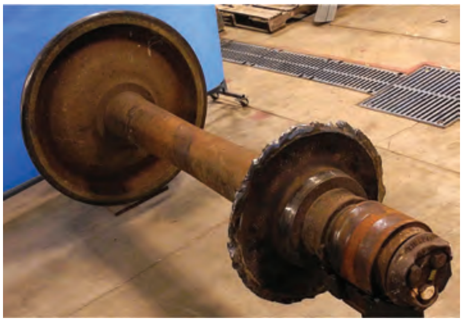

Fig. 50 As-received wheelset with portion missing

Fig. 51 As-received rim sections viewed from the back rim face. Circled area indicates initiation region