TECHNOLOGY DIGEST
TD-15-014
©JUNE 2015
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.

Damage Observed on the Treads of Wheels Removed from Revenue Service

Harry Tournay, Sabri Cakdi, and Kerry Jones

Summary

High impact wheels (HIW) removed from service for inspection by Transportation Technology Center, Inc. (TTCI) suggests that there are three generic tread damage types:

- Spalling, including brake-related and apparently continuous spalling
- Delamination, resulting in shelling and possibly HIW
- Scuffing-related tread damage, associated with surface damage (scuffing) of the tread, which progresses to form cracks and HIWs.

The classifications presented in this *Technology Digest* form a reference catalog for those conducting further inspections of wheel damage. This may assist in classifying and quantifying the different damage modes observed in service and may result in the identification of further as yet unidentified modes.

This work is part of the Association of American Railroads' Strategic Research Initiatives Program for TTCI to establish the root causes of rolling contact fatigue. Further research by TTCI into the root causes for the observed damage continues.

Please contact **Harry Tournay (719) 584-0704** with questions or concerns regarding this *Technology Digest.* E-mail: Harry_tournay@ttci.aar.com

INTRODUCTION

As part of work being performed under the Association of American Railroads' Strategic Research Initiatives Program, TTCI is tasked to establish the root causes of rolling contact fatigue in both wheels and rail. TTCI has inspected HIWs removed from service and has identified and categorized them in respect to tread damage modes.

Terms and Definitions

Spalling is a generally accepted term for the damage resulting from wheel slip. Slip generates intense local heating of the wheel in the region of the contact patch. The heated material is rapidly quenched by the bulk material of the wheel, and martensite is formed. Martensite has a larger unit volume than the parent material in the body of the wheel, and local residual stresses are created. Untempered martensite is also brittle. Subsequent rolling of the wheel causes pieces of the martensitic material to break out of the wheel tread, which results in HIWs.

Delamination is generally attributed to high subsurface stresses immediately below the contact patch. The maximum shear stress in the Hertzian stress field lies approximately 1/8-inch beneath the wheel tread surface and, together with resulting work-hardening and residual stresses, may cause delamination of the tread material. This material may subsequently break out of the tread to form shelling, a generally accepted damage mode generally resulting in HIWs. The reason for using the term "delamination" rather than shelling is that inspections suggest that the delaminated material does not always break out or break out completely from the tread and may cause other failure modes. These failure modes will be further investigated and reported later on in the SRI program.

Scuffing is a term used here to describe the surface damage associated with high steering tractions in low rail contact.[1] HIWs have been associated with lead axle low rail contact. High steering tractions may cause scuffing or pitting of the tread surface. This creates voids on the surface that allow local material flow and surface crack formation. These surface cracks grow and result in the break out of material from the tread to form HIWs.

OBSERVATIONS

Spalling

The following two types of damage have been observed during TTCI inspections and associated with spalling:

(1) Brake-related Spalling
This damage is typically associated with unreleased hand brakes and is cataloged here for completeness (Figure 1).

Figure 1 shows the results of a single slip event; however, multiple slips can occur.

(2) Continuous Spalling
An unusual form of tread damage has been observed (Figure 2). It has been provisionally cataloged as "continuous spalling," because it has the appearance of a spall, but occurring in a continuous slip mode.

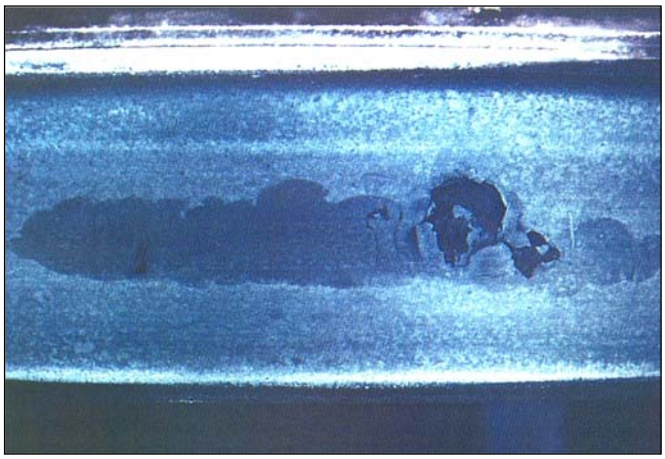

Figure 1. Typical Brake-Related Spalling showing Etched Martensite

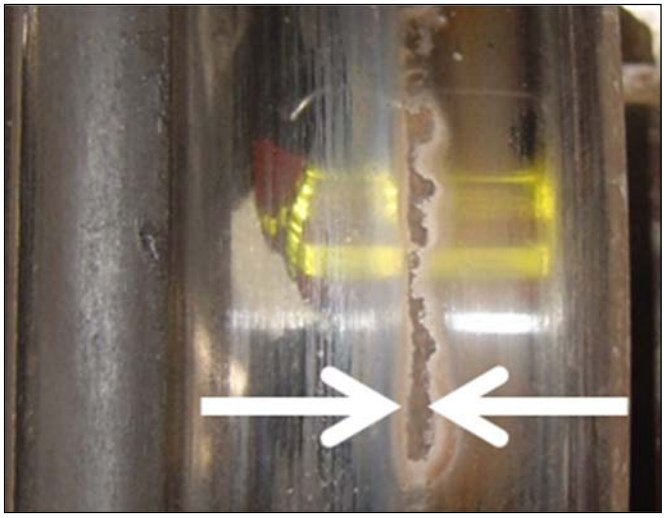

Figure 2. Continuous Spalling

Continuous spalling occurs on or near to the tape line (Figure 2). It is of limited width (Figure 3), which suggests a small contact patch and, in turn, light car conditions. The edge of the region of damage towards the flange is generally more sharply defined and linear than that to the field side. Material break out is preceded by lateral cracking (Figure 3).

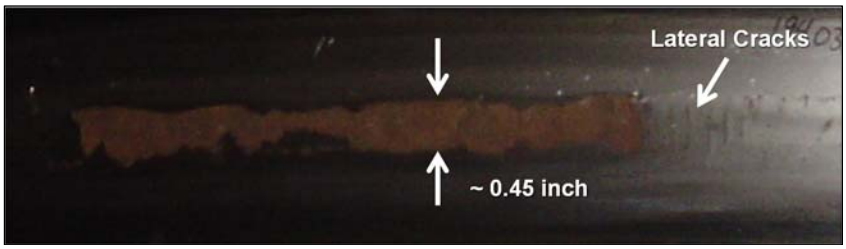

Figure 3. Continuous Spalling: Detail

Delamination

Delamination occurs typically at the depth of the maximum shear stress associated with Hertzian contact (approximately 1/8 inch below the tread surface) (Figure 4).

Delamination can occur without material break out. Figure 4 shows regions of delamination indicated by ultrasonic (UT) inspection. Care should be taken interpreting the borders of this delaminated area. The indicated area is probably larger than the actual delamination as UT measurement is a function of the size of the UT probe and the "spread" of the UT signal into the wheel.

Delamination can also result in material break out resulting in shelling, as Figure 4 shows. This results in HIWs and was the reason for removal of the wheel from service.

Note that the shelled wheel in Figure 5 shows no sign of surface cracks that might be indicative of scuffing-related failure discussed elsewhere in this TD. Figure 5 shows details of the shelling failure. There are no signs of fatigue beach marks that might be associated with crack growth. TTCI research suggests that beach marks may be worn-away through fretting during the delamination stage of failure prior to break out of the delaminated portion of the tread.

Scuffing-Related Tread Damage

Scuffing-related tread failure is associated with surface damage (scuffing) of the tread, generally on the field side of the tape line. This progresses to the formation of cracks, generally at 45-degrees to the direction of rolling, and then to the break out of material from the wheel tread to form HIWs.

Failure is initiated by high tractions in low rail contact. The failure mechanism occurs as follows:

- Low rail tractions, acting generally at 45 degrees to the direction of rolling, cause wear debris to be removed from the tread surface.
- This results in lines of pitting or scuffing at approximately 45 degrees to the rolling direction (see Figure 6).
- Subsequent rolling results in surface flow and subsequent crack formation (see Figure 7 and left-hand side of Figure 6).
- Further rolling causes the cracks to widen and break out in a progression similar to what is observed from the left- to right-hand side of Figure 6.

Figure 4. Delamination and Shelling

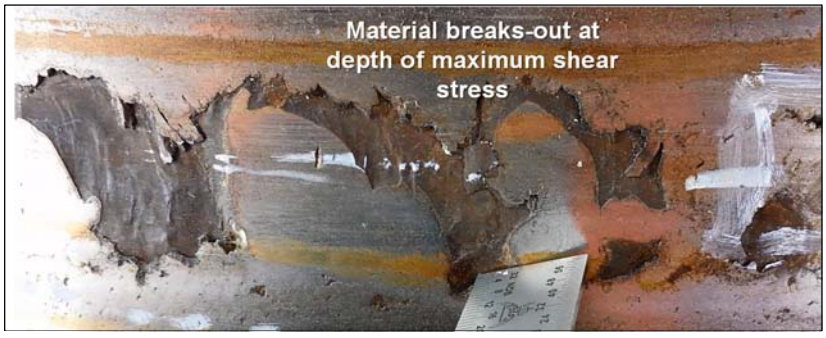

Figure 5. Detail of Shelling Failure

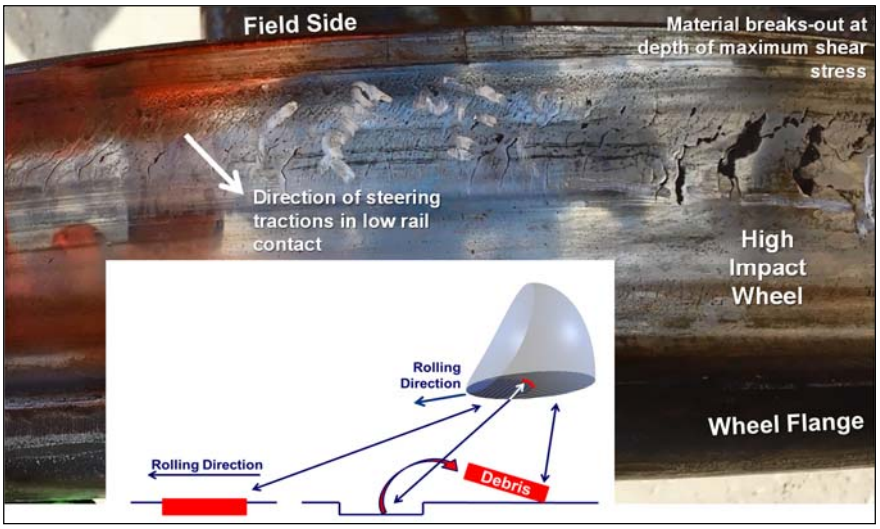

Figure 6. Scuffing-Related Tread Failure

Figure 7. Material Flow and Crack Formation Associated with Scuffing

Scuffing-related tread damage may be related to the development of field-side crack bands.

CONCLUSIONS

Inspections of wheels removed from service for HIWs suggest that there are three generic damage types:

- Spalling
- Delamination
- Scuffing-related Tread Damage

Brake-related spalling and continuous spalling have been observed and associated with spalling.

Delamination can occur without material break out. Delamination can also result in material break out resulting in shelling, resulting in HIWs.

Scuffing-related tread failure is associated with surface damage (scuffing) of the tread, which progresses to form cracks, generally at 45-degrees to the direction of rolling, and then to the break out of material from the wheel tread to form HIWs. Scuffing-related tread damage may be related with field-side crack bands.

Further research into the root causes for the observed damage continues.

The classifications presented in this TD form a reference catalog for those conducting further inspections of wheel damage. This may assist in classifying and quantifying the different damage modes observed in service and may result in the identification of further as yet unidentified modes.

ACKNOWLEDGEMENTS

The authors wish to thank TTCI engineers Greg Giebel and Megan Archuleta for their assistance on this project. CSX supported this research.

REFERENCES

1. Tournay, Harry M. December 2009. “Review of the Mechanism for the Formation of Thermal Mechanical Shells.” *Technology Digest* TD-09-041. Association of American Railroads, Transportation Technology Center, Inc., Pueblo, CO.