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Wheelset Dimensions and Design Issues for Special Trackwork

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Summary

Transportation Technology Center, Inc. is developing wheelset dimension guidelines for design of North American mainline special trackwork. The design wheelset includes the likely range of each wheelset dimension of interest and its effects on special trackwork performance. Design of switches and frogs for optimal performance is possible for a nominal wheelset. The job becomes more difficult when one considers the full range of wheelsets in service.

This *Technology Digest* describes the vertical and lateral envelope in which wheelsets are likely to be when traversing special trackwork. A brief discussion of the range of each dimension and its potential effects on special trackwork design/performance is presented.

Allowable dimensions were compiled from the mechanical standards of the Association of American Railroads (AAR) and the track safety standards of the Federal Railroad Administration. In addition to interchange standards, the trackwork designer must also check with the railway for any noninterchange standards wheelsets that may be operating. Vehicles that do not meet AAR interchange standards may include locomotives, passenger cars, track inspection, or maintenance of way equipment and freight cars.

Important wheelset parameters that affect special trackwork design include:

- Wheel back-to-back spacing — this is the wheelset equivalent of track guard face gage
- Wheel tread width and profile — these affect switch point to stock rail and frog point to wing transfer design

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INTRODUCTION

Design of special trackwork encompasses many considerations. Because these locations are the control points of the railway, it is essential that they perform as safely and efficiently as possible. Capacity can be significantly affected by the design and subsequent performance of switches and frogs. In the drive for efficiency, standard designs are often used. This includes assumptions about the traffic characteristics for the switch or frog.

This *Technology Digest* identifies critical wheelset dimensional tolerances for use in the design and maintenance of North American mainline special trackwork. These include the likely range of each wheelset dimension of interest and its effects on special trackwork performance. Design of switches and frogs for optimal performance is possible for a nominal wheelset. The job becomes more difficult when one considers the full range of wheelsets in service.

Allowable Wheelset Dimensions

Figure 1 describes the nominal dimensions of North American freight car wheelsets. Wheelsets that exceed these dimensions are considered unfit for service, as defined under AAR's mechanical standards and the Federal Railroad Administration's (FRA) *Track Safety Standards*.[1,2,3] Nominal dimensions for locomotives and passenger cars wheels can be different, as Table 1 indicates. This diagram and table will assist track-work designers in determining whether they have provided an adequate clearance envelope.

The following briefly describes wheelset dimensions and how each may affect track-work design and performance.

Tread Width. Tread width, along with track gage determines how much surface area there is available for wheel-rail contact.

Flange Width. The width and shape of the flange can affect the position of the opposite wheel in a wheelset. It may also affect the location of the wheel with respect to a field side (switch point) guardrail.

New Profiles. The standard new or retrued profile for North American freight car wheels is the AAR 1-B with a 1:20 tread taper and a flange angle of 75 degrees, which may have wide or narrow flanges.[1] The new or retrued profiles for locomotives and passenger cars vary depending on the vehicle owner and operating authority, including the AAR freight profiles and profiles recommended by the American Public Transit Association.[4] Depending on the particular profile, the tread taper may range from cylindrical (i.e., no taper) to 1:20 taper. New flange angles commonly range from 65 to 75 degrees.

Profile Wear. Other than depth of tread hollowing, there are no specific limits on the worn shape of the wheel running surface profile. The tread profile can vary from cone shaped to cylindrical to hollow worn. Wheel profile affects essential features of switch and frog design. In the transfer zones, where wheels transfer from stock rail to switch point or from frog wing to frog point, a good understanding of wheel profiles in service is essential. The shapes and relative heights of the frog and switch running surfaces will determine where and how smoothly wheels transfer from wing to point or from stock rail to switch point. Variations of wheel profile between the two wheels on a wheelset are relatively common. AAR rules require that both wheels on a wheelset are replaced at the same time. However, differences in vehicle performance or car operations can cause asymmetric wheel wear. For example, trucks that warp in curving may produce flange wear in the right wheel of the leading wheelset and the left wheel of the trailing wheelset. These differences in profile can cause unusual steering forces and wheelset positions in special trackwork.

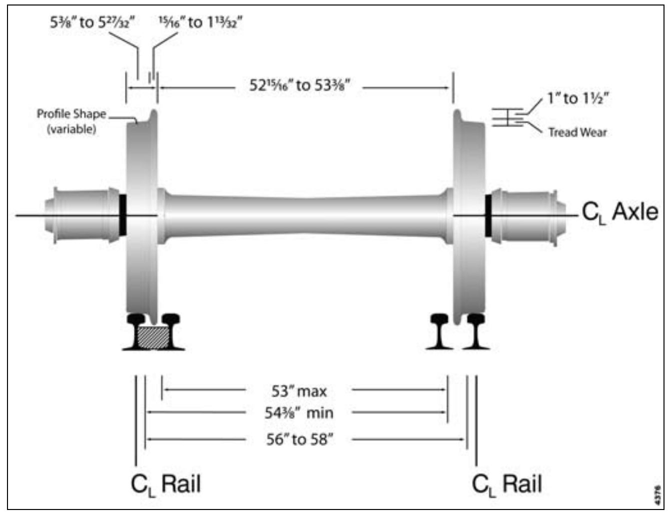

Figure 1. Freight Wheelset Dimensions

Table 1. Wheelset Dimensional Tolerances

	Wheel Width (inch)	Flange Width (inch)	Back-to-Back Space (inch)	Flange Height (inch)
AAR New Wide Flange Freight & Passenger	5.7188 +/-0.125	1.3750 +0.0313/ -0.0938	53 min. 53 3/32 max.	1.0865 +0.0625/ -0.0
AAR New Narrow Flange Freight	5.7188 +/-0.125	1.1563 +0.0625/ -0.000	53 min. 53 3/32 max.	1.0663 +0.0625/ -0.0
AAR New Non-freight	5 1/2 +/-1/8	1 5/32 +3/16/-0	53 3/32 min. 53 3/8 max.	1.000 +1/16/ -0.0
AAR Field Manual, Rule 41 (worn freight)		15/16 min. thin flange	52 15/16 min. 53 3/16 max.	1½ max. tall flange
FRA 49CFR229 (worn locomotives)		7/8 min. thin flange	53.0 min 53.5 max. (narrow flange) 53.25 max. (wide flange)	1½ max. tall flange

Wheel/Rail Contact Angle. The maximum contact angle between the wheel and the rail is a function of how the flange shape mates with the rail gage face. Higher contact angles provide a greater margin of safety from flange climb.[5] The maximum wheel-rail contact angle can never be greater than the lesser of the maximum flange angle and the maximum rail gage face angle. Flange angles for new wheels can range from 65 to 75 degrees but typically wear to a steeper angle. Switch points need to be designed to have the same slope as the steepest part of flange. However, Figure 2 illustrates that initial contact with the point will still result in wheel-rail contact angles less than the maximum and increased risk of flange climb.

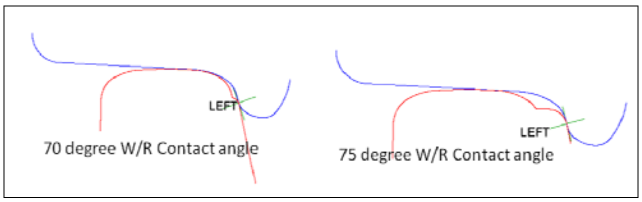

Figure 2. New AAR1b Wheel/Rail Contact with New Switch Point

Chamfers. Locomotive and some other wheels can have a field side chamfer on the tread. This is usually a 45-degree cut made when wheels are reprofiled. A 2008 change in the standards limits this cut to 3/8 inch in height and width. This chamfer can affect the design and function of frog wings, switch point risers, and switch point guards. It effectively shortens the width of the tread. It also can reduce the angle of contact between the wheel and a switch point guard. This will make it easier for the wheel to climb the guard.[6]

Flange Height. Flange height is approximately 1 inch (as measured from tip to tape line tread surface) for new wheels. The flange usually grows with mileage as the tread portion of the wheel wears. Thus, a 0.5-inch range of flange heights can be expected in service. This dimension is important for determining the flangeway depth and shape in frogs and switches. It is also important for designing flange bearing track components and vertical switches.

Tread Wear. Tread wear affects running surface profile and flange height as described above. Tread wear limits are in place for structural reasons, as well. If tread wear was even and equal to flange height loss, then the tread wear limit would remove wheels that have lost sufficient material to become a structural risk. This is the wheel equivalent of a head height loss limit for rails.

Out of Round. Wheels that are out of round will impart a dynamic load to the track and rail at each revolution. Depending on the shape of the wheel, the out of round profile may also generate unusual steering forces in the wheelset. Out of round forces should be accommodated in the dynamic load service environment used to design the special trackwork.

Back-to-Back Spacing. Wheel back-to-back dimension limits are the track equivalent of track gage. They also affect the design width and shape of flangeways, rail face gage, and rail check gage. Most track-work designers use the AAR interchange standards for design. However, wheel back-to-back spacing for locomotives and passenger cars (not covered by AAR interchange standards) can be larger, as Table 1 indicates.

Allowable Track

Table 2 shows the relevant track dimensions allowed by FRA speed category for typical freight tracks.[3] Track that accommodates higher speed passenger trains must meet tighter tolerances.[7] Note that the allowance for track gage is significantly larger than the allowance for wheel back-to-back spacing or flange wear. This reflects the differences in function and design philosophy used by vehicle and track designers.

Table 2. Critical Track Dimensions

	FRA Class 5		FRA Class 4		FRA Class 3	
	Min. (inch)	Max. (inch)	Min. (inch)	Max. (inch)	Min. (inch)	Max. (inch)
Gage	56	57½	56	57½	56	57¾
Guard face gage		53		53⅛		53⅛
Guard check gage	54½		54⅜		54⅜	

Track Gage. Track gage is the distance between the running rails, measured at the gage point (5/8 inch below top of rail). Track gage has been specified to be within a given range in North American freight operations to facilitate the free interchange of vehicles across individual railways. The allowable variation in track gage with track speed can pose some difficult challenges for special trackwork designers. Most designers assume a narrower range of track gage (i.e., a maintenance range) than is allowed under track safety standards. The effects of track gage on special trackwork design include point slopes, point elevations, vehicle steering, etc. Wide track gage can cause issues with wheel transfer zones in that it may shift the locations where wheels transfer from frog wing to point or stock rail to switch point. Deviations in gage or track alignment can affect wheelset steering through switches. This is especially detrimental for precision or high speed routes, where track gage and alignment are precisely controlled to minimize forces and wear on switch point tips. Track gage which is too narrow can also cause problems with wheel climb and rail rollover forces in switches. Field side switch point guards are especially vulnerable to wheel climb if track gage is narrower than expected. In frogs, narrow gage can affect the functions of guardrails, making them ineffective in protecting the frog point.

Guardrails and Flangeway Flares

All guardrails and flangeway flares should be dimensioned for the wheelsets used. The purpose of guardrails and flangeway flares is to guide wheels down the proper path through frogs and, in the case of switch point protectors, switches. These guards help prevent derailments and wheel/rail damage from high dynamic load events, such as a wheel striking the end of a frog point. The guard should guide the wheel to the proper location in the turnout that will minimize forces and wear of turnout components.

Wheelset dimensions affecting guard check gage include wheel back-to-back, flange width, tread width, and wheel profile. Wheelset dimensions affecting guard face gage are wheel back-to-back spacing, flange width, and tread width.

Flangeway flares at guardrails and at the ends of frogs should guide wheels to the desired path with as low a dynamic load as possible. Industry practice has been changed from straight flares to horizontal circular curve entry for guardrails based on vehicle-track dynamics modeling.[8,9] The same circular entry shapes should be applied to entry flares on frogs.

Switch point guards (i.e., field side guards that keep flanges away from the point of switch) are especially vulnerable to unintended problems due to wheelset dimension variations. Track maintenance handbooks do not specify track gage for use with switch point protectors. The current mechanical and track tolerance allow situations where the envelope between the point protector and the opposite rail is too small to allow legal wheelsets to pass. Wheelset dimensions affecting switch point guards include wheel tread width, flange width, guard distance from gage line, and track gage.

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