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Study on Wheel Wear for Heavy Axle Load Freight Cars Running on Chinese Da-Qin Coal Line

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Summary: Da-Qin line is the first coal transportation dedication line in China with total length of 653 km . Its annual volume in 2010 achieved 400 million tonnes. The train can be operated at hauling tonnage of 10,000 tons and 20,000 tonnes, 2.5 days per cycle. It runs at the highest operation density in the world. However wheel wear became a problem after the coal car axle load was increased. Therefore a special study was conducted on wheel wear for the C_{80B} stainless steel coal gondola car with ZK6 bogie based on special operation conditions of Da-Qin line. Wheel and track wear were measured on site and interaction between wheel and track were simulated. Test data were analyzed and compared against wear wheel for heavy axle load freight cars in other foreign countries. An assessment was made on wheel wear for freight coal cars after increase of axle load, recommendations made for reducing wheel wear and recommendations for further studies provided..

Index words: Heavy haul; Freight car; Wheel; Wear; Da-Qin Coal Line

1. INTRODUCTION

To facilitate the development of heavy haul transportation in China, Qiqihar Railway Rolling Stock Co., Ltd.(QRRS) developed in 2003 the ZK_6 bogie of 25t axle load. It has become the staple for C_{80} gondola coal cars of 80t payload running in the Datong- Qinhuangdao railway line (Da-Qin line) and also for different types of 70t payload freight cars. It has so far been installed on almost 60,000 freight cars. However in the past two years, the users complained about severe vertical wear on the wheel tread of ZK_6 bogie of C_{80} freight cars in Da-Qin line, and uneven wear on some wheel flanges. To address the two issues, QRRS conducted successively six research studies on wheel wear of ZK_6 bogie[1], and three studies on service conditions of the brake shoe together with respective manufacturers[2]. QRRS and Centre for Surface Transportation Technology of National Research Council Canada (NRC-CSTT) joined hands to conduct studies including simulation of wheel/rail wear[3].

2. WHEEL WEAR SITE INVESTIGATION

QRRS has conducted successively six site studies on wheel wear of ZK_6 bogie. 2,435 freight cars have been inspected. The inspected freight cars and bogies were basically as follows:

The types of freight cars were C_{80}, C_{80B}, C_{70}, X_{2K}, C_{80H}, C_{80BH}, C_{70H}, X_{2H}, all of which are 25t axle load, except for the $C_{70(H)}$ freight car, which is 23t axle load. But the X_{2K} flat car is not fully loaded in service. All freight cars in inspection had served 6 to 24 months, running approximately 120,000 to 500,000 km.

2.1 Wheel tread wear

2.1.1 Average Wheel Tread Vertical Wear for 23t and 25t Axle Load Freight Cars

Wheel tread vertical wear for C_{80}, C_{80B}, C_{70}, X_{2K}, C_{80H}, C_{80BH} and C_{70H} freight cars are shown in Table 1, Figure1. The data in the inspection are grouped according to car type. Average wheel tread vertical wear for wheels at different positions every 100,000km is shown in figure 1. It is found in table 1 that,

(1) Monthly average wheel tread vertical wear

For C_{70} and C_{70H} freight cars of 23t axle load, wheel tread vertical wear are basically the same. For C_{80}, C_{80B}, C_{80H}, and C_{80BH} freight cars of 25t axle load, wheel tread vertical wear are similar. X_{2K} freight car is between 23t and 25t axle load as is not fully loaded in service. The monthly average wheel tread vertical wear for 25t axle load freight cars (except X_{2K}) is 1.74 times that for 23t axle load freight cars.

(2) Average wheel tread vertical wear in 2 years of depot repair period ranges between two and five millimeters.

Table 1 Wheel Tread Vertical Wear for Various Types of Freight Cars

Car Type	Units	Bogie Type	Axle Load /t	Monthly Average Wear/ (mm/month)		Wear after 100,000km/mm	Wear after 1.5 Years/mm	Wear after 2 Years /mm
C_{70}	248	ZK_6	23	0.126	0.130 (average)	0.603	2.261	3.014
C_{70H}	117	ZK_5		0.141		0.675	2.531	3.374
C_{80}	777	ZK_6	25	0.223	0.226 (average)	1.069	4.010	5.347
C_{80B}	347			0.230		1.104	4.138	5.518
C_{80H}	128	ZK_5		0.247		1.183	4.437	5.916
C_{80BH}	178			0.212		1.018	3.818	5.090
X_{2K}	88	ZK_6		0.154	——	0.738	2.768	3.691

Note: 140 units of C_{70} gondola cars with flexible fulcrum ZK_6 bogie are not included.

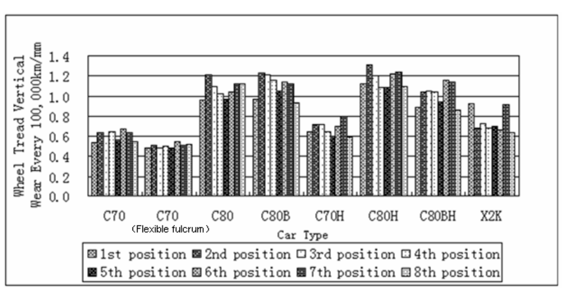

Figure 1 Average Wheel Tread Vertical Wear for Wheels at Different Positions Every 100,000km

It can be seen from the Figure 1 that the average wheel tread vertical wear varies for different wheel positions, but not greatly, and randomly. For each type of freight car, compared with average wear on all 8 wheel treads, the wheel tread vertical wear on the side of two dead lever fulcrums are slightly greater. Only a few C_{80BH} reach the maximum value of 1.307mm/10^5km.

2.1.2 Wheel tread vertical wear beyond 8mm condemning limit

As for C_{70}, C_{80}, C_{80B} and X_{2K} freight cars, wheels with vertical wear beyond the 8mm condemning limit are counted according to the service measurement intervals at which they are maintained, of 1.5~2 years, 1~1.5 years and 1year (see Table 2). Figure 2 is a histogram of wheel tread vertical wear percentage beyond condemned limit verses service time for C_{80} gondola cars. It shows that, the percentage of wheels with condemnable wear increases considerably at a longer service level.

Table 2 Wheel Tread Vertical Wear Beyond Condemned Limit

Service Time	Numbers of Inspected Freight Cars			Numbers of Wheels Beyond Condemned Limit			Percentage		
	C_{70}	C_{80B}	X_{2K}	C_{70}	C_{80B}	X_{2K}	C_{70}	C_{80B}	X_{2K}
Up to 1 year	87	244	52	0	2	0	0%	0.82%	0%
1～1.5 years	70	103	36	2	27	0	0.357%	3.28%	0%
1.5～2 years	91	0	0	6	-	-	0.824%	-	-

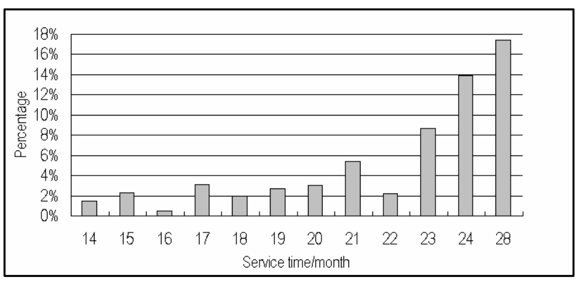

Figure 2 Histogram of Wheel Tread Vertical Wear Beyond Condemned Limit verse Service Time for C_{80} Gondola Cars

2.2 Wheel flange wear

The flange wear for wheels inspected from various types of freight cars such as C_{70}, C_{80}, C_{80B}, X_{2K}, C_{80H}, C_{80BH} and C_{70H} are shown in Table 3.

2.3 Relative Tread Wear Rates

A literature review revealed limited comparative data with respect to tread wear. All of the QRRS car types suffer lower average rates of tread wear for each kilometer travelled when compared with Swedish and Canadian freight cars, and also British passenger rolling stock. The Canadian freight applications, having the heaviest axle loads and consisting of roughly 50% curves, suffer the highest tread wear rates (Figure 3).

Table 3 Wheel Flange Wear Percentage for Various Types of Freight Cars

Type	Inspected Qty.	Number of wheels	Percentage				Service time/ month	Mileage/ 10^4km
			30≤X	28≤X < 30	26≤X < 28	X < 26		
C_{70}	139	1112	98.38%	1.08%	0.54%	0%	18-22	36-44
C_{70H}	68	544	99.64%	0.18%	0%	0.18%	14-16	28-32
C_{80}	532	4256	88.58%	7.07%	2.98%	1.37%	19-24	40-50
C_{80H}	68	544	83.82%	9.19%	4.04%	2.95%	20-24	41-50
C_{80B}	103	824	95.1%	3.28%	0.85%	0.73%	15-17	36-41
C_{80BH}	100	800	99.3%	0.7%	0	0	10-11	24-26.4
X_{2K}	36	288	95.83%	2.78%	1.04%	0.35%	18-21	30-33

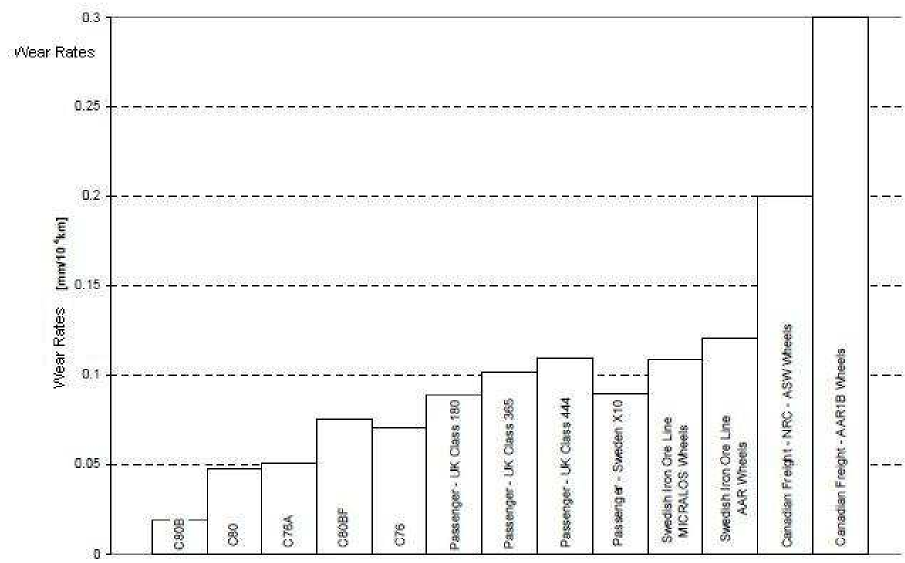

Figure 3: Average Tread Wear Rates for QRRS Car Types, Compared with Published Data from the UK and Sweden

2.4 Ratio of Flange wear to Tread Wear

Another approach to determining whether the wheel wear rates on QRRS vehicles on the Da-Qin Line are unusual is to look at the ratio of flange wear to tread wear. On QRRS, it was previously determined that flange wear is not the dominant mode, with wear life being dictated by tread wear, wheel hollowing and wheel diameter mismatch. The data from a Canadian fleet that also uses flexible bogies is not much different – the rate of tread wear is roughly the same as that for flange wear. Since that captive Canadian railroad is exceptionally well maintained with good friction management and wheel/rail maintenance practices, the equal flange/tread wear observation should not be considered typical of North American operations. There is little doubt that a more typical fleet will show greater rates of flange wear. Although NRC has data from a wide range of fleets around the world, the Canada and Brazil fleets shown are the only ones for which the initial flange width is known with confidence and from which wear rates can be calculated. The Brazilian fleet uses a standard 3 piece truck, is not well lubricated and clearly suffered higher rates of flange wear. The data points in Figure 4 indicate that a number of profiles were measured to have essentially no flange wear and yet there is significant tread wear of up to 6mm.

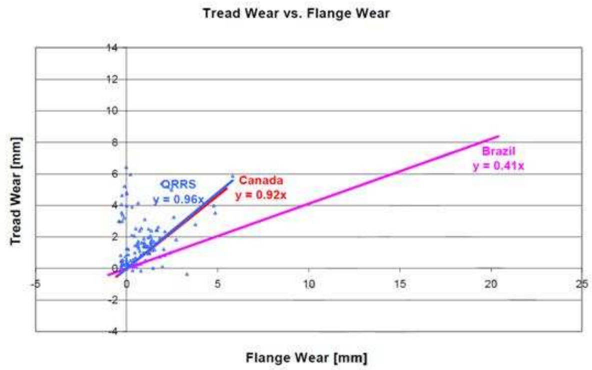

Figure 4: The Ratio of Flange Wear to Tread Wear for the QRRS Population of Measured Wheels

3 WHEEL/RAIL INTERACTION SIMULATION

The National Research Council Canada's Centre for Surface Transportation Technology (NRC-CSTT) and Qiqihar Railway Rolling Stock Co., Ltd (QRRS) worked together to model and analyze rail forces and wheel wear on freight vehicles operating on the Da-Qin Line [3]. The C80 car type was chosen for this work.

NRC-CSTT worked with QRRS to collect parameters for the vehicle, car body, bogie, suspension, wheelset and any other relevant data. The representative vehicle, wheel-rail and track models were built based on available information provided by QRRS. The measured data such as wheel profiles, rail profiles and track geometry were organized and used for the modeling purpose. NUCARS (2009 version) was used for the simulation. Based on the collected data, the vehicle model, wheel-rail interface model and track model were constructed in the NUCARS environment. Results obtained by NRC-CSTT's simulations were filtered and sorted and in particular the wheel-rail forces and wheel wear of freight vehicles operating on Da-Qin Line were analyzed. Effects of key vehicle/track parameters were investigated, primarily with respect to wheel-rail force and wheel wear.

4 WHEEL/RAIL PROFILE COMPATIBILITY

Four cases of the unworn and worn wheels running against the unworn and worn rails were considered. Only the case of worn wheel running against the worn rail is discussed here. The profile compatibility plot of the average worn wheel running on the average worn tangent rail is shown in Figure 5. There are few jumps in the rolling radius difference (top-left) plot and the resulting conicity is a low 0.16. The contact map (bottom row) shows a conformal one-point contact scenario, with reasonably well controlled contact stress (middle row) until heavy gauge-corner contact occurs. A separate quasi-static curving analysis on a 1000m radius curve found that this conformal contact scenario results in much reduced contact stress compared with the unworn shapes, a finding that was later confirmed by the NUCARS modeling.

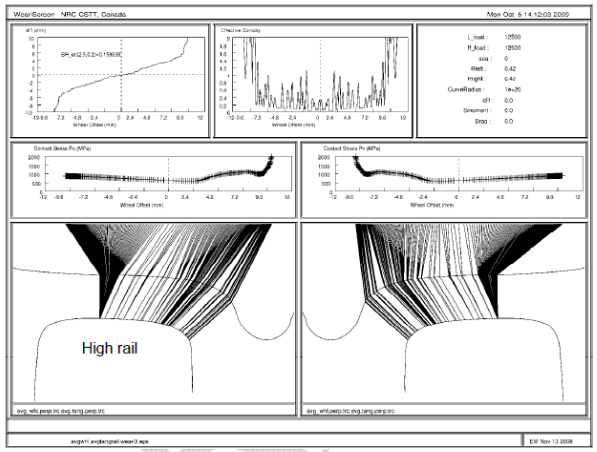

Figure 5: The Contact Map of the Average Worn Wheel on Worn Tangent Rails

5 CONCLUSIONS

Based on analysis of the measured worn wheel profiles, we can conclude that the QRRS wheels on the Da-Qin line:

- Do not appear to hollow worse or more rapidly than other systems.
- Typically exhibit less flange wear than other freight systems (Figure 4).
- Suffer a wheel tread wear rate less than that found in the literature for any other fleets (Figure 3).
- Wear approximately the same or less on the flange than on the tread. This differs from most other systems where flange wear is noticeably higher than tread wear (Figure 4).
- The current adapter and frame bracing suspension stiffness appear to allow for satisfactorily alignment of the wheelsets (i.e. self-steering), even in sharper curves. The angles-of-attack based on the NUCARS simulations are much lower than those typically experienced by the 3-piece North American bogies. Combined with the low number of curves and their relatively low degree of curvature, it is not surprising that the QRRS cars experience relatively low rates of wear compared with many other freight railways.

Wear is a natural phenomenon associated with friction and slip, both of which are unavoidable in an operating railroad. Wear is therefore a natural consequence of the wheel/rail contact and can never be eliminated, but it can be managed. For the Da-Qin Coal Line heavy axle load freight cars, a study for optimizing the unworn shapes (a modest reduction in wheel conicity and improved pummeling [4] through rail profile design) for selecting suitable rail hardness is recommended.

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