Wheel Wear Comparison of Different Locomotives

Fig. 1: Four-axle bogie locomotive Gravita 10BB

VOITH

The continued strain of rail and wheel during railway service leads to unavoidable wear. This is why rails need to be reground and wheels need to be re-profiled. In addition, re-profiling can only be done a few times until the replacement of all wheelsets is needed. Heavy wear occurs especially in narrow curves which can primarily be found on industrial tracks, an important field of operation for shunting locomotives. In this application, three-axle locomotives are often used, whose wheelsets are fixed to the main frame in the longitudinal direction. In conjunction with the stiff mounting and the absence of radial adjustability, the long wheelbase of the outer wheelsets leads to unfavorable angles of attack of the wheels while negotiating narrow curves, resulting in heavy wear of wheel and rail. Due to these limitations, alternative concepts for wear efficient running gears, which allow for a radial adjustability of the wheelsets and radial steerability, were developed. This results in lower angles of attack corresponding with lower wear of wheel and rail.

As part of a masters-thesis, the wheel wear of two different types of running gears of three-axle locomotives were calculated and compared to the behavior of the conventional two-bogie locomotive Gravita 10BB (DB Class 261). To ensure comparability between these different concepts, all simulation models are subjected to equal static axle loads. As all simulations were carried out without traction forces, the wear affected by straight tracks can be neglected. Hence, further investigations are based on curved tracks only.

WEAR CALCULATION IN SIMPACK

In order to compare different types of rail vehicles regarding the wear of wheels and rails, complex procedures can be simulated appropriately with multi-body simulations. SIMPACK is ideal for these comparisons because it offers the add-on module Rail Wear, which includes two different wear laws for calculating the adhesive wear of rails and wheels.

Negotiation of narrow curves results in a striking of the flange of the leading wheelset against the rail in some of the examined models. Using the wear law by Archard, this striking literally leads, with standard wear coefficients, to cut outs on the wheel flange.

Thus, the second available wear law by Krause/Poll is used, which generates substantially smaller cut outs and provides easier handling for the solver. In a next step, suitable wear coefficients have to be chosen. In fact, for a quantitative calculation, these coefficients need to be figured out for any new application. This is why there is a wide range of variation in the literature. To achieve better solver performance, the moderate wear coefficients by Zobory [1] turned out to be most suitable.

In order to achieve realistic wear-caused material removal, the wheel profile needs to be adapted regularly during the wear calculation process. This is done via a script, which updates the profiles as follows: The model is simulated in three subsequent track sections per loop. After each simulation, the corresponding wear of the wheel profiles is calculated and later summed up. In the following step, the wear is multiplied by a distance factor (which accounts for the difference between simulated and realistic traveled distance) and calculated into worn wheel profiles, which are then used for the next loop. The sections used are shown together with their weighting factor in Table 1. To achieve a comparable wear on both sides of each wheelset, every section is designed as a double bend with some transition in between.

Negotiating such narrow curves often results in a striking of the flange against the rail. During simulation, the handling of these contact patches turned out to be difficult. As the simulation regarded only a few typical scenarios, contact led to unrealistic punctual wear on the flange. This resulted in profile functions that do not increase monotonically along the lateral wheel coordinate y. In order to avoid such simulation behavior the model had to become more detailed.

On the one hand, track irregularities were added to all tracks so that the contact patch between rail and flange is no longer fixed to a static point. On the other hand, the friction coefficient between flange and rail has been reduced to simulate flange lubrication, where a lubricant is locally sprayed onto the wheel flange. Flange lubrication is usually provided to decrease flange wear and noise emission in narrow curves. Furthermore, the distance factor needs to be chosen carefully to achieve a compromise between reasonable CPU-time and the accuracy of the calculated wear profile. With the distance factors used in this case, a total distance (not including transitions) of 1,000 km was simulated by 20 runs of the script.

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Section	Curve radius	Curve length	Track gauge	Velocity	Distance factor	Percentage
	[m]	[m]	[mm]	[km/h]	-	[%]
1	80	40	1455	5	25	2
2	190	200	1445	20	20	8
3	350	500	1440	30	90	90

Table 1: Track parameters

THE FOUR-AXLE BOGIE LOCOMOTIVE

In conventional four-axle bogie locomotives like the Gravita 10BB, the wheelsets are fixed in longitudinal direction within bogies. Due to the small wheelbase in the bogies and their ability to rotate against the main frame, this type of locomotive shows generally acceptable wear behavior in narrow curves, which usually is better than the one shown by the common three-axle locomotives. Thus, the behavior of the Gravita 10BB is used as a reference throughout this study. Fig. 2 shows the original wheel profile as well as the wheel wear of the first right hand wheel of the Gravita 10BB after simulation of 1,000 km curve distance. As can be seen, the wear is divided into two different areas, flange and tread. This is a result of different contact patches between wheel and rail. On the flange, an outer wheel in the curve causes wear, whereas on the tread, wear

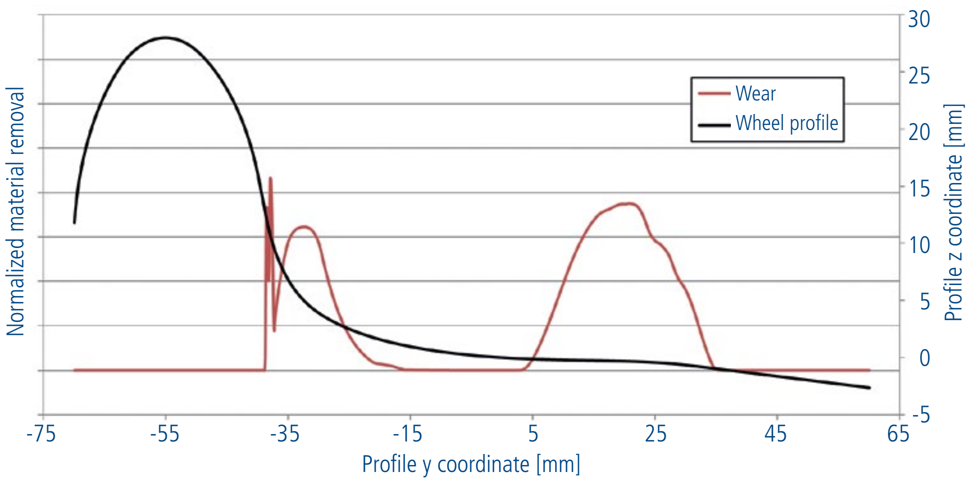

Fig. 2: Material removal of the first right-handed wheel after 1,000 km of the Gravita 10BB

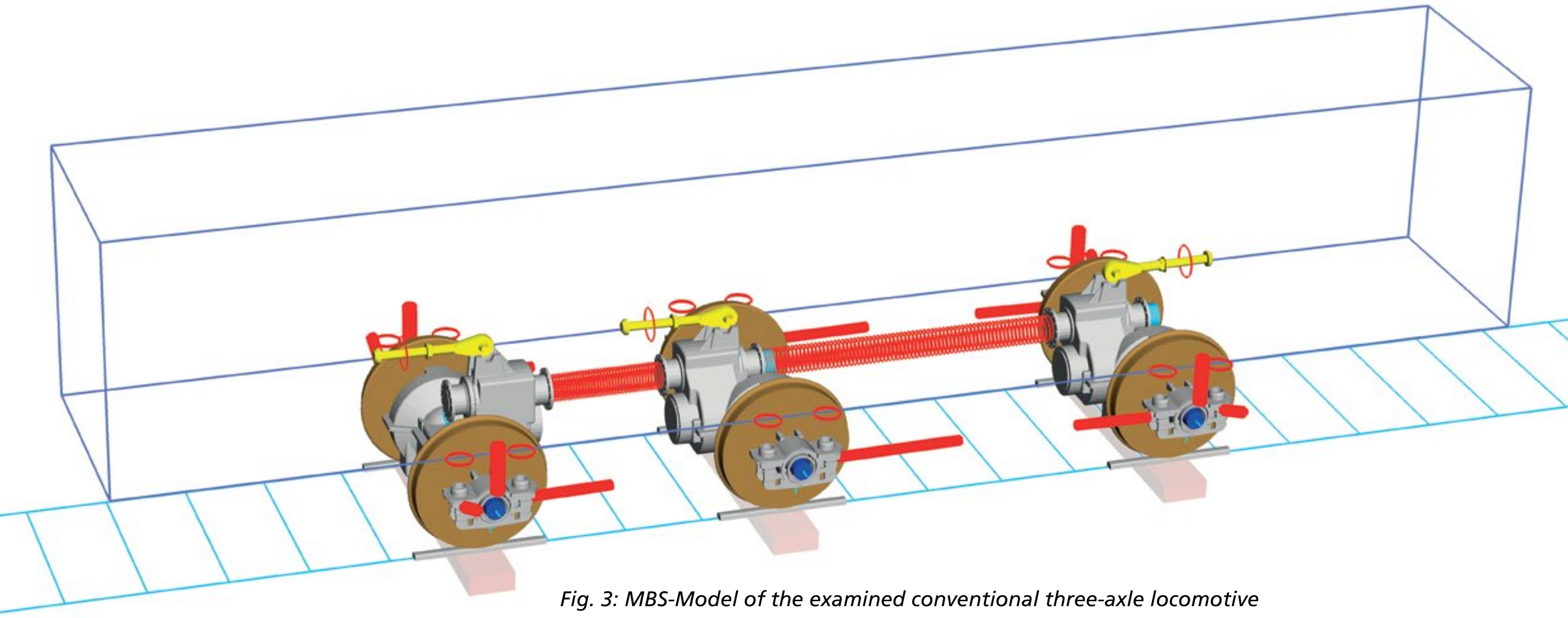

Fig. 3: MBS-Model of the examined conventional three-axle locomotive

is induced on an inner wheel. Due to the simulation of flange lubrication, slightly less wear is calculated on the flange. However, severe punctual wear on the flange can clearly be seen as a peak.

THE CONVENTIONAL THREE-AXLE LOCOMOTIVE

As opposed to the aforementioned Gravita 10BB, wheelsets of conventional three-axle locomotives are directly linked to the main frame and fixed in longitudinal direction. In lateral direction, the outer wheelsets are also fixed, whereas the inner wheelset is movable and not necessarily centered between the outer wheelsets.

Therefore, a radial adjustment of the wheelsets in narrow curves is not possible. Together with the long wheelbase, this results in large striking angles and heavy wear of wheel and rail. The inner wheelset, however, adjusts in lateral direction and generates only small striking angles, which lead to lower wear.

Fig. 4 shows material removal caused by wear after a simulated 1,000 km. The distribution of the wear along the profile is essentially the same as calculated for the Gravita 10BB. But in comparison to the Gravita 10BB, the wear is significantly higher. Notably the wear peak on the flange shows an increase of up to 70 %.

THE WEAR-EFFICIENT THREE-AXLE LOCOMOTIVE

In contrast to the conventional three-axle locomotive, a wear-efficient running gear has been examined, where a modified wheelset linkage does not only allow a radial adjustment of the wheelsets while negotiating curves, it even supports the adjustment by

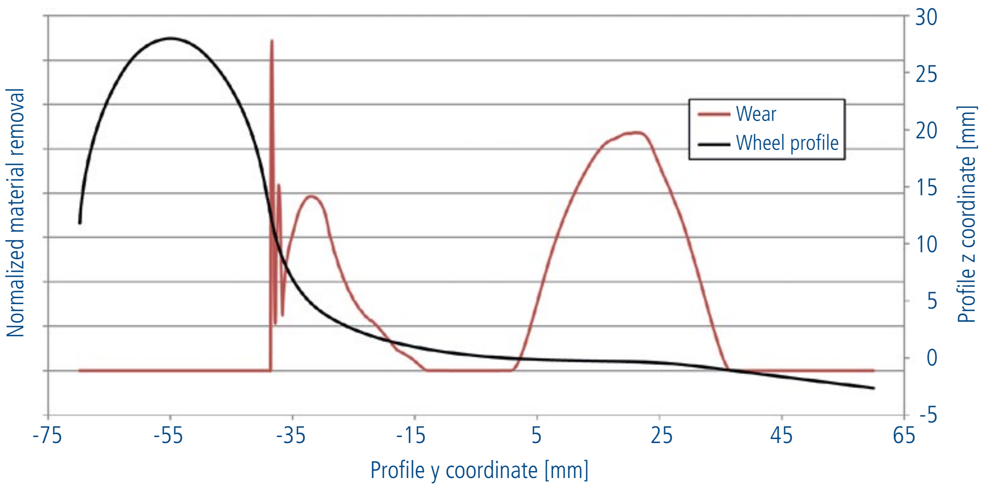

Fig. 4: Material removal of the first right-handed wheel after 1,000 km of a conventional three-axle locomotive

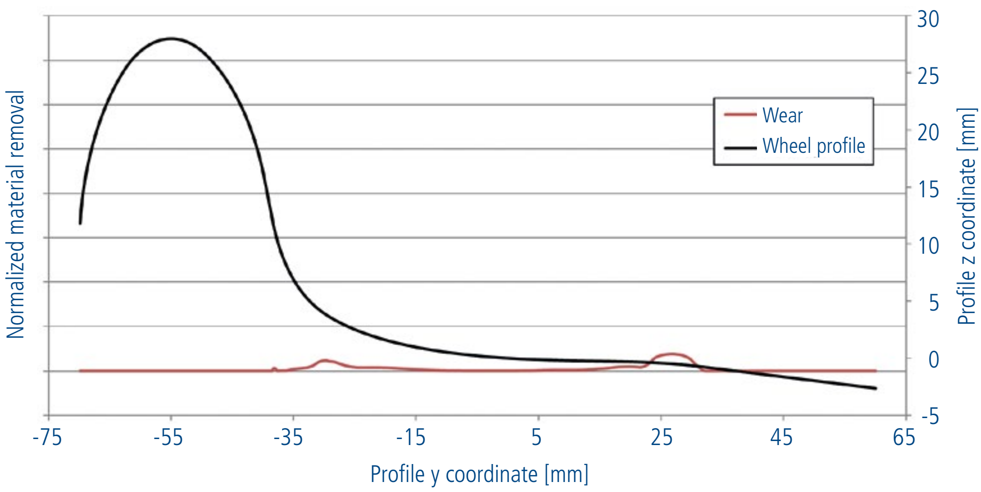

Fig. 5: Material removal of the first right-handed wheel after 1,000 km of a wear-efficient three-axle locomotive

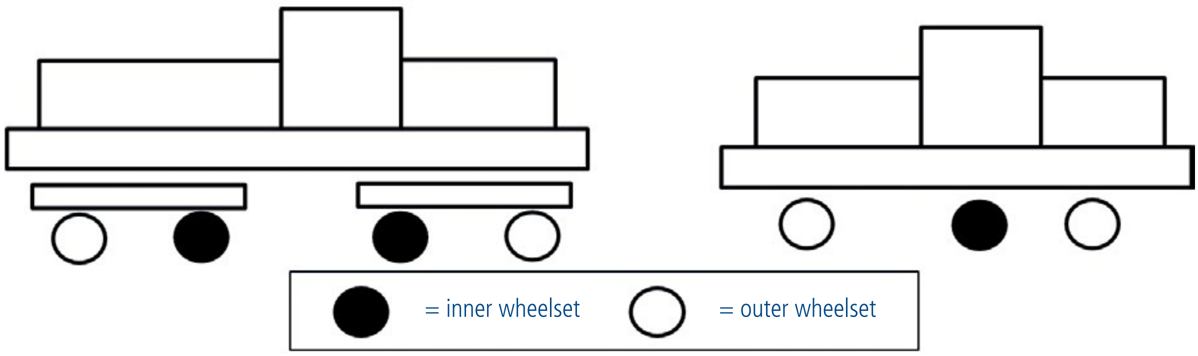

Fig. 6: Wheelset layout of the Gravita 10BB (left) and a three-axle locomotive

constructional elements. Because of the radial adjustment, the striking angles are reduced to a minimum, resulting in lower wheel-rail forces, and thus, lower wear of wheel and rail. Also, a homogenous wear of all wheels is expected.

To ensure good comparability, all important geometric dimensions like wheelbase, etc., remain the same as from the conventional three-axle locomotive.

In Fig. 5, the material removal over 1,000 km is plotted for the wear-efficient type. As the outer wheelsets are able to adjust radially while negotiating curves, striking of the flange against the rail is technically negligible. As a result, the peak caused by severe punctual wear disappears. Apart from that, the distribution of wear is similar to the other simulated locomotives.

COMPARISONS OF WHEEL WEAR

To allow a significant comparison of the above-presented locomotives, it is necessary to consider both travelling directions. In case of the Gravita 10BB, where bogies and wheelsets are positioned symmetrically, the wear on both bogies is the same.

In contrast, wear can differ between both ends of three-axle locomotives due to an off-centre mounting of the inner wheelset, see Fig. 6.

Fig. 7 shows the accumulated material removal for the inner and outer wheelsets of the examined locomotives after simulation of 1,000 km per travelling direction. The reference locomotive, Gravita 10BB, shows a uniform level of wear on all its wheelsets. However, the conventional three-axle locomotive comes along with heavy wear on its outer wheelsets, which is nearly twice as high as the correspondent wear of the Gravita 10BB. Additionally, the wear distribution between the wheelsets is much worse, as the wear on the inner wheelset is up to 75 % lower than on the outer wheelsets.

For the wear-efficient three-axle locomotive, the situation is totally different. Not only is the wear for all wheelsets up to 92 % lower than the wear of the reference locomotive Gravita 10BB, but the wear distribution between the wheelsets differs up to a maximum of only 15 %. In conclusion, the results clearly show that using wear efficient running gears, whose wear behavior outperforms conventional bogie locomotives, can significantly reduce the wear of three-axle locomotives.

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CONCLUSION

SIMPACK Rail Wear add-on module now offers the possibility — in early phases of a project — to simulate the wheel wear of different vehicle types using showcase tracks and compare qualitatively the accumulated wear. Especially when the wear behavior of a reference vehicle is known, as in the Gravita 10BB, the expected wear of other examined vehicles can be classified.

A quantitative prediction of wheel wear is not yet possible, as the available wear laws are too inaccurate to handle the complex realistic conditions. However, a realistic prediction of wear is not needed for a comparison as done in this examination.

Further simulations considering realistic traction behavior is the next planned step in creating a fully functional model.

REFERENCES

[1] I. Zobory, "Prediction of Wheel/Rail Profile Wear" in Vehicle System Dynamics, No. 28, 1997, pp 221–259

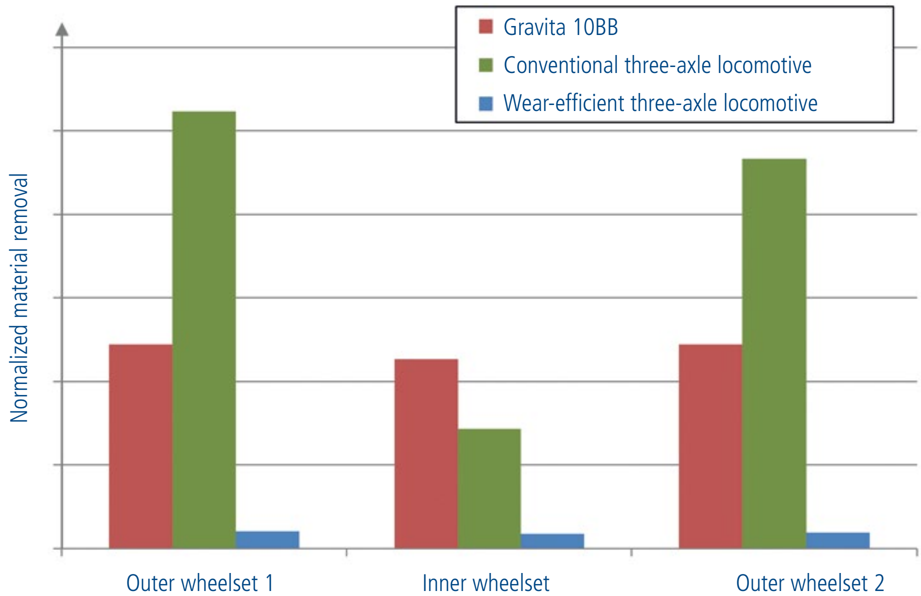

Fig. 7: Material removal of the wheelsets after 1,000 km per each direction