A Railway Wheel Wear Prediction Tool based on a Multibody Software

JOURNAL OF THEORETICAL
AND APPLIED MECHANICS
48, 3, pp. 751-770, Warsaw 2010

A RAILWAY WHEEL WEAR PREDICTION TOOL BASED ON A MULTIBODY SOFTWARE[1]

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The wheel wear prediction is a key-topic in the field of railway research as it has big impact on economical and safety aspects of trainset design, operation and maintenance. The aim of this work was to implement a flexible and predictive railway wheel wear tool that, starting from a specific vehicle mission, provides the wheel profile evolution as a function of the distance run. The wear estimation tool consists of the use of a sequence of pre and post-processing packages, in which the methodologies now presented are implemented, interfaced with a commercial multibody software that is used to study the railway dynamics. The computational tool is applied here to several simulation scenarios. The purpose is to demonstrate its capabilities on wear prediction by evaluating the influence of trainset design and of track layout on the wheel wear growth. Special attention is also given to study how the wear evolution is affected by the friction conditions between the wheel and rail.

Key words: railway dynamics, vehicle-track interaction, wheel profiles updating, track geometry, flange lubrication

1. Introduction

The increase of the world population, the growing energy prices and several environmental factors have promoted the expansion and development of railway transport in the last few decades. Nowadays, passenger trains have to

[1]The paper was presented at the ECCOMAS Thematic Conference on *Multibody Dynamics* which was held at Warsaw University of Technology on June 29 – July 2, 2009.

travel faster, with improved safety and comfort conditions. Furthermore, the competition with other transportation systems has increased greatly. For short and medium distances, modern high speed trains are able to compete with air transportation, having the advantage of presenting better energy efficiency and causing less pollution. For larger distances, the railway system is still the most economical means for transportation of goods and starts to have some competitive edge in the passenger transportation. On the other hand, the railway operators are demanding reductions in the overall operational costs. In this regard, they put particular attention to the railway vehicles maintenance costs and to the aggressiveness of rolling stocks on the infrastructures, i.e., the track damage.

In order to improve the competitiveness of the railway systems, railway vehicle manufacturers are investing large resources in research and development activities. These research activities contribute decisively to the development of new design concepts by using recent simulation techniques, modern production methods and innovative optimization procedures. The purpose is to develop sophisticated railway vehicles that answer to the increasing demands for faster, safer and more comfortable vehicles, but also that they have lower life cycle costs and are more ecological.

An important issue arising during the design phase of a new rolling stock is the optimisation of the dynamic performance of the railway vehicles. This is a complex issue since it is multidisciplinary and, therefore, requires the use of computational tools that represent the state of the art in railway dynamics. These tools must be able to characterize the modern designs and predict the vehicles performance by using reliable and validated mathematical models. Such models should consider boundary conditions and external loads, and must represent accurately track geometry and wheel-rail contact conditions. Therefore, the development and use of such computational tools is of paramount importance during the design stage of a project. It allows performance of several simulations of the railway vehicles, under various scenarios, to test the performance of different mechanical and structural solutions in order to reach an optimized design. In addition, analysis can be carried out to evaluate the impact of design changes or failure modes risks in a much faster and less costly way than the physical implementation and test of those changes in real prototypes.

Nowadays, partnerships have been established between the industry and universities to improve the integration of Academic research work within the industry and to develop a better understanding, within universities, of the industrial needs. A good example of such a collaboration is the Project AWARE

(ReliAble Prediction of the WeAr of Railway WhEels), which is coordinated by ALSTOM Transport and has, as partners, the University of Sheffield, the Technical University of Lisbon (IST) and the University of Zilina. This project is funded by the European Union to meet its transport policy objectives for the improvement of efficiency and competitiveness of the European railway transport system. AWARE is a Transfer of Knowledge project with the objective of developing a methodology to predict the wear evolution on railway wheels.

The wear computational tool developed in this work is used to predict the wheel wear evolution in several operation scenarios. In particular, the influence of trainset configuration, of track layout and of friction conditions between the wheel and rail are studied. The scenarios of wheel flange lubrication are also considered here.

2. General overview of the wear prediction tool

The computational tool developed here to predict the wear of railway wheels consists of using a commercial Multibody Software (MBS) to study the railway dynamic problem and a purpose-built code for managing its pre- and post-processing data in order to compute the wear. According to this strategy, an initial wheel profile is provided and the MBS runs a simulation for a pre-defined travel distance. Then, the wear prediction tool collects the necessary data from the dynamic analysis results and calculates the wear, i.e., the amount of material to be removed from the wheel surfaces. The resulting updated profiles are then used as the input for a new dynamic analysis in the MBS. This methodology is repeated as many times as required by the user in order to be representative of the trainset service conditions. The wear tool is implemented in MATLAB (Hunt *et al.*, 2001; Lyshevski, 2003) and the MBS used to study the railway dynamic problem is VAMPIRE (AEA Technology plc, 2004; DeltaRail Group Ltd, 2006).

In real situations, many trainsets are operated in different tracks. Therefore, when predicting the wear evolution on the wheels of a railway vehicle, this issue has to be considered and the wear studies should be performed using the track models (geometry and characteristics) that represent the real operation conditions. In the wear computational tool presented here, there are no limitations with respect to the length of the track models or to the number of models to use. In fact, after each simulation with the MBS, the wheel profiles are updated and used as the input for a new dynamic analysis in the MBS.

This new dynamic analysis can be performed with the same track model or with a different one. This approach allows computation of the wheel wear with better precision by reproducing the real service conditions of the railway vehicles. The result is the wheel profile evolution, in respect of the distance run, for the vehicle mission specified by the user.

A schematic representation of the wear computational tool is shown in Fig. 1 and it consists of the following steps:

1. Prepare the input data for computation;
2. Prepare the wheel-rail contact data files;
3. Run the multibody dynamic analysis;
4. Read the multibody dynamic analysis output;
5. Compute the wear, i.e., amount of material to be removed from wheel surfaces;
6. Update and smooth the wheel profiles.

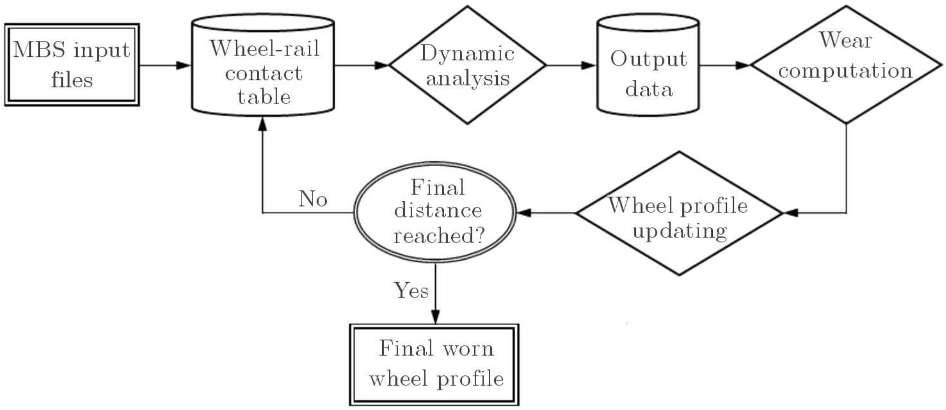

Fig. 1. Schematic representation of the wear prediction tool

The wear evolution study ends when the total simulated distance matches the total distance defined by the user. In the following, the main steps of the wear prediction tool are briefly described as the detailed description of the tool is outside the scope of this text. Nevertheless, the interested readers are referred to the works (Quost *et al.*, 2008a,b; Tassini *et al.*, 2008, 2009).

2.1. Wear computation

This is the core of the wear prediction tool as it computes the amount of worn material to be removed from the wheel surfaces, starting from the MBS dynamics results. It can be considered to be divided into three parts: i) Contact model; ii) Wear function; iii) Wear distribution. The contact model processes the dynamic analysis results to obtain the wheel-rail contact parameters. The wear function uses these contact parameters as the input to compute the quantity of worn wheel material. The wear distribution allocates the quantity of worn material along the wheel profile.

Concerning the contact model, two alternative methods have been implemented, global or local, depending on the way they solve the wheel-rail contact problem (Andersson *et al.*, 1998; Dukkipati and Amyot, 1988; Garg and Dukkipati, 1984; Johnson, 1985; Kalker, 1979, 1990; Pombo and Ambrósio, 2008; Pombo *et al.*, 2007). In the global approach, the contact parameters are obtained by studying the contact problem on the whole wheel-rail contact patch, considering the mean values of normal and tangential forces. In the local method, the contact problem is studied by dividing the wheel-rail contact area into small cells and evaluating the contact parameters individually for each cell.

The wear functions relate the energy dissipated in the wheel-rail contact patch with the amount of worn material to be removed. In general, these wear laws use a set of contact parameters, namely the normal and tangential forces and the relative slip velocities (creepages), as the input to compute the wear. In the literature (Beagley, 1975; Bolton and Clayton, 1983; Braghin *et al.*, 2006; Dearden, 1960; Enblom, 2006; Jendel, 2002; Lewis and Dwyer-Joyce, 2004; Lewis *et al.*, 2009; Lewis and Olofsson, 2004; Pearce and Sherratt, 1991; Ramalho, 2008; Ramalho and Miranda, 2006; Tassini *et al.*, 2009) different methods for estimating wear of railway wheels can be found. These methods are based on real wear data acquired using different experimental techniques, with the twin disc arrangement being the most common. Three of the wear functions developed by the British Rail Research (Beagley, 1975; Bolton and Clayton, 1983; Dearden, 1960; Pearce and Sherratt, 1991), by the Royal Institute of Technology from Stockholm (Enblom, 2006; Jendel, 2002), and by the University of Sheffield (Braghin *et al.*, 2006; Lewis and Dwyer-Joyce, 2004; Lewis *et al.*, 2009; Lewis and Olofsson, 2004; Tassini *et al.*, 2009), are implemented in the computational tool described here and can be selected by the user. Other authors (Meinders and Meinke, 2002) use a wear modelling approach with coefficients from the literature to determine the amount of mass loss caused by the contact forces and slip values.

In the wear studies performed in this work, the wear function developed by the University of Sheffield is used (Lewis and Dwyer-Joyce, 2004). It relates the wear rate, representing the weight of lost material [μg] per distance rolled [m] per contact area A [mm^2], to the product $T\gamma$, where T is the tangential contact force and γ is the global creepage. This formulation is based on the twin disc experimental data acquired from the contact between discs made of R8T wheel material and UIC60 900A rail material. These experimental tests have identified three wear regimes, mild, severe and catastrophic, for the contact between wheel and rail materials. Notice that these materials are the ones used to assemble the vehicles and tracks considered here. The equations governing the University of Sheffield wear function are defined in Table 1.

Table 1. Equations for the University of Sheffield wear function

Wear regime	Wear range $T\gamma/A$ [N/mm^2]	Wear rate [μg/m/mm^2]
Mild	$\frac{T\gamma}{A} < 10.4$	$5.3\frac{T\gamma}{A}$
Severe	$10.4 \leqslant \frac{T\gamma}{A} < 77.2$	55.0
Catastrophic	$\frac{T\gamma}{A} \geqslant 77.2$	$61.9\frac{T\gamma}{A}$

2.2. Wheel profile updating and smoothing

After obtaining the quantities of worn material, the wheel profiles need to be updated in order to be used as the input for the next dynamic analysis. In the wear prediction tool described here, two alternative approaches are implemented: i) Localised profile updating and; ii) Intersection profile updating.

In the localised approach, the worn surface values for the same wheel-rail relative lateral displacement band are summed. Then they are converted to a depth of the material and are removed from the corresponding wheel profile point, which is the wheel-rail contact point for that relative displacement. This method requires a subsequent smoothing procedure in order to spread the wear along the profile.

In the intersection profile updating method, for each wheel-rail relative displacement considered, the wheel and rail profiles are geometrically intersected and the profile is modified, spreading the worn surface along the wheel profile, following the same shape of the intersection area. This approach only requires the application of a light additional smoothing. For a more detailed description of the wear tool, the interested readers are referred to the works (Quost *et al.*, 2008a,b; Tassini *et al.*, 2008, 2009).

3. Wear studies

The wear computational tool implemented in the scope of the project AWARE is demonstrated here through its application to several simulation scenarios. The purpose is to demonstrate the capabilities of the tool on wear prediction. This is done by evaluating the influence on wear of the train design, of the track layout and of the friction coefficient between the wheel and rail.

3.1. Influence of trainset design on wear

In order to analyse the influence of the trainset configuration on the wear evolution, a comparative study is carried out using two different trainsets. For this purpose, two simulations are run using two vehicle models, but keeping unchanged the remaining input data and the analysis parameters required for the wear computation.

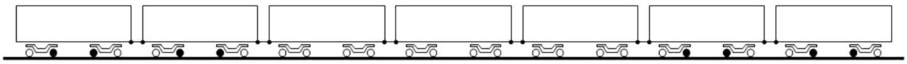

Fig. 2. Non-articulated conventional trainset

The first case study considered here is a non-articulated conventional trainset. This trainset is composed by seven vehicles interconnected by linking elements, as represented in Fig. 2. Due to its configuration, it is assumed that, concerning the wear studies performed here, the dynamic behaviour of each vehicle has insignificant influence on the others. Therefore, each vehicle of this trainset can be studied independently, as shown in Fig. 3. In this way, during the wear studies, the multibody vehicle model is only built for one vehicle of the trainset, called hereafter as Vehicle 1. The vehicle considered is one motor vehicle of the trainset, which has two motor wheelsets, represented in black in Fig. 3, and two trailer wheelsets, represented in white.

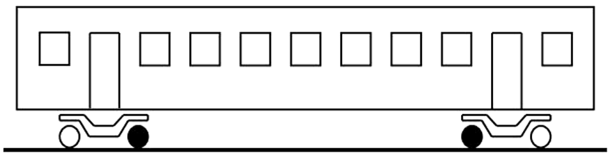

Fig. 3. Representation of Vehicle 1 – from a non-articulated conventional trainset

The second case study is a three-vehicle articulated trainset with Jacobs's bogies, as represented in Fig. 4. This trainset is composed of four bogies, where the two bogies of the extremities are motored (represented in black), and the two middle bogies are trailers (represented in white). Due to its configuration, the dynamic behaviour of each vehicle of the trainset affects the performance of the others. Therefore, the whole trainset has to be considered when building the vehicle model, which is used by the MBS to run the dynamic analyses during the wear study. Hereafter it is named as Vehicle 2.

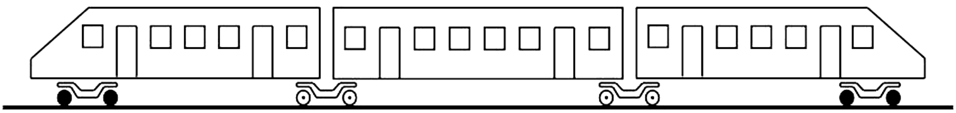

Fig. 4. Representation of Vehicle 2 – articulated trainset with Jacobs' bogies

The comparative wear study between the two vehicles is made on the track between the cities of Cuneo and Ventimiglia, from the Italian rail network. This track has about 96 km length and it is particularly curved, with 61% of its curves having radii with less than 450 m, as represented in Fig. 5. For this reason, hereafter it is called as "Severe Curved Track". The vehicles are initially equipped with new wheels, with S1002 profile, and the track model is assembled with UIC60 rails, with 1/20 cant.

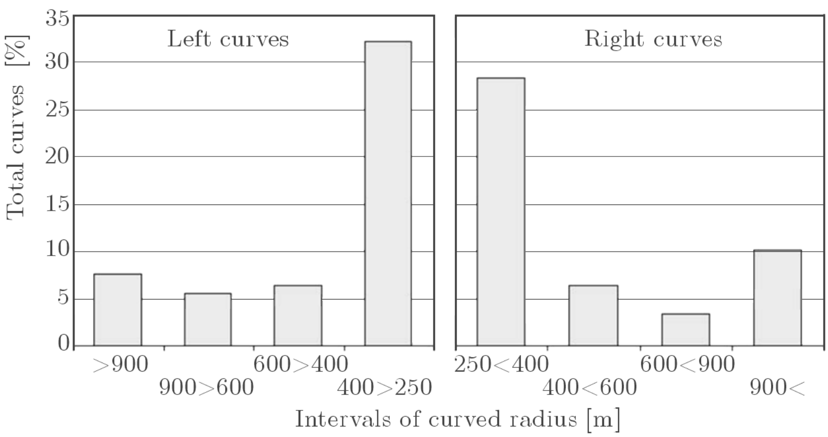

Fig. 5. Curve radii distribution of the "Severe Curved Track"

The wear study is carried out by performing 52 outward and return journeys of both Vehicles 1 and 2 on the Cuneo-Ventimiglia track until reaching the total distance of 5000 km. The vehicles velocity is defined according to the real service conditions, varying between 80 and 95 km/h on that track. In Table 2, the analysis conditions are summarised.

The results presented in Table 2 show that the CPU time required to run the wear study with Vehicle 2 is 173% higher than the one needed to run

Table 2. Analysis conditions for trainset design wear studies

Wear study	Railway vehicle	Distance reached	CPU time required
Reference Comparison	Vehicle 1 Vehicle 2	5000 km	+173%

the same simulation with Vehicle 1. This difference results from the fact that the multibody model of Vehicle 2 is composed by three railway compositions, with all respective bodies and mechanical components, whereas the model of Vehicle 1 is only constituted by one composition. These differences in the sizes of vehicle models mean that the dynamic analysis of Vehicle 2, performed with the MBS, takes more time to run. In addition, Vehicle 2 has 8 wheelsets while Vehicle 1 is composed by 4. This also implies that more computational time is required to study Vehicle 2 since the wear calculations and the profile updating procedures need to be done for each wheelset.

In the following, the wear results are presented for the first wheelset of both vehicles. The new and the worn profiles, on the left and right wheels, after 5000 km of trainset operation are given in Fig. 6. From these plots, no differences are perceptible between the results obtained with the two vehicles. The wear depth results are presented here in order to analyse such differences.

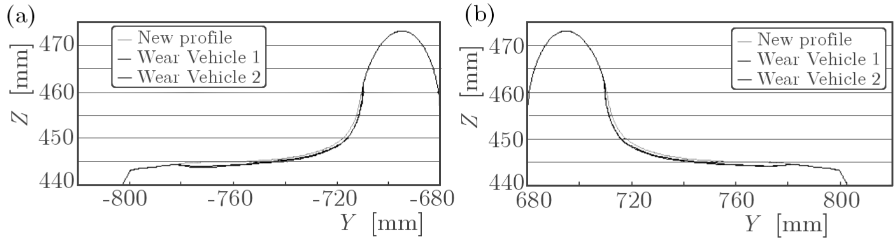

Fig. 6. Influence of trainset configuration – new and worn profiles on: (a) left wheel; (b) right wheel

The wear depth results, obtained with Vehicle 1, are depicted in Fig. 7 for the left and right wheels. In order to study the wear progression, these values are plotted for the travelled distances of 2500 and 5000 km. The results are presented as a percentage of the maximum wear depth value obtained on both wheels. Figure 7 shows that, in the tread zones of both wheels, the majority of worn material is removed in the first 2500 km. On the wheel flanges, it is observed that the wear evolution is nearly uniform along the total distance studied. The wear evolution results also show that, after 5000 km of trainset operation, the highest wear on the left wheel occurs on both the tread and flange zones, while, on the right wheel, it occurs on the flange.

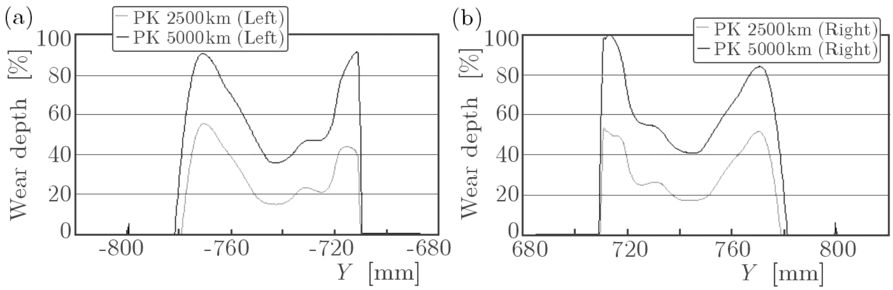

Fig. 7. Wear evolution results of Vehicle 1 on: (a) left wheel; (b) right wheel

In Fig. 8, the wear depth results on the left and right wheels of Vehicle 2 are depicted. These are presented as a percentage of the maximum wear depth value obtained on both wheels for the travelled distances of 2500 and 5000 km. As for Vehicle 1, it is observed here that, in the tread zones of both wheels, the majority of the wear happens in the first 2500 km. On the wheel flanges, the wear evolution is nearly uniform along the 5000 km studied. The results also show that, after 5000 km, the highest values of wear on the left wheel occur on the tread zone, whereas, for the right wheel, the wear depth is higher on the flange.

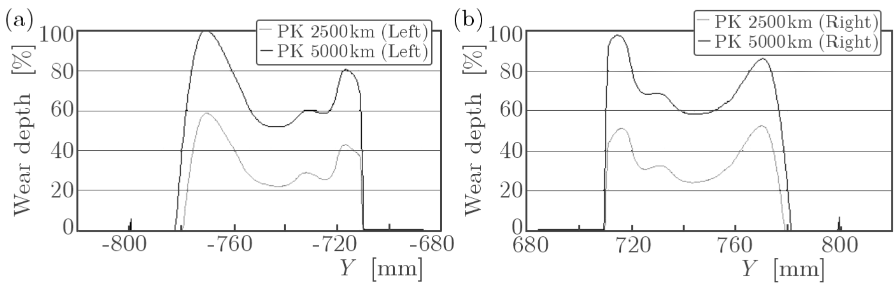

Fig. 8. Wear evolution results of Vehicle 2 on: (a) left wheel; (b) right wheel

The comparison between wear depth values on the wheels of both vehicles, after 5000 km of trainset operation, is presented in Fig. 9. These results are presented as a percentage of the maximum wear depth value obtained. It is observed that, in general, the quantity of worn material obtained with Vehicle 1 is less than the one obtained with Vehicle 2. Additionally, the wear distribution along the profiles is similar on two vehicles. In fact, the results reveal that the highest wear values occur on both the tread and flange while, on the transition between these profile zones, the wear is 20 to 40% lower.

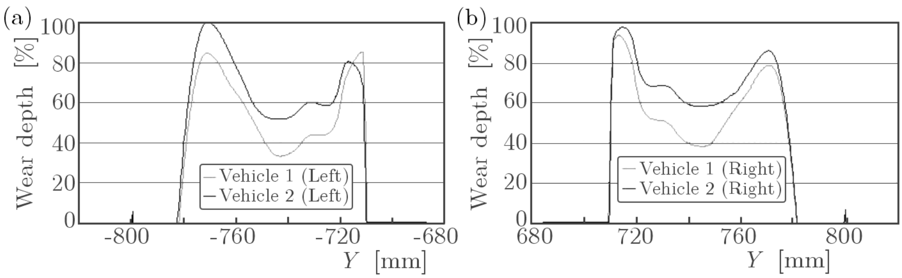

Fig. 9. Comparison of wear depth results of Vehicle 1 and 2 on: (a) left wheel; (b) right wheel

3.2. Influence of track layout on wear

The objective now is to analyse the influence of the track layout on the wear evolution. For this purpose, a comparative study is carried out using two different track layouts and keeping unchanged the remaining input data and the wear analysis parameters. The vehicle model used in the two simulations is Vehicle 1, represented in Fig. 3. The first track considered here is the severe curved track, which has the curve radii distribution shown in Fig. 5. The second track considered has the same length of the previous one but its geometry is mainly straight. Hereafter it is called as "Light Curved Track" since 85% of its curves have radii higher than 450 m, as shown in Fig. 10.

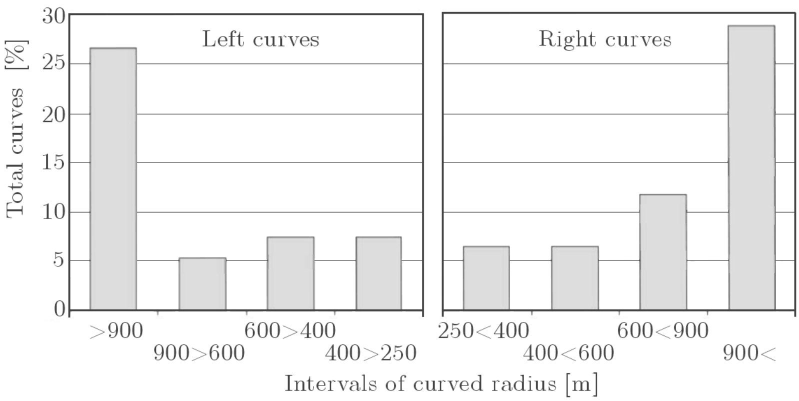

Fig. 10. Curve radii distribution of the "Light Curved Track"

The comparative wear study is carried out by performing several journeys of Vehicle 1 on both tracks until reaching the distance of 5000 km. The track models are assembled with UIC60 rails and the vehicle is initially equipped with new wheels with S1002 profile. In both cases, the vehicle velocity varies between 80 and 95 km/h along the track length. In Table 3, the analysis conditions are summarised. It is observed that the wear study with the light curved track requires less computational time than when performing the same simulation with the severe curved track.

Table 3. Wear scenarios for different track layouts

Wear study	Track layout	Distance reached	CPU time required
Reference Comparison	Severe curved track Light curved track	5000 km	−15%

The wheel profiles, obtained with the two tracks, are presented in Fig. 11 for the left and right wheels of the leading wheelset of the vehicle after 5000 km of operation. From these plots, slight differences are perceptible among the results. In the following, the wear depth results are presented in order to assess such differences.

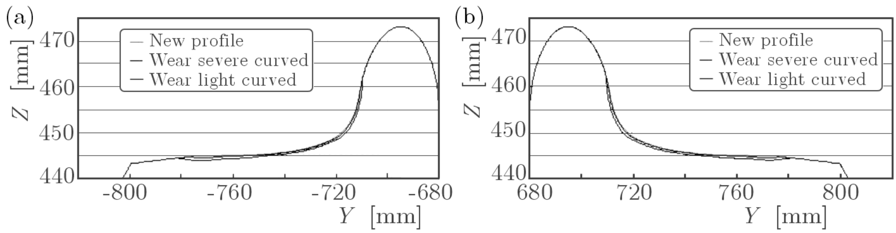

Fig. 11. Influence of track layout – new and worn profiles on: (a) left wheel; (b) right wheel

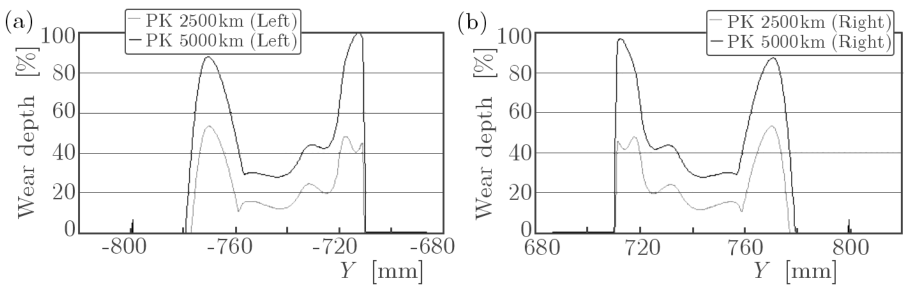

Fig. 12. Wear evolution results of light curved track on: (a) left wheel; (b) right wheel

The wear evolution results on the left and right wheels, obtained with the severe curved track, are depicted in Fig. 7 and were already analysed in this text. For the light curved track, these results are shown in Fig. 12. The wear depth values are presented as a percentage of the maximum value obtained on both wheels for the travelled distances of 2500 and 5000 km. As for the severe curved track, it is observed that, in the tread zones of both wheels, the majority of wear happens in the first 2500 km. On the wheel flanges, the wear evolution is nearly uniform along the total distance studied. The results from Fig. 12 also show that, after 5000 km of operation, the highest values of wear on both wheels occur on the flange zones.

The comparison between the wear depth values obtained when travelling on the two tracks, after 5000 km of operation, is presented in Fig. 13. The results are presented as a percentage of the maximum wear depth value obtained. The severe curved track has a larger number of tight curves and the results show that these geometrical characteristics generate higher levels of wear. In fact, this track originates wear depth values 20 to 40% higher than the light curved one. It is also observed that the wear distribution along the profiles is similar using the two tracks. The results reveal that the highest wear values occur on both extremities of profiles while, on the intermediate zone, the wear is 30 to 60% lower.

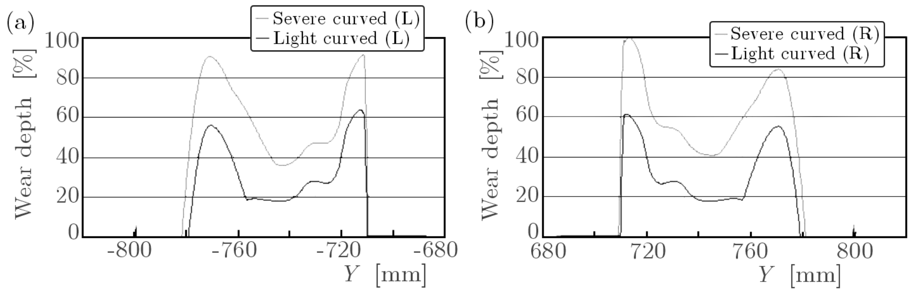

Fig. 13. Comparison of wear results of severe and light curved tracks on: (a) left wheel; (b) right wheel

3.3. Influence of friction conditions on wear

In order to analyse how the wear evolution is affected by the friction coefficient μ between the wheel and rail, three simulations are carried out with different values for this parameter. The friction coefficients on the wheel tread and flange are defined, according to the values presented in Table 4, in order to represent three different scenarios of trainset operation. The wear simulations are run using the same input data and the same wear analysis parameters, except the friction coefficient. The friction values are maintained constant and applied over the whole track length. The vehicle model used is Vehicle 1 (Fig. 3) and the track model considered is the severe curved track

(Fig. 5). The wear studies are carried out by performing several journeys on the track until reaching the total distance of 5000 km. The results presented in Table 4 show that the CPU time required to run the wear studies is nearly the same for all scenarios of friction conditions.

Table 4. Wear scenarios for different friction conditions

Wear study	Friction conditions	μ_{Tread}	μ_{Flange}	Distance	CPU time
Reference	Normal conditions	0.25	0.25		
Comparison 1	Very low friction	0.10	0.10	5000 km	−1%
Comparison 2	Very dry conditions	0.40	0.40		+2%

The left and right wheel profiles, obtained with the different friction coefficients between the wheel and rail, are depicted in Fig. 14. A zoom-in of these profiles is presented in Fig. 15 in order to allow a detailed view of the differences among them.

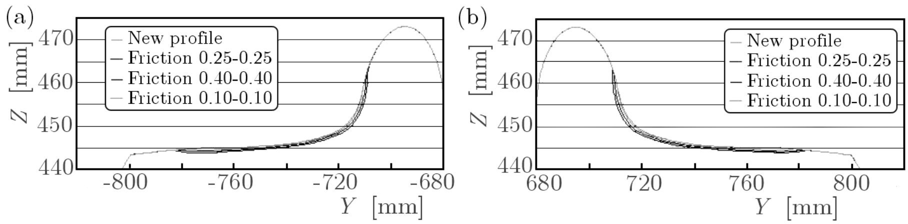

Fig. 14. Influence of friction conditions – new and worn profiles on: (a) left wheel; (b) right wheel

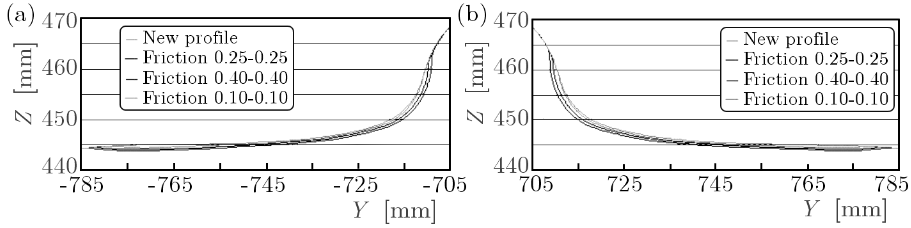

Fig. 15. Influence of friction conditions – zoom of profiles on: (a) left wheel; (b) right wheel

The comparison between the wear depth values obtained for different frictions conditions, after 5000 km of trainset operation, is shown in Fig. 16. These results are presented as a percentage of the maximum wear depth value obtained. It is observed that the higher friction coefficients originate greater levels of wear. In general, differences between 15 and 20% of wear depth are detected among the three scenarios studied here. In addition, it is observed that, for the two scenarios of lower friction between the wheel and rail, the highest wear values occur on both the tread and flange zones of the profiles. For the scenario of very dry conditions, the wheel flanges are the zones subjected to higher levels of wear. This result is perhaps not surprising as changing the friction coefficient will, as well as altering the dynamic response of the vehicle, lead to different $T\gamma$ values being generated in the wheel-rail contact. This will give different levels of wear and maybe even a transition to another wear regime. It should be noted that the causes of varying friction, for example water or oil in the contact, will also change the wear mechanism, and the wear data currently used in the model is for dry conditions. More work is required to build-up wear curves for contaminated contacts to overcome this problem. The same issue applies to the modelling in the next Section where flange lubrication is mimicked by altering the friction coefficient in this region.

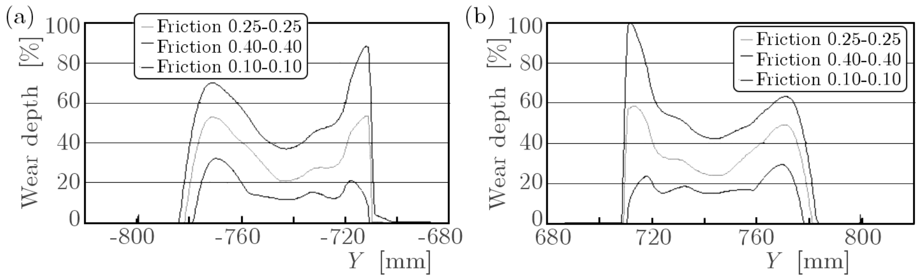

Fig. 16. Comparison of wear results with different friction conditions on: (a) left wheel; (b) right wheel

3.4. Influence of wheel flanges lubrication on wear

With the purpose to study how the wear growth is influenced by the wheel flanges lubrication, two additional wear studies are performed here. They consist of studying the scenarios of normal conditions and of very dry conditions, described in Table 4, but using reduced friction coefficients between the wheel flanges and rails. The wear analyses are run using the same input data and the same wear parameters described in the previous section, except the flange friction coefficient. In Table 5, the analysis conditions for the scenarios of flange lubrication are summarised.

Table 5. Analysis conditions for wheel flanges lubrication scenarios

Flange lubrication scenarios	μ_{Tread}	μ_{Flange}
Normal conditions	0.25	0.10
Very dry conditions	0.40	0.10

The comparison between the wear depth results obtained with and without wheel flanges lubrication for the scenarios of normal conditions and of very dry conditions are depicted in Fig. 17 and Fig. 18, respectively. These values are presented as a percentage of the maximum wear depth value obtained in each case.

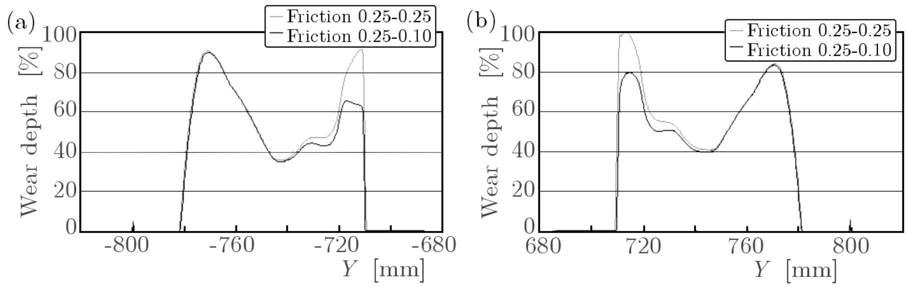

Fig. 17. Wear results with flange lubrication for normal conditions on: (a) left wheel; (b) right wheel

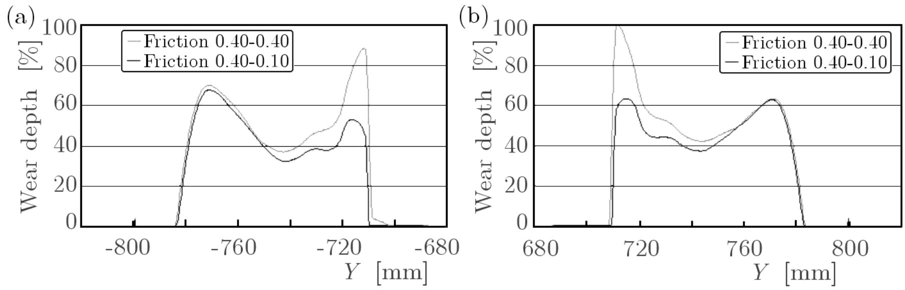

Fig. 18. Wear results with flange lubrication for very dry conditions on: (a) left wheel; (b) right wheel

The results presented here show that the reduction of the friction coefficient on the wheel flanges has significant advantages in terms of wear evolution on that zones. In the normal conditions scenario, the results from Fig. 17 demonstrate that the flange lubrication originates about less 20% wear on the flanges, after 5000 km of trainset operation. For the scenario of very dry conditions, the results depicted in Fig. 18 show that about 35% of wear reduction can be achieved on the wheel flanges when using lubrication of that zones.

4. Conclusions

In this work, a computational tool to predict the wheel profiles evolution due to wear of a given railway system is presented. The wear prediction tool consists of pre- and post-processing packages that are interfaced with a commercial MBS. The MBS is used to study the railway dynamic problem and its input and output data are managed in a proper way to compute the wear evolution.

The wear tool is applied here to several operation scenarios. The studies carried out aim to evaluate the influence on wear growth of train design, track layout and friction coefficient the between wheel and rail. The comparison of results obtained with the two railway vehicles considered here reveals that, in general, the wear on the vehicle from a conventional trainset is less than the wear obtained with the trainset having Jacobs' bogies.

The comparative wear study between two tracks with different layouts was also performed here. The results show that the wear depth values on the track with a larger number of tight curves are 20 to 40% higher than the ones obtained in the track with mainly straight geometry.

In this work, a comparison between the wear evolution results obtained with different friction conditions is also performed. It is observed that higher friction coefficients originate greater levels of wear. Differences between 15 and 20% of wear depth are detected among the three scenarios studied. Regarding the wear evolution on railway wheels, the most favourable scenario is the one with low friction between the wheel and rail.

The wear prediction tool allows defining separately the friction coefficients on the wheel tread and flange. This feature is used here to study the influence of wheel flanges lubrication on wear growth. The results show the importance of using flange lubrication devices as the reduction of the friction coefficient on these zones can significantly reduce the wear progression on the railway wheels.

Acknowledgements

The work presented here has been developed in the framework of the European Project AWARE (Reliable Prediction of the Wear of Railway Wheels). The project is supported by the European Community under the Sixth Framework Programme Marie Curie Actions: Host Fellowships, Transfer of Knowledge (TOK-IAP) with the contract number MTKI-CT-2006 – 042358.

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Modelowanie zużycia kół pojazdów szynowych za pomocą narzędzi symulacyjnych opartych na oprogramowaniu dla układów wielobryłowych

Streszczenie

Przewidywanie stopnia zużycia kół pojazdów szynowych jest zagadnieniem o kluczowym znaczeniu w badaniach taboru kolejowego pod względem ekonomicznym, bezpieczeństwa, eksploatacyjnym i serwisowym. Celem tej pracy jest opis zastosowania elastycznego narzędzia komputerowego pozwalającego na symulację procesu zużycia kół w zależności od rodzaju pojazdu szynowego lub całego składu, w efekcie którego

otrzymuje się ewolucję profilu kół w funkcji przebytej drogi. Narzędzie to wykorzystuje sekwencję pakietów do pre- i post-procesorowego przetwarzania, w których zawarto najnowsze metodologie obliczeń zintegrowane z komercyjnym oprogramowaniem stosowanym w kolejnictwie do badań dynamiki pociągów. Narzędzie to zaprezentowano na przykładzie różnych scenariuszy odnoszących się do kilku konkretnych warunków jazdy. Głównym celem było zademonstrowanie efektywności symulacji zużycia kół poprzez ilościowe określenie wpływu rodzaju składu pociągu i parametrów trasy na przebieg tego zużycia. Szczególną uwagę zwrócono na wrażliwość metody w odwzorowywaniu profilu kół w zależności od warunków tarcia pomiędzy kołem a szyną.

Manuscript received November 12, 2009, accepted for print February 26, 2010