

1 Introduction

Railway vehicles owe much of their reputation as eco-friendly and future-oriented means of transport to the simple but highly efficient wheel-rail interface. In fact, it is here where all fundamental functions for rolling stock transport are integrated, namely the generation and transmission of supporting, guiding and driving or braking forces [1, p. 17].

The high energy efficiency of railway transportation is due to very low losses in rolling contact [2, p. 6] as rolling resistance decreases with smaller deformations and lower hysteresis of the contact partners in the vicinity of the contact patch [3, p. 12]. The privileged position of railway systems as compared with road transport in terms of rolling resistance is evidenced in Table 1.1, which lists the ratio of rolling resistance force to normal load, also known as rolling resistance coefficient.

Table 1.1: *Rolling resistance coefficient of different wheel/tire designs [4, p. 49]*

Wheel/Tire	Rolling resistance coefficient [–]
Mainline railway wheel with roller bearings	0.0007–0.002
Conventional tram wheel	0.0015
Rubber tram tire	0.002–0.003
Cross-ply tire on asphalt	0.01

As usual, outstanding advantages come at a price. In this case, the fact that very high loads are transferred through a very small contact patch leads to an extremely high contact pressure in comparison with typical values encountered in land transport as listed in Table 1.2. Not surprisingly, this high mechanical demand is accompanied by several undesired phenomena such as material yielding, wear, fatigue and corrugation among others [2, pp. 6–11].

Table 1.2: *Maximum contact pressure on contact patch at typical operating conditions*

Wheel/Tire	Maximum contact pressure [MPa]
Passenger car tire [5, p. 67]	0.18–0.45
Truck trailer tire [6, p. 770]	0.90–1.76
Mainline railway wheel [7, p. 154]	950–1329

As little resemblance exists with other engineering systems, the study of deterioration mechanisms in wheel-rail contact has constituted a separate field

of research that goes back to the middle of the 19th century [8]. Almost two centuries later, the mechanical characterization of wheel-rail contact remains a central research topic in rail vehicle technology.

Determining the size and shape of the contact area is an essential step in the process of finding the traction distributions that characterize the solution to the contact problem [9, p. 63]. In this respect, numerical methods offer invaluable insight into the contact patch, which is why multiple models have been developed to reproduce the contour of the interface as well as the forces transmitted through it. Even though the remarkable accuracy of numerical methods is beyond question, the recent rise of verification and validation procedures has put a spotlight on the need for experimental methods that are capable of quantifying the deviation of models from reality.

Several experimental methods have been developed aiming to fill this need, including the monosheet pressure measurement films manufactured by Fujifilm, which are shown in Figure 1.1. These are produced in different varieties to encompass a wide range of measurable pressures.



Figure 1.1: *Portfolio of monosheet pressure measurement films*

The potential of these films has already been demonstrated as they could capture the shape of the contact area originated between wheel and rail for different relative positions in the laboratory [10, pp. 117–135]. As shown in Figure 1.2, numerical and experimental outcomes were found to be in good agreement.

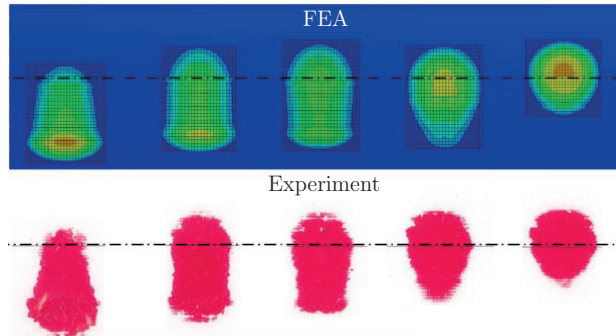


Figure 1.2: *Qualitative comparison between numerically and experimentally determined wheel-rail contact patches [10, p. 128]*

So far, the application of the film has for the most part been limited to qualitative assessments due to the systematic error caused by the interposed layer. Whereas pressure measurement films excel in applicability and cost, their use as a validation tool is unconceivable unless all factors that condition the measurement procedure are identified and their effect on the resulting contact patch is investigated.

The present work tackles this pending issue by resorting to academic case studies in order to characterize thoroughly the governing mechanics of the measurement procedure. The error originated in wheel-rail contact area measurements is quantitatively determined by falling back on a combination of analytical, numerical and experimental approaches. The implications on potential validation activities by means of pressure measurement film are also discussed.