Curve noise: research without an end?

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1 Introduction

Curve squeal is by far the loudest noise produced by rail vehicles, **Figure 1**. This is a well known fact and as a result considerable research has been – and indeed continues to be – conducted worldwide. There are too many publications in this field to be familiar with and appropriately evaluate all of them. There is general consensus, however, on the cause of curve squeal, namely the fact that lateral displacement of a rigidly coupled wheelset in a curve causes frictional forces between the wheel rolling on the inner rail and the inner rail itself (**Figure 2**). The wheel rolling on the outside is guided over the flange on the outside rail and friction here occurs only between the flanges of the wheel and rail. The resulting noise is a screeching sound. The frictional forces in turn activate the natural frequencies of the wheel and rail. There is also agreement that adjusting friction levels alters the lateral glide and thereby reduces squeal noise. So why is research still being carried out if we know what the solutions are?

This article outlines one or ideas as to how to put these solutions into practice. Whether these measures eliminate squeal on curved tracks will depend largely on those responsible for implementing them.

2 Solutions

There are three possible approaches when seeking to reduce squeal noise on tight curves.

2.1 Solution A: Prevent lateral displacement

If lateral displacement is prevented then no friction occurs and no frequencies are activated. Numerous studies have been carried out in an attempt to achieve this but so far only a few successful applications of the solution have found their way into practical use. Lateral displacement can be largely eliminated by positioning the wheelsets in the curved track radially, the aim being to achieve an angle of attack approaching zero. **Figure 3** (see also **Figure 4)** shows some typical angles of attack during travel in curves. Various technical solutions have been developed and tested with varying degrees of success. [1] This potential solution also entails altering the flange geometry and setting different inclinations on the inner and outer rails.

2.2 Solution B: Reduce frictional forces

Another way in which to prevent frictional forces is to alter the frictional status of the wheel and the rail. It emerged very early on that little or no squeal occurs in rainy weather. Numerous studies were therefore conducted to replicate rainy conditions by applying appropriate substances such as artificial rain, lubricant and build-up welding. When applying such solutions care must be taken to ensure that they do not extend the vehicle's stopping distance beyond permissible limits.

Alloy components having a 'lubricating' effect within the wheel and rail materials likewise influence friction but unfortunately also promote wear.

2.3 Solution C: Reduce structure-borne noise created in wheel and rail

Another solution is to convert the vibration energy produced into heat through appropriate technical applications. Devices for absorbing wheel and structure-borne noise have been developed for this purpose and have proved extremely successful. On the other hand, all damping measures tested on the rail so far have been only moderately successful [2], [3], among other things because the wheel – at least in urban-transport vehicles – is the primary source of noise.

2.4 Recognised but not implemented

In principle, all solutions used in practice are based to some degree on the three principles outlined above, the actual materials used and designs followed differing to a greater or lesser extent.

The activation mechanisms and possible solutions have been known about for at least 30 years yet virtually all transport companies still encounter squeal in urban transport at one time or another. Why is this so and what can be done to prevent it? This is the first question to be asked when one considers how much research and development has been conducted precisely to reduce what is a disturbing noise. At a distance of 7.5 m from the centre of the track, measurements yield a maximum acoustic pressure level in the order of L_{pAFmax} = 105 dB(A). For those living within this radius, this is a justifiable reason for complaint.

It should be noted here that rubber-suspension wheels do not prevent squeal altogether but simply result in different frequencies being activated.

3 Strategies

So if all this information is known, why has it not been applied? People living alongside railway tracks are certainly asking this question, as are, to some extent, passengers . What – credible – answer can be given?

It is worth emphasising that throughout the world many transport companies have made considerable efforts to reduce squeal to a great extent and all the larger ones, certainly, have already tested out one or other of the three principles detailed above.

It should also be made clear – as a general point and not only to those individuals directly affected – that even the solutions we are currently familiar with cannot eliminate noise completely. All additional measures, whether involving the vehicle (bogie, wheel), the wheel/rail contact area, or the rail itself require both material and personnel, neither of which comes cheap. Research and development to date may have yielded solutions, but thus far, with the exception of natural rain, all are costly despite the substantial research funds spent. Here too, the question certainly arises as to whether further research based on the existing wheel/rail system can achieve anything more. It must be clear in this context that the wheel/rail system has limits which must be observed unless the entire system is to be called into question.

In terms of costs, then, what might help to lower them? One possibility might well be to standardise measures. In addition, setting out uniform standards might also be considered as might larger-scale production runs. For example, in [4] the author calls for all new local rail-transport vehicles to be fitted with wheel sound absorbers. Indeed, numerous practical examples [5], [6] have demonstrated that with proper design such a solution can largely alleviate the problem. Yet despite these absorbers, under certain general conditions low-level squeal may still occur and additional steps must therefore be taken; these can be specifically selected and applied once the noise occurs. A catalogue of measures [7] in this regard is already available and R&D should seek to optimise and standardise these.

Another general question must be settled too, namely who is to blame for the noise? Can the public take themselves out of the equation and say that the transport company alone is responsible for the noise produced by rail traffic? Or are they, both as passengers and as those demanding the carriage of goods and people, not also partly responsible? Since in many countries measures to prevent noise are financed through taxes, the public indirectly assumes this responsibility (albeit often not entirely voluntarily). Consideration must be given to whether some sort of 'noise-prevention' tax should be introduced to finance the measures required to reduce high levels of curve noise (as well as other noise and vibrations).

4 What is to be done?

Section 3 sets out a range of options for translating the findings of R&D in practice. Some of these are noble wishes that will be impossible to implement without political intervention. Given the free circulation of goods within the EU, largely uniform requirements must be produced.

The following specific steps could prove useful:

1. Setting out uniform evaluation criteria for curve noises;
2. detailing a uniform procedure for measuring, evaluating and recording the specific noise occurring in a curve;
3. listing the general conditions under which measurements are to be performed: a special section outlining the general conditions applicable or a corresponding test bed via which critical situations can be examined might be used for this purpose;
4. determining the underlying technical requirements of measures to reduce curve noise;
5. standardising measures (defining standards);
6. setting out rules on how to apply the measures;
7. monitoring compliance with the required noise-emissions levels in curves. Both onboard and fixed systems can be used for this [8].

Test conditions capable of yielding clear results are critical to accurately evaluating the measures used. For example, STUVA operates a test circuit which has been specifically converted to be able to replicate the general conditions detailed [9]. This facility allows 'climate' conditions to be adapted to any given critical situation. The system itself consists of a rotating, 10m-long tube to which a wheel can be attached at each end. As such, original wheels can be used and various measures applied to them to test their effectiveness in preventing noise emissions in curves.

The simplest solution for monitoring noise emissions is to fit vehicles with simple and inexpensive microphones. These are positioned in each bogie. The noise signals they pick up can then be recorded and assessed based on section data (and, in the open air, using GPS coordinates) when a predetermined level or other criteria are exceeded. This option offers several benefits as detailed below.

1. The entire section in question (curves) can be permanently monitored).
2. Problematic curves can be identified.
3. Clear data are produced which can serve as evidence in the event of complaints by local residents.
4. Targeted measures can be adopted: for example, the measurement data can be used to manage the use of friction-altering materials on the rail, thereby ensuring that the precise amount required is applied.
5. Such data can also be used to gain a deeper understanding of how noise is created and, therefore, of how best to reduce it. This is especially true as regards the impact of weather and, coupled with data collection in the vehicle, further conclusions as to the effects of general vehicle conditions. This also includes the much-documented changes in the modal behaviour of the wheels caused by wear and re-profiling on underfloor lathes. What impact does this have and how can it be adapted into a suitable solution?
6. Some transport companies report that in practical use the wheel absorbers break off. This has been observed specifically with tramways, where in certain areas the absorbers hit the paving stones projecting above the top of the rail. From the point of view fitting absorbers to vehicles on a broad scale (see above), it might well be possible to solve this problem by designing the wheel and the mounting the absorbers appropriately. There are certainly practical examples of solutions where such problems are not encountered.

It is critical that measures adapted to the relevant requirements are applied consistently and in a targeted fashion. Depending on the general conditions, a particular measure may prove successful either alone or in combination with others.

5 Summary and Outlook

The causes of curve squeal and the main solutions for preventing such noise are outlined above. Practical experience has shown that the measures applied achieve a good degree of success and it is questionable whether further intensive research alone will help to solve the problem definitively. Research in this field has already been conducted over far too long a period – research which frequently serves to do nothing more than confirm what has long been known. I therefore propose that action be taken to implement on a consistent basis the tried and tested solutions with which we are already familiar.

The best thing to do is... just do it!

(freely adapted from a quotation by Erich Kästner)

6 Literature

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[9] Krüger, F., Amende, D., Martini, K., Steckel, L.: URBAN TRACK – Tests on a test circuit and hydro-pulse facility for embedded tracks. September 2008.

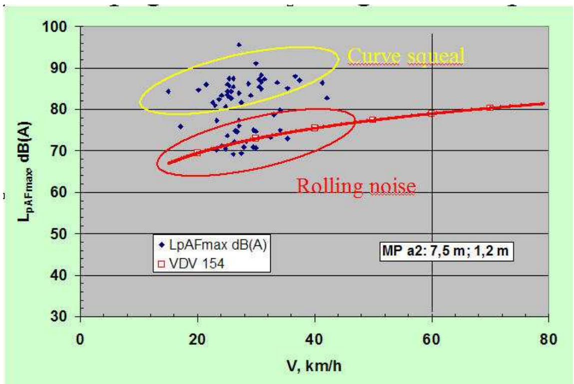

Figure 1: Noise level L_{pAFmax} at 7.5 m beside the track centre line, 1.2 m over rail level

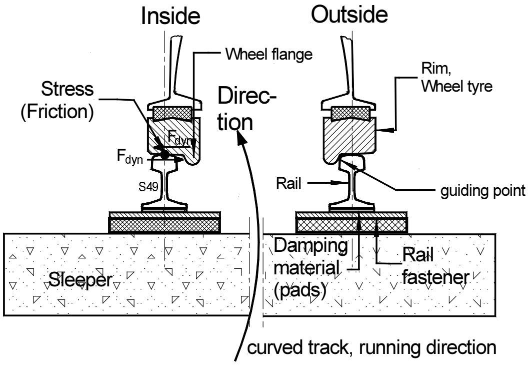

Figure 2: Forward wheel-set in the curved track. Right: guidance on the flange. Left: lateral movement to the curve centre (friction causes squeal)

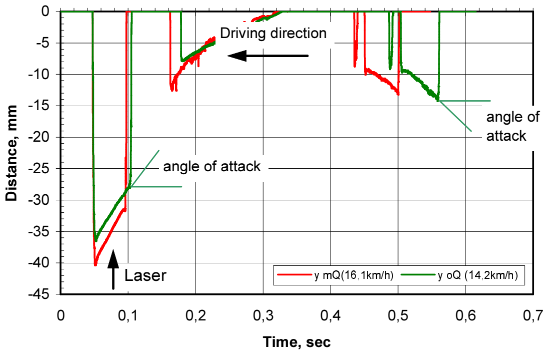

Figure 3: Angle of attack of wheels in the curved track, outer rail (no radial configuration of the wheel-sets), R = 35m

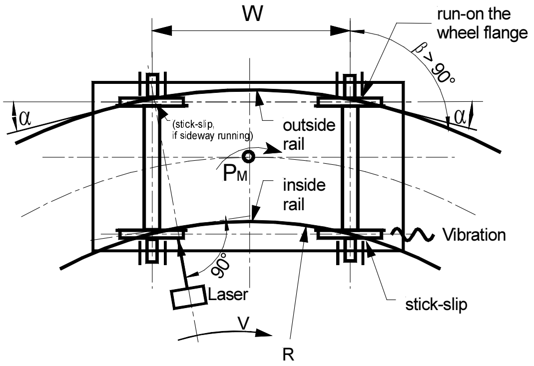

Figure 4: Curve passage of a bogie with non controllable wheel-sets.

α	striking angle (wheel/rail angle of attack)
W	wheel base
R	track curve radius
V	train velocity

$$\sin \alpha = W / 2R$$

Two movements:

1. Running of the wheel-flange onto the rail head;
2. Rotation of the bogie around the centre point P_M