Railway Engineering: Performance Over Time

COURSE SYLLABUS

Week 1: Long-term performance

Even perfectly designed railway systems will accumulate problems over time and over different locations. The question is not *if* these problems arise, but *when*, *where* and *how often* they occur. In this first week, we will explore the most common problems in railways and look at the components and failure modes that are the underlying causes.

1.1 Major Problems

Although there are some general problems in railways, which can be found in systems all around the globe, there are also system-specific problems. In this first hour, we will explore the major issues for the most common types of railway systems, analyse which aspects might make these problems unique, or whether there are more overlapping characteristics between systems than unique ones.

1.2 Sensitive Components

Since there is overlap in major problems between the different railway systems, we will find the components that are more sensitive to failures than others. In this second hour, we will focus on these sensitive components, and examine why these components fail the most often.

1.3 Failure Modes I Fatigue

Although it is good to know which components fail and why, it is also important to understand what failure modes are responsible for these failures. These failure modes are discussed in the final three hours of this week.

First, we focus on fatigue. Due to endless load and unload cycles, fatigue is definitely one of the main failure modes in railway systems. The effects of fatigue on different parts of the railway system will be shown, both in rolling stock and infrastructure.

1.4 Failure Modes II Wear

Wear is another important failure mode in railways. The slow reduction of material eventually leads to the weakening of the components. This reduction of material will happen wherever contact takes place between different surfaces. In this fourth hour, the focus will be on the most common case of wear in railway systems: rail and wheel contact.

1.5 Failure Modes III Others

Although fatigue and wear are the most common failure modes in railways, there are also some component-specific failure modes. In this fifth hour, we will discuss these failure modes.

Week 2: Consequences and Maintenance

In this week, we shift focus to examine the consequences of the problems, and which corrective activities, including repairs and maintenance, can be taken in order to solve the problems.

2.1 Damage through interaction

Even though many problems in railways appear to be isolated events, there are often connections between failures, even when they might be at completely different locations and many months apart. In this hour, we will look at how problems in one component can influence the integrity of other components and thus cause new problems in the future.

2.2 Reactive maintenance

Luckily, when there are problems in the railway system, these usually do not cause big accidents. In these cases, simple repairs can be sufficient to bring the system back into operation. In this section, we will look at what repairs can be done and under what conditions these are commonly performed.

2.3 Track maintenance

With reactive maintenance, we wait for the problem to arise and we have to face all the related consequences such as delays and financial losses. But is there an alternative? Preventing some of these problems is possible and can be very advantageous from both an economic and operation perspective. In this hour, we will look at what preventive measures can be taken for tracks.

2.4 Vehicles maintenance

Of course, preventive maintenance is not only limited to tracks. In railway vehicles, preventive maintenance can also solve many problems before they happen. In this hour, we will look at what maintenance is performed on railway vehicles on a regular basis and how this helps to prevent the problems discussed in the first week of this course.

2.5 Electrical Maintenance

Next to track and vehicle failures, electrical systems also cause a relatively large part of the disturbances in railway networks. In this hour, we will look at how preventive maintenance is performed on electrical systems within railway systems, and the opportunities there are for further improving maintenance, and thus reducing the effect of disturbances.

Extra: Ask the Professor

Throughout the course, Professor Rolf Dollevoet will be available to answer any questions you have in fortnightly videos. He will give you feedback and counter-questions as well!

Week 3: Degradation processes

Even though it is good to know which failure modes cause the most common problems in railways and how they can be prevented, the only way to optimize prevention is to monitor where these failure modes initiate from. Monitoring is only possible when we have a complete understanding of the degradation processes underlying these failure modes. In this week, we will dive into the physical behaviour of these degradation processes.

3.1 Steel fatigue

Fatigue of materials is a common problem in many industries. In the case of railway systems, steel fatigue is the most common form. In this hour, we will explore the causes of fatigue in general and more specifically in steel. The influencing parameters will also be explained. Furthermore, we will look at how fatigue can be reduced through design choices.

3.2 Wear Mechanisms

Wear is the second most commonly seen degradation process in railways. This is not only limited to the wheel-rail contact, but can also be seen between the pantograph and catenary or the breakpad and breakdisk of a train, for example. In this hour, the physical behaviour of wear will be discussed, giving you knowledge on how to predict the amount of wear taking place in a system.

3.3 Rolling Contact Fatigue

Rolling Contact Fatigue (RCF), can be seen as a specific form of wear, which is related to steel fatigue as well. In this hour, the causes and consequences of RCF are discussed. Furthermore, we will look how to reduce the growth of RCF.

3.4 Examples of wear

In this hour we will focus more closely on the contact behaviour between two surfaces and how this is related to wear. With this knowledge we can look at mitigating measures that can be taken to reduce wear, while also considering the consequences they have for the railway system as a whole.

3.5 Ballast Degradation

Ballast degradation is a complex process because of the special function ballast has in a railway system (dampening vibrations), combined with the fact that ballast consists of separate objects rather than forming a single structure. In this hour, we will look specifically at ballast behaviour, the degradation of ballast and the consequences this has for the ability of the ballast to perform its unique function.

Week 4: Strategic Monitoring

Now that we know the physical behaviour of the problems in railway systems, it is possible to monitor this behaviour. In this week, we will explore the existing monitoring solutions, but also focus on how to design new monitoring tools.

4.1 Monitoring solutions

In the first hour of this week, we will start with a general introduction on monitoring solutions. From here, we will look at some examples of monitoring solutions currently used in railway systems.

4.2 Setting up systems

In general, monitoring solutions are based on the use of sensors combined with a data acquisition system and data storage. However, due to the enormous amount of possible equipment an almost infinite amount of system can theoretically be designed. The question to be answered in this hour is: What should be considered when selecting the right set-up for a monitoring system?

4.3 Key Performance Indicators

Having available measurements is important for railway systems, but it is arguably even more important is to be able to systematically use that information to improve the overall performance. During this hour, we will analyse the design of key performance indicators (KPIs), which help monitor the evolution of important problems in railway systems from different perspectives: the technical level, tactical level and managerial level.

4.4 Structural Health Monitoring

Over the last years, integration of monitoring solutions into the lifecycle of structures in general has become very popular. In the last two hours of this week, we will delve into Structural Health Monitoring (SHM). We will start by looking how SHM differs from other monitoring solutions and its advantages. Next, we will look into the importance of integrating SHM in the whole design process.

4.5 SHM Implementation

In this hour, we will focus on the implementation of SHM. The most important steps in the implementation process are discussed, including design, feature selections, detection of anomalies, selection of algorithms, neural networks for railway.

Extra: Forum Discussions

During the course you will also be invited to join us for problem-solving discussion on the complexity of railway systems engineering. Professor Rolf Dollevoet will take part in these interactive sessions, responding to your answers with further complications to challenge your knowledge.

Week 5: Maintenance Optimization

Well-informed maintenance decisions can only be made by having knowledge of the degradation process and sufficient data of the current status of a component. However, the process of translating the knowledge and information into a maintenance decision is complex. In this week, we will look at how to make these maintenance decisions, and what to consider for optimizing the maintenance operations.

5.1 Maintenance Management

In week two, we looked at reactive and preventive maintenance. In this hour, we will go deeper into what drives the decision for selecting the type of maintenance, and how this can differ per system. The evaluation of the necessity of maintenance will be discussed.

5.2 Main Characteristics

This hour will cover RAMS which stands for Reliability, Availability, Maintainability and Safety. These are characteristics that any civil infrastructure system in operation should have. In the case of railway systems, availability and safety are always in the top of the priorities of any railway operation. In this hour, we will analyse RAMS from the railway perspective and how to influence them so to maximize the resilience of the infrastructure.

5.3 Life Cycle Costs

Even though construction costs are very important, these are not the only costs to be considered when evaluating a railway project. Nowadays, evaluation of life cycle costs in operations is considered more important by railway infra managers. Thus, even though a huge replacement might not happen this year, the infra managers can already get prepared to assume the costs of one that is coming in 5 or 10 years ahead. In this hour, we will look deeper into life cycle costs in railways, and how this approach can also be used for making maintenance decisions.

5.4 Data and maintenance

We will make the link between data and maintenance in the fourth hour of this week,. Nowadays, with the availability of high amounts of data with different reliabilities, maintenance decisions are often based on a complex process. In this hour, we will look at what techniques are available for dealing with uncertainties in data, and how big data can help in this process.

5.5 Decision making

In the last hour of this week, we lay down the final content to connect all the knowledge of the previous weeks into a single conclusion: making the most optimal decisions for maintenance. This starts from a general viewpoint on decision making and concludes with examples of applications in railway systems.

Week 6: Case study

We challenge you to put your knowledge of the whole course together by analysing a case study on railway design.

In this case, you take the perspective of a railway specialist, hired to advice the local railway company on monitoring and maintenance issues. During of your working days, suddenly you receive the following 4 warnings about the system.

- Warning 1: high continuous vibrations have been measured on one train axle.
- Warning 2: the presence of multiple cracks has been detected in the rail in a curve.
- Warning 3: irregularities in the track geometry have been detected at the transition from ballasted track to the track on a steel bridge.
- Warning 4: increased track vibrations have been measured around a rail-weld on a steel bridge.

For the assignment, you will choose one of the following warnings and write a report that considers the following:

- possible sources of damage and the failure modes
- the advice you would give if no maintenance crews are available short term
- possible monitoring solutions
- a design solution to prevent problems
- what you would do if all 4 problems are taking place in the same system at the same time