Norges Teknisk-Naturvitenskapelige Universitet

TPK4186 - Advanced Tools for Performance Engineering
Spring 2020

Assignment 1: A Braking System

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Contents

1 Introduction

1.1 Presentation of the Problem

As a reliability engineer, you are asked to study the following (hypothetical) rail train braking system pictured in Figure 1.

This system is actually the combination of two safety-related systems. One is a high-demand train primary braking system. The second one is a second level of protection consisting of a low-demand emergency braking system.

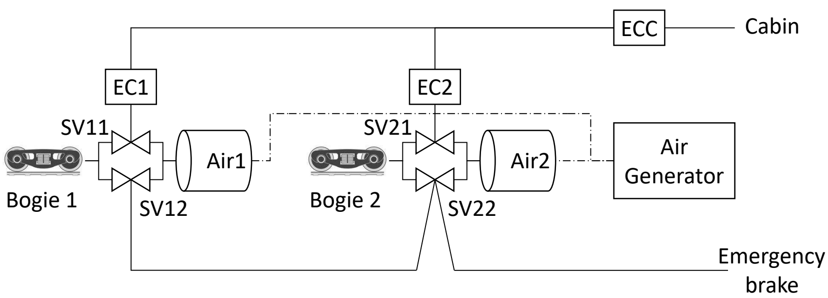

Figure 1: A braking system

The high-demand braking system is activated by the train driver through a general electronic controller ECC and two electronic controllers EC1 and EC2 (one for each bogie of the carriage). This system sends electronic signals to operate the brakes on each bogie via solenoid valves (SV11 for the first bogie, SV21 for the second one). The degree of braking is proportional to the signal. The system is normally energized to hold brakes off. The output of the solenoid is de-energized to apply the brakes.

In addition to this primary braking system, there is a separate emergency braking system. This system consists of an electric wire that runs the full length of the train and is connected to an emergency button in the drivers cabin. This electric circuit holds normally the brakes off. The emergency solenoid valves S12 and S22 are de-energized to apply full braking pressure to the brakes.

Each bogie has its own air supply reservoir topped up by an air generator. Air pressure has to be applied to operate the brakes. Each bogie braking system is independent. It is sufficient that the braking system on one of the bogies works for the train to the able to stop.

1.2 Requirements

The objective of this assignment is not only, nor even primarily, to assess the probability of failure of the braking system, but rather to show your modeling skills.

Here follows a number of requirements.

1. You must provide your model together with a small document explaining how it is organized, what it is doing and reporting experiments you have performed with it. You may also provide additional files such as those you use to assess your model.
2. You must make explicit all of your hypotheses. It is not a problem to make some restrictive hypothesis, but it is a problem if you do not mention it and do not justify it.
3. Assuming your name is Jack Sparrow, all of the above files must be included in a zip archive named:

   `TPK5120 - 2020 - Assignment1 - Sparrow Jack.zip`

   The deliverable of the assignment is this zip archive.
4. The assignment must be made invidually.
5. You must design your models in an object-oriented style.
6. Recall that the quality of a model can be evaluated along three criteria: its completness, its correctness and its maintainability:
   - A model is complete if it describes all functionalities of the system under study. Some functionalities are however more important than other. You must first concentrate on the main functionalities, then develop the "nice-to-have" ones.
   - A model is correct if it is bug free. To ensure that your model is correct, test it, extensively.
   - A model is maintainable if it is well presented, if the identifiers are significant, and so on.

2 Tasks

Here follows the series of tasks that you are asked to complete.

2.1 Architecture of the System

Design the functional and the physical architectures of the system.

It is of primary importance to take into account all of the functions of the system. In particular, you have to distinguish functions involved in the regular operation of the train from safety functions. The loss of these functions may actually involve different failure modes of the physical components.

2.2 Model

Design a Cassis model for the braking system. Your model is intended to support a reliability study of the system:

- It must reflect the functional and the physical architecture of the system.
- It must encompass the different safety goals.
- It must take into account the different failure modes of components. Do not forget "false positive".

2.3 Assessments

We shall assume that the different failure modes of components obey exponential distributions. However, as we are in the design phase of the system, we do not know the failure rates. The objective of the study is actually to determine these failure rates given that:

- The failure rates should be given per millions of kilometers rather than per hours.
- There are technological limits to what is feasible (browse internet to find them).
- The probability of an accident due to a loss of the braking capacity should be less than 1.0×10^{-4} per million of kilometers.
- The probability that the train is stopped due to a problem of the braking system should be less than 5.0×10^{-2} per million of kilometers.

You have to justify your safety allocation (and to show that it meets the safety objectives).

2.4 Further Readings

Although it is not required to do the assignment, you are suggested to have a look at the following report (it is easy to find on internet).

railway-safety-performance-2016.pdf