PACCAR – Brake Timing

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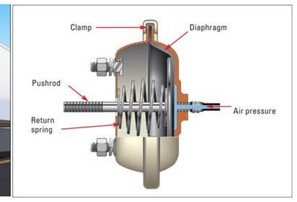
Introduction

- Most commercial semi-trucks, including PACCAR's, utilize pressurized air brakes to stop themselves.
- Because brake activation requires air to physically travel through the system, the flow of air through the system is critical to determine how long the brake system will take to respond
- A model will represent how long it takes for the brake application to be applied a under differing conditions

A PACCAR Semi-Truck



An airbrake

Problem Statement

Our team's mission is to model the braking behavior under differing conditions by testing a physical model and then comparing it to a simulated value.

Problem Requirements

Primary

- Get within a 5% accuracy of simulated value to real values with a program

Secondary

- Create thorough documentation to ensure that the efforts are repeatable
- Test using different tube and fitting conditions to represent the different types of trucks created by PACCAR
- Measure air pressure from the application of the brake pedal to when the brakes are applied, and when it is released

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Physical Element Testing

Element Calculations

- Characteristic variables are chosen by their constant value despite pressure, temperature, and final velocity conditions.
- Used calipers, rulers, anemometers, and differential pressure sensors
- Equations derived from fluid mechanic concepts

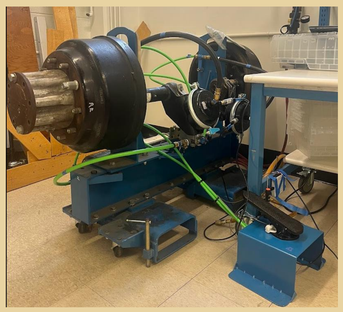
An example of the testing setup, configured for a fitting test.

Experimental Variables

Fittings	Tube	Valve
Angle Sizing Initial Pressure	Bend Radius Sizing Initial Pressure Length	Initial Pressure

- In total, 22 elements (fittings, tubes, and valves) were tested with 4 pressure trials each to ensure repeatability
- An excel calculation sheet was created to help the calculation process

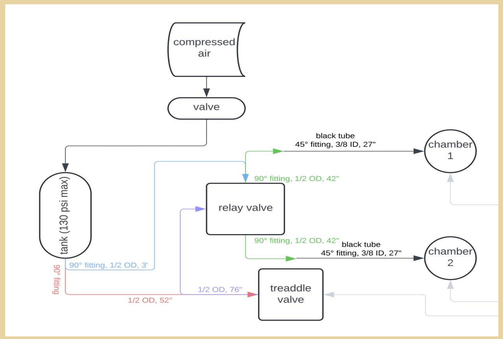
Physical Testing Set Up



Only the "Dummy Axle" above was modeled, as we did not have access to a full semi-truck. This might affect extrapolation to a larger system.

- Tubes and fittings are interchanged, then the brake is activated
- Pressure readings versus time are generated sensors on a data acquisition device
- The brake is applied instantaneously with a piston.

The piston application



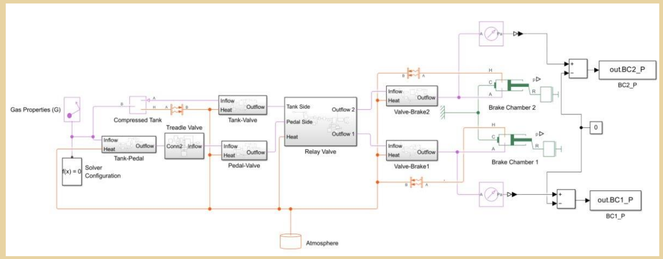
A block diagram for the original configuration.

Simulation Modeling

SimScape Fundamentals

- MATLAB-integrated modeling platform with iterative discrete-time solver.
- SimScape is based on single-element blocks, such as a pipe or fitting, with continuity equations relating the input and output states.

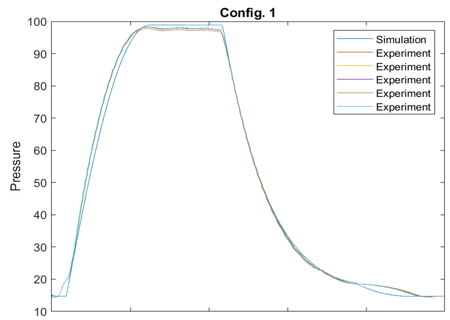
Our System

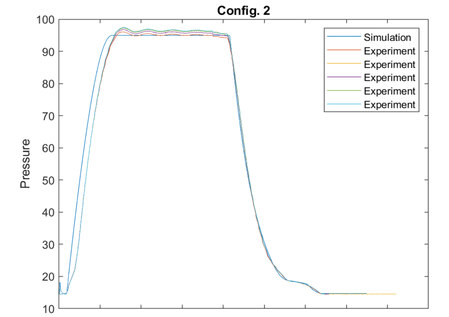


The SimScape model of the simplified brake system.

- The model is fully adjustable via a MATLAB script, so many simplified brake system configurations can be modeled.
- The model was validated with experimental data, shown to the right for two configurations.
- Individual element properties are calculated internally from the values retrieved from physical element testing

Results





Plots of the experimental and simulated responses from two configurations.

Error Quantification

The following results were from 5 different system configurations with 10 different pressure readings.

	Brake Application	Brake Release
RMSE	0.023 seconds	0.033 seconds
Standard Deviation	0.005 seconds	0.033 seconds
Threshold Point Accuracy	2.2% - 14.7% (7.6% average)	2.2% - 4.1% (3.0% average)

- Much of the error comes from the noticeable change in rate of the experimental data at low pressures
- Major deviation at 2 of the sampling points
- Behavior was unable to be accounted for in the simulation as of now and is an area for improvement in the future.

To the right is a QR code that will lead you to the sources we've used for our images and our research