Targeting experimental efforts using cyber-physical models

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Who are we? Who am I? - Agenda

- Tech Talk: “Targeting experimental efforts using cyber-physical models”
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- Introduction
- Case 1 – Thermostatic Expansion Valve
- Case 2 – Admission & Exhaust Valve
- Conclusions

Introduction

Rationale & Motivation

- Reduce experimental effort in general
- Use more time on promising configurations
- Automate screening of large sets of possible configurations
- Optimize settings prior to tests

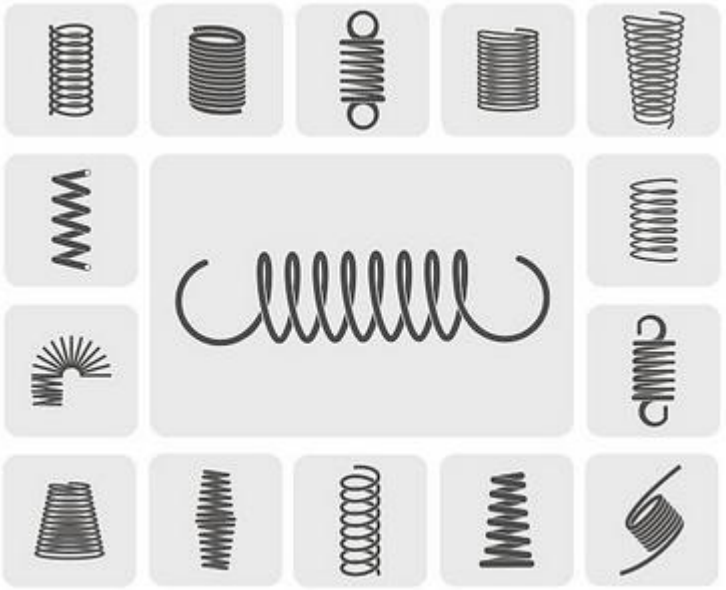
Cyber-physical Models

- Create models based on the physical components of a system
- Implement functions that describe the interaction of these components

- Requires knowledge about the system to reduce complexity
- Identification of relevant parameters is not always trivial

- This is *not* a “cyber-physical system” (physical system controlled by algorithms or cloud software)

- Example: Steel Spring
  - Many, many types and properties
  - Neglect: weight, fatigue strength, shape, material, connection type, heat capacity, …
  - Use: spring constant



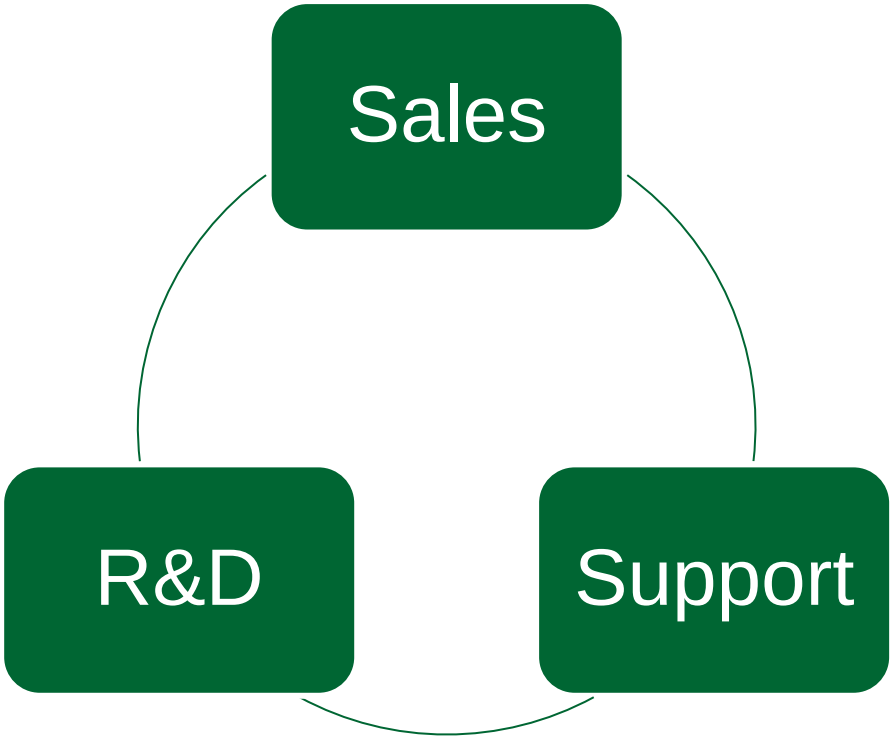
2 Different Cases and Purposes: Overview

- Two cases illustrate the opportunities:
- A similar component, a valve, handled in different ways
- Result accuracy vs. flexibility
- Data security vs. data accessibility

Case 1 – Thermostatic Expansion Valve

Case 1 – Thermostatic Expansion: Requirements

- Accurate reproduction of performance
- Use a component database to retrieve properties of system components
- Limited choices and input possibilities, validated settings, not all users are experts (support, sales and R&D)
- Create new assemblies of existing components (R&D)
- Estimate performance of existing products: corner cases and parameter sweep (support)

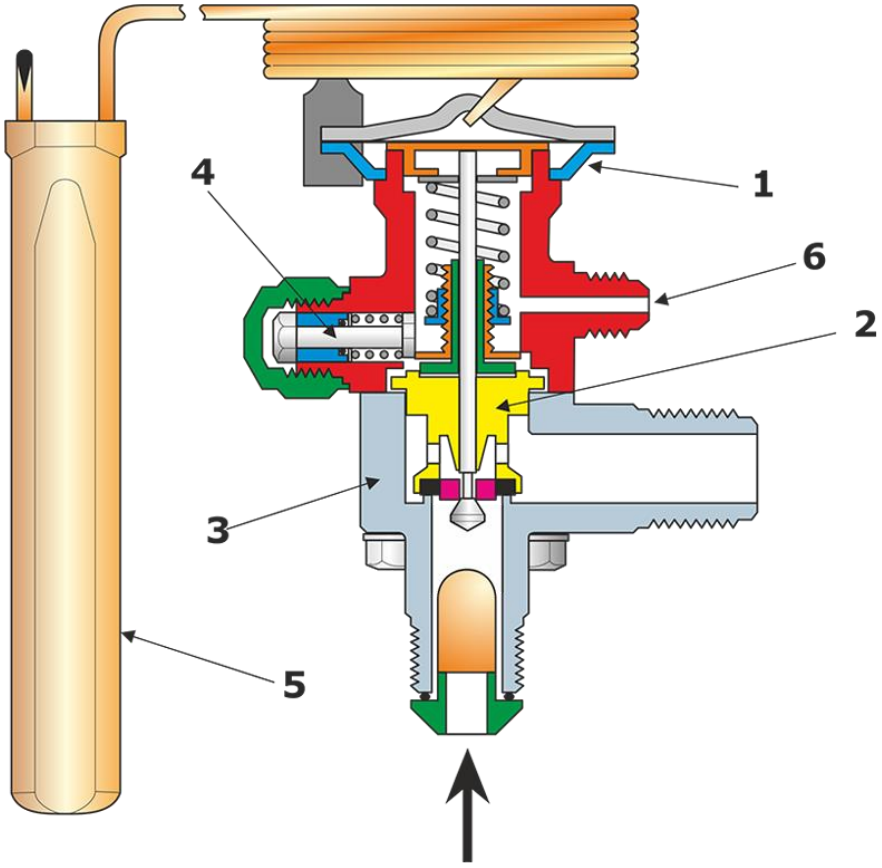


- **Reduce workload of R&D caused by questions from sales and support**
- **Assist R&D with new designs**

Case 1 – Thermostatic Expansion: Components & Models

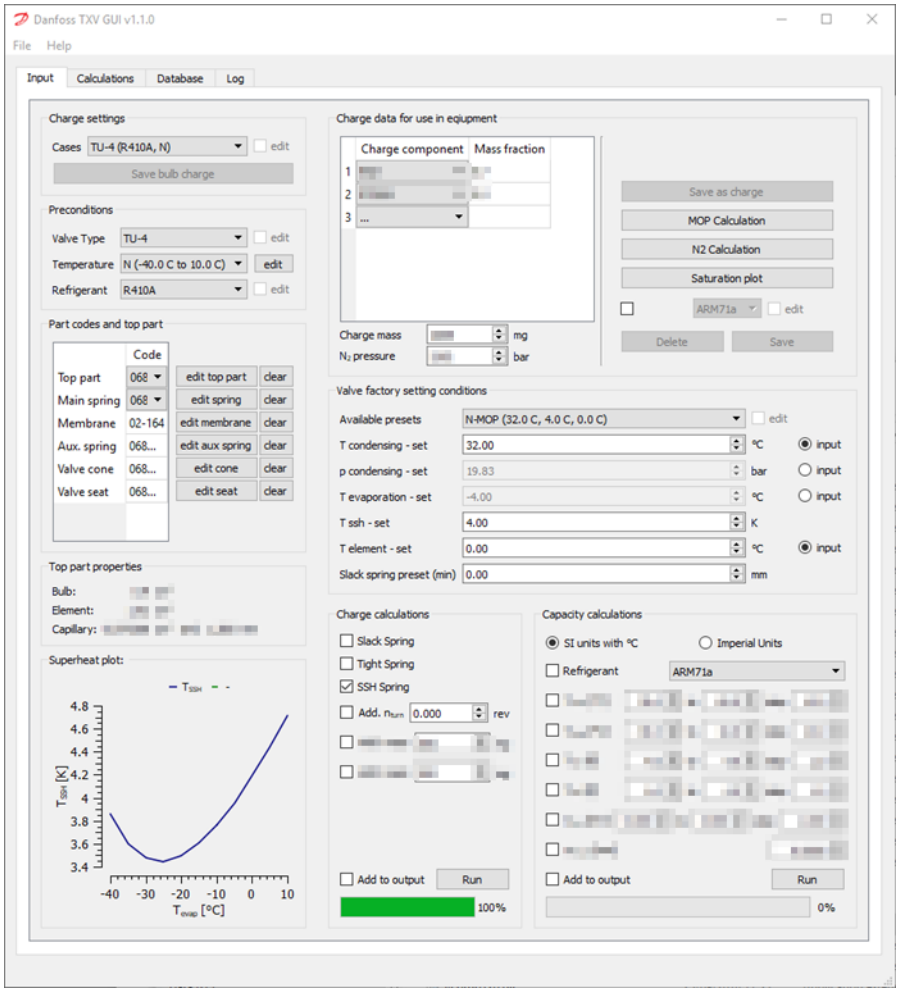
- The device controls the cooling capacity of a refrigeration system
- Employs a force balance based on pressure differences and springs
- Self-acting, controls refrigerant flow based on temperatures

- Pressure can be adjusted using custom bulb charges
- Spring forces are modified using washers and nuts



Case 1 – Thermostatic Expansion: Results & Outcome

- Model and user interface written in C++
- Use encrypted database and parameter tables to protect IP
- Users are sales and support in Denmark, China and Mexico
- Power users are R&D in Denmark, they release new database versions.
- R&D carries out 90% less experiments for sales and support



Case 2 – Admission & Exhaust Valve

Case 2 – Admission & Exhaust: Requirements

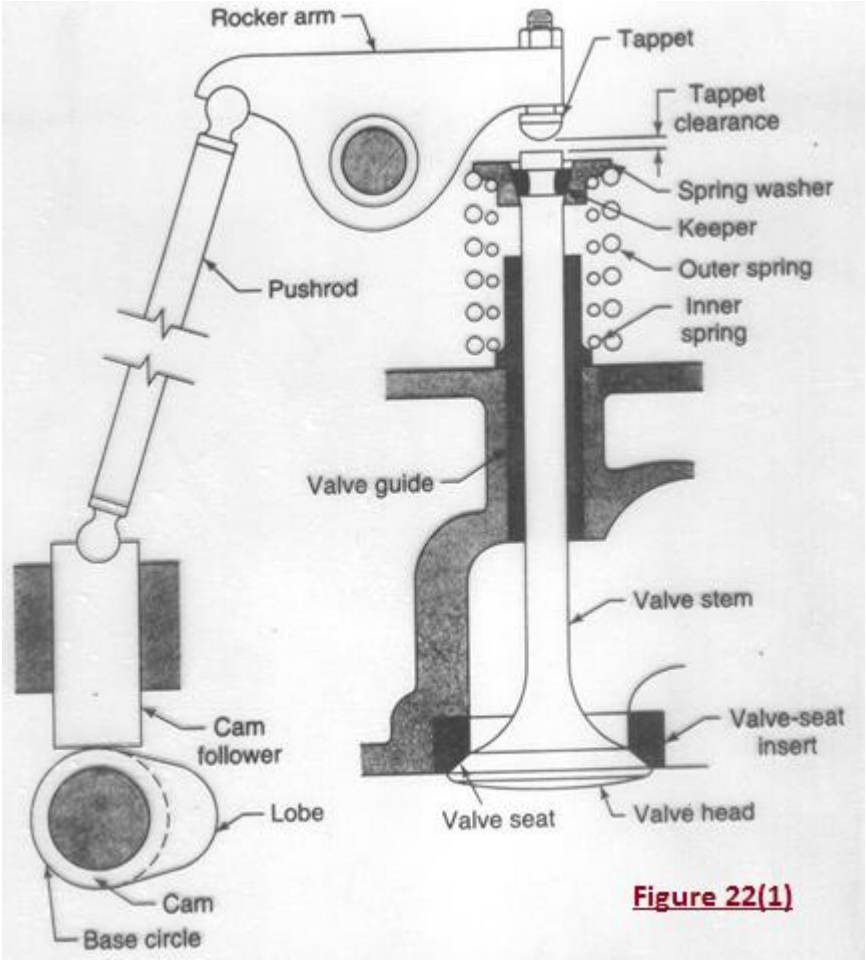
- Flexible estimation of performance
- Almost all settings available in GUI
- Quick access to equations and code
- Parameters to define valve geometry
- Modifiable valve control settings
- Stable calculations, R&D might want to push the system to the physical limits

- **Help R&D to define parameter spaces for experiments**
- **Use more time on promising designs**

Case 2 – Admission & Exhaust: Components & Models

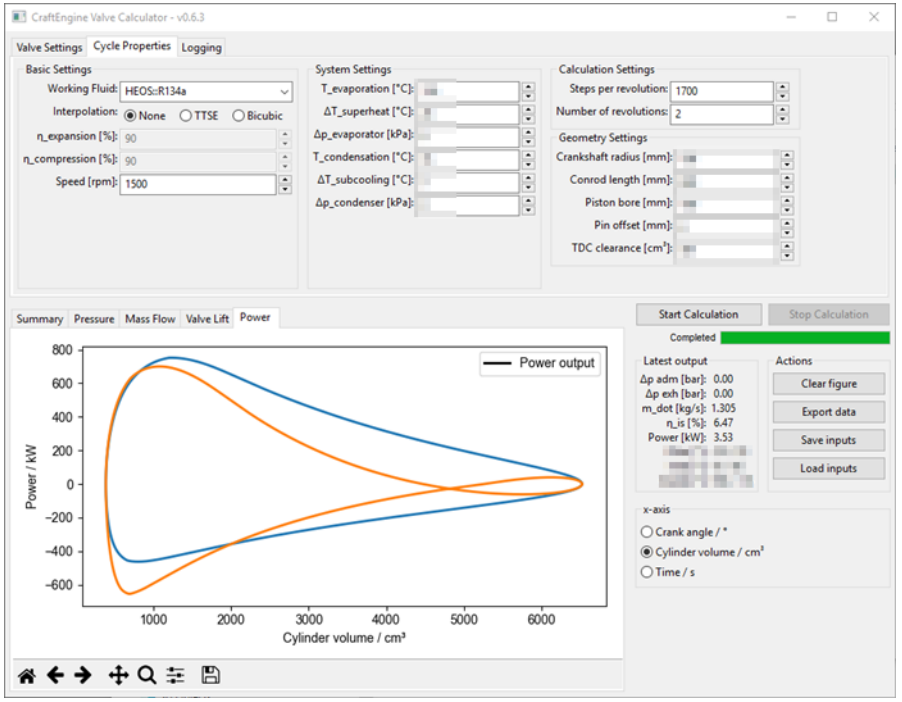
- Target is a compression and expansion machines
- Valves control gas exchange processes in cylinder-and-piston devices
- Actuated valves allow higher RPM and increase flexibility

- Throttling losses have to be minimized
- Over- and underexpansion have to be avoided (control)



Case 2 – Admission & Exhaust: Results & Outcome

- Model and user interface written in Python
- Accelerated design cycles and targeted experimental campaigns
- R&D maintains different branches for different purposes
- For R&D use only, version for sales is planned for 2019
- Much fewer prototypes produced



Conclusion