Innovation Services

High-precision equipment

Model based design for a fluid stream heater

High-precision engineering example

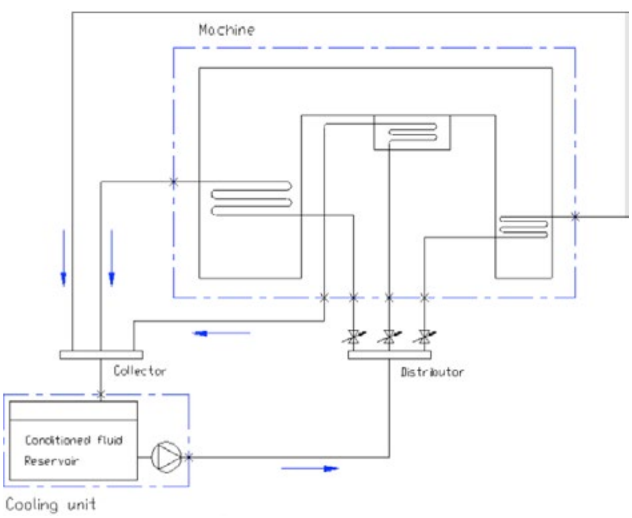
In systems where a cooling liquid is applied for heat removal and/or thermal conditioning, the cooling liquid is commonly temperature controlled via an external reservoir.

This global temperature control of the coolant limits the performance:

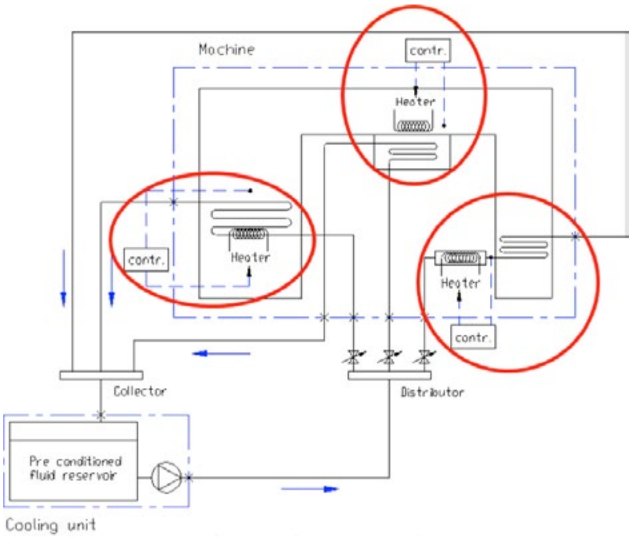
- fast temperature control is unfeasible due to the large reservoir volume and the delay between reservoir and system module
- only a single temperature setpoint is possible for the entire system
- inaccuracies in coolant temperature arise due to the parasitic heat load on channels between reservoir and system module.

Application of local temperature control allows for:

- accurate (mK level) temperature control in or close to the system module
- fast temperature adaption (e.g. to anticipate heat loads)
- multiple temperature setpoint in the different system modules
- minimization of coolant flow and vibrations.



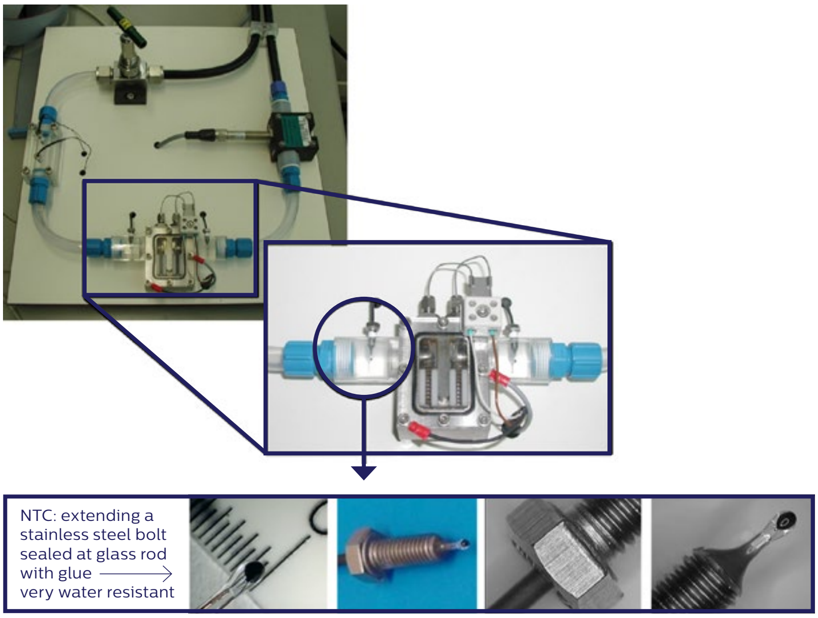
Global control



Local control

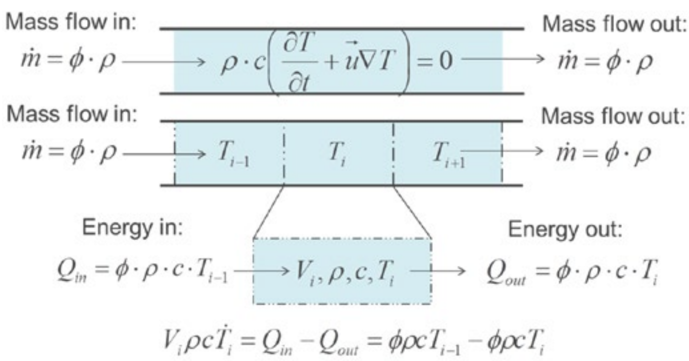
Experimental setup

Local temperature control of fluid streams have been investigated internally at Philips Innovation Services. In the setup water with a 0.1K accuracy is supplied to a control unit that comprises of an in-house developed feedforward and feedback sensor and a heater.

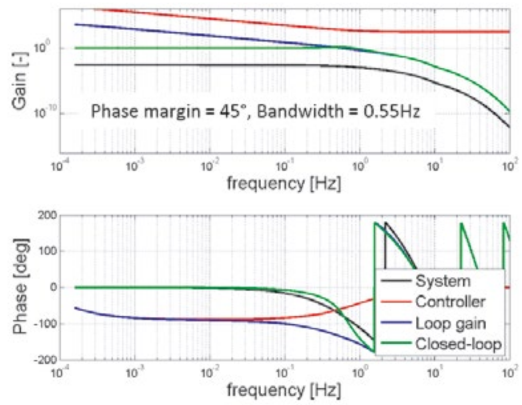


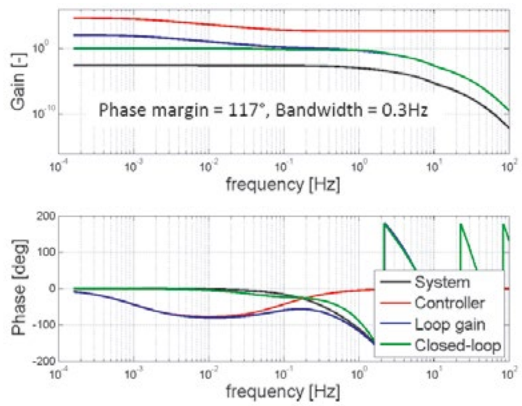
Precision engineering modeling and analysis

The system is investigated computationally via lumped-mass models, in which the coolant flow can be modeled via mass transport links. As such the relatively simple lumped-mass model allows for accuracies close to that of Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) models.



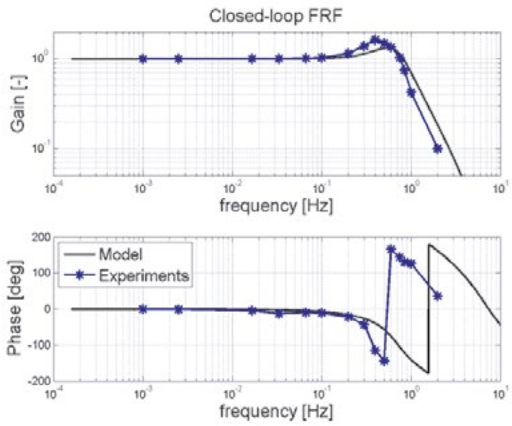
The lumped-mass model, set up in the state-space formulation, allows for application of standard control theory. As such dedicated control laws (considering desired performance specifications) can be devised to control the outgoing water temperature of the control unit.

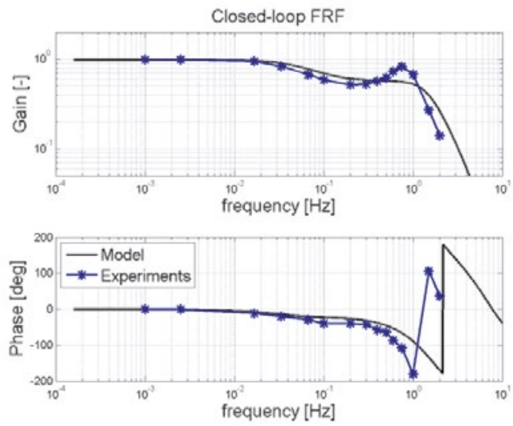




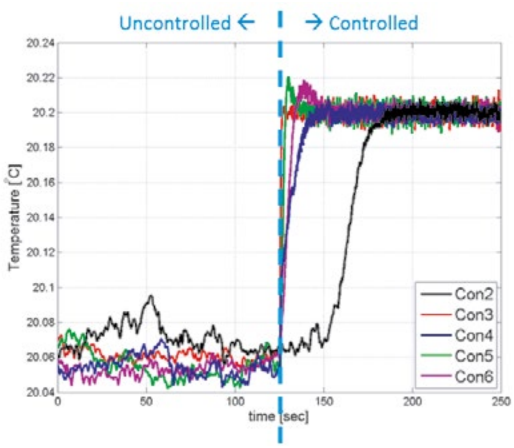
Application to experimental setup

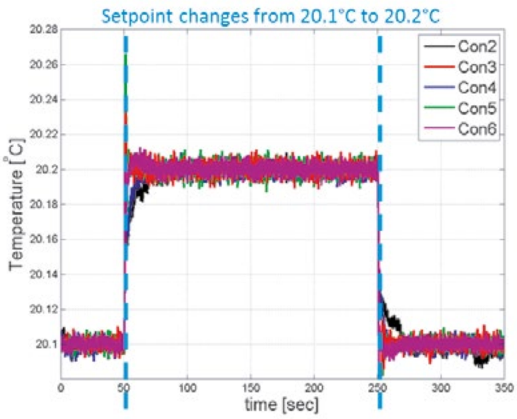
Comparison of the computational simulations and measurements performed show a good correlation:





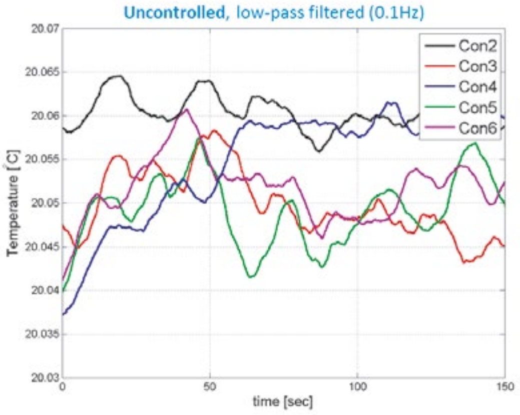
Application of the model-based controller to the experimental setup then leaves the desired performances (compromises between low noise level and quick response to setpoint changes need to be made):

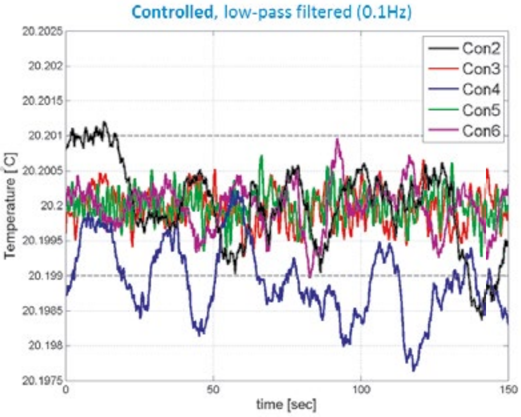




As such much better stability level of the water leaving the control unit (TFB) can be achieved compared to the water going in (TFF). Note that (dependent on the desired performance) the noise level in specific frequency ranges can be minimized.

The final improvement in water temperature stability can be obtained by filtering the sensor data to eliminate the sensor noise from the data. As can be seen, for controller 3 and 5, an improvement in water stability of a factor 20 is obtained.





Conclusions

Philips Innovation Services key features:

- system level thinking (here: global vs local control)
- effectively combines competences (in this case thermal and control)
- quick realization:
  - in-house development of hardware
  - systematic model-based approach: lumped-mass modeling approach allows for flexible, efficient and accurate analysis of the thermal control behavior
  - mass flow of coolant incorporated in model→ allows for model-based controller design/synthesis
- strong experimental skills:
  - closed-loop performance tested closely mimics performance predicted by model.

Interested how Philips Innovation Services can support your high-precision engineering project?
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