Smart design of burner and heat exchanger prevents noise emission from heating systems

Heating systems are designed to work as robust and stable as possible. However, the thermal interactions of these systems always make them prone to instability. A very common instability observed in heating systems is called “thermoacoustic instability” that occurs when combustion and sound in the heating system couple together. An unstable source of heat creates expansion waves—similar to sound waves—that may reflect from various elements in the system (such as walls). The reflected sound waves may subsequently affect the heat balance in the system and create a feedback loop and resonance. This phenomenon has been studied in rocket engines and gas turbines for centuries, but the complexity of the recent heating systems has once again brought it to the attention of researchers.

This PhD research started with major questions about how the existence of the heat exchanger in a heating appliance may affect its thermoacoustic behavior. The heat exchanger is designed to reverse the temperature increase caused by the burner. In addition, sound waves alter the heat absorption of the heat exchanger. Moreover, the distance between the burner and heat exchanger is drastically reduced in recent heating system designs. Consequently, mutual interactions between them may occur. This motivates a detailed investigation about the combined thermoacoustic behavior of the burner and heat exchanger in heating appliances. Particularly, the aim is to answer these questions:

- What are the separate thermoacoustic behaviors of burners and heat exchangers?
- What kind of interactions are to be considered between the burner and heat exchanger that may affect the thermoacoustic behavior of the complete system?
- Is it possible to decouple the effects of the burner and heat exchanger? If so, how can one decouple these effects and use them to design more stable heating appliances?

To approach the formulated problems and questions, various configurations of the burner and heat exchanger are studied using theory, measurements and computer simulations. Details about how the response of the burner and heat exchanger can be affected by their shape and fluid flow are studied.

By studying the simplified and realistic configurations, the following general conclusions are formulated regarding the thermoacoustic behavior of the burner and heat exchanger, as well as their interactions:

- Both the burner and heat exchanger are thermoacoustically active
- Combined behavior of the burner and heat exchanger is crucial to system stability
- Next to the burner, the heat exchanger also considerably affects the system stability