Physics-Based Modeling and Control of Residual-Affected HCCI Engines

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Abstract

This paper outlines a 2-input, 2-state control-oriented system model of the residual-affected homogeneous charge compression ignition (HCCI) process. The combustion timing and peak pressure are the model states, while the inducted gas composition and effective compression ratio are the model inputs. The resulting model accurately captures the system dynamics and allows the simultaneous, coordinated control of both in-cylinder pressure and combustion timing. To demonstrate this, an H_2 controller is synthesized from a linearized version of the model. Experimental results show the H_2 controller's capability to dictate step changes in both combustion timing and peak pressure (or work output) within about 4-5 engine cycles. Furthermore, reductions in the standard deviation for both combustion timing and peak pressure are seen once the controller is activated. The approach therefore provides accurate mean tracking, as well as a reduction in cyclic dispersion. Another benefit of the simultaneous coordination of both control inputs is a reduction in the control effort required to elicit the desired response. Instead of using a peak pressure controller that must compensate for the effects of a combustion timing controller, and vice versa, the coordinated approach optimizes the use of both control inputs to regulate both outputs.