

Regulation of Load Distribution in CHP Boiler Hanger Rods: A Coupled-System Optimization Approach

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ABSTRACT

Suspended steam boilers in combined heat and power (CHP) plants rely on large-scale hanger rod systems whose load distribution governs structural safety and long-term durability [1]. During operation and maintenance interventions, these systems progressively lose their initial force balance and require periodic regulation. Current adjustment procedures remain largely empirical and neglect the strong mechanical coupling between rods, analogous to bolt crosstalk in multi-bolt assemblies. As a result, regulation is time-consuming, inefficient, and often fails to approach an optimal force state.

This contribution presents a coupled-system optimization framework for regulating load distribution in CHP boiler hanger rods, explicitly accounting for interaction effects between successive adjustment steps. The framework is integrated with a vibration-based method (VBM) used to identify the current force distribution in the hanger system, providing a non-invasive and experimentally grounded input for the regulation process. The system is formulated as a constrained multi-variable optimization problem, with the objective of minimizing the force spread between the most and least loaded rods under practical limits on the number of regulation actions. A multi-rod hanger configuration from an operating CHP plant is considered, with a five-rod subsystem used as a representative benchmark.

Four regulation strategies are investigated and compared: (i) an analytical force-based method, (ii) an incremental displacement-based method, (iii) stochastic random sampling, and (iv) a reinforcement-learning-based approach. Analytical and finite element models (FEM) are employed to capture the coupled mechanical response of the system, while optimization techniques explore efficient regulation paths in the discrete–continuous action space. All optimization-based methods outperform the intuitive industrial strategy, reducing the force spread by more than 50% in the benchmark system. Reinforcement learning shows the most robust performance and scalability, indicating strong potential for application to full-scale multi-rod systems with dozens or hundreds of hanger rods.

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REFERENCES

[1] Piotr Duda, Łukasz Felkowski, and Andrzej Duda: Applied Sciences 2024, vol. 14, p. 5720.