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Optimal performance of stroke quantum heat engines

We investigate the optimal performance of a theoretical class of stroke heat engines, where the coupling to heat baths is separated from the work extraction process. Furthermore, we focus on minimal engines in which both the number of strokes and the available frequencies in the working body are minimized. For these simplest thermal engines, we developed methods for efficiency optimization, which—due to the nonlinearity of the problem—is significantly more challenging than the linear work extraction process. In particular, we optimized a minimal engine consisting of a single-frequency working body that couples separately to a cold bath, a hot bath, and a work storage system (without energy-level transformations) [1]. We found that within this minimal setup the engine can operate only via coupling provided by non-Markovian thermal operations, rather than standard thermalization. Next, we considered a two-frequency Otto-like engine operating in two strokes [2,3]. We proved the optimality of Otto efficiency and then suppressed it by introducing a catalyst (i.e., a degenerate, cyclic ancillary system). The catalytic enhancement not only delivers better efficiency at a fixed power but also enlarges the engine's operational domain. Furthermore, in the limit of an infinitely dimensional catalyst, we revealed an ultimate thermodynamic limit on efficiency at a given power (i.e., work produced per cycle) for an arbitrary two-stroke engine. This construction generalizes a reversible engine that, unlike the Carnot engine, operates at finite power between two distinct sets of temperatures (one for engine mode and the other for reverse heat pump mode). Finally, we demonstrated that the catalytic enhancement of discrete engines can be realized in continuous operation within standard Markovian dynamics. This finding paves the way for a general mapping between discrete and continuous quantum heat engines.

[1] M. Łobejko, P. Mazurek, M. Horodecki, Quantum 4, 375 (2020)
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[3] T. Biswas, M. Łobejko, P. Mazurek, M. Horodecki, Phys. Rev. E 110, 044120

Theme

Theme 1. Energy advantage and cost of quantum technology

Primary author: ŁOBEJKO, Marcin (University of Gdańsk)

Co-authors: Prof. HORODECKI, Michał; Dr MAZUREK, Paweł; Dr BISWAS, Tanmoy

Presenter: ŁOBEJKO, Marcin (University of Gdańsk)

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