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Cyclic Variations in Internal Combustion Engines

Benjamin Böhm[1] · Andreas Kempf[2]

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Preface

This Special Topic Issue presents a collection of articles from current research on cyclic variations in engine combustion. The studies feature high-resolution in-cylinder measurements by laser diagnostics, advanced numerical simulations of in-cylinder processes, and statistical methods for characterizing cyclic variations and analyzing their causes. The papers also show how the interplay of diagnostics, numerical techniques and statistical methods generates progress in the understanding and the modelling of a very complex science and engineering problem.

Cyclic variations continue to be a major obstacle to achieving better efficiency, higher power density and lower emissions in internal combustion engines—no matter whether fossil fuels, non-fossil fuels or even hydrogen-based fuels are burned. Cyclic variations may involve very "weak cycles" with failed combustion (misfires), but also very "strong cycles" with destructive knock or "mega-knock" events that result from (premature) autoignition. For conventional spark-ignited engines, strategies exist to avoid such extremes: Weak knock can be detected by knock sensors and mitigated by a later spark timing, but this reduces cycle efficiency. Misfire, on the other hand, is largely the result of failed inflammation and poor early flame propagation. It can be avoided by ensuring that the engine is operated at a sufficient margin from the extinction limit—again, at the cost of reduced efficiency.

Understanding the causes and mechanisms of cyclic variation would enable engineers to optimize engine designs, to devise new control strategies and to potentially implement new combustion strategies. Engines could be operated closer to their stability limit, where the best efficiency and lowest emissions are achieved. A further optimization of spark ignition engines is thus possible if the causes of cyclic variations are known and modelled by suitable tools.

To date, cyclic variations are neither fully understood nor can they be described in a predictive manner—but significant progress has been made in recent years. Part of this progress is reported in the present Special Topic Issue. While the timing of this progress might appear inopportune, near the end of the fossil-fuel era, the issue of cyclic variations

✉ Andreas Kempf
andreas.kempf@uni-due.de

1 Institute for Reactive Flows and Diagnostics, Technical University Darmstadt, Darmstadt, Germany

2 Universität Duisburg-Essen, Duisburg, Germany

will remain with carbon–neutral fuels (produced from renewable sources) and carbon-free energy vectors (like ammonia or hydrogen) that will continue to be burned in internal combustion engines in applications where batteries or fuel cells are not cost-effective, sustainable, or sufficiently robust.

Dr. Benjamin Böhm—Special Issue Guest Editor
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