



Engine combustion network special issue

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Editorial - Engine Combustion Network (ECN) Special issue

Lyle Pickett, Gilles Bruneaux, Raul Payri

The Engine Combustion Network (ECN) is an experimental and modeling collaboration dedicated to the improvement of Computational Fluid Dynamic (CFD) modeling, particularly at engine-relevant conditions occurring at high temperature and pressure where quantitative experimental data is sparse. Beginning in 2009, a working group established an internet data archive library (centrally at <http://ecn.sandia.gov/>) and directed experiments at specific injector and ambient gas conditions pertinent to those in engines. With the generous donation of fuel injectors by Robert Bosch LLC and Delphi Technologies the voluntary international working group agreed to perform experiments at the same target conditions, so named “Spray A” for the first diesel target and “Spray G” for the first gasoline target. The massive dataset generated and archived has become a serious focal point for CFD model improvement, and diagnostics have advanced to provide more quantitative results. To date, we estimate that over 75 different diagnostics have been performed by more than 20 institutions at Spray A conditions. And more than 30 institutions have performed CFD of Spray A using improved models, with results shared openly at ECN workshops. We also know that many more in the engine industry use the ECN archive to evaluate their own CFD and design practices, ultimately producing cleaner and more fuel-efficient engines.

The rationale for participating voluntarily in the ECN may be compared to that of a cycling peloton, as shown in Figure 1. Engine combustion is complex, requiring substantial effort to understand the effect of certain variables or modeling assumptions. A researcher proposing a new diagnostic (e.g. #76) can save tremendous energy if building upon the previous 75 diagnostics, rather than repeating all of these diagnostics individually. Likewise, new modeling ideas are generated by contemplating a wide range of assumptions or results, without necessarily writing and debugging each version of the code on your own. Like cyclists enjoying the slipstream produced by riders at the front of the peloton, these researchers move quickly and advance faster. Soon, they push forward to the front of the group, making unique discoveries that rapidly advance the science of engine combustion, at a pace that would be impossible if working on their own. The need to work closely and precisely together increases according to the difficulty of the problem or if there is a lack of resources to pursue the problem. Cyclists would call this a strong headwind. We recognize that engine combustion research faces strong headwinds at the moment, increasing the need to work together efficiently.

WHY JOIN IN THE ECN?



Figure 1. Main motivation to participate in ECN

Active ECN participant share different roles in the peloton. Sometimes they ride in the middle, staying abreast of the activities and monitoring the growing data archive. At other times, they ride to the front, producing world-first models, simulations, and experiments. As shown in Figure 1, ECN workshop topic leaders go to the front, providing remarkable contributions for the entire community. Beginning with ECN1 in 2011, in-person ECN workshops have been held every 18 months including events in Ventura (USA), Heidelberg (Germany), Anne Arbor (USA), Kyoto (Japan), Detroit (USA) and Valencia (Spain). While ECN participants are invited to share any individual work in monthly web meetings, workshops are a special opportunity to synthesize results on chosen research topics and questions. Organizers and topic leads gather experimental and modeling results per specific guidelines advertised beforehand. They address standardization of experimental and modeling metrics, along with uncertainties, to reach quantitative comparisons. They evaluate repeat and standardized datasets from multiple groups to solidify findings, and they incorporate submissions of unique diagnostic and modeling advancements. The side-by-side comparison provided forms an expert review of the current state of the art for diagnostics and engine modeling, enabling the community to identify needed future directions. The ECN workshop experience provides depth not commonly observed at conferences or within individual research papers as could be found in the three collaborative papers that were the main outcome of the first workshop ECN1 [1][2][3]. We can confidently say that unique discoveries, science, and future directions are revealed at each workshop, thanks to active ECN participants and topic leaders working closely together, following ECN guidelines and standards to enable a fast peloton! Their collective contributions are provided in several of the articles provided in this special issue.

Beyond the organization of the ECN, we believe that the group's success has depended strongly upon adhering to the "spirit of the ECN." The "spirit" includes: (1) not highlighting individual laboratories or groups, but rather, common research problems; (2) not duplicating conference presentations at

workshops, but focusing on synthesis, expert reviews, and future direction; (3) freely revealing what does NOT work, or what is broken, rather than what is “publishable.” Regarding (3), we use the colloquial phrase that in the ECN we should “air our dirty laundry,” calling attention to problems that need to be fixed or “cleaned.”

This sentiment is captured nicely in the 2018 TED talk by astronomer Phil Plait entitled, “The secret of scientific discovery? Making mistakes”[4]. Dr. Plait had worked as part of a Hubble Telescope team attempting to identify the first exoplanet (a planet outside of the solar system). A different group led by Andrew Lyne thought they had discovered the first exoplanet and even made a publication stating so in *Nature* in 1991. But after Lyne discovered his data was in error, Lyne made a speech at the 1992 American Astronomical Society meeting announcing that he had made a mistake. The audience received his difficult speech with ovation, rather than criticism! Next, at this same meeting, Aleksander Wolszczan stood up and announced that his team had discovered several exoplanets. They knew about the problems that Lyne had encountered (because Lyne shared openly), they corrected for them, and were able to overcome the problems.

We have had many experiences in the ECN where “airing dirty laundry” has led to discovery and progress. One of the earliest activities was to replicate the same Spray A experiments in different (and somewhat unique) spray chambers [5]. Repeating diagnostics in different facilities, or using the same models in different CFD codes, is extremely important as we find that it tends to reveal hidden biases at each institution. Unless these differences can be understood and explained, these differences constitute more realistic uncertainties, both for experimental and modeling practices. The Spray A condition is to inject n-dodecane fuel controlled at 363 K into gas at 900 K and 22,8kg/m³ [6]. The massive temperature difference makes it difficult to control these boundary conditions, and new techniques were developed to understand and stabilize the boundary conditions—a work that continues today. In comparing different facilities, we found that injector cooling created water condensation from cooled combustion products onto the face of the injector in one facility. The water film affected the fuel spray injected through it, but it also caused oxidation and pitting inside the injector nozzle. Measures were taken to correct the problem. Early results also showed that the measured liquid-phase penetration varied significantly between facilities and with the use of different optical techniques. Also, CFD processing metrics did not match those of the experiment. New diagnostics, standards, and best practices have now been developed. Another “dirty laundry” shown by early CFD simulations of Spray A was that no ignition or combustion was predicted! Available chemical mechanisms for n-dodecane at that time were for aviation gas-turbine combustors, tuned to consider flame speeds, but neglecting autoignition chemistry. ECN research has inspired development of completely new detailed and reduced mechanisms, specifically for high-pressure engine conditions not addressed previously. There are many other examples where “peloton-leading” discoveries were made after identifying supposed problems. A partial list includes discoveries for internal nozzle flow [7][8][9][10][11], plume interactions[10][12][13], velocity[10][13], mixing[8][14][15], soot[16][17][18], and supercritical mixing behavior[19].

Based upon the usual tracking metrics, the ECN has made remarkable progress since its founding 10 years ago. As shown in Figure 2, citations of ECN work are increasingly rapidly. There have been more than 1000 citations to the central ECN website [6], and the website attracts more than 30,000 sessions per year from users all over the world. A usage study shows that ECN papers have a 40% higher impact factor than papers on comparable subjects and within comparable journals [20].

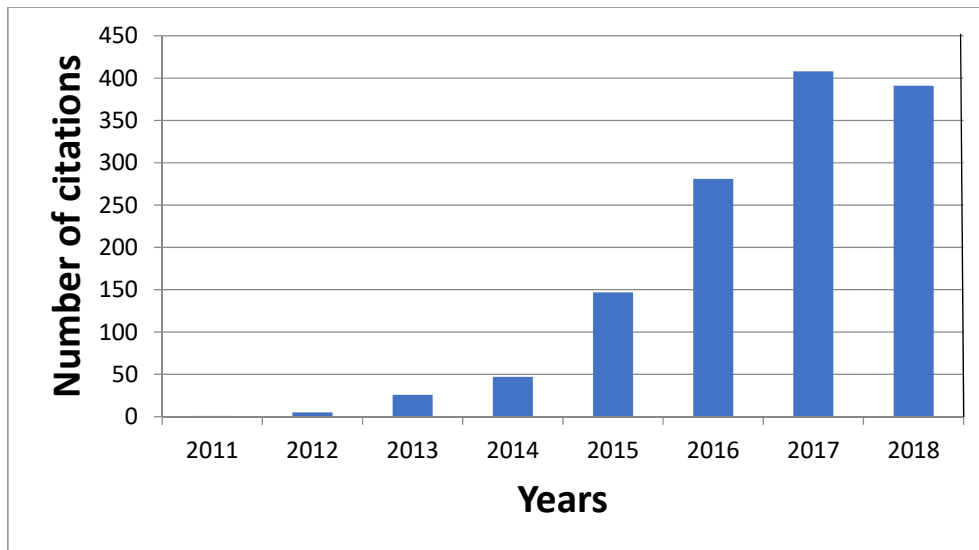


Figure 2. Number of WOS citations to ECN related work per year

Although the progress is encouraging, there is potential to go much farther. While rooted at certain target conditions (with many diagnostics at high confidence), the ECN already applies parametric variations (e.g. in temperature or fuels) to prove model capability over a large range of conditions (without model tuning). Ideas such as Ducted Fuel Injection (the spray flows through a duct) have already been applied at Spray A conditions, showing essentially zero soot formation [21].

As an organization, we see the ECN as a model for pre-competitive and collaborative research to accelerate our understanding of physical phenomena and the development of technological solutions for the benefit of society. The need to improve internal combustion engines remains urgent, with many far-reaching impacts on society. Scott Bailey, president of TULA, recently reported that it is expected that another billion internal combustion engines will be made through the year 2040 [22]. Our simple mission is to make these engines better! Through the ECN, we aim to provide researchers around the world with a collaborative platform for the exchange of experimental and simulation data, friendly atmosphere beneficial to open and transparent exchange, and a forum for discussion to define relevant research areas.

Going into details of what is included in this special issue we have 16 new papers [23]-[38] covering all aspects of Engine Combustion Network activities. There are 10 papers related to Compression Ignition Engines [23][24][25][26][27][28][29][30][31][32] while there are 6 papers related to Gasoline Direct Injection [33][34][35][36][37][38], indicating that the research community is still trying to improve Diesel engines even though the bad reputation they are facing lately. Dividing the papers into experimental or CFD work we have 5 papers [23][24][25][33][34] that deal with advance experimental diagnosis while 13 papers deal with CFD [26]-[32],[35]-[38], this is also a trend in the research community moving more and more into modelling work. The final division that could be performed is between internal nozzle flow and spray characteristics with 11 papers related to this field, and five papers related to combustion around the original n-dodecane Spray A case [6] and some variations

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