Dear reviewers,

I extend my gratitude for your positive comments on my thesis, and for the useful suggestions that you gave me in order to improve the overall quality of the work. In the following you can find the answers to your questions that are highlighted in blue for the first reviewer and in green for the second reviewer. In the highlighted version of the thesis you can find the modifications with the respective colors.

Best regards,

Daniele Iemmolo

Overall Rating of Thesis

Overall Rating: Based on your experience as a thesis evaluator, how would you rank this thesis among all theses you have evaluated so far?: A (between 5% and 10%)
Recommendation: Minor Revisions
Comments - Please comment on the originality, methodology, results and perspectives of the work described in this dissertation: The thesis discusses the potentiality of using alternative fuels and advanced combustion modes in production internal combustion engines to reduce pollutant emissions and allow the energy diversification in the automotive field. Specifically, the first part of the thesis is focused on the possibility of controlling the fuel composition when bio-gas and HCNG fuelling is considered for spark-ignition engines. This section is interesting and adequately supported by the analysis of results. The second part of the thesis concerns the use of advanced combustion mode based on PCCI in compression-ignition engines. Even if the topic is not completely new, the argument is properly discussed and satisfactorily investigated. The effort to merge the two parts of the thesis is appreciable and appreciated.
Minor changes can further improve the quality of the proposed work.

Introduction
The text seems somewhat general; a more detailed discussion would be useful, with references, or the two introductions (i.e. from chapters 2 and 3) could be merged in a single one.
-Introductions were merged into a single one.

Chapter 2
2.3. Experimental set-up and tested blends
A brief “error analysis” could be performed.
- A brief error analysis has been evaluated in the “2.4.4.3 Input variation analysis” section.

More details would be interesting on the difference between the two lambda sensor signals (i.e. for rich and lean mixtures).
- Two different controllers were used for lean or rich mixture, even if tests have been made in stoichiometric conditions and ECU control relies on the engine lambda signal. Controller types have been added in the experimental setup section.

Even if the evaluation of the oxygen sensor signal is a good base for adjusting injection time, the actual limit of adjustment (i.e. normally used by ECUs to compensate differences in injector performance, volumetric efficiency and minor changes in fuel A/Fst) can interfere with the proposed method. A more detailed discussion on the matter would be interesting.
- A discussion has been included in “2.4.4.3 Input variation analysis” section.

2.4. Performance and combustion analysis
The use of different number of decimals in the same graph is somewhat ‘un-academic’; also, the range for each parameter should be correlated to the error level (i.e. IMEP can be stated with a resolution of 0.05 bar, but the error most likely exceeds this level).
- Charts have been corrected.

A ‘Final remarks’ section could be used only at the end of the chapter.
- Final remarks sections has been merged into a single one at the end of each chapter.

2.5. Fuel composition estimation

Reference to figures should be consistent throughout the text (i.e. Fig. 2.5 instead of Fig.1).
- Figures have been corrected.

Units should be provided for each parameter.
- Some units were omitted for sack of readability. Units are provided in the international system where not specified. A statement has been added at the beginning of the chapter.

If the Aeff parameter was determined, it is unclear why the offset value is required.
- Aeff has been determined for a comparison with the results pertaining the offset value. The offset value is not required by the method itself, but it has been used by the engine producer to characterize the injector.

Data scatter in Fig. 2.6. is attributed to changes in battery voltage; given that this latter parameter can be relatively easily measured with cycle-resolved time resolution, a quantification of this effect would be interesting, in relation to other more probable influences such as flow measurement uncertainty.
- A discussion about Vbatt effect has been included in the error analysis section.

Chapter 3

Reference is made to (a,b) seemingly without correspondence as well as [1*] and [2*].
- References have been corrected.

It would be interesting to motivate the choice of a low load point (i.e. 1800 rpm and 1 bar BMEP), given that such conditions are already characterized by low PM and NOx emissions.
- The choice has been motivated in Preliminary experimental analysis on PCCI combustion section. The problem was mainly due to the fact that the tested engine has not been designed for PCCI operations so it became extremely difficult to increase the load and having at the same time a stable performance.

Phrase ‘This technology can highly improve diesel combustion, which is commonly affected by cycle-by-cycle and cylinder-by-cylinder variations’ is slightly ambiguous and needs rewriting.
- The phrase has been rewritten in order to highlight that such variability is typical of PCCI operations.

Figure 3.7b caption: insert pressure instead of temperature.
- Caption has been corrected.

3.4.3 Design of experiments and Model-based optimization of PCCI combustion

Table 3.5 (Opt4) please correct.
- Table has been corrected.

3.5.3 Results and discussion

The method used for evaluating EGR unbalance should be briefly presented.
- The method has been briefly presented.

The discussion related to figures 3.16 and 3.17 is somewhat confusing; the effect of each control method and possible mechanisms of influence should be detailed.
The discussion has been rewritten in more details, highlighting the effect of combustion timing on PFP and CN dispersion.

For consistency, load could be expressed as BMEP rather than torque.
Changes have been implemented.

Subsections ‘Jet fuel’ and ‘Injector with reduced flow’ need to be expanded, with more detailed motivation for performing these checks within the context of the overall aim of the study.
- No relevant differences were found testing different fuels and the reduced flow injector, for this reason the in-depth analysis has not been provided. Anyway, subsection have been expanded with more details on the overall purpose of the tests.

Overall Rating of Thesis

Overall Rating: Based on your experience as a thesis evaluator, how would you rank this thesis among all theses you have evaluated so far?: A (between 5% and 10%)

Recommendation: Admit

Comments - Please comment on the originality, methodology, results and perspectives of the work described in this dissertation: The doctoral dissertation addresses two aspects of controls of the process of combustion in internal combustion engines: adaptation of a spark ignition engine on biogas of variable composition and properties, and control of a compression ignition engine during premixed combustion (PCCI) operation. Both topics are of current interest in the field and of relatively high relevance to the society, the first contributing to the utilization of renewable gaseous fuels, and the second to the reduction of two primary diesel exhaust pollutants, particulates and nitrogen oxides.

Throughout the work, the author demonstrates broad understanding of the field, in-depth knowledge of engine combustion control, practical engineering approach, thoughtful design of experiments, organized presentation of data, qualified critical discussion of the results (notably on pages 25, 54, 56, 59, 61, 84, 87), and excellent writing skills. Theoretical knowledge is apparent from calculations related to fuel metering, while conduction of experiments showcases practical skills. I highly command the approach to build the controls, as much as possible, on the existing set of sensors and hardware in production engines.

The writing is very logical, interesting, easy to understand. Presentation is well structured and flows nicely. The quality of English language is excellent for a non-native speaker.

The accomplishments of reducing PM and NOx emissions using PCCI combustion, at a relatively small penalty in fuel consumption, on a production engine are quite remarkable.

The findings are useful and key portions of the thesis were published or accepted for publication. Mr. Iemmolo is a co-author of at least six peer-reviewed articles: ref 1, ref 2 (now accepted, in print, to be published 9/2017), ref 17, ref 19, and two papers not cited in the thesis: Spessa et al., SAE 2017-01-0695; and d'Ambrosio et al., Energy Procedia, 101, 2016, 909-916.

I expect that the contribution of Mr. Iemmolo to these articles, along a review of his other publications not appearing in the thesis, will be summarized during the defense.

There are few minor shortcomings:
p. 5, nitrous oxides should be nitrogen oxides
- Changes have been implemented.

p. 39, scale of the graphs makes it difficult to read, I suggest using 0-100% of the declared range that is examined here.
- Unfortunately the graphical tool used does not permit to change the scale of each variable.

p. 60, reference conditions for Fig. 3.3 and subsequent should be stated here (they are given much later in the work).
- Reference conditions in terms of calibration parameters have been implemented.

p. 65, Table 3.5, error in EGR valve value for last line
- Changes have been implemented.

p. 77, Fig. 3.18 and p. 78, Fig. 3.19: units on y-axis: should be dimensionless instead of %
- Changes have been implemented.

p. 85: Fig. 3.24 is not present in the manuscript; it appears that Fig. 3.26, not mentioned in the text, is actually Fig. 3.24
- Changes have been implemented.

References are not in consistent format.
References have been corrected.

Overall, the work is of high quality, and demonstrates that Mr. Iemmolo has the necessary skills to independently pursue research, as would be required from a holder of a Ph.D. degree. Therefore, I recommend its admission for defense.

Questions to be answered during the defense:
Answer to the proposed questions are given in the following.

p. 8: Why HCNG has higher metal deposits on spark plugs than CNG?
According to Bauer, C.G., Forest, T.W., 2001. Effect of hydrogen addition on the performance of methane-fueled vehicles. Part I: effect on S.I. engine performance. International Journal of Hydrogen Energy, Volume 26, Issue 1, Pages 55-70, ISSN 0360-3199: "The higher concentration of iron on spark plugs for HCNG fuel may be due to high temperature coupled with the corrosive wear of engine components The other cause may be the interaction of water and iron at high temperature and pressure. Further studies need to be carried out to ascertain these findings".

p. 22, last four lines: Are differences for mechanical efficiency statistically significant? What is the uncertainty (or your best estimate of uncertainty) of the data?
-The difference can be considered relevant for the speed of n=1250 rpm since following a brief error analysis the mechanical efficiency results in an uncertainty of about ±3%, which correspond to 0.025 on the absolute value for G25 and CNG. For HCNG the uncertainty resulted to be halved with respect to the above mentioned values.

p. 26: How did you determine if the outlier was due to an experimental error?
Because the point was replicated several times and the results were different in just 1 test. So at the end just 1 outlier was identified.

p. 33: You select a blend that is closest to the actual composition of the fuel. Can you interpolate?
Yes, actually I also "reversed" the identification process and compute a hydrogen content estimate, but this can be done just with a mixture of hydrogen and CNG with no other components. Actually, in the reality this can be misleading since other constituents influence the result. For instance, with reference to table 2.6, using the engine MAF to identify HCNG15, the result was of about 18% of hydrogen content, which is nearest to HCNG20 than HCNG15: this results to be consistent to the reported error on the identification.

p. 38: How would you realize fuel consumption measurement as a part of an ordinary production engine?
The fuel-flowmeter of the test cell was used to have a reliable comparison since it is the most accurate among the three measurement devices. On-board it can result quite an expensive solution to mount a fuel flow meter like, for instance, Gills flow meters adopted in F1 and homologated by FIA, which does have a commercial solution as well, but at a price of about 6000 euros, which is not feasible. So that one can use the air flow measurement and the lambda sensor to calculate the fuel mass flow as illustrated and implemented in the method. Anyway, this approach will be less precise.

p. 59 last paragraph: How did you identify the set of conditions at which constant NOx is obtained?
"A constant NOx condition" just refers to a constant NOx value on the graph.

p. 60, fig. 3.3a: what are individual points on the graph? Different EGR rates?
Yes, it is an EGR sweep. The points are the same of those of Graph 3.3b. EGR sweep were performed by varying the position of the exhaust flap. These reference conditions were added in the previous page as you suggested above.

p. 60: Is the injection pressure constant for data in Fig. 3.3.-3.7.?
Yes, reference conditions were added in the previous page as you suggested above.

p. 60: What are the reference conditions (SOI, MFB50, …)?
Reference conditions were added in the previous page as you suggested above.

p. 62, Fig. 3.6: MFB50 appears to be too early – could this contribute to the lower thermal efficiency in the PCCI mode?
Yes, it does contribute since the combustion start and develop well before TDC, during the compression phase. This has a detrimental effect on thermal efficiency. A solution will be to further extend the ignition delay by cooling more the EGR and using a lower compression ratio as we are testing right now with a prototype version of the same engine optimized for PCCI operations.

p. 63, Fig. 3.7: Please explain the Y-axis units.
Intake temperature has been adimensionalized to a reference value for confidentiality reasons.

p. 63, last sentence: What was the result of evaluation of the drift?
For this engine working point, drifts were actually not present. Drift were present at higher loads and were most likely due to a fouling of the EGR cooler, which is not designed to sustain such high values of EGR, that, by the way, contains really high concentrations of HC. HC condensates on the EGR cooler walls

resulting in a detrimental effect in terms of thermal performance of the cooler and pressure drop as well.

p. 64, fourth line: What is the justification for using second order function? Is there an underlying or expected relationship? Why not linear, logarithmic or exponential?
It has been found that such a function is a trade-off between having a relatively simple model and an accurate response. The second order function has practically never been used with all its regressors terms. Using a step-wise regression eliminates those regressors that are not useful for the response, and possible exponential of logarithmic behaviors where taken into account by applying a Box-Cox transformation when needed.

p. 64, before Table 3.4: Which tests were chosen as validation tests?
They were chosen randomly in the input space by means of a space-filling DoE.

p. 64, Table 3.4: Please explain the meaning of statistical summaries (column headings)
R^2 is the coefficient of determination. R^2 adjusted is the coefficient of determination which takes into account of the number of coefficients of the model, since the standard R^2 tends to 1 as the number of coefficients in the regression function is augmented. PRESS R^2 is a coefficient of determination which is computed by means of a PRESS statistic, which excludes the i-th test and computes the R^2 on the other terms. In this way one can obtain a cross validation without strictly having a validation set of tests. The same explanation are valid for RMSE (root mean squared errors), with the addition of having a validation RMSE resulting from independent validation data.

p. 68: Should multiple injections be considered for PCCI operation?
Some PCCI operations are achieved by means of multiple injections. For instance with an injection just after the intake valve closing and a second injection exploited to ignite the mixture. Other solutions employ a multiple after injection in the surrounding of TDC to diminish the noise due to the premixed combustion. But these techniques have a detrimental effect on HC and bsfc. When a late injection strategy is adopted, multiple injections are quite common and can be used to lower the CN since the ignition delay is not so extended as with early injection strategies.

p. 70: why cp/cv=1.37?
It is a reference standard value that is commonly used for single zones approach, in particular by indicating software.

p. 79/80: Would you recommend a higher capacity EGR system, in order to reduce losses due to pressure drop on the flap?
Yes. In the prototype engine derived from the F1C that we are testing now, we are adopting an EGR cooler from a 11 liters heavy-duty engine.

p. 80: sixth line: Please specify which more detailed study and provide a reference. Later in the paragraph, you state that same hardware was used in ref. 81, this is, however, a 1988 paper. Please explain.
This part referred to the previous chapter results. It has been corrected now.

p. 86: Please clarify 0.5 g HC – is this per test, per start, per kWh?
It is the summation of the total HC produced during the transient test. It has been clarified.

p. 86: N repetitions – if possible, state how many
It has been stated. We performed 5 repetitions.

p. 87: Is pressure sensing in every cylinder commercially viable? Do you have an estimate of the costs added?
The cost added per unit is around 100-150 euros. I highlight that a disturbed pressure signal was tested in order to replicate the signal noise that will results from pressure transducers of lower quality. Unfortunately, it was not possible to test those kind of commercial transducers on this engine because of design restrictions on the seat of the glow-plug in which they have to be mounted.

p. 91: What are references 1* and 2*? Are references 1 and 2 papers referred to as (a,b)?
References have been corrected.

Please summarize your contribution to the six peer-reviewed manuscript identified earlier in this review.
I will summarize them during the defense as you suggest.