Chapter 9
Concluding Remarks

The *ultimate green diesel engine*—the one with *zero harmful emissions*, with *theoretically minimal fuel consumption*, and running on *environment-friendly renewable fuels*, is something that will always remain out of reach. However, reaching the exact theoretical limits is not as important as is the question: how close to these limits can we push a modern diesel engine. By looking back into the last decade, one can only be astonished what a tremendous progress was achieved by diesel engine developers and producers. Fuel consumption decreased substantially, exhausts became much cleaner, and the engines became lighter and smaller due to downsizing in piston displacement volume and number of cylinders. From that point of view one can be very optimistic for the future. In spite of that, one should be aware of several hard nuts still waiting to be cracked in the coming years. Two of the perhaps mostly exposed are briefly addressed in the following.

The first serious problem is related to the introduction of alternative fuels. A modern diesel engine is developed for mineral diesel. Mineral diesels are quite well regulated in terms of quality, purity, and so on. In spite of this good regulation, the usage of modern diesel engines revealed several problems related to diesel fuel quality and purity. On the other hand, these problems were practically negligible in traditional engines with mechanically controlled fuel injection systems. The point here is that, as the diesel engine technology advances, the fuel quality and purity problems rise. In this context, the introduction of alternative fuels is a very problematic scenario. Namely, alternative fuels come in such a variety in terms of their composition, quality, and purity, that it seems practically impossible that a modern diesel engine would be able to consume at least some of these fuels efficiently, without risking any harm or damage. At a first glance the situation looks quite frustrating. Namely, we know from engineering practice that the more we improve some system/technology, the more precisely the input data specification needs to be. For diesel engine development, fuel characteristics are probably the most important input data. But the introduction of alternative fuels scatters these data in an extremely wide range. The consequences can also easily be seen from the experimental results, assembled in this book; the measured quantities may vary dramatically in dependence on, e.g., type of biodiesel. For this reason, it would be

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of great help to engine developers, if the governments would do every effort to bring out good classification, appropriate standards, and regulation of alternative fuels. Unfortunately, this will also be very hard to do since alternative fuels production technologies are still developing. And we know that one cannot write good standards and regulation, if the technologies under consideration are still under intensive development.

The second important problem is related to modeling and computation. During the whole history, engineers improved and optimized their designs or products. At first, this optimization was mainly driven by intuition and experiments. But, as the modeling and computation methods developed, numerical simulation became an ever more important factor. For a system/technology at the development stage being not very close to the limits, rather simple numerical models can be of great benefit and can significantly contribute to the improvement of the product. But, the more the development stage of some system approaches the theoretical limits, the more sophisticated and accurate numerical models are needed in order to achieve at least some improvement. A diesel engine is such a complex system, that we are far from being able to simulate it as a whole with the accuracy, expected nowadays. If one just looks at the most important process in the engine: fuel starting from within the injector, traveling through the injector nozzle orifice, entering the combustion chamber, atomizing and mixing with air, evaporating, and eventually burning, one must recognize that full 3D modeling and computation of this process still represent a major problem. The difficulties range from unacceptably long computation times, over numerical instabilities, to numerous uncertainties, related to the modeling. In practice this means that even if we can manage to get some results, we cannot be very sure what we have actually got. To mitigate the situation, partial modeling is often applied in practice, e.g., by modeling the spray development from the nozzle orifice exit downstream. So far so good, but setting the boundary conditions at the nozzle orifice exit manually, introduces another source of error, which has to be taken into account properly. Once we will manage to run numerical simulation of diesel engine processes efficiently and accurately, this will set the base for the use of another important tool—systematic numerical optimization. If efficient computational models are available, the only exposed problem in this step is the additional computational effort. Namely, one must recognize that the computational effort, needed for the optimization of a considered system, may be one, two, or even three orders of magnitude larger than the computational effort, needed for the response analysis of the system. In other words, if the response computation takes, for example, one day, optimization may potentially take a completely unacceptable time span.

At the bottom line, pushing a diesel engine toward its theoretical limits, is not and will not be an easy task. However, by considering the immense efforts put into the diesel engine-related research at the universities and companies, one can be confident that the future of the green diesel engine looks pretty bright.