Flame Propagation and Heat-Transfer Effects in Spark Ignition Engines

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I. INTRODUCTION

The essential characteristics of the internal combustion engine are ultimately determined by the processes that take place in the combustion chamber. It is these processes that generate the power output, the heat losses, and the formation of pollutants and therefore determine the trade-off between efficiency and emissions. The need thus arises to identify and qualify the significant physical processes that take place in the combustion chamber. Only after this accomplishment is it possible to establish a control of the major parameters that influence the combustion process so desired design goals can be achieved. In the past an acceptable level of understanding of the phenomenon involved has been reached through an analysis of experimental evidence and the pursuit of theoretical investigations. The processes inside the combustion chamber of an internal combustion engine involve a broad range of different subjects. The characterization includes chemistry, thermodynamics, fluid mechanics, and heat transfer, to mention a few of the most important fields as outlined in Fig. 1. Furthermore, the combustion process takes place in such a highly complex environment that an accurate and detailed description on a fundamental level cannot be done with present-day knowledge. Through numerous experiments a large amount of information has been acquired allowing the key processes to be identified and investigated in more detail. Guided by these experiments and the theoretical analysis, semiempirical methods have been used to develop the internal combustion engine, and such two-sided investigations are necessary for the successful development of the internal combustion engine. Though today's engine is highly
sophisticated, continued research efforts produce an increased understanding of the different processes leading to an improvement of the overall engine performance.

In this chapter we will focus on the aspects of fluid mechanics and heat transfer that influence the combustion process. Examination of the different phenomena listed in Fig. 1 will reveal that nearly all of them are strongly dependent upon the behavior of the gases explaining the importance of the fluid mechanical processes. Together with the description of these processes some theoretical models will be shown so the reader may gain an impression of the subject and an entry to the current literature available.

## II. MODES OF COMBUSTION

During the induction stroke a fresh charge is taken into the combustion chamber and starts mixing with the residuals that are present. The mixing process continues in the compression stroke where the combustion process begins with the discharge of energy in the spark plug gap. After the ignition of the gases has created a volume of plasma, the combustion process proceeds to establish a flame kernel that is able to propagate into the unburned charge. The ignition process is, in general, controlled by chemical effects and the fluid properties, which is also the case for the initial combustion that creates the flame kernel. However, the latter process is more sensitive to the flow field in and around the burning gases. Once the flame kernel has grown large enough, it is gradually transformed into a fully developed propagating flame. In the traveling flame fluid mechanics usually dominates, but chemistry may become important, depending on the properties of the flow field and the charge composition. Eventually the flame has engulfed most of the gases and during the final stage of the