Ignition Flame Kernel Growth Under Idle Simulated Conditions*

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Introduction

At idle operation, current spark ignition engines typically exhibit what is referred to as "engine roughness". This is generally attributed to poor ignition quality as a result of the relatively low temperature, low pressure, dilute charge conditions at idle operation. More specifically, however, it is a consequence of the slow and non-repeatable growth of the ignition flame kernel immediately following ignition.

In this study, ignition flame kernel growth has been studied in a turbulent flow reactor under conditions which simulate the turbulent flow field in an engine at idle operation. The experiments were conducted with a propane-air equivalence ratio of 1.0, at a pressure of 1 atmosphere, temperature of 300 K, mean velocity of 1 m/sec, turbulence intensity of 0.5 m/sec and turbulence integral length scale of approximately 3 mm. Of particular interest were the effects of charge dilution and ignition energy on the ignition flame kernel growth rate and its variation. Charge dilution, which can be as high as 30 percent at idle, was varied between 0 and 30 percent with nitrogen addition. Ignition was achieved with standard automotive systems, arranged to supply variable energy and duration sparks using standard plugs.

Experimental

A schematic drawing of the turbulent flow reactor used in this study is shown in Figure 1. Air, supplied by an air compressor, is mixed with propane fuel well upstream of the test section to insure complete mixing. Turbulence is generated by first passing the fuel-air mixture through two 0.8 mm wide slots designed to produce flow with large scale turbulent motion which then passes through a converging section designed to break-up the large scale eddies immediately before entering the test section. The test section is 13 mm by 64 mm in cross-section. The 64 mm wide test section walls are made of quartz to provide optical access for the laser shadowgraph measurements of the ignition flame kernel growth. A standard J-gap spark plug is flush mounted in one of the 13 mm wide walls of the test section. The test section geometry is representative of a "pancake" shaped combustion chamber with side wall ignition.

Three different ignition systems were used in this study. The first was a General Motors high energy ignition (HEI) system which had an available voltage of 35 KV, an ignition energy of 60 mJ and an ignition duration of 4 milliseconds. The second ignition system consisted of two HEI systems which were triggered simultaneously and provided a spark energy of approximately 120 mJ in 4 milliseconds. Both the single and the double HEI driven sparks were initiated by a breakdown phase of less than 100 nanoseconds duration and 1 mJ energy followed by a glow discharge whereby the remaining ignition energy deposition occurred. Primarily as a result of heat loss to the spark electrodes from the cathode fall region of the spark, the efficiency of the glow discharge is only approximately 10 percent while that of the breakdown phase is approximately 94 percent [1-3]. Therefore the effective ignition

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energy for the single and the double HEI systems was approximately 7 mJ and 13 mJ, respectively. The third ignition system was a single HEI system with an additional 150 pf capacitance across the spark gap which increased the breakdown energy to approximately 7 mJ, resulting in a total effective ignition energy of 13 mJ.

The ignition energies referred to above were determined from the voltage and current time histories in the case of the glow discharge and from the breakdown voltage and the spark gap capacitance in the case of the breakdown phase. The voltage and current time histories were measured with a Tektronix high voltage probe and a Pearson inductive current probe, respectively. These signals were recorded with a 12 bit A to D at 30 KHz. The breakdown voltage was measured with a 100 MHz storage oscilloscope. Typical voltage and current time histories for the single HEI system are shown in Figure 2, along with the glow discharge power versus time.

The ignition flame kernel growth rate was determined from laser shadowgraph measurements recorded at 2000 frames per second on a Spin-Physics video camera system. The shadowgraph images were then digitized, from which the effective flame kernel diameter versus time was determined.

Preliminary Results

Results representative of those to be presented are shown in Figure 3 where the effective flame kernel diameter is plotted versus time following the start of ignition. In this particular case, the operating conditions are 1 atmosphere and 300 K with a mean velocity of m/sec, a turbulence intensity of m/sec and a turbulence integral length scale of 8 mm. The two growth rate curves correspond to equivalence ratios of and as indicated. A single HEI system was used in both cases. The effect of equivalence ratio on flame kernel growth is primarily through a change in the laminar flame speed, as would also be true for the effect of charge dilution.

References

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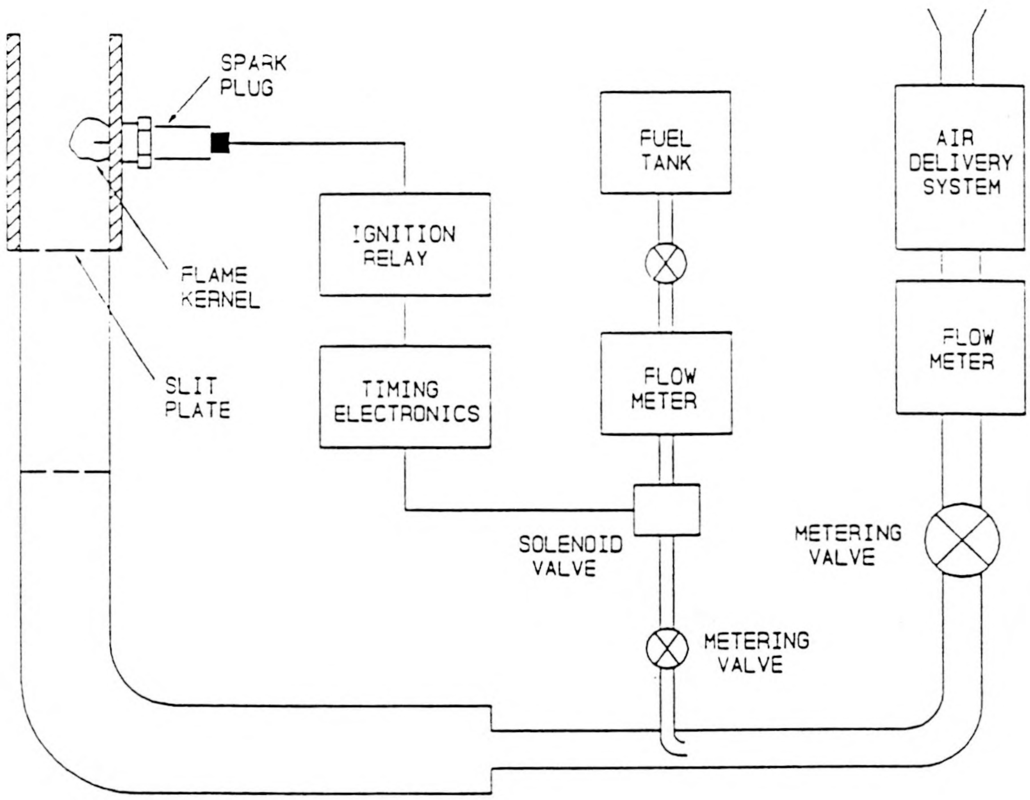


FIGURE 1: TURBULENT FLOW REACTOR

FIGURE 2: IGNITION SYSTEM CHARACTERISTICS

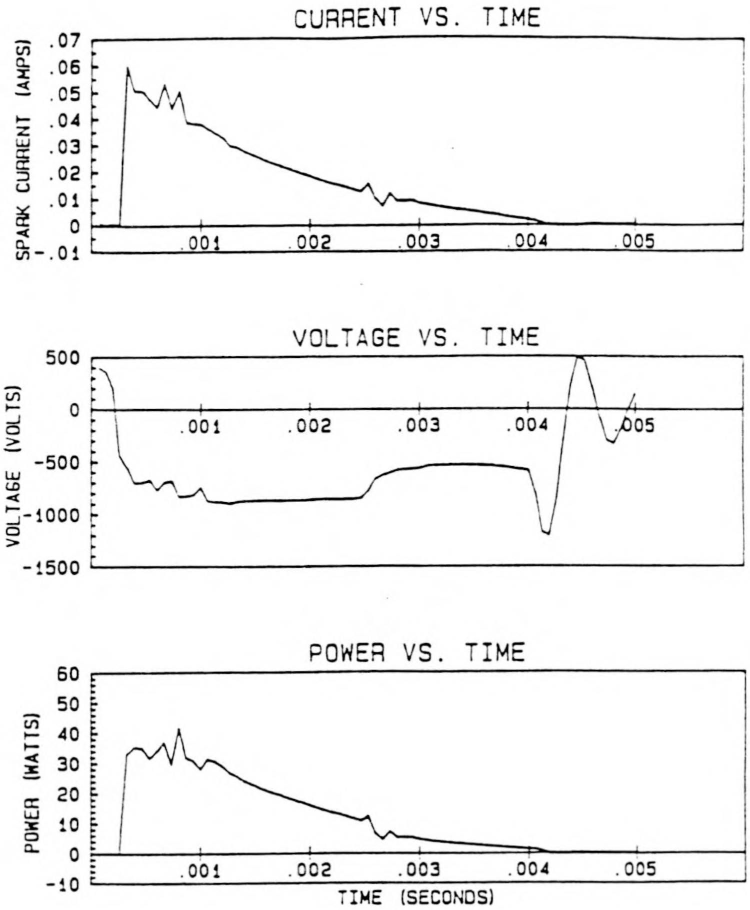
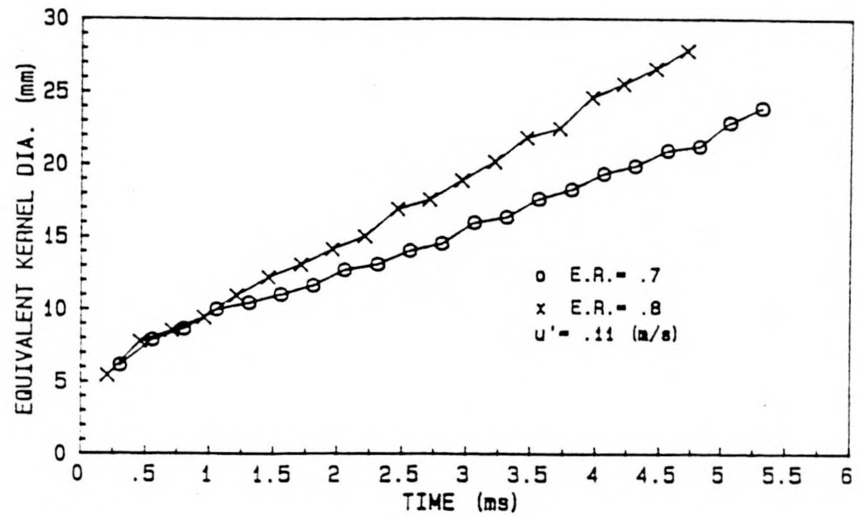


FIGURE 3: TYPICAL GROWTH RATE CURVES



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