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Homogeneous charge engines - basis of cyclic variations

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by

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The objectives of the Grant required investigations of cyclic variations in a homogeneous-charge engine initially with gas combustion and the air from ranging from near quiescent to the incorporation of swirl and tumble by valve inserts. Later experiments were performed with unleaded gasoline. The measurements included local velocity and cylinder pressure through the four strokes of a single-cylinder engine, under motored and firing conditions and with examination of the flame kernel growth by combinations of photography and flame-ionisation gauges. In all cases, the measurements of in-cylinder characteristics were linked to performance as measured in terms of speed and its variability, load and emissions. The experiments progressed to consider deviations from homogeneous charge and included consideration of stratified charge with local injection of a rich mixture in the vicinity of the spark gap so as to establish a flame kernel which would propagate securely into an overall weak mixture.

The engine used for all experiments had one cylinder and was arranged with optical access to the combustion chamber through windows in the head and through the flat piston. It was able to operate with combustion at moderate speeds and loads with the former controlled and measured by the signals from a shaft encoder and the latter exerted by a brake which also served to motor the engine when required.

The instrumentation was specially arranged from the experiments and comprised pressure transducers, flame ionisation gauges and a laser-Doppler velocimeter with the resulting signals transmitted to a computer together with

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those from the encoder to enable real-time signals and ensemble averages to be considered. Changes to the air flow were made possible by shrouds which were added to the inlet valve to allow a variation of swirl and tumble numbers over a reasonable range. It should be noted, however, that the flow characteristics generated by shrouds may be different from those generated by port geometry partly in terms of volumetric efficiency and partly because the shapes of the swirl and tumble profiles achieved with the same numbers may be different. Fast photography, with film and CCD camera, was used to observe the flame-kernel growth and the results related to those from the pressure transducer and ionisation gauges.

In general, cyclic variability improved with deviations from the quiescent chamber and attention was given to their frequency range. More interesting results were obtained with leaner mixtures which led to consideration of the extent to which injection of gas mixtures in the vicinity of the spark plug at the time of ignition could improve performance. With homogeneous charge, the benefits of local injection were small and improved as the mixture became leaner so that a small quantity of fuel and air, with the same equivalence ratio as the port-injected mixture improved the mixing in the vicinity of the spark and also the combustion as a consequence of the small-scale fluctuations. The improvements were considerable at equivalence ratios of around 0.75 and tended to extend the lean limit of operation. This limit was improved further by the injection of a small quantity of slightly rich mixture so that operation was possible with equivalence ratios of the order of 0.5 and with acceptable drivability. In-cylinder measurements showed that this was made possible by the establishment of a robust initial flame kernel which was able to propagate through the lean mixture.

Descriptions and results of the various investigations are documented in the papers listed in the attached appendix. Copies of the papers have been provided. Results of the investigation were discussed regularly at the Sandia National Laboratories and at meetings of the Department of Energy.

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APPENDIX; PAPERS PUBLISHED WITH CONTRIBUTIONS FROM GRANT DE-FG04-91AL 75332

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A Enotiadis, A Lingers, C Vafidis, J H Whitelaw and H-M Xu (1992) Mixture turbulence characteristics during flame propagation in a spark ignition engine. Proc SIA/STA Int Symposium on 'The Powertrain; Development and Future.' Valencia.

C Vafidis, J H Whitelaw and H-M Xu (1992) Conditional and Frequency Analyses of LDV Signals From a Gas-Fuelled Engine. Proc. 6th Int. Symp. on Applications of Laser Techniques to Fluid Mechanics, Lisbon.

H-M Xu and J H Whitelaw (1993) An experimental study of gas velocity, flame propagation and pressure in a spark-ignition engine. SAE Paper 932702.

C Arcoumanis, C-S Bae, H M Xu and J H Whitelaw (1994) Imaging of Lean Premixed Flame in Spark Ignition Engines. SAE Paper 942052.

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D Hull, J H Whitelaw and H-M Xu (1994) An approach to stratification in lean-burn spark-ignition engines. DOE, SAE P-289, 265-272.

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H-M Xu and J H Whitelaw (1995) Cyclic variations in a lean-burn spark-ignition engine without and with swirl. SAE paper 950683.

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