PROGRESS REPORT NO. 10

DIESEL IGNITION AND COMBUSTION

Effect of Fuel-Air Ratio and Coolant Temperature on Ignition Delay and Other Combustion Phenomena

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I. BACKGROUND

A program of activity to study the combustion process in supercharged diesel engines has been developed at The University of Michigan. This program is primarily concerned with the ignition delay and the effect of the several parameters on it. A special concern is given to the effect of the pressure and temperature of the cylinder air charge and engine speed on ignition delay. The program also includes the study of the effect of these variables on the other combustion phenomena such as smoke, rate of pressure rise, and maximum pressure reached in the cylinder.

The different types of delay have been studied in detail and an emphasis is made on the pressure rise delay and illumination delay. The instruments needed for the measurement of these two delay periods have been developed and a continuous effort is being made to improve their accuracy.

This research is being made on two experimental diesel engines. One is the ATAC high output open combustion chamber engine, and the other is a Lister-Blackstone swirl combustion chamber engine. Three fuels have been used in these tests.

II. OBJECTIVES

A. To study how gas pressure at the time of injection affects ignition delay and combustion. The effects are to be studied at pressures ranging from approximately 300 to 1000 psia.

B. To study how gas temperature at the time of injection affects ignition delay. The temperature ranges from approximately 900°F to 1500°F.

C. To study various combinations of pressures and temperatures to determine whether density is an independent variable affecting ignition delay.

D. To conduct all these studies with three fuels: CITE refree grade (Mil-F-45121) fuel, diesel no. 2 fuel, and Mil-G-3056 refree grade gasoline.

E. To study the effect of engine speed on the ignition delay and the other combustion phenomena. The engine speed covered a range from 1000 rpm to 3000 rpm.

F. To study the effect of the coolant temperature on the combustion process and the wall temperatures. Coolant temperatures range from 150°F to 300°F.

G. To study the effect of anti-smoke additives on the combustion process and the smoke. The anti-smoke additive is Lubrizol barium compound.

H. To study the effect of fuel-air ratio on the ignition delay and the other combustion phenomena. This study is run at two levels of coolant temperature.

III. CUMULATIVE PROGRESS

A. LISTER-BLACKSTONE ENGINE

Cumulative progress has been made in the following areas:

1. Review and analysis of previous work
2. Theoretical analysis
3. Experimental work on Lister-Blackstone engine
4. Comparison between the present work done on the Lister engine and previous work in bombs and engines

B. ATAC-1 OPEN COMBUSTION CHAMBER ENGINE

The cumulative progress made on ATAC-1 engine can be divided into three major areas:

1. Engine instrumentation
2. Experimental work
3. Theoretical work

1. Engine Instrumentation

The engine has been instrumented and all the instruments calibrated to measure the following:

a. Power output and engine speed
b. Gas pressure during the cycle
c. Illumination due to combustion
d. Wall surface temperature during the cycle
e. Wall temperature in the fire deck near the inlet and exhaust valves
f. Fuel pressure before the injector
g. Injector needle lift
h. Air flow rate into the engine and its temperature and pressure before the inlet valve
i. Fuel flow rate
j. Intensity of smoke in the exhaust gases, their temperature and pressure

2. Experimental Work on ATAC

A. Experiments were made on the ATAC engine to study the effect of temperature on ignition delay and combustion characteristics of the following fuels:

a. CITE refree grade (Mil-F-45121) fuel
b. Diesel no. 2 fuel
c. Mil-G-3056 refree grade gasoline fuel

The experimental results of this part were given in Progress Report No. 8, under A2A, A2B, A2C, and A2D series.

B. Experimental work to compare between the combustion phenomena and the rate of heat release for the three fuels, under naturally aspirated conditions.

The several computer programs made for these elaborate computations proved to be very successful, and can be used in future heat release computations under any set of running conditions.

C. Experimental work to study the effect of engine speed on the ignition delay and other combustion phenomena. Engine speeds covered a range from 1000 rpm to 3000 rpm.

D. Experimental work to study the effect of coolant temperature on the combustion process of CITE fuel. The coolant used for these tests was ethylene glycol at temperatures up to 305°F. The experimental results of this part were given in Progress Report no. 9.

3. Theoretical Analysis

A thermodynamic analysis was made to study the different types of energy and processes taking place during the ignition delay, and to compare between the different definitions used in the literature for the ignition delay. This study will be published in an SAE paper which will be presented in the International Meeting in Detroit, on January 17, 1969.

IV. PROGRESS DURING THIS PERIOD

During this period the experimental and analytical work on the ATAC engine has been completed, as follows:

A. To study the effect of the fuel-air ratio on the ignition delay and other combustion phenomena. This series of tests was run at two different cooling water temperatures, 170°F and 250°F.

This study included the effect of the fuel-air ratio on the following:

1. Ignition delay
2. Thermal loading on the coolant and the lubricating oil systems
3. Wall temperature in three locations in the combustion chamber

    a. at the surface of the valve bridge in the fire deck.
    b. in the fire deck at a point midway between the gas side and coolant side, near the inlet valve.
    c. as in b, near the exhaust valve.

4. Smoke intensity
5. Exhaust gas temperature
6. Peak cylinder pressure
7. Brake mean effective pressure
8. Brake specific fuel consumption

B. To study the effect of the anti-smoke fuel additive on the ignition delay and the other combustion phenomena in the ATAC-1 engine. This study was made using diesel no. 2 fuel with and without 0.5% Lubrizol barium additive (SMOGO).

This study included the effect of the anti-smoke additive, over a wide range of intake pressures and temperatures, on the following:

1. Smoke intensity
2. Ignition delay
3. Exhaust gas temperature
4. Surface wall temperature
5. Peak gas pressure
6. Maximum pressure gradient due to combustion
7. Rate of change of pressure gradient
8. Brake specific fuel consumption
9. Apparent activation energy of the pre-ignition reactions

The ignition delays were found to be longer with the anti-smoke additive than with diesel fuel alone. This would indicate that the anti-smoke additive affects the rate of the pre-ignition reactions. It was also noticed that the two series of tests with and without SMOGO were made with different coolants. The runs with SMOGO were made with ethylene glycol as a coolant (following the runs of the effect of coolant temperature on combustion, as reported in Progress Report No. 9). Meanwhile, the runs with the fuel without SMOGO were made with water as a coolant. This had the effect of changing the wall and exhaust gas temperatures; although the coolant temperatures were kept at a constant level of 170°F in the two cases. The wall surface temperature is expected to affect the heat losses and the gas temperature. It was thought, then, that the variation in the coolant might be a factor that caused the variation in the ignition delay.

To eliminate the error in the ignition delay measurements caused by the change in the wall temperatures it was decided to repeat the two series of runs, with and without the additive, using the same coolant. In this repeated series the coolant used was ethylene glycol, at 170°F.

The results of these runs showed that, in general, the anti-smoke additive has a negligible effect on the ignition delay.

The details of the technical information on the effect of fuel-air ratio and coolant temperature on ignition delay and other combustion phenomena will be reported in the final report.

V. FUTURE PLANS

To finish writing the final report for project. This will include all the work done on this project.

VI. SIGNIFICANT ACCOMPLISHMENTS

The experimental work on the project has been completed, and the instrumentation proved to be very effective in measuring and recording all the data needed.

The analytical work has been completed and resulted in publishing the following three papers before the Society of Automotive Engineers.

1. "Ignition Delay in Diesel Engines." Presented at the SAE Annual Meeting in January 1967. Published in the SAE Transactions, 76, paper no. 670007.

2. "Correlation of Air Charge Temperature and Ignition Delay for Several Fuels in a Diesel Engine." SAE paper no. 690252 to be presented at the SAE Annual Meeting, Detroit, on January 17, 1969.

3. "Diesel Exhaust Smoke: Effect of Some Fuel and Engine Factors on Its Formation." This paper is scheduled for the SAE West Coast Meeting to be held in Seattle, Washington between August 11-14, 1969.

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