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Improvements in petrol engine performance with ultrasonic fuel atomisation

- by -

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S U M M A R Y

Initial studies of the effect of air-fuel mixture preparation on piston engine performance have been conducted on a four cylinder 1600 cc petrol engine using conventional carburation and ultrasonic fuel atomisation. The performance of the engine, under various conditions of operation, has been assessed on the basis of specific fuel consumption and brake mean effective pressure.

Whereas only minor differences in performance were found under full power condition at part throttle running of the engine with ultrasonic fuel atomisation improvements in fuel consumption in excess of 10% were observed. These improvements appear to be the direct result of better mixture preparation. Indirect benefits of improved mixture preparation may be a reduction in exhaust smoke and hydrocarbon emission from the engine.

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1.0 Introduction

In recent years automobile petrol engine performance has improved as a result of increased compression ratio. To meet the needs of engines with these high compression ratios, higher Octane number grades of fuel have been introduced, closer control over fuel distillation range has been exercised and special fuel ignition additives developed. The development of fuel carburation has to some extent kept pace with these advances. Modern carburettors give, to a high degree, effective control of air-fuel mixture over the operating range of these engines. In one important respect, however, carburettors have not advanced, that is in their ability to atomise the fuel they so carefully meter. This aspect is of direct importance to the operation of each cylinder in the engine since unevenness in mixture distribution, the result of poor atomisation, can cause cylinder peak pressure fluctuations which reduce the performance of the engine considerably[1]. In addition uneven carburation resulting in the supply of a weak mixture to one cylinder of the engine can lead to "knock", although the normal Octane requirements of the fuel have been satisfied. Also an indirect aspect of mixture preparation which is becoming important, particularly in built-up areas, is that of exhaust smoke and hydrocarbon emission.

Since the extent to which fuel preparation affects these factors is virtually unknown, studies have been undertaken, initially to assess the performance changes of a typical modern multi-cylinder petrol engine, with varying degrees of fuel atomisation. The engines performance with conventional carburation giving a comparative datum for the studies.

2.0 Scope of initial studies

The object of the studies described in this report was primarily that of establishing to what degree fuel should be atomised in order to improve upon the engines performance with a conventional carburettor.

For this purpose an ultrasonic atomiser [2], capable of producing fine sprays over the desired fuel flow range, small enough to mount in the engines induction system and requiring only small operating fuel heads, appeared to be most attractive.

Initial tests were therefore undertaken to compare the performance of the engine with ultrasonic fuel atomisation and conventional carburation.

3.0 Apparatus and techniques

The piston engine employed in these studies was a Hillman Super Minx, four cylinder, water cooled four stroke petrol engine, of 1592 cc capacity and 8.3/1 compression ratio, on loan from Humber Limited, Coventry. A detail specification of the engine is given by Ohinouye[3].

The engine was mounted on a conventional test bed, power being transmitted through a Hardy-Spicer shaft to a DPX 3 Heenan & Froude water dynamometer. Provision for motoring and starting the engine was made with a 50 horsepower electric motor driving through a dog-coupling which automatically disengages when the engine transmits power to the dynamometer.

The revolutions of the engine were counted with the help of a Langham-Thompson counter through the combination of a photo-cell pick-up and a rotating disc, with equally spaced holes near its periphery, mounted on the Hardy-Spicer shaft.

The amount of fuel consumed during running of the engine was measured by timing the flow of fuel from $^1/_8$ and $^1/_4$ pint measures in the engine fuel feed line. The air flow into the engine was determined by measuring the pressure drop across a 2.0 in. diameter sharp edged orifice mounted in the wall of a 26 cubic foot air box. The air box had sufficient volume to damp out pressure fluctuations across the orifice plate, whose discharge coefficient was assumed to be in accordance with that of Kastner[4].

The flywheel of the engine was marked with a top dead centre indication and degree quadrant for No.1 cylinder. This enabled ignition timing to be examined when the flywheel was observed with a stroboscope. Exhaust gas temperature was measured with a shield thermocouple immediately downstream of the exhaust manifold, and engine oil and coolant temperatures were closely controlled with variable water flow heat exchangers.

3.1 Carburation

The carburettor normally used on the Super Minx engine is a down draught, single choke Zenith, but because of the difficulty of varying the mixture strength of this carburettor it was also proposed to use a variable choke S.U. carburettor to cover a wider range of operating mixture ratios.

Fuel flow to the ultrasonic atomiser was controlled manually through fine needle valves under a fuel head of approximately four feet. Special Fischer & Porter flow meters were calibrated in order that the flow to the atomiser could be observed continuously and accurately. The power supply and electrical control of the atomiser were the same as detailed in reference 2, and its maximum power consumption was approximately 10 watts. The operating characteristics of the atomiser are summarised in Fig.1 and its operation in still air conditions is shown in Plate 1. Plate 2 shows the method of mounting the atomiser in the induction system of the engine, more details of which are shown diagrammatically in Fig.2.

3.2 Mixture distribution

Since mixture distribution would possibly change for the different carburation systems employed in these studies, it was desirable to assess any variations that occurred. A thermocouple plug method[5], using Champion N5 plugs, proved satisfactory giving a quick qualitative assessment. However, where considerable differences in distribution were suspected, gas samples were extracted at a point 1 inch downstream of each exhaust port through 3 mm diameter steel tubes. These gas samples were cooled and dried before passing to a continuous flow Infra-red gas analyser which determined mixture strength

4.0 Test procedure and results

Initial engine performance test runs were made with the standard fixed choke Zenith carburettor and results obtained for a variety of engine speeds at full throttle and half throttle settings. Dynamometer load, fuel consumption, exhaust gas temperature and ignition timing were measured. This test procedure was repeated with the ultrasonic atomiser in operation in place of the Zenith carburettor and performance in terms of brake mean effective pressure and specific fuel consumption calculated and corrected for ambient pressure and temperature.

Because of the difficulty of varying mixture ratio with the Zenith carburettor, tests were also conducted with a variable choke S.U. carburettor over a wider range of conditions. Repeat tests were also carried out with the ultrasonic atomiser mounted in the same induction system. A summary of the test conditions is shown in Table I.

The results of these performance comparisons are shown in Figures 3, 4 and 5. It should be noted that the throttle setting quoted for each test is related only to the carburettor butterfly opening and not to the proportion of full load which the engine takes at the specified speed.

Table I.

TEST	CARBURETTOR	AIR-FUEL MIXTURE	AIR-BOX	THERMOCOUPLE PLUG/GAS SAMPLES	THROTTLE SETTINGS	R.P.M.
1	Zenith	Fixed	NO	NO	Full & $\frac{1}{2}$	4200 3000 2000
2	Ultrasonic	Variable	NO	NO	Full & $\frac{1}{2}$	4200 3000 2000
3	S.U.	Variable	YES	YES	Full, $\frac{1}{2}$ & $\frac{1}{4}$	3500 2500 2000 1500
4	Ultrasonic	Variable	YES	YES	Full, $\frac{1}{2}$ & $\frac{1}{4}$	3500 2500 2000 1500

5.0 Discussion

With the exception of one set of S.U. carburettor results, at 2000 rpm, full throttle performance comparisons of Zenith and S.U. with the ultrasonic atomiser show only minor variations. This would tend to suggest that the mixture preparation of the ultrasonic atomiser under these high flow conditions is the same as that of the carburettors. From the fuel flow rates observed for these test conditions the droplet size produced by the ultrasonic atomiser, under still air conditions, would be approximately 115 microns.

The performance comparisons at part throttle conditions all show the ultrasonic atomiser to have considerably improved specific fuel consumption. Since under these conditions the fuel flow rate is lower than that at full throttle, the droplets produced by the atomiser are smaller, approximately 85-90 microns. Under these conditions improvements in mixture distribution were noted through thermocouple spark plug measurements and exhaust gas sampling.

In addition, since the percentage of fuel evaporated would be higher, one would expect a more homogeneous mixture to pass into each combustion chamber resulting in an increased burning rate. This was demonstrated to some extent by the fact that while using the ultrasonic atomiser, exhaust gas temperatures were comparatively lower than those when carburettors were in use. In addition to the fact that under such conditions more work is being performed on the piston, the proportion of unburned gas and droplets leaving the chamber would be reduced thus possibly tending to reduce smoke and hydrocarbons in the exhaust.

Although at quarter throttle conditions the ultrasonic atomiser still shows considerably better specific fuel consumption than the S.U. carburettor, the general level is higher than at half throttle conditions. This difference may be due to the reduced mean air velocity through the induction system resulting in a greater proportion of wall wetting. Since the level of turbulence will also be reduced under these conditions, mixing of the fuel and air would be poorer. General levels of mixture distribution, indicated by the thermocouple plug method, however, appeared to be quite good under these conditions.

The differences in specific fuel consumption observed in these performance comparisons are shown in Fig.6 (Minimum fuel consumption values have been used).

A possible improvement over this initial method of studying the effect of mixture preparation would be to use multiple ultrasonic atomisers, say one per cylinder, in order to reduce the droplet size variation associated with one atomiser.

6.0 Conclusions

From the preceding observations the following conclusions can be deduced:-

(a) At full throttle conditions conventional carburation prepares the fuel-air mixture as thoroughly as the ultrasonic atomiser employed in these tests.

(b) At part throttle running of the engine, improvements in specific fuel consumption amounting to values between 10 and 18% can be achieved with ultrasonic fuel atomisation.

References

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