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PEAK PRESSURES IN THE RING PROCESS.

Outline:-

When adjusting to optimum output, the maximum pressures are equally great both in the gasolene- engine process and in the ring-process. In the gasolene-engine process peak pressures increase steadily with the ignition-advance, whilst in the ring-process they decrease again when the injection-advance is larger than was necessary for optimum output.

When comparing the gasolene-engine process and the ring-process, diagrams show a power-gain for the ring-process through the start of pressure-rise at the top dead centre and a slower pressure decrease in the expansion-stroke.

When testing the heat of the coolant, we find that it is by 25% larger in the gasolene-engine process than in the ring-process.

Introduction:-

When dealing with working processes of engines it is important to examine not only the mean effective pressure which may be reached, but also the peak pressure of the combustion. Upon the extent of this power depends the dimensioning of pistons, piston-rods and bearings.

It is quite well known that the peak pressures of the Diesel-engine are very high, not only as a consequence of the high compression pressure but also because of the sudden combustion start. It was for this reason that during the development of the Diesel engine efforts were constantly made to obtain a smoother combustion e.g. by using pre-combustion-chambers.

It was, however, necessary to develop a special bearing-alloy:- the lead bronze. The ring-process starts the ignition of a gasolene mixture with Diesel type combustion. Therefore the question arises whether the peak-pressures will correspond to those of the gasolene-engine or to those of the Diesel engine. In the latter, case it would be more difficult to convert available gasolene aero-engines to the ring-process.

Besides peak pressure experiments, investigations of the heat balance was also necessary.

Conduct of the tests.

The tests were carried out on an I.G. Research-engine (No.2) with a DB 6001 cylinder under the following conditions:-

Speed:- 2000

compression ratio:- 1:8

Camshaft:-	Fv 4 B d A 1 B
Valve timing:-	inlet opens: 25° before the T.D.C. inlet closes: 75° after the B.D.C. exhaust opens: 53° after the B.D.C. exhaust closes: 25° after the B.D.C.
Boost-air temperature:-	80°
Boost-pressure:-	760 mm Hg
Cooling-water temperature:-	80°
Oil temperature:-	80°
Fuel:-	75% CV2b + 25% ET 110
Fuel-nozzle:-	960/22.9/41 (L'Orange)
R-Nozzle:-	DV 2312/1 (hole 0.3; 30° gg. exhaust-valve)
R-fuel quantity:-	22 mm ^{3}/cycle
Sparking-plug	DM 225 T 1

The fuel-nozzle was in its allotted place; the two sparking-plugs were opposite, as usual. In the ring-process, one sparking-plug was replaced by a dummy-plug, the other by the R-nozzle. The quartz-pick-up was in a special hole.

We tried first of all and as accurately as possible to obtain information about the peak pressures as a function of the speed. This was done by supplying a constant heat-quantity for each cycle, and adjusting the best power at various speeds by changing the injection-advance.

When repeating the tests, however, we observed deviations which were too great to allow a reliable assessment, because the injection-advance was set by mere trial and error. Therefore the tests were limited to one speed only, and we examined the influence of ignition-advance in the gasolene-engine process, or of injection-advance in the ring process, on power and peak pressures, maintaining a constant fuel quantity.

We shall have to investigate the influence of various speeds and temperatures on peak-pressures by special tests.

In contrast to the Diesel engine, where there are only small differences between the individual combustion cycles, the diagrams for the gasolene engine process and for the ring-process frequently show considerable differences. In order to assess the courses of combustion, it is necessary to take a great number of diagrams which will give us a good picture of the variations.

Results:-

(a) Peak Pressures:-

The tests were carried out with the same excess-air of 0.92, i.e. with full load in both the gasolene engine process and the ring process. This corresponded to a heat supply of about 132 x 10^3 kcal/hr. The R-fuel quantity in the ring process was 22 m^3/cycle which meant 7.7 Vol-% of the fuel quantity.

Page 1 shows diagrams comparing the results of the gasolene and Diesel tests. The maximum output which could be obtained in both cases. It was about 9.8 kg/cm^2. Because of a rather long pipe between the surge tank and the cylinder this particular test-stand obviously did not yield the same output as others.

We measured the peak pressures from diagrams which showed 30 working cycles each. Since each cycle has a course of combustion of its own, we obtain a given region in which the peak-pressures take place and the limits of which are shown. We must not forget that this does not give us the exact spot in this regio n where most of the peak pressures occur. Furthermore the average is not to be found in the centre of the two limits. We must try to obtain the true mean value by further tests.

In the tests here, we can only find out whether the maximum values of the peak pressure differ in the two processes. The best mean effective pressures were reached under the following conditions:-

Process	Ignition-advance	M.E.P.	Peak Pressure	d
Gasolene-Engine	40°	9,8	38.5-52.5	14.0
Ring-process engine	50°	9.6	43 - 52	9.0
do.	70°	9.7	44 - 55	11.0
do.	80°	9.7	41 - 51	10.0

The differences between maximum and minimum value,- the latter based on the former,- are also shown on page 1. We find that ring-process engine runs more evenly. Its smallest variation is 18% as compared to the 25% of the gasolene-engine. It is remarkable in the ring-process that the peak pressure is in about direct relation to the M.E.P. So if we decrease the M.E.P. by excessively early injection, the peak pressure follows. In the gasolene-engine process, however, the peak pressure increases steadily and continues to do so even when the M.E.P. decreases again because of an excessive ignition-advance. A further difference of the two processes is that in the ring-process the change of injection-advance influences the M.E.P. much less than the ignition-advance in the gasolene-engine process. The injection advance may be altered e.g. between 50°- 80° without noticeably affecting the M.E.P This is shown by the numerical table. As regards control we come to the important conclusion that the injection-advance need not be so carefully adjusted as the ignition advance of the gasolene-engine process. Besides there is no danger for the equipment when exceeding the limit.

We find a few diagrams on page 2. They also show at the same time the peak pressure curves from page 1. We should say here that we showed only one particularly characteristic photo for each point measured each time. The variations seen on this photo consequently do not give us the complete variation region as represented by the limit curves. We showed on page 3 the highest diagrams occurring at each test point which, - as limit values of what was observed,- allow a certain comparison between the gasolene-engine process and the ring process. We see one fundamental difference from these diagrams. In the gasolene-engine process the combustion starts long before the dead centre, the compression curve gradually turning into the combustion curve. In the ring-process, however, combustion starts with a distinctive bend in the curve near the dead centre. The injection-advance angle has only very little influence, indeed, which is also proved by the small change in the M.E.P. when changing the injection-advance angle, a fact we mentioned before. The rate of pressure rise may be larger in the ring-process, as shown by pages 4,5 and 6. (Compare e.g. on page 4 the curve for 40° ignition-advance in the gasolene-engine process with the curve for 50° injection-advance in the ring-process on page 5). In the gasolene-engine process the rate of pressure-rise increases still further with the excessive ignition-advance of 50° and even exceeds the maximum rate of pressure rise of the ring-process. With an ignition-advance of 60°, however, we observed a decrease again. In the ring-process the rate of pressure rise decreases again considerably when the injection-advance angle is greater than 60°, as can be seen on page 6. With an injection-advance angle of 70° (cf. page 1) ,which is the most satisfactory for power output, the same rate of pressure rise is obtained as with the gasolene-engine process at its most favourable ignition of 40°.

In fig. 1186 we show a gasolene diagram at 40°, ignition-advance with a ring-process diagram at 70° injection-advance, and we selected two diagrams which happened to have approximately the same peak pressure. The start of combustion in the gasolene-engine process before the dead top centre means additional compression-work which leads to an area of loss when compared to the ring-process.

(Diagram showing course of pressure in the gasolene-engine process and the ring process)

A second "loss area" is caused by the fact that during the expansion-stroke pressure decreases quicker than in the ring-process.

This phenomenon can be found generally and not only with these two diagrams. This means that - if the gasolene-process is to yield the same power as the ring-process - this can only be done by a higher peak pressure.

This means that the only way in which to obtain the same power with the gasolene-engine process as with the ring-process, is, to raise the peak pressure in the gasolene-engine process. The true mean values of the peak pressures must consequently be higher in the gasolene-engine process than those of the ring process.

In tests during which the R-fuel was not injected across the combustion chamber but into a pre-combustion chamber, we obtained the diagram form which is characteristic forthe gasolene-engine process. More thorough tests are necessary in order to solve these questions completely.

(b) Heat of coolant

We may deduce from the different course of combustion in the gasolene -engine and ring-process that there are slo differences in the heat balance, and that the heat quantities rejected to the cooling-water are different.

This was already pointed out by "BMW Spandau" (IIIM-Report No. 464 of September 9th, 1941). Tests with air-cooled engines showed that the cooling was obviously too strong. It was found for instance that at a test-point marked:- "cylinder-head centre" we could observe temperatures of 220° with the gasolene-engine process, and 180° with the ring-process. By removing cooling-fins with a weight of not less than 1.7 kg per cylinder we succeeded in increasing the head temperatures to the usual value of the gasolene-engine process.

By exhaust analyses we tried at first to find differences, if any, in the course of combustion. The results are put down on page 7 and show that the experimental points of the two processes lie with sufficient accuracy on common curves.

Tests of coolant-heats are shown on page 8 We used here a cylinder DB 6001 under conditions similar to those of the previous chapter.

We had, however, another test-stand so that higher outputs were achieved. The circulation of the coolant was throttled down as far as possible within safety-limits, and this caused a jump in temperature of about 10°. Page 9 shows the power of the I.G. pump used for cooling comparing it with that of a coolant-pump type DB 601. In addition there is a curve, supplied by "Daimler-Benz".

The heat rejected to the coolant is considerably greater at the power peak in the gasolene-engine process than in the ring-process. If we call the coolant heat of the ring-process at this point 100%, the heat discharge of the ring-process (sic) (? gasolene engine) is 125%. Reckoned on the whole heat supplied, the coolant heat in the gasolene- engine process is about 3% greater than in the ring-process.

The ring process reaches the greater part of the coolant-heat at high excess-air which is obviously caused by slow combustion.

By a more exact investigation, which is not shown here it was clearly found that the experimental points at 1.53 and at 1.92 were faulty, and therefore they were not taken into consideration for the position of the curve.

The exhaust-and oil temperatures which were also measured do not prove that an increased exhaust temperature gives compensation for reduced coolant heat.

We do not know what causes the reduced coolant heat. This is all the more remarkable in that the form of the diagram described in the previous section suggests a certain after-burning during the expansion stroke. It is intended to carry out thorough tests about the course of combustion and to solve the question of the coolant-heat at the same time.

Diagrams

Page 1:-	Comparison of peak pressures in the gasolene-engine and ring-process in their relation to ignition-advance or injection-advance respectively. Cylinde DB 6001 compression ratio 1:8 Speed = 2000 r.p.m. $\lambda = 0.92$.
Page 2:-	Influence of the ignition-advance on the course of combustion with advanced injection
Page 3:-	Course of pressure
Page 4:-	Pressure speed $\frac{dp}{d\varphi}$ Gasolene-engine process $10^\circ - 60^\circ$ ignition-advance
Page 5:-	Pressure speed $\frac{dp}{d\varphi}$ Ring Process $30^\circ - 60^\circ$ injection-advance
Page 6:-	Pressure speed $\frac{dp}{d\varphi}$ Ring-process $60^\circ - 100^\circ$ injection-advance
Page 7:-	Composition of the exhaust- gas gasolene-engine-process and ring-process compared.
Page 8:-	Coolant-heat gasolene-engine process and ring-process compared
Page9 :-	Power of coolant-pump

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