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POSSIBLE IMPROVEMENTS IN GASOLINE ENGINES.

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POSSIBLE IMPROVEMENTS IN GASOLINE ENGINES.*

By S. Ziembinski.

Mines' formula for determining engine power, employed by Fisk for automobiles, leads constructors to build engines of great power per liter of stroke volume.

Up to the present year, the Renault Company had not followed this method, preferring, first of all, as in steam engines, to increase the efficiency, i.e. full economy and long functioning without appreciable wear.

But in the year (1921) we yielded to the former method and studied high-compression engines. Since such studies are of the greatest importance for aircraft engines, we consider it of interest to give an account here of the experiments tried with a special engine, which has served for investigating the different points in the program adopted.

This program had three main objects:

1. Elimination of vibrations; ? ?
2. Increase of maximum efficiency;
3. Conservation of this efficiency at the highest possible speeds.

The first object was accomplished by reinforcing the crankshaft, lengthening the connecting rods and lightening the pistons or masses in alternating motion.

The second object was accomplished by a reasonable increase of the compression; by making the compression chamber

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as compact as possible, so as to insure good mixing and perfect combustion of the gases; and by giving the right shape to the intake and exhaust pipes, for assuring a good respiration of the engine.

The third object was accomplished by the same means as the first, since they improve the mechanical efficiency; also by a suitable shape of the intake and exhaust pipes, enabling the preservation of a high efficiency in spite of high gas velocities, exceeding 100 m/sec (328 ft/sec). In an automobile engine, this is necessary in order to retain the low (or idling) speed.

The basis of our study was an engine with four cylinders 95 x 160 mm (3.74 x 6.3 in.), with the valves on the side, these characteristics being retained.

Intake.- Several engines were mounted with the carburetor facing the valve side of the cylinders and with channels cast in the cylinder block. We have always found losses of power resulting from difficulties of casting, pipes with elbows, constrictions, roughness and even ridges impossible to remove.

An engine with the carburetor on the valve side immediately regained the lost power, because it was possible to take all the precautions for assuring a good flow of the gases, good evaporation of the gasoline and its uniform distribution in the cylinders. This arrangement, however, only gave good results when the gases were heated. The first heating was produced in a jacket traversed by the exhaust gases. As soon as the engine began to give a good total power, it could not run

without this jacket. Although it attained a temperature of about 100°C (212°F), its flanges were not heated, but, at a distance of 10 mm (.39 in.) from the exhaust gases, were covered with dew on very warm days, even in September.

The most important results were obtained with the following arrangement: The gases, after leaving the carburetor, contained globules of gasoline which, at the first bend, are thrown by their centrifugal force against the wall of the pipe. This wall was brought into contact with the exhaust manifold by the interposition of an aluminum block, for insuring rapid heat conduction. All classic treatises on engines had predicted a diminution of power due to the expansion of the gases admitted into the cylinders, but the engine investigated gained greatly in power and especially in regularity of functioning.

We found that a knowledge of the flow of gases, based on study in an aerodynamic laboratory, gave very important results. Applied alone, however, this knowledge may lead to false conclusions. It was sometimes necessary to depart from it, in order to regularize the distribution or evaporation of the globules. Thus (from this departure) we might lose 1% of the power and yet gain 10% from the improved evaporation. A Renault airplane engine only ran well after a sharp bend was introduced into the intake pipe. Previously, a pipe with rounded elbows led many globules into the manifold. These were almost totally absorbed in the first cylinders, which in this way received a much richer mixture than the following cylinders.

The introduction of a sudden bend, at the entrance to the manifold, created at this point a violent eddy, which evaporated a large portion of the globules and projected the remainder of the gasoline farther into the manifold. In this way, although the quantity of gases introduced into the engine was slightly diminished, its quality was much improved.

Exhaust manifold.- Few constructors have paid attention to the fact that, in engines containing more than four cylinders, the exhaust of each cylinder overlaps the following. The first cylinder is near the end of the exhaust stroke, at low pressure, though there is yet much gas to exhaust, when the following cylinder begins to exhaust with a much greater pressure. If the latter reaches the manifold suddenly without special precautions, it creates a back pressure and naturally arrests the exhaust of the preceding cylinder, which is thus prevented from completely emptying itself. Our investigations have led us to the construction of a manifold in which each exhaust, instead of hindering that of the preceding cylinder, serves, on the contrary, to exhaust it better, by drawing away the remaining gases.

The engine with our old manifold gave less power than without any manifold at all, but with the new manifold it gave more power. In a manifold of this kind, high gas speeds are obviously possible.

Valve chambers.- In nearly all existing engines, provided with the best intake and exhaust pipes, there are sudden changes

of cross-section in the valve chamber and ridges against which the gases are obliged to strike with loss of power. Aerodynamics teaches us that it is better to admit at certain points local constrictions followed by a gradual widening, as in a Venturi tube, than to allow abrupt changes in cross-section. By applying this principle, we obtained an appreciable gain in power.

Compression chamber.- Up to the present time, this has received very little attention. Only one improvement has been adopted by the constructors and this consists in placing the valves directly on the cylinder head, which naturally makes the compression chamber much more compact. In an engine with the valves on the side, the plan of the chamber is automatically determined by the bore of the cylinder and the diameter of the valves. The height is nearly constant and corresponds to the desired compression. We found that this shape could be advantageously modified in accordance with the two following principles:

1. To compress the gases into as compact a volume as possible, either above the piston or above the valves, by reducing to the minimum the height of the upper side.

2. To cause the entering gases to sweep the walls of the cylinder and the piston head during the intake stroke, in order to evaporate the adhering globules of gasoline, and to mix the gases well during the compression stroke, in order to have a perfect homogensity at the moment of ignition. Lastly, to

bring the spark as near the center of the mixture as possible. The application of these principles gave us a 30% increase of power.

Length of connecting-rods.- It would be foolish to insist on the importance of giving to the connecting-rods a length always in excess of twice the stroke. All old and new treatises advocate it, but constructors show an increasing tendency to reduce this length, especially in aircraft engines. Some engines have a length of connecting-rod as low as 1.6 times the stroke and in no case does it exceed twice the stroke.

The reasons for this lengthening are well known, so we need not repeat them. We will simply call the attention of constructors to Fig. 1 (curves 1 and 2), which speaks for itself.

It would likewise appear trite to say that the pistons must be as light as possible. However, this truism remains in the domain of theory, without penetrating sufficiently into the bureaus of research. In Fig. 1, three different weights of pistons were employed: ordinary connections made without regard to lightness; others lightened 20%; and still others with their weight reduced 47% from the original weight (curves 2, 3 and 4). The results are sufficiently eloquent to convince any one. They are all the more important, because they correspond to an intake and exhaust velocity of over 100 m/sec (328 ft/sec) and to an average piston speed of 17 m/sec, (55.77 ft/sec) without wearing the contact surfaces.

Pistons.- It has been possible to effect this lightening only with aluminum pistons. The great objection to employing aluminum is its excessive expansibility, which causes a clanging when the pistons are cold. We easily remedied this difficulty by changing the axis of the piston or by giving special shapes to the piston, so as to enable its being heated without appreciable increase in diameter.

It is also necessary for the greater portion of the heat, imparted by the gases to the piston head, to be transmitted to the cylinder walls by the part of the piston containing the rings, without heating the surface of the piston proper.

Piston rings.- It is very important that these should not be too hard. The friction between the piston rings and cylinder walls considerably diminishes the mechanical efficiency. The experiment of removing two rings out of three per piston resulted in an 8% gain of power. It is evident that too hard piston rings wear the cylinders as likewise too short pistons. We accordingly adopted very light piston rings and very short pistons.

The problem of the piston rings is essentially a metallurgical problem. If the metal is homogeneous, soft and elastic, perfect tightness can be obtained, even with very light rings.

Crank shaft.- In the construction of the crank shaft, we endeavored to avoid the vibrations of the engine due to flexure and torsion of the crank shaft, which are the principal causes of vibrations in polycylinder engines. It is a recog-

nized fact that six-cylinder engines often give more vibrations than four-cylinder ones, even with the pistons, the crank shaft and the fly-wheel balanced to the last gram, which reduces to zero the resultant of the forces of inertia and of the centrifugal forces. This is due to the fact that the crank shaft of a six-cylinder engine is much more subject to torsional vibrations and especially to the fact that its vibration period is much longer. It may therefore become troublesome in a six-cylinder engine below the maximum speed, while not appearing at all in a four-cylinder engine.

We took an engine which vibrated strongly at all speeds. We balanced the connecting-rods and pistons, the crank shaft and fly-wheel. The engine ceased to vibrate, save at two particular speeds in the ratio of one to two, thus demonstrating that the crank shaft is the chief cause of engine vibrations.

Scientists are now giving special attention to torsional vibrations. It seemed to us there might be other, no less important, vibrations due to the flexure of the crank shaft in the vertical plane passing through its axis, especially in four-cylinder engines with three bearings and in six-cylinder engines with three or four bearings. To test this point, we took the crank shaft of a four-cylinder engine with three bearings, which vibrated, and reinforced it simply from the torsional point of view. We made it more rigid about its longitudinal axis and lightened as much as possible the masses outside its axis of rotation, especially the crank pins. The engine, how-

ever, continued to vibrate. We then strengthened the crank shaft against flexure in the axial plane, especially in the long bearings, i.e. in the ones between the first and second and the third and fourth crank pins, when the vibrations immediately disappeared.

In conclusion, it may therefore be stated that crank shafts with a small number of bearings have two kinds of vibrations, those of torsion and of flexure, while crank shafts with bearings between every cylinder and the next have practically only torsional vibrations.

Engine vibrations should be eliminated at any cost, even aside from the question of the comfort of the passengers. First, because many breaks are due to the vibrations. The recent large German aircraft engines, with bores of over 200 mm (7.87 in.), have all failed from the rupture of parts (including even the crankcase) caused by the vibrations. In the second place, vibrations absorb power and lessen the mechanical efficiency of the engines.

A third disadvantage of vibrations (which has as yet received but little attention) is the more rapid wear of the contact surfaces. We have observed that the wear of the crank pins and the ovalization of the cylinders were appreciably more rapid in strongly vibrating engines than in non-vibrating engines.

After taking all the above-mentioned precautions, i.e. after we had reinforced the crank shaft, lightened the pistons the most possible and eliminated the vibrations, we were able

to keep the dimensions of the wrist pins the same as before. The engine revolved twice as fast and developed twice as much power. The wrist pins presented perfect contact surfaces without the least play.

In passing from a small engine to a larger one, the bearings wear out more rapidly, even if they are made according to the same coefficient of wear, i.e. a quantity which is the product of the rapidity of friction times the unit pressure and which consequently represents the work of friction.

This results, in our opinion, from the fact that the coefficient of friction is considered constant and independent of both speed and pressure. This is far from the truth, since the coefficient of friction varies greatly with these two conditions. The last German edition of Hütte, not yet translated into French, contains a very complete summary of tests by different experimenters on the friction of lubricated surfaces. Fig. 2 shows the variations of this coefficient.

In seeking to express the variations analytically, we found that μ corresponded very accurately to the formula

$\mu = k \left(\frac{v}{p}\right)^{\frac{1}{2}}$, k being a constant, independent of v and p.

Under these conditions, the work of friction is not proportional to v and p, but to $v^{\frac{3}{2}} p^{\frac{1}{2}}$ and, in computing the bearings of a crank shaft, account must be taken of a coefficient of friction K corresponding to the expression $K = v^{\frac{3}{2}} p^{\frac{1}{2}}$.

At the present date, our investigations are not yet fin-

ished, but we have already given 105 HP to an engine which previously had only 43 HP. Most of the improvements are also applicable to aircraft engines and would increase their efficiency and longevity.

We insist principally on the need of reducing, to the uttermost, the weight of the pistons and of lightening the connecting-rods; and also on the need of strengthening the crank shafts and lengthening the bearings. In lengthening the bearings, the engine will be lengthened several centimeters and its weight increased several kilograms, but it will become much more reliable and will be able to revolve much faster, so that its total power will be increased.

It is no longer necessary to limit the speed of the engine to that of the propeller. Reduction gears are being demanded more and more. The adoption of a reduction gear allows the engine speed to be increased up to limits required by other considerations. We think 3500 R.P.M. can be profitably adopted from now on.

We accordingly predict a rapidly revolving engine, with very light pistons and longer connecting-rods. It will easily develop 25 HP per liter of stroke-volume and will function satisfactorily for the needs of commercial aviation.

Translated by the National Advisory Committee for Aeronautics.

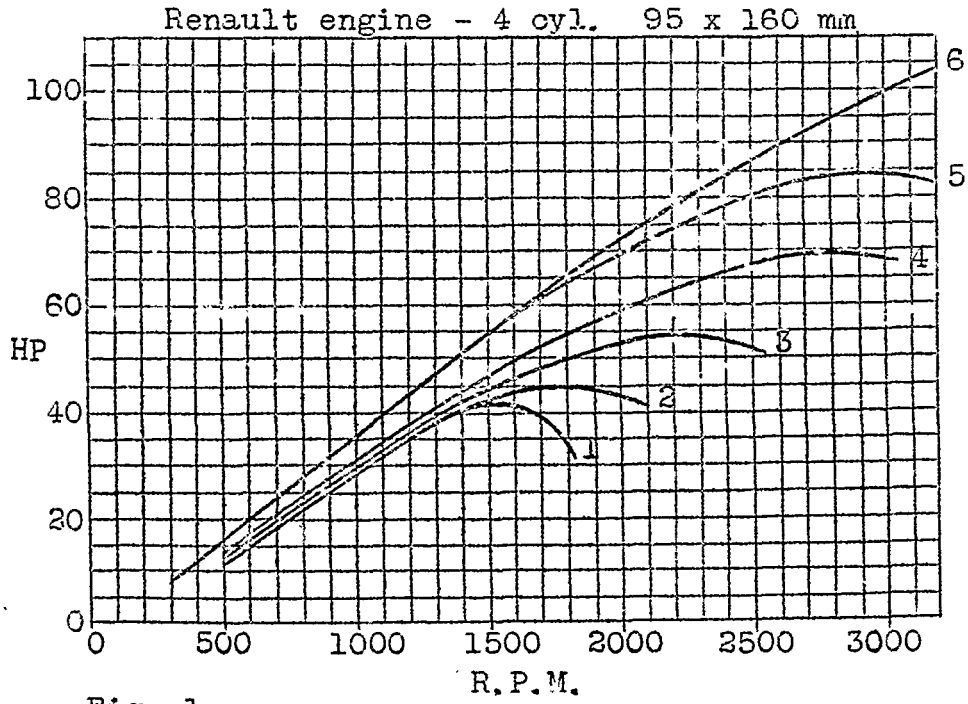

Fig. 1.

1 Old engine.
2 " " connecting rods lengthened.
3 " " " " " light pistons.
4 " " " " " extra light pistons.
5 " " " " " light pistons;
new compression chamber and manifolds;
valve lift increased.
6 New engine; connecting rods lengthened;
extra light pistons.

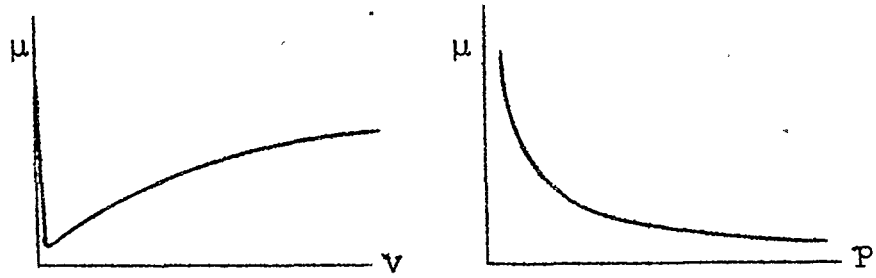

Fig. 2. Variation of coefficient of friction μ with velocity and pressure (v and p).

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