INDIANA SECTION PAPER

HIGH-SPEED ENGINES OF SMALL PISTON DISPLACEMENT

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In addition to using a smaller quantity of fuel per horsepower-hour, the small high-speed internal-combustion engine has other important features of advantage which are stated. The authors outline specifications intended to secure these advantages.

The high-speed racing engine designed by the authors, which won the 500-mile race on the Indianapolis Speedway in 1920, is illustrated and described in detail, its distinctive features being commented upon.

The automobile should be built to a higher standard for the use of the high-speed engine. The builder should work to a greater degree of precision and, as the working parts of the engine are all light and stressed fairly highly, this necessitates the use of properly heat-treated high-grade materials. Few small cars of this type seem to give satisfaction. The authors look for further developments to counteract this in the near future.

Fuel economy is one important reason for the high-speed engine of small piston displacement. Gasoline was little thought of 25 years ago; the idea that some day we might be without it was a matter of small interest. Today, conditions have changed. The automobile has advanced beyond all expectations and the consumption of gasoline has increased in like proportion. A comparison of the price ratio between gasoline and the automobile of 10 years ago with the ratio of today shows that the automobile has advanced very little, but that gasoline has advanced from three to four times the former price. The low cost of fuel is one reason that has enabled us to carry on large automobile production in this country. What will happen if the cost of this fuel goes beyond the reach of the buying public? The large production of automobiles which we have been enjoying will be cut down materially and conditions will parallel those of Europe. What good will it do to build cars at a low price, if the cost of maintenance is beyond

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the reach of the middle classes? The conservation of fuel is a foundation for large production. Unless the car builder works to that end, or the petroleum producers find a substitute fuel, the automotive industry will suffer.

In addition to using less weight of fuel per horsepower-hour, the small high-speed engine has important features. One is that of light weight, which is a great step toward economy; less power is required to propel the car, less tractive effort is needed and the strain on the tires is not so severe. The flexibility of a high-speed four-cylinder engine approximates that of the "multicylinder" engine. The buying public is more familiar with the general construction of the four-cylinder engine than with that of the other types. The cost of repairs also is an important item; the fewer the number of parts that require overhaul, the better the owner should be pleased.

ENGINE SPECIFICATIONS

Now that the reasons for such an engine and its importance have been stated, we will outline some specifications. The engine should be of the four-cylinder type. As has been said, a high-speed engine should have as few moving parts as is possible; the having of fewer moving parts tends to make it more reliable. It also makes a short engine, which allows more body room and decreases the chances for torsional vibration in the crankshaft. The engine should have a displacement of about 165 cu. in. for a car with a wheelbase of approximately 118 in., a bore of say 3¼ in. and a stroke of 5 in. The valves should be located in the head, as this gives a more ideal combustion-chamber, and should be at least 1⅝ in. in the clear with a lift of at least ⅜ in.

The camshaft should be overhead and run in a bath of oil, but it should be arranged so that no large quantity of oil can get to the valves and cause trouble; otherwise the oil will be drawn in around the inlet-valve stem and have a tendency to foul the cylinders and cause a smoky engine at low throttle-positions. The drive of an overhead camshaft has been more or less a problem. A silent chain is out of the question and the ordinary bevel gear is too noisy, but it seems that the application of a helical bevel gear would solve this problem. The drive from the crankshaft should be taken through a pair of spur gears, to prevent the tendency of crowding because of any lateral motion of the crankshaft. From the spur gear, the drive should be through bevel gears and a vertical shaft to the camshaft, a suitable coupling being devised between the cylinder and the head to enable the head to be removed, the carbon deposit cleaned out and the valves ground, without disturbing the timing of the engine. We recommend an overhead camshaft because we believe that lifter-rods and rocker-arms are not practical for high-speed work. The inertia forces of the rocker-arms and lifter-rods run too high to be overcome by any reasonable amount of spring-pressure; it is difficult also to lubricate them properly. In addition, it is almost impossible to maintain proper adjustment, the engine becomes noisy and must be tampered with continually.

The crankshaft is of course a fundamentally important part of this engine. It should be counterbalanced. The crankpins and main bearings ought to be not less than 2⅛ in. in diameter, and there should be at least three main bearings. It is well to drill the crankpins hollow, reducing their weight and at the same time keeping the material at a point where it will do the most work.

The piston, wristpin and connecting-rod must be very light. The length of the connecting-rod should not be over twice the stroke. In the case of the engine described this would be 10 in. The reason for making these parts light is to reduce the load on the bearings as much as possible and to eliminate to a great extent the vibration caused by the differential speed of each pair of pistons as they pass the top and the bottom centers. This type of vibration becomes clearly evident at high engine speeds and cannot, of course, be overcome entirely in a four-cylinder engine.

The cylinders should be cast in block and surrounded with plenty of water, especially around the valves. At high speeds the heat becomes very great at these points; lack of water means distortion of the valve seats, which would cause a drop in power if the engine were run at wide-open throttle. When there is no room for a spark-plug in the top center of the combustion-chamber, we recommend the use of two spark-plugs, one in each side of the combustion-chamber; this gives excellent water circulation around the spark-plugs. We have found that, with engines having spark-plugs in each side, by cutting out the spark-plugs on one side there was a considerable drop in horsepower. Of course, this is more noticeable in engines of relatively large bore than with those having a small bore; but it has considerable effect on both, especially with the fuel mixtures we have to burn at present.

The lubrication of the engine should be a pressure-feed in all cases, and oil should be pumped through the engine in as large a quantity as possible. Provision should be made also for carrying a large quantity of oil in the engine; this will give the oil a chance to cool off before being pumped through the engine again. A compartment should be provided in the bottom of the crank-case where the oil will not be agitated, so that the carbon deposits and dirt can settle out. Clean oil adds materially to the life of the engine. We believe that before long engines will be fitted with small centrifugal oil-cleaners that can be removed, cleaned out and replaced without much trouble.

Carburetion on an engine of this type is another problem. To obtain efficiency at high speed the manifold must be large; it should be 1¾ to 1⅞ in. for an engine of the size which we are discussing. A manifold of this size will probably give trouble by loading-up at low engine speeds, and this would interfere with securing the good performance that people look for in an automobile. However, this trouble might be overcome by the use of a double manifold and carbureter, one large and one small, the latter to be used in taking care of speeds up to 25 m.p.h. and the former coming into play from there on. As most of the running of a car is done between 15 and 25 m.p.h. the small carbureter could be run practically wide-open all the time. This undoubtedly would give high economy and, owing to the high velocity of the gases, there would not be a tendency to load-up.

The inlet-manifold should be carefully worked out to assure even distribution of the gases. With a large manifold and a large volume of gas at a high velocity there is a tendency for the gas to bank-up toward the two end cylinders. If this occurs, the two middle cylinders starve and immediately the exhaust-valves of cylinders Nos. 2 and 3 become overheated and burn.

A high-speed engine should be equipped with a four-speed transmission driving direct on the third and geared-up on the fourth speed. On smooth level roads the fourth speed could be used, giving good touring speeds at moderate engine speeds and lengthening the life of the engine. The automobile should be built to a higher standard for the use of the high-speed engine.

To be successful the manufacturer should work to a greater degree of precision and, as the working parts of the engine are all light and stressed fairly highly, this necessitates the use of high-grade materials properly heat-treated. Several attempts have been made in this country to produce high-speed engines, but for some reason they have not been very successful. However, there are a few small cars of this type that seem to give very good satisfaction, and we look for more developments along this line in the near future.

The Engine Described

Fig. 1 shows the high-speed racing engine designed by us, which won the 500-mile race on the Indianapolis Speedway in 1920. It is necessary in this type of high-

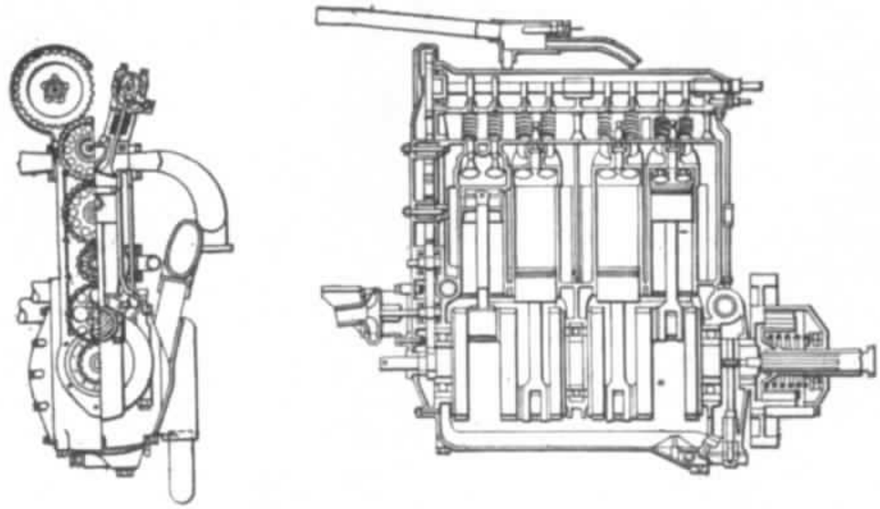

Fig. 1—Section of a High-Speed Racing Engine Having a Small Piston Displacement

speed engine to cut down the friction as much as possible. We attempted to do this in several ways. One is that the water-pump and the ignition system, which consists of a generator and a distributor and forms a unit with the water-pump, are placed in front of the engine and driven by what can be called the idler gears. The last named form part of the set of spur gears which drive the camshafts. Thus we eliminated several gears which usually run off to one side or the other to drive the water-pump and the ignition system. This makes a very clean, narrow and accessible engine.

This engine has two overhead camshafts in separate housings. The valve-actuating mechanism consists of