THE HORSELESS AGE

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The Sleeve Valve Motor Discussed by Charles Y. Knight.

In a Lecture at the Automobile Club of America the Inventor Describes Its Features of Construction and Operation, and Reviews the History of Its Introduction.

Before an audience of several hundred automobile enthusiasts, including many prominent motorists, engineers and manufacturers, Charles Y. Knight on Tuesday evening of last week delivered a lecture on his Silent Knight Motor at the clubrooms of the Automobile Club of America. Mr. Knight described in some detail his many and varied experiences in first introducing his motor abroad when the Daimler Co., of Coventry, England, adopted it, closely followed by Panhard & Levassor, of France; the Minerva Co., of Belgium; the Sigma Co., of Switzerland; the Mercedes Co., of Germany, and the Daimler Co., of Italy.

During the lecture Mr. Knight described the motor and its action by the use of the large wooden model which had been in the showwindow of the Stearns Co.'s New York branch for the past two weeks. He answered questions in regard to lubrication, cooling and wear of moving parts, he said that one of his motors which has been run 100,000 miles shows no signs of wear on the sleeves, and expressed his belief that even 1,000,000 miles would not cause any appreciable wear on these parts. In part he said:

Since the advent of the sleeve valve motor in Europe no fewer than 250 patents have been issued by England, France, Germany and Austria covering suggestions for the improvement of the sleeve valve engine.

In addition to these there have also cropped out innumerable suggestions for flat slide valves, rotary valves, flat disc valves, round ring valves, rotary sleeve valves and various piston valves. The inventors of these motors seem in few cases to have gone further than registering their idea with the patent office.

THE OUTSTANDING FEATURE.

The outstanding feature of the motor is the substitution of sleeve valves for poppet valves. This innovation in the explosion motor is wholly original, to the extent of my knowledge and belief, with myself. It is not so much the novelty of the valve and the elimination of noise which have contributed to the success of the motor, because admittedly other motors with other valves have been producd which were fairly quiet.

When I first began the exploitation of the sleeve valve motor I vigorously combatted the use of the term "slide valve" in connection with it. At that time the very suggestion of that form of valve in connection with the internal combustion motor was sufficient to cause all interest in a four-cycle motor to vanish. The position of the slide valve in the art at the time was well set forth by Frederick Remsen Hutton, E. M. Ph. D., Professor of Mechanical Engineering in Columbia University, in his work, "The Gas Engine," under date of 1903, which says of valves of internal combustion engines on pages 249 and 250:

"The valves of nearly all combustion engines *are made to lift to open, inasmuch as it* WOULD BE DIFFICULT *to secure lubrication of a sliding surface under the condition of heat to which these valves are exposed. This difficulty has been the occasion of abandoning the sliding valves of the early designs.*"

Now you will doubtless ask in your own mind why, if all former slide valve internal combustion engines were failures, have you cause to believe that the sleeve valve type will be successful? Wherein lies the substantial difference which enables your structure to accomplish that which had hitherto been abandoned by those engaged in the art?

As I have previously intimated, the successful operation of the sleeve valve engine is the result not of one, but of a great number of characteristics. The failure of former devices has been almost wholly due to the impossibility or impractibility of lubricating the highly heated sliding surfaces which were employed in those types of sliding valves. Now, a failure to lubricate may result from a number of causes, no one of which, if taken alone, might render the operation impractical. The sleeve valve motor differs from all former types of slide valves in that it encircles the piston and forms the outer walls of a combustion chamber. In other types of valves, when the explosion occurs, not only are the sliding surfaces subjected to the intense heat of the explosion and the blow torch action of the exhaust, but the extreme pressures as well. Failure of lubrication might be brought about by either of these causes, but is almost certain to result from a combination of both. The old type slide valve was forced by the intense explosion hard down upon its seat and was necessarily moved under the same intense heat and pressure.

THEORY OF LUBRICATION.

The most difficult surface to lubricate is a hot sliding surface subjected to intense heat combined with high pressure. Two flat surfaces working together strongly resist the squeezing of the oil from between them when conditions are such that the viscosity of the oil may be preserved to a reasonable extent, but increase this pressure, heat the surfaces to a point where the oil thins up like water and it soon finds its way to the outer edges as a result of the reciprocating movements essential to the functioning of the valve. In rotating surfaces, particularly when the rotating action is supplemented by the pumping action of the stopping and starting of the reciprocating parts, the oil which is squeezed out at one impulse through high pressure could be automatically replenished by the succeeding shock of the return movement of the reciprocating masses, but there is no such action present in the operation of the slide valve, and the tendency is wholly to squeeze the oil out.

VALVES ARE BALANCED.

In the concentric sleeve valve these conditions are almost wholly eliminated. Since the sleeve valve wholly encircles the piston and forms the side walls of the explosion chamber these valve seats are not subjected to high pressures, as the explosions against the walls of the valve are entirely balanced. The cylindrical walls as a result of their form are not in the least affected as to position by the explosion.

ALLEGED BURNING OF PORTS.

The first criticism that was directed against this construction in the early days was that the ports in the sleeve valves would burn. It might suffice to state that they do not, but inasmuch as the cause of their immunity from damage from heat is easily explainable, I shall dwell to some extent upon this feature.

The ports in the inner sleeve are sealed through the lapping of their openings with a wide ring, which we call the junk ring. This ring is similar in construction to the ordinary piston ring, only much wider, in order to seal the ports. Underneath the junk ring there is placed a second or spring ring for the purpose of insuring perfect contact with the interior of the sleeve. Both rings are split like a piston ring. Above them are two or three ordinary piston rings to bar the escape of any gases which might pass the break in the junk ring.

These rings are all set in the inwardly projecting water-cooled head in which is located the spark plug. The water reaches within a fraction of an inch to the bottom of the inside of the head. The cylinder surrounding the sleeves and head is also water jacketed, so that the sleeve valve reciprocates between water-cooled walls and the sleeve junk ring and ports are cooled upon both sides.

At the time of the explosion the ports in the inner sleeve are central with a wide junk ring. Hence, from the time of the greatest heat until the temperature in the explosion chamber is reduced to at least half the ports through which the exhaust gases pass are not exposed to heat at all. Therefore, their lips and surfaces are not only immune from the fierce heat of explosion, but the entire section of the sleeve carrying them is pushed up after every explosion and rubbed against the water-cooled surfaces which serve to prevent the accumulation of heat at this vital point. None of the valve mechanism is ever brought in contact with the heat as are the poppet valves, whose heads are always subjected to the highest temperature generated in the explosion chamber which reach almost the melting point of steel.

LUBRICATION.

Now, let us turn to the very important subject of lubrication The critic is surprised to learn that the clearance between the sleeves and cylinder is not of great importance. He has overlooked the fact, previously stated, that the real valve is in the head and is never exposed to the pressure or the heat of the explosion and is kept upon its seat not by the pressure of the explosion, which can never reach it, but by the spring of rings similar to the ordinary piston ring. In short, if rings are a success on the piston they are equally practicable in this position on the head.

The valving of a four-cycle motor is much different from the functioning of any other mechanism of the pump order. Coincident with the pressure and explosion stroke, the cylinder must be sealed in a manner which admits of no defect. The contact between the valve and its seat must be perfect. This function is performed by the wide ring engaging the interior of the inner sleeve.

During the exhaust and aspiration strokes a different condition prevails. The pressure in the cylinder has dropped to at least forty pounds to the square inch before the lower lip of the exhaust port in the inner sleeve slides over the bottom of the wide ring upon its downward or exhaust stroke. The intake and exhaust ports are so arranged in this inner sleeve that the latter leads the former by about one-sixteenth of an inch. This gives the exhaust gases an opportunity to sufficiently escape to reduce the pressure in the explosion chamber almost to atmosphere before the lower lip of the intake port is exposed to their heat. This means that the danger of these gases blowing out between the lips of the inner and outer sleeve on the intake side is prevented, the liberal clearances between the two sleeves required for lubrication not furnishing sufficient aperture to cause leakage of the exhaust into the intake ports.

Upon the aspiration stroke, there is never in excess of a few pounds vacuum developed in the cylinder as a result of the suction with closed throttling. Therefore the necessity for a very close fit between the upper lip of the outer sleeve and the lower lip of the water-cooled cylinder which serves to seal the exhaust port during this aspiration stroke is not essential.

SUCTION DISTRIBUTES OIL.

If necessary, clearances as great as between the piston and cylinder can be employed between the two sleeves and between the outer sleeve and the water cooled cylinder wall. There is always more or less of a vacuum at the intake ports as a result of the necessity of placing a suction upon the spray nozzle of the carburetor. These ports extend about one-third of the way around the cylinder and sleeves. The lower ends of the sleeves are constantly immersed in the spray of oil in the base. The oil which naturally clings to the lower ends of the sleeves when they reciprocate in this base is slowly but surely drawn upwards by the suction of the pistons. That this suction does draw the oil from the base between the sleeves and the cylinders is most easily demonstrated by placing a motor upon the block, driving it from power through a belt and placing an obstruction over the intake port, creating a vacuum around the sleeves. Inside of a minute or two remove this obstruction or cover and a small pool of oil will be observed to have accumulated therein. But if there is no vacuum around these intake ports, they will remain free from oil no matter what length of time the motor may be turned over with a belt.

This oil, drawn from the base between these surfaces, must necessarily distribute itself between the faces of the sleeves as a result of a capillary attraction.

In fact, instead of being difficult to lubricate, these sleeves are the first to attract any oil that may be flying about, and in cases where bearings have burned out and pistons seized the sleeve surfaces were found to have been bountifully lubricated.

COOLING.

Will the motor cool?

This is another question which might be answered by citing the fact that some 8,000 of these motors are now in the hands of the public doing the most drastic service in cars operating upon European roads with smooth stretches hundreds of miles in extent where unrestricted speed is possible. Not only this, but reports of official tests are available which will leave no doubt in the mind of the disinterested seeker of the truth as to the perfect cooling of this type.

WEAR ON SLEEVES.

I am asked, "What about the wear upon these sleeves?"

Let us analyze this subject. The pressure, as before stated, amounts to only about one-third of the amount of that to which the piston is subjected; they travel from one inch to 1⅛ of an inch, while the piston is traveling once up and down its stroke, as the motion is one to two. Therefore, if the stroke of the piston is 5 inches the piston is traveling about 10 inches to the sleeve one. Logically it would appear that the wear between the sleeves should be one-tenth of that between the faster traveling piston and inner sleeve. But the piston is equipped with strong expanding rings and reciprocates against a surface which is exposed to the highest temperature of the burning gases. Its lubrication can never be so good as between the sleeves and cylinders.

Actually there is no appreciable wear between the surface of the sleeves where they engage each other and the water-jacketed cylinders. I am satisfied that under normal conditions one of these sleeves and the water-cooled cylinders would not deteriorate a particle through a road use of a million of miles. We have several instances where they served in a motor which covered more than 100,000 miles with no evidence of wear after the first few hundred miles; that is, after the surfaces had become smooth.

The interior of the inner sleeve where work the rings and the piston, of course, will show wear, just the same as the cylinder of the poppet valve motor in which the piston works. But instead of finding it necessary to replace an entire outer cylinder, as in the case with the poppet valve type, the inner sleeve only is required.

POWER TO DRIVE SLEEVES,

But it must require a great deal of power to drive these sleeves, the critic will venture. The power required to drive these sleeves is surprisingly small. In a six cylinder, 67 horse power Daimler motor this loss of energy was measured through the introduction of a differential mechanism between the eccentric shaft end and the chain sprocket which drove it. Power recording apparatus was attached, and it was found that when the motor was developing 75 horse power at 1,200 revolutions a minute upon the brake, two horse power was absorbed in driving the twelve 5-inch sleeves. But for the necessity of driving these sleeves the motor would have developed 77 instead of 75 horse power—not a very serious loss of power.

The weight of the inner sleeve of the 4⅞x5⅛ inch size is 9 pounds; of the outer sleeve, 8 pounds; at the greatest power, assuming 0.1 as the ratio of friction to pressure, 90 pounds are required to slide these sleeve valves against each other and the pressure of the piston. The inertia of the inner sleeve when the motor is turning 1,200 revolutions per minute is something like 60 pounds, while that of the outer sleeve is less than 50. Taking the inner sleeve of the one subject to the greatest stresses, because of its greater weight, we have 9 pounds of weight to raise, 90 pounds of friction to overcome at one point only, 60 pounds of inertia to counteract at the outer and inner ends of the stroke; a total of 160 pounds against 250 in case of the poppet valve.

Being positively connected, however, the silence of the sleeve valve is not affected by increase of load or travel, and it is as quiet at 50 as at 15 miles an hour.

SLEEVES MOVE WITH PISTON WHEN UNDER PRESSURE.

In connection with the functioning of these sleeves, however, I desire to call your attention to a very important feature of their motor. At the time the explosion occurs in the cylinder both the piston and the sleeves are at the top of the stroke. They start downward simultaneously and move together until the piston has reached the bottom of its stroke and the pressure in the cylinder has been practically reduced to atmospheric. Now, it will be realized that instead of the sleeve requiring power from the eccentric shaft to drive it downward, the friction of the piston against its walls would have done so had no other means been provided, but, of course, it would not have stopped at the right point. We have the maximum side pressure of the piston during this explosion stroke.

While the piston returns the sleeve continues downward, and the two elements are driven by their mechanism in opposite directions. But upon this stroke there is no lateral pressure upon the sleeve, because the piston is only dispelling the exhaust gases. Hence there is no resistance to the travel of the sleeve.

When the piston reaches the top the sleeves have reached the bottom of its stroke, and again they start moving in opposite directions. But, as this is the suction stroke, again there is no friction of consequence, the piston having no pressure upon it. The piston having drawn in the gases starts upon its return stroke, and the sleeve continues upward. Here there is the lateral pressure of the piston which meets the resistance of the compressed gases, and the sleeves are again under pressure. But here again the pressure aids them in their upward movement.

STICKING OF VALVES.

Now remains another objection to meet with regard to the substitution of sleeve valves for poppet valves. It is urged that if the poppet valves stick no damage is done, but if the sleeve valves are injured as a result of neglect or lack of lubrication the matter is serious.

Now, to what extent is this serious? Several years ago, before I had had the experience I later acquired with these motors, I listened to this argument and provided a remedy. The device merely consists of a weak point in the outer sleeve connecting rod, so inserted as to give way well before the power required to pull the sleeve should reach a point where the lug might be broken off. As these lugs, the way they are designed today, require over 6,000 pounds pressure to fracture them, and each and every one of our licensees informed me that they saw no necessity in practice for the adoption of this precaution, it was never attached to a single motor. It is true, there have been cases of breakages of these lugs where lubrication has been neglected. The first motors produced abroad were equipped with an almost obsolete lubrication system.

MISCELLANEOUS ADVANTAGES.

I have endeavored here to make clear the reasons why the sleeve valve type of motor has proven a practical success. I have taken it for granted that the audience fully appreciate the advantages of an explosion chamber free from pockets or vestibules, the merit of liberal and direct and unobstructed port openings, the absence of unenclosed working parts and the advantage of a valving system which compels the positive opening and closing of ports which cannot get out of synchronism, and also of the general cleanliness and symmetry of design possible with this construction as well as the absence of any surfaces except the piston against which the explosion can act.

There will be doubting Thomases unquestionably. Self-interest compels many who would otherwise appreciate these advantages to be blind to them and seriously question the practicability of the structure as a whole.

DAIMLER CO.'S UPS AND DOWNS.

It was urged against our motor in England that but for the fact that the great Daimler Co. was in a tight place financially it would never have undertaken to bring out this motor. Such argument was scarcely consistent, although based upon the fact that the company's last year with the poppet valve motor showed a loss of £49,000, or almost $250,000, while in the ten months just closed its profits upon the manufacture and sale of sleeve valve cars amounted to £185,000 gross and £150,000 net, or $750,000, and that its stock advanced from 16 shillings under the poppet valve to 72 shillings under the reign of the sliding sleeve; the Minerva Co., of Belgium, second to adopt the sliding sleeve valve, saw its shares advance in value from 60 points under the poppet valve to 360 under the sliding sleeve.

Abroad the leading concerns located in different countries with no interests in common and no communications with each other saw the necessity for embracing an opportunity to acquire the rights to manufacture a device which they could not with honesty to themselves and justice to their shareholders do other than admit was superior to their former motor.

THE LICENSEES.

The three original concerns which adopted the Daimler motor, which has been for fifteen years in universal use throughout the world, were the first to take up the motor of American origin and invention. And I have had the pleasure of seeing the signature of Paul Daimler, son of Gottlieb Daimler, whose name is so generally known throughout the world, on contracts. The motor has not only been adopted by these three leading concerns, but in addition by the Minerva, of Belguim; the Sigma, of Switzerland; the Daimler Co., of Italy, and the Russell Motor Car Co., of Canada, in addition to the licensees in the United States. In this country the first to take up the motor was the Stearns Co., of Cleveland, whose engineers two years ago went across to England for the purpose of looking it up. The second was the Stoddard-Dayton, of Dayton, O.; the third the Columbia Motor Car Co., of Hartford, Conn., and the fourth the Atlas Engine Co., one of the oldest and best known manufacturers of the steam engines and boilers in the United States.

RUMORS HAD TO BE DISPROVED.

When the Daimler Co. first adopted this motor it attracted practically no attention. They thought nothing until about the time of the show, 1908, when it was exhibited at Olympia, and where it was the chief centre of attention. Then rumors began to circulate. The first statement I heard was that every one of the twelve cars they sent to the show had been seized and that they had been sent back to the factory in Coventry.

At the end of the show things began to get thick, as they say in England. It really got to be rather embarrassing. In a spirit of friendliness the chairman of the technical committee of the Royal Automobile Club, one of the most competent organizations in the world, and himself a most capable engineer, came to the chairman of the Daimler Co., Mr. Percy Martin, and said:

"Mr. Martin, you will understand that there is a tremendous amount of talk and criticism of the sleeve valve motor. There has never as yet been a public test made of the Knight motor."

Mr. Martin said: "I have been perfectly aware of this fact. There has never been a test, and we have been considering what we might do."

This test is now a matter of history. Instead of developing 49 horse power in 132 hours under test the 38 horse power motor averaged close to 55. The only stop was when the water connection broke and flooded the magneto and the coil vibrators loosened on the 22 horse power motor. The motors were taken off the bench and put in a full bodied car and driven 119 miles to Brooklands. For 2,000 miles they averaged 42 miles an hour with a fuel consumption of 21 miles per gallon. Then they returned to Coventry and were put back on the bench to see what condition the motors were in after this 2,000 miles of running. Instead of this motor producing 54 horse power it produced 57 for five nours, and the 22 horse power developed within a fraction of 39. The motors were taken down, there was no perceptible wear on any of the fitted surfaces, no burning of ports, no wear on the sleeves and no considerable amount of carbonization in the combustion chamber.

Some Points Concerning the Design of Rotary Valve Motors—III.

Different Designs of Rotary Sleeve and Piston Valves—Difficulties Encountered in Their Design—Proportions of Parts.

By Eugene P. Batzell.

LENGTH OF BEARINGS REQUIRED.

The length of bearing zone required in order to keep the valve tight is comparatively small, and, generally, if the length is sufficient for bearing purposes it will be more than sufficient to keep the gas in. A bearing length of ¾ to 1 inch should suffice for barrel valves up to 2 inches in diameter, and with a diametrical clearance in the bearings of 0.0015-0.0025 inch they will be tight enough to hold explosion pressures of 300 to 350 pounds per square inch. Disc valves of the rigid type, as shown in Fig. 1, show practically no leakage when the outer edge of the valve extends $\frac{5}{32}$-$\frac{3}{16}$ inch beyond the valve port.

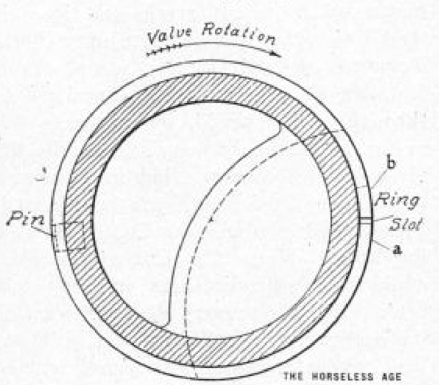

Fig. 19.

PACKING RINGS.

The foregoing figures for barrel and disc valves are applicable only when the workmanship is of the highest grade, insuring the prescribed accurate fits of parts, otherwise extra packing means must be provided, as, for instance, flexible metal rings. While such rings are of value in connection with all types of valves, even if the workmanship is good, they are particularly desirable on slow speed, high compression motors. They are absolutely necessary for valves which are so arranged that there is a great difference in the temperature and heat expansion of the valve and its seat, so that a clearance of 0.004-0.005 inch must be provided. In experimenting with such motors without packing rings, smoke could be seen escaping at the ends of the valve, although the operation of the motor was not otherwise noticeably affected, even at a speed of only 300 r. p. m. The bearing zones at the valve ends were about 1½ inches long, the valve diameter was approximately 2½ inches, and the explosion pressure exceeded 400 pounds per square inch. Oil was liberally supplied to the bearings. After exchanging the valve for another, with a diametrical play of 0.012-0.015 inch (merely for experimental purposes), the engine would not operate regularly. The first of these experiments did not prove that the comparatively large clearance of 0.004-0.006 inch is impracticable, but in order that the motor may be right it must hold compression and explosion without noticeable loss, which requirement was not met by this design, and packing rings are therefore a desirable feature in it.

ROTATING PACKING RINGS.

The application of packing rings to rotating bodies deserves some consideration, because their action in that case is different from what it is when they are applied to reciprocating bodies like pistons. Any expanding ring on a piston, whether of the concentric or eccentric type, has a comparatively large clearance at its inner surface, and is not disturbed by the motion of the piston, which is in a direction perpendicular to the plane of the ring. When the ring rotates in its own plane it has to be securely fastened to the main rotating body, and its spreading tendency should be sufficiently strong so that the friction acting on it will not deform it and prevent it from properly fitting the valve and valve chamber wall. If the ring is weak and its clearance in the groove is large, then it could be shifted on the valve and force the latter out of its true position in the chamber.

Referring to Fig. 19, which shows a ring pinned in the middle to the valve body, it is readily understood that if the valve rotates in the direction indicated by the arrow, the friction causes the upper part of the ring to press against the wall of the valve chamber with gradually increasing force, and the lower half with gradually decreasing force. This uneven distribution of the pressure tends to dislocate the valve. The ring may be anchored at one end, as at *a* in Fig. 19, in which case the pressure of the ring against the wall will increase over its whole length, the same as in expanding band clutches, brakes, etc. Although this insures proper alignment between the ring and chamber, the high pressure, which is apt to result in a tight grip, is objectionable. For this reason it is better to anchor the ring at the leading end—*b* in Fig. 19. The friction then will tend to loosen the ring, but it will always exert a certain pressure against the wall and can insure a good fit all around its circumference. The necessary requirements in such a ring are that there should be an outward pressure at every point of the circumference, without dead zones which may be caused by overstraining the material. The clearance between the ring and the bottom of the groove should be as small as possible—just enough to permit putting the valve into its chamber with the ring tightly compressed. A concentric ring is to be preferred to an eccentric one, for

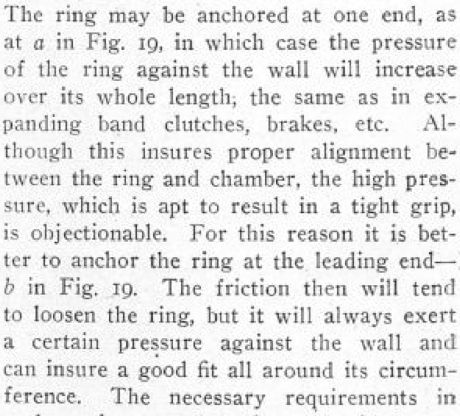

Fig. 20.

the reason that with the former the clearance between the ring and the groove can be made a minimum all around.

"LABYRINTH" PACKING.

Packing rings with special springs for spreading them are hardly suitable for this