differs from the ordinary carbureter lies in the fact that pure air only is admitted through the inlet valve. The amount of air so admitted is controlled by a slotted, hollow cylinder *A* (see Fig. 4), the orifice in which can be made to register with the opening in the inlet valve through an automatic control connected with the throttle or the gasoline pressure regulator. The raw kerosene is led from the pressure-regulating tank, into which it is forced by a rotary pump, into the atomizer *B* which is screwed into the cylinder head. This atomizer consists of an inverted automatic poppet valve, the head of which projects into the cylinder nearly over the head of the piston. The stem of this valve is hollow, and surrounding it is an auxiliary air space connected with the outer atmosphere. As the liquid kerosene under pressure rushes into the atomizer, it is broken up into fine particles and united with the proper quantity of air admitted through the auxiliary opening and through the hollow stem. To be sure, this is not a *bona-fide* vapor (it is merely a fine spray), but it is admitted directly into the combustion space of the cylinder, mixed with the proper quantity of air entering through the inlet valve and immediately compressed; there has been no opportunity for condensation, for the atomization practically has taken place within the cylinder itself.

The pressure on the fuel is regulated by means of a variable column of mercury *C* extending into the space into which the kerosene is pumped. This pressure can be controlled by the same levers that throttle the supply of air admitted to the cylinder, but this would not be sufficient regulation to provide for the demands of the motor at all speeds, if the supply depended entirely upon this pressure and the suction of the piston in the cylinder. To obtain the proper regulation, there has been devised what is probably the most ingenious carburetion attachment to be found in use. Before the raw kerosene is admitted to the atomizing chamber, it is forced through a needle valve at *D*, the stem of which constitutes the armature of a solenoid. This solenoid is a coil of wire that is excited by the current derived from a low-tension magneto. The stem of the needle valve (assuming, of course, that it is made of a magnetic metal) serves as the plunger or armature of the solenoid and is drawn into the interior of the hollow coil whenever the current passes through the wire. When the coil is not excited, the needle valve is held in place on its seat by means of a spring that effectually prevents the passage of fuel to the atomizer when the motor is not running. By means of an electric circuit-breaker which may be geared to the crankshaft of the motor, the number of current excitations or

"pulsations" imparted to the coil may vary with the speed of the engine, and a supply of fuel proportionate to the demands of the engine will thus be obtained. This kerosene carbureting device has passed the experimental stage and is now used on many French cars.

To the ordinary motorist, familiar with the comparative simplicity and efficiency of the gasoline carbureter, these various devices for obtaining power from kerosene may seem somewhat complicated, but to the business man who will look deeper and see in them the real solution of the problem created by the constantly increasing cost of gasoline, they give evidence of the stability of the internal combustion engine and of its ability to adapt itself to whatever fuel may be used. These carbureters are in use to-day in all parts of the country, and if the owner of the pleasure car still prefers to pay the excessive price for gasoline, when a satisfactory substitute at half the cost is available, it may be but small consolation for him to know that the arrival of the time is inevitable when he will be forced to make the change. But whether the change will come soon or late, it is a satisfaction to the truck owner to know that one of the most important problems of his delivery and hauling system is being solved, and that the future of motor transportation is brighter than ever, even before gasoline leaped in price.

Ball Bearings—Their Construction and Application*

Advantages of Ball Bearings and Their Use in Industrial Equipment

By F. H. Poor

THE results of extensive tests which have been performed with the view of determining the relative coefficients of friction for various types of ball, roller and sliding bearings, show a marked superiority of the ball bearing as regards the coefficient

Fig. 1.—Methods of securing the inner race to the shaft.

of friction. These tests also show that the coefficient of friction for ball bearings varies between very close limits at different loads and speeds, while the coefficient of friction for sliding bearings extends through a very wide range for even small changes in speed or load. The friction in sliding bearings is dependent upon the bearing surfaces, the lubricant, the method of lubrication, the load to be carried, and the pressure per unit of measurement, together with the speed and temperature.

It would seem that a roller bearing would be more efficient than a ball bearing, on account of the larger contact surfaces between the outer and inner races, but this is not the case, inasmuch as it is almost impossible to obtain pure rolling motion in a roller bearing. The reasons for this are as follows: (1) It is extremely difficult to commercially produce hardened rollers which are exactly cylindrical. (2) Straight rollers will not carry an end thrust. (3) If there is any tendency for the shaft to twist, or if there is any deflection in the shaft due to the load, there is a tendency for the rollers to twist out of their normal path, and this leaves only a short part of the roller under actual load. To help the roller bearing out, however, there are combinations of annular and thrust roller bearings, but they have not found as wide application as ball bearings have.

Ball bearings are used principally for the following reasons: (1) There is less loss of power on account of the lower coefficient of friction. (2) The friction of a ball bearing is independent of the viscosity of the lubricant, or of the temperature thereof. (3) The frictional resistance at starting is very much lower than in sliding bearings. (4) The scraping of bearing linings and fitting them to the shaft is not necessary. (5) There is practically no danger of the bearings running hot. (6) The bearing housings mounting ball bearings are very much shorter than sliding bearings. (7) A

ball bearing of proper construction can adjust itself to deformations of the shaft, or strains in the housings.

The reason why a larger ball can take less load than a smaller ball can readily be understood. It is because with an increased volume it is harder to obtain a thoroughly hardened ball. In the matter of speed, the reduction of capacity of the larger ball is due to the tiring out or "fatigue" of the material. Other tests have shown, however, that the tiring out of the steel is caused by the number of load applications and not by the rapidity with which they change. From actual tests with balls, Prof. Goodman of the Institute of Civil Engineers in England derived a formula for the allowable load, in which he took into consideration the velocity of the balls. These tests have shown that the carrying capacity of a one half inch ball, for example, while it is much greater than that of a one quarter inch ball under static load decreases very much more rapidly than a smaller ball under a given increase in speed for each size.

It is of great importance for all the balls in a bearing to be finished absolutely spherical, and as nearly of the same size as possible. A large ball in a bearing will take more than its share of the load and thus become overloaded; and at the same time, it will have a different velocity from the smaller balls, which will result in sliding friction either between the ball and the retainer, or if there is no retainer, between the balls themselves. First-class balls can now be manufactured within spherical limits of 0.022 millimeter (0.00008 inch) and are sorted in classes in which the diameter of the balls does not vary more than this amount.

A ball bearing of the right design must comply with the following requirements: The balls must have pure rolling motion, and the races must be so designed that without increasing the friction under load, they give a maximum bearing surface.

Fig. 2.—Electric motor equipped with ball bearings.

To fulfill the first requirement, the tangents to the balls at their points of contact with the races must be parallel to the axis of rotation of the balls. This rule, however, is frequently neglected. Ef-

Fig. 3.—Ball bearing applications for combined radial and thrust load.

orts have been made to solve this problem by designing ball races with three or four contact points for the balls, but the increased number of points of contact for the balls developed considerable additional friction, and practically all bearings actually in general use have only two points of contact.

In the construction which is dealt with in this article, the contact surfaces on both the inner and outer races are practically equal, and in addition to this the bearings have the following distinct advantages: Increased reliability because of the fact that the bearings, though made to standard dimensions, have a double row of balls, and because the method of having the outside race spherically ground allows the bearing to automatically adjust itself to any deflection of the shaft or inaccuracy in the mounting or machine frame structure. Furthermore, both rows of balls are loaded evenly, and it is possible to assemble and disassemble the bearing, if necessary, without destroying it. This last feature may seem extremely simple, yet it is important for the reason that it does away with the slots in the inside and outside rings, and the races are thereby made continuous.

We now come to the discussion of the material from which the bearings are made, which must have the greatest possible hardness in conjunction with toughness after hardening. Furthermore, the steel must be free from slag, and be perfectly homogeneous. Some ball bearing factories are using casehardened races, but aside from the danger of the hardening not being even, there is also the danger in this construction of the races being permanently deformed. It is absolutely impossible to caseharden steel balls because the main requirement to prevent a ball from permanent deformation is through and through hardening. Accordingly, we have to use a material for both balls and races which, in addition to the above-mentioned qualities, has also the quality of being easily and uniformly hardened throughout. The steel must be forged

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or rolled so that the grain is as close as possible.

It may be said that the use of ball bearings in rotating machines is practically unlimited. The following points must be observed in their design if ball bearings are to work at their full advantage: (1) We must consider, as we do in other types of machines, whether the load or speed is variable, and the conditions which are to determine the selection of a heavy enough bearing to meet the machine requirements. (2) The bearings must be mounted so that the outside race cannot squeeze out of true. (3) When the shaft is revolving, the inside race of the bearing should be fastened securely to the shaft, making it practically an integral part thereof. The best means of doing this is to drive the bearing upon the shaft and hold it securely between a shoulder on the shaft and a lock-nut, or by using an adapter sleeve made with a taper to fit in the bearing. By using bushings over a shaft between the bearing inner races, several bearings can be held on the shaft by one nut. In no case should there be any play between the inside race and the shaft because of the possible danger that the ball bearing race willpeen down the shaft and ruin it. (4) Only one bearing should be held sideways to take up lateral movement of the shaft, the other bearings being mounted free to move laterally in their housings. This is to allow for elongation or contraction of the shaft, due to changes in temperature or other causes. (5) Ball bearings must be lubricated, although the amount of lubrication required is very small. The lubricant must be chemically neutral, and for general applications, a mixture of vaseline and vaseline oil, or a good mineral oil is recommended. (6) The bearings must, in all cases, be protected from dirt, dust, dampness, and oxygen.

Ball bearings have been applied on electric motors with excellent results, a typical mounting being shown in Fig. 2. For this class of machinery the medium type bearings should be selected, and it is important for all of the bearings to be secured to the shaft on account of the high speed and vibration of the machine. It will be noted that the bearing on the left-hand side has a very small

lateral clearance in order that it may take up any possible lateral movement of the shaft. The bearing nearest the pulley is left free to adjust itself, and attention is drawn to the two types of mount-

Fig. 4.—Radial bearings on loose pulley counter-shaft.

ings for the bearing next to the pulley. The bearing in one case is held securely against the shoulder by a sleeve between the pulley and the inner bearing race, and in the other case by a locking-nut.

Fig. 3 shows a ball bearing mounting for a cir-

cular saw spindle. It will be seen that this application of ball bearings is designed for a combined radial and thrust load. In considering ball bearings of various types of machines, it was not definitely stated that the load conditions are of material importance in determining the proper selection of bearings for different duties. As a general practice in bearings selected for belt-driven machines, it is customary to allow a factor of safety of approximately five, that is, the ball bearings must be selected of such a capacity that the catalogue ratings are practically five times the normal figured load to which the bearings are to be subjected. This factor of safety may seem extremely large, but all of us appreciate that in many cases the tension of the belt is subject to the careless handling of inexperienced workmen, and one cannot foresee to what extent the belts themselves, or the bearings, may be subjected to abuse. In addition, it may be pointed out that belts running at high speeds are usually heavy, and in addition to the pressure to which they subject the bearings, there is every likelihood that pulleys will suffer the constant pound and shock of heavy belt lacing, joints, or the possible accumulation of lumps of grit, sticks of wood, or other materials which may be caught between the belt and the pulley. This is particularly true in train lighting service, woodworking machines, etc.

In the matter of selecting bearings for woodworking machines, we have found that it is necessary to allow a wide factor of safety, particularly on band saws. These saws, in operation, are usually adjusted to a certain tension by means of levers or balancing weights. If the saw becomes heated there is bound to be expansion in the blade, and while the adjusting levers or balance weights may compensate for the increased length of saw, due to heating, the bearings are liable to be cramped after the machine is shut down, due to the contraction of the saw blades. On gear drives it is customary to allow a factor of safety very close to three times the normal driving power of the gears, this factor being used for the purpose of allowing for backlash, sudden shocks, or reversals.

Hydraulic Plate Shears

By the Paris Correspondent of the Scientific American

THE steam hydraulic slab shears shown on our front page are of interest not only on account of their powerful build, but also for the various electric and hydraulic features embodied in their makeup. The shears were built by a firm of Sheffield, England, for use in a Scotch construction works. The new shears are built for handling and cutting hot steel plate of 24 inches thickness by 48 inches width, or 18 inches by 66 inches width, and it takes only 12 seconds to make the cut and come back to position. In the middle of the upper framing is mounted the main hydraulic ram for driving down the shear blade for cutting the slab, this blade working together with a corresponding fixed blade mounted on the table. The hydraulic ram is of large size and has 41 inches diameter with 2 feet 4 inches stroke. On the present steam hydraulic system the hydraulic pressure is produced by using a pair of steam-hydraulic intensifiers which work with a steam pressure of 80 to 100 lbs. per square inch, making the maximum hydraulic pressure for the shears 2 to 2½ tons per square inch.

In order to guide the ram in an exactly vertical stroke, its lower end is fitted into an ample crosshead which slides upon four steel columns. The shear blade is mounted on the lower end of the crosshead. On the massive foundation are the front and back roller tables for the ingoing and delivery sides, the feeding-in side, being shown in forward position on our photograph. The feed mechanism comprises a set of 5 cast-steel rollers of 21 inches diameter and 5 feet 3 inches length, the first three rollers being geared together, while the two rollers lying next the shears are mounted on a spring carriage so as to allow for play and to give the necessary adhesion of rollers to slab for driving it forward. These two rollers are driven by friction disks in order to save space. The design of the delivery end of the machine presents points of special interest.

As in all slab shears the delivery end has a yielding table upon which the end of the slab rests while it is being cut. Ordinarily this yielding table is simply depressed by the pressure of the shears. This is not altogether satisfactory, and in the new machine the table is caused to drop by an independent movement which is adjusted so as to keep pace exactly with the descent of the shear. Like the feed end, the delivery table also carries a set of geared rollers. But these are mounted in a square box frame moving in a pit. Underneath the table is quite an elaborate mechanism to give it the required motion. The frame is supported as a whole upon a pair

of hydraulic cylinders and descends under hydraulic pressure at the same rate as the shears during the cutting operation.

The rollers are driven by a 40 horse-power electric motor, while a press holding the slab down flat upon the roller is operated from a separate 10 horse-power electric motor.

The Arabian Date Trade

IN OMAN there are groves of date palms covering an area of sixty miles long and averaging two miles in width, in the coast country known as the Bahtinah; an estimated half-million trees in the Wadi Semail; large groves at Rostock—in fact, everywhere where water is to be obtained this plant is cultivated. The uses of the product of the palm are many. The stems furnish timber which, though of a poor sort, is very valuable when no other is to be obtained; buds of the male palm are considered a great delicacy; the habitations of all the poorer natives are made of the fronds; the fiber of the stem is twisted into serviceable ropes; the seeds are pounded and made into cattle food; while the fruit is at once the staple food of man and beast, and an article of export equal in value to all other exports from Oman combined. About 15,000 tons of dates, valued at over \$600,000, are shipped annually from the port of Maskat in steamers, and the export in native vessels is perhaps as large, for every year at the beginning of the season the harbors of the gulf are full of dhows and baggalas from the Yemen, the African coast, and Zanzibar, waiting for cargoes of dates.

The annual rainfall in Oman is only about five inches, consequently irrigation is everywhere necessary; and as the methods and appliances are very simple, the lifting of the enormous volume of water needed involves a tremendous amount of labor. In the district of Maskat there is one contrivance which is used for this purpose. It consists of a sheave fixed some 12 or 14 feet above the well, a rope, and a leather bucket made with a flexible rent in the bottom, so as to be self-emptying. Power is supplied by a bullock traveling up and down an inclined plane excavated in the ground, and it is possible for one man and beast with this appliance to raise a thousand gallons over a lift of 20 to 25 feet in an hour, though work is rarely done at such a rapid rate. Many efforts have been made to introduce improved pumping machinery, but so far without success. According to the American consul at Maskat, date trees are propagated solely from offshoots, and never intentionally from seed. The young trees ordinarily come

into bearing the fourth year after being set out. Pollination is effected by hand. Small crops, principally alfalfa, are grown in the spaces between the trees. In Oman, dates begin to ripen in May, and from then on until November the fresh fruit (rattab) is always to be obtained in the bazaars. There are numberless varieties, each with a separate name, but not more than half a dozen kinds are readily distinguishable by anyone but an Arab or an expert. The dates grown near salt water are little esteemed, being called "donkey dates" from the fact that they are largely used as food for these animals. Those from the mountain valleys are prized most highly, the variety known as the Hlassa being considered best of all, both by natives and Europeans. A prominent date grower and dealer in Oman gives the value of an average palm at \$40, and the annual yield as 400 lbs. of dates. Dry, wet, and hand-selected dates are exported. The first are sent to India, where they are used as food, and where their consumption is prescribed as part of the various social and religious observances. The price is about 2½¢ per lb. In harvesting dates which are to be shipped as "wet," they are piled upon a piece of matting spread upon the ground, trampled into a compact mass, and then packed in wicker bags holding about 100 lbs. The larger part of the entire crop is prepared in this manner, and from Maskat sent to Mecca, the Yemen, and in enormous quantities to India. Recently India has begun to take small quantities of hand-packed dates of second quality, but the choice hand-selected dates are all shipped to the United States, and the methods adopted in getting them upon the market are entirely different from those prevailing in handling any other kind. These dates are of a variety known as Fard. They are all grown in the Wadi Semail, a mountain valley about seventy miles from Maskat, and every one that is fit to ship goes to America, their pre-eminence in that market being due to their superior keeping and shipping qualities. The trade is an old one, there being records of sailing vessels from Salem and New Bedford leaving Maskat date-laden for New York as far back as 1843, and the business is known to have existed before that time. The Wadi Semail is a perennial stream, and all available land in its vicinity is irrigated by a fine system of ditches, so old that the Arabs have no tradition as to when or by whom the canals were built. The Fard dates—which the natives believe cannot be grown outside this one valley—are harvested in the last days of August, and are bought by dealers or taken by money-lenders who have advanced funds against the crop at a price which usually realizes to the grower a little more than 1 cent a lb.—*Journal of the Society of Arts.*