WHAT happens when a dry bearing seizes? **WHY** are big-end bearings so heavily stressed? **HOW** does a two-stroke manage on 20:1?

Big-end Lubrication Problems

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ON the face of it, the big-end bearing in a two-stroke racing engine running at around 10,000 r.p.m., as all the good 125s do nowadays, has about the same job to do as in a four-stroke running at the same speed. The loads due to gas-pressure are not so high, of course, but these are of less importance than the inertia loads, which are about the same whichever cycle of operation is employed.

Yet, whereas it is customary—indeed, vital—to feed many gallons of oil through the four-stroke bearing, its two-stroke counterpart has to make do with the tiny supply of lubricant contained in (say) a 2 : 1 petroil mixture, of which the greater part goes out through the cylinder anyway.

Even supposing that the whole of the oil managed to pass through the two-stroke's bearing, in the course of an hour's running this would amount to less than a pint, which seems such a ridiculously small amount compared to the 30 gallons or so poured through a pump-fed bearing in the same time that the reasons for the discrepancy are obviously worth examining.

Causes of Failure

First of all, what limits the life of a roller-bearing big-end? It can fail mainly through three causes:

(1) Pitting or flaking of the roller-tracks through overloading, a process which usually takes some time and is really a type of fatigue-failure.

(2) General slackness due to gradual and inevitable wear, which may hasten the onset of flaking due to the resultant hammering.

(3) Total seizure, which can sometimes occur with startling rapidity, heat being generated locally at such a speed that the cage (if any) practically melts and the rollers may become hot enough to weld themselves together, while the metal of the rod or flywheels, only a fraction of an inch away, has not been hot enough to become discoloured. (Polished steel commences to assume a light straw colour at 220° C.)

Of these three causes, the first we can omit from this discussion, as it is more a matter of longevity rather than of safety. The other two are to a degree bound up with each other, the last being a special case in which the heat caused by the rubbing friction unavoidably present in any form of roller big-end is generated at a much greater rate than it can be removed.

Main bearings give very little trouble, though they rotate just as fast as the big-end, and ball or roller bearings are run at much greater speeds on grinding spindles, turbine motors and similar mechanisms. But there is a fundamental difference in working conditions between any bearing which rotates around a fixed axis and the big-end, which, besides rotating, is moving in a circular path around the crankshaft axis and is thus subjected to centrifugal forces which are not present in the main bearings under steady conditions.

These forces have the effect of causing the rollers to press outwards (Fig. 2) and, if no cage is fitted, the inter-roller pressure is cumulative and the outermost pair rub against each other with a severity which increases as the square of the crankshaft speed. As an example, take the case of a bearing containing 12 rollers, each .312 in. in diameter and .312 in. long, on a crank-radius of 45 mm.; the maximum inter-roller pressure in round figures is 40 lb. at 5,000 r.p.m., increasing to 57 lb. at 6,000 r.p.m. and 98 at 7,000.

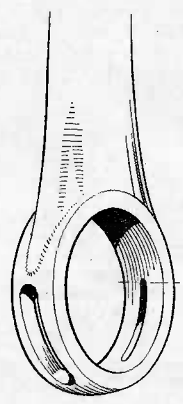
To prevent this action, which tends towards roller wear, if nothing else, slotted cages have been adopted in which each roller is separated from its neighbours by a bar and the load existing between each roller and its restraining surface is reduced to the radial component of the centrifugal force at any given instant (Fig. 3). As each roller passes through the centre-line of the cylinder, it momentarily ceases to bear on the bars at all, its centrifugal force being carried by a pure rolling action; but all the radial components from the several rollers acting together on the cage tend to throw it outwards—as, of course, does its own weight as well.

Usually it is the practice to make the cage a running fit on the crankpin, relieving the bars of the cage or locating it on raised shoulders to avoid any lapping action on the roller-tracks, and examination of any cage and pin which has seen some service will show that wear is only evident on the inner side of the pin. Since any oil present is also thrown outwards, the inner side is automatically the drier, therefore it would be more logical (and, in fact, this has been done in some instances) to make the cage a clearance fit on the pin and a running fit in the bore of the outer race, so that it would constantly get the benefit of any oil present.

Cage Design

For the sake of lightness, the cage is usually made of a strong aluminium alloy, and in order to avoid any possibility of differential thermal expansions taking up all the clearance, even under extreme conditions, it is necessary for the cage to be quite a loose fit inside the sleeve, but this is not very detrimental.

There is still another factor to be considered, namely the oscillating action superimposed upon the main rotation by reason of the angular swing of the connecting rod.



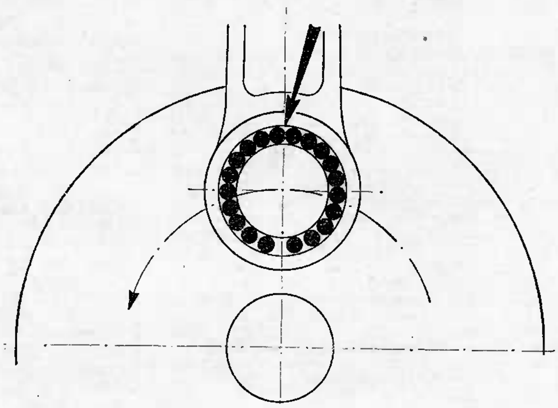


FIG. 1 (left) : One accepted method of lubricating a two-stroke big-end—through slots which do not interrupt the most heavily loaded areas. FIG. 2 (right) : How the rollers in an uncaged rotating assembly tend to crowd at the outer side of the pin (arrowed).

The rod can be considered as swinging about the gudeon-pin, its motion being opposite to that of the crank-pin at top dead centre, but in the same direction at bottom dead centre (Fig. 4). Since the maximum angular motion of the rod occurs at these two points, and with the usual proportions of rod-length to crank-radius is equal to one-quarter of the crankshaft speed, the actual instantaneous rotational speed of the big-end at say, 8,000 crank r.p.m. is 10,000 r.p.m. at t.d.c. and 6,000 r.p.m. at b.d.c.

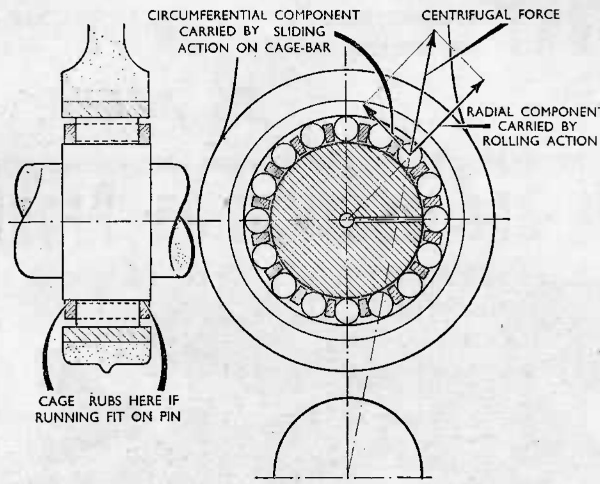


FIG. 3 : Two views of a caged roller big-end, showing (left) where friction occurs if the cage is a running fit on the crankpin and (right) how the load between each roller and its restraining surface is reduced to the radial component of the centrifugal force.

Skidding Effect

Since the cage-speed in relation to the pin is exactly half that of the sleeve, then the whole cage and roller assembly has to change its angular velocity from 5,000 to 3,000 r.p.m. and back again 133 times a second, which obviously it is disinclined to do. The lighter it is, of course, the better, hence the use of small-diameter rollers and light-alloy cages; but, however light the assembly, the action is bound to increase the loads between the rollers and the cage and may well lead to a skidding effect if the frictional force between the rollers and tracks becomes less than the force required to oscillate the cage.

So one can see that there are several possible sources of friction, and therefore some degree of lubrication is essential. Up to a certain point, this need not be very great. T.T.s have been won with engines lubricated only by occasional shots from a hand-pump simply squirting oil into the crankcase, and thence into the big-end (somewhat problematically) through a couple of holes, while even today the Speedway J.A.P., normally not running much above 6,000 r.p.m., performs very well with a flow to the big-end which is only a fraction of that normally provided on a racing engine.

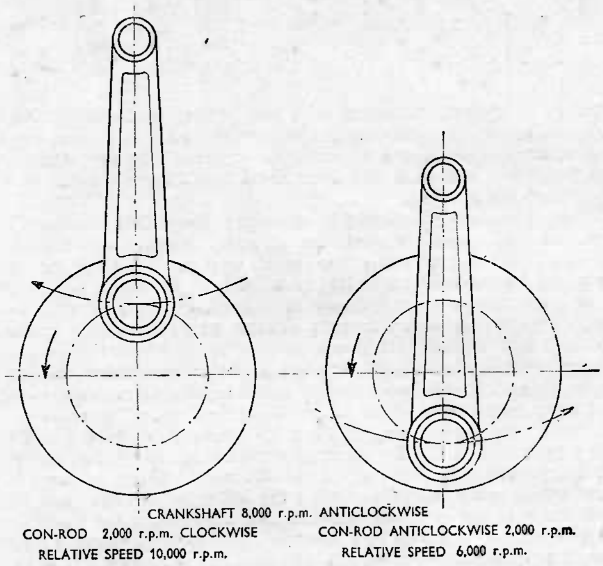


Fig. 4 : The effect of the angular swing of the connecting rod upon the rotational speed of the big-end at constant crankshaft revolutions.

Yet, if you have an engine to spare and are not worried about expense, you can try the experiment of cutting off the oil supply while running it at full bore on a dynamometer and watching the result. Momentarily, nothing happens, then the speed will rise a little and suddenly, boong!—the thing locks up solid, the whole process taking only a minute, or maybe less.

The phenomenon of a slight increase in power just before a lock-up has frequently been observed by riders, and is probably due to a reduction of internal friction and oil-drag as the lubricant remaining becomes hotter and thinner, but the *sudden* climax needs some explaining.

It is a well-established fact that if any caged ball or roller bearing fitted to a high-speed spindle is run full of oil, it will become very hot through the churning action set up in the lubricant. This has led to the development of other systems, such as that in which a jet of compressed air is used to blow oil in the form of mist into the bearing, so lubricating it and cooling it at the same time; there is little more than a film of oil present on any of the surfaces, and so no extraneous heating from churning.

On the other hand, if enough oil is poured through by a circulating system, heat is carried away with the stream and can be dissipated elsewhere, this being the normal state of affairs with an ordinary dry-sump engine. Cutting off the oil-feed stops this flow, but the bearing is momentarily still full of oil, which rapidly heats up due to frictional heat plus churning heat. At around 300° C. (depending on its composition) the oil will start to vaporize off, and at 450° the rollers will commence to bond themselves to the aluminium cage, after which complete seizure follows immediately.

How Much Oil?

The inference is that there is a " pessimum " (opposite of " optimum ") quantity of oil which is particularly conducive to seizure, and either more or less is required to permit continuous operation. This is only a theory, of course, and open to question by anyone with a more detailed knowledge of the subject, but it may help to explain the satisfactory life of the two-stroke bearing with very much less lubrication than the four-stroke.

The two-stroke has, in addition, another thing in its favour. The crankcase is continuously ventilated by air which is cooled by evaporation of the fuel contained in it, whereas the air inside a four-stroke may be somewhere in the region of 100° C.

Heat generated in the two-stroke big-end, therefore, has more chance of being dissipated directly through the surface of the big-end to the air. In that connection, although racing rods are usually highly polished, it would be more logical to dull the surface by shot-peening, or even to blacken it with one of the chemically applied finishes commonly used for rust-proofing, in order to increase its rate of heat-dissipation.

Silver Plating

There has also been a trend recently towards the use of steel for cages, as steel cages can be made just as light as aluminium ones of the same strength by suitable heat-treatment. A refinement which has not, to the writer's knowledge, yet been used would be to silver-plate the cage, as this treatment (used, for instance, on some aero-engine components) is excellent for preventing seizure between two steel surfaces. Or what about titanium as cage material? Nearly half the weight of steel for the same strength, it is well worth considering, even if it *is* difficult to machine.