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Experiences with Ring Sticking Tests on lubricants.

(Lecture, read at the conference of the Lubricant panel ofthe DVL in Berlin on the 7/8 May 42)

GENERAL:

A survey of the state of motor lubricant testing in the single cylinder BMW 132 is given and the shortcomings of the process are pointed out. In spite of many unexplained effects which together may cause wide deviations in the accuracy of the measurements, this process is still suitable for the testing of lubricants. A few alternatives for possible improvements are indicated and the influence of temperature and operating conditions is explained.

Lubricant testing in engines, as with all research on lubricants is still in the development stage. The examination of lubricants regarding their tendencies to deposit formation in the engine, particularly ring-sticking, is far from being a test such as for instance the very much simpler and more exact determination of the knock rating fuels. Many factors, such as temperature, fuel, replacement parts, as well as unknown effects play their part in the formation of deposits and influence the results in such a way that the accuracy of the measurements becomes unsatisfactory. The difficulty of obtaining a running time accurate to 10% can be seen by a comparison of laboratory tests on lubricating oils. Notwithstanding the extremely simple and favourable test conditions for instance for the Coke test, the accuracy is only ± 15%.

It is a thankless task to survey past investigations of lubricating oils, as only little positive can be said about results of fundamental tests.

We nevertheless accepted the invitation of the DVL to report on our experiences with tests on ring sticking. I believe that a summary of these experiences, even with partly negative results, may stimulate new ideas. In this sense the lecture may be a contribution to co-operative research on lubricant problems.

1. Test equipment and procedure, with particular reference to temperature control.

2. Means of improving the determination of the end of the test (Tests with free ring grooves etc.)

3. Running times and their reproducibility.

   a) With Reference oil

   a1) Spread over different time intervals (Influence of wind direction, replacement parts etc.)

a2) Spread with different cylinders, mean values as well as single runs, testing of cylinders in different engines, spread of cylinder temperatures (spark plug gasket) at constant control temperature.

a3) Dependence of running time on the overall running time of the cylinder, piston clearance, piston ring clearance and the percentage sticking of the ring.

a4) Running times depending on cylinder temperature (head temp.) with injection pump, with carburetter. Different inclination of the temperature curve. The higher curve of running time with carburetter.

b) With oils of different manufacture running time spread bigger than with Rotring caused through a longer absolute running time, unstable behaviour of additives etc.

4. Running times and deposits.

a) Analysis of deposits.

b) Relationg of the formation of deposits to the analytical values of new and used oils.

c) Sludging tendencies of oils, examinations in the engine (Opel and BMW tests)

5. Influencing factors not yet known.

a) Temperature of piston ring grooves.

b) Oil circulation and amount of oil spray on the piston. (Dependence of oil pressure and with it the amount of oil spray on the big end clearance and losses in the oil ways) Oil consumption.

Before I come to the main subject, may I first be permitted to give a short survey on the actual ring sticking testing at the technical Test-Station.

The conditions under which the runs were operated are commonly known; a detailed description can therefore be dispensed with. Emphasis is again put upon the accuracy of engine and temperature regulation, as these are of the utmost importance for the running time. The whole lay-out is given in the following diagram.

(Diagram 1218 - Layout of the BMW 132 supercharge and Lubricating oil test engine).

The engine with brake and accessories are in a soundproof room, whereas the instrument panel is in a separate room. An observation window is provided. A number of control panels are situated in a corridor and serve their respective test engines. The output efficiency is measured by a water brake with rapid balance and an electromagnetic revolution counter. The brakewater pressure is kept constant by means of a pressure regulator. The accuracy of the torque measurements is ± 100 g at a load of 30 kg.

The equipment allows a fuel adjustment to ± 0.5% vol. by regulating the pump. This seems to be sufficient as the consumption by weight varies also slightly with the temperature. The exhaust gases are removed by a blower giving a vacuum of 180-200 w.g., which at the same time takes away the outlet cooling air. The cooling air is produced by a second blower delivering at a controlled temperature of 20°, the temperature control being by mixing on the inlet side of the blower. The inlet air for the engine is preheated and kept at 40°C. The preheating occurs in the induction air surgetank by an electric heating arrangement connected to a sensitive regulator. Such an adjustment works to ± 0,5°. The temperature is recorded by resistance thermometer for the air and lubricant, and by thermocouples for the cylinder. The thermocouples are standardised to 0,1°C and permit an accuracy of adjustment of ± 0.5°C. The controlled temperature for previous test runs was the temperature of the exhaust spark plug seating. But the uncertainty of the condition of the plug as well as alterations in position and shape of the plug gaskets due to frquent dismantling, led to the use of elements peened into the cylinder head. As a safety measure double elements are used, so that when one is out of order the other will still function. If these elements are skilfully installed the difference in temperature measurement amounts at its maximum to not more than 1°C. This is very good considering the difficulty of recording the temperature of bodies in a cooling stream. The inlet temperature of the lubricant is electrically controlled at 120° ± 0.5°.

For close supervision of factors affecting ring temperature specific consumption, cylinder head temperatures and exhaust gas temperature are recorded on an automatic chart, especially as these runs are carried out in shifts.

Two photographs of the lay-out follow

(Diagram 1206 - General view of lubricating Oil Test Stand)

When rebuilding we used the lay-out in which the control room is sound proof and separated from the actual testing machinery, to spare the operator as far as possible from the noise and smell of the engine, as the tests are run throughout two 12 hrs shifts. In the photograph you see the test engine with the air shaft removed and the various accessories. The starter motor and the water brake are hidden by the Tacho balance. On the left is the pressure regulator for the brake water and at top right the induction air surge tank with installed electric heater. In the right foreground the tall oil tank can be recognised. As the oil consumption is measured by volume the long container is advantageous for reading the liquid level.

The next photograph shows the arrangement of the instrument panel in the control room.

(Diagram 1207 - View of Control Gear of Lubricating Oil Test Engine)

With the exception of starting and the hourly checking of the oil consumption all the operations can be watched and adjusted from within the control room.

The condition for the evaluation of a ring sticking test is an absolutely cear-cut end of test. We had the opportunity to observe during 1500 test runs the indications provided by blowby and power drop. During that time various steps were taken to improve the indication. I should like to report these tests in greater detail, since at many test-stations the end of the tests is, in my opinion, not well enough defined.

At the end of the test the ring groove deposits should hold the ring in such a way that blowby and power drop occur. To show an appreciable drop in power the decrease of the m.e.p. in consequence of the blowby must be great. Generally that decrease is the greater, the greater the stuck portion of the ring. Thus, a totally fixed ring should give the best value. From the following it will be seen that this condition is not favourable for the determination of the running time. It has been often observed that a ring is stuck so that the majority of the carbonaceous oil residue is formed behind the ring and the ring is pressed outwards. In that case it would still be gas-tight despite total sticking and such a test could be run for hours without any blowby or decrease in efficiency being observed. In such cases the end of test is only noticeable when the temperature equilibrium of piston or cylinder is slightly disturbed, and blowby then occurs. This assumption is supported by the fact that this happens mostly with runs of excellent temperature equilibrium throughout the test, where practically no adjustments of the set temperatures have been necessary. It is therefore desirable that the test should result in at most with a 80-90% stick. Other test-stands work on the same lines. If one assumes that there is only a very short time interval between beginning of sticking and total sticking, then the error in evaluating two runs with different proportions of the first ring sticking cannot be too great. It is very difficult if not impossibleto use a method of evaluation based on a 100% stick.

Measures taken to improve the indications of sticking are briefly described in the following.

One aspect which effects the sticking of the ring is the turning of the ring during running, as shown by disturbing periodic variations of the blowby. To investigate the influence of the turning and position of the ring on the sticking, tests were run with pinned rings not only recently but also at the beginning of the test runs with the BMW 132. In some of the cases the running times were shorter than with free rings, in other cases the opposite took place.

Compared with the normal ring arrangement the spread was the same. The above test effected no improvements. Also with pinned rings a conditions was created which is not found in practice. The tests were therefore discontinued.

The blowby was increased by omitting certain piston rings. Tests with such arrangements gave the following results.

If the first ring and the scraper are left in their grooves, then the lateral support for the piston is not sufficient, the rings break, and a high blowby is obtained right from the beginning. It is impossible then to detect the end of test on account of peak pressures on the graph caused by short time disturbances of the oil film. A further disadvantage is the piston wear caused by local overheating through the continous blowby.

If the first and third ring are left in their grooves and the second groove is drilled for the gas flow, then the above mentioned conditions are improved, but local overheating of the first ring and occasional piston erosion still occur.

A real improvement without these disadvantages was achieved when the third ring was removed. The groove of the missing ring is provided with four, 3 mm. holes spaced around the circumference to facilitate blowby into the crankcase. It is also of advantage not to use too small a ring gap for the second ring, so that there is little restriction for the blowby. This arrangement gave, except in a few cases, a very definite end to the test with sticking of the first ring. The sealing action of the second ring prevents overheating of the ring portion of the piston.

In the following illustration several typical blowby curves, are given.

(Figure 1225 - Curves of Blow-by on the BMW 132 N Oil Test Engine).

The pressure is recorded with Ring balance and automatic chart and reads from right to left. The three top runs show the most common curves with distinct pressure increases.

Number 4 gives the pressure increase with the ring becoming stuck apparently rather slowly. The blowby pressure oscillates but increases progressively, the power drop is at first very small and ultimately reaches a value of 2%. Number 5 shows the recorded pressus for a lubricant with insufficient lubrication qualities. This happens mainly with materials which decompose at high temperatures, so that the first ring does not receive sufficient oil and in consequence allows the gas to pass. As these diagrams show a very definte blowby reading can be obtained. Therefore the last described ring arrangement was kept, even until to-day. It allows in nearly all cases satisfactory recognition of the end of test.

Although the end of test end is established by this method, the running times still show considerable divergencies even with the same lubricant and exact control of test conditions.

We tried to determine the reason for the different spread of Rotring oil results obtained at different times. We compared runs at different periods in relation to various deliveries of cylinders, pistons and rings. No relation could be established however. Following a hazy assumption that these spreads are somehow influenced by the composition of the intake air, we compared test runs on reference oil over a considerable period at different wind speeds and wind directions.

The possibility that only small amounts of impurities, such as are found in the air of a chemical factory, may cause different ring sticking behaviour is suggested by the consideration that during a 10 hrs run 2000 Kg air are used to the 8-10kg of oil circulation. This possibility is the greater since the development of synthetic lubricants proved the efficiency of homoeopathically small amounts of so called inhibitors to influence the running time. In this case also no relation could be established.

(Diagram 1215 - Reference Oil Running Time and Direction of Wind.)

One point which was better established was the different behaviour of individual cylinders in regard to running times and temperatures. The next figure shows a comparison of such runs.

(Diagram 1209 - Running Times of Rotring Reference Oil on different Cylinders)

From this comparison it can be seen that for different cylinders different mean values are obtained. These runs have been taken from the test series of four different engines, but only such series were used which contained two or more control test runs on Rotring. Also examined was the influence of the different test equipments on the running time with the same cylinder. Only slight differences between the various engines were shown. Thus Rotring reference Oil gave, the same cylinder, in engine 1 seven hours, in engine 3 six hours, fifty minutes and in engine 4 seven hours. Another cylinder had the very short running time of 4 hours 55 min., in engine 1, whereas engine 4 gave a running time of 4 hours 30 min. A third cylinder ran in engine 4 —— for 8 hr. 40 min. and in engine 2 for 8 hr. 15 min. Even if these values appear to show good agreement, one has to conclude that the great differences between the cylinders are not caused by the different engines. It is probable that the remaining differences between various runs with the same cylinder are caused by other circumstances

A further proof of the different behaviour of various cylinders is given, when the spark plug gasket temperatures of different runs at constant cylinder head temperature are plotted.

(Diagram 1210 -Spark Plug Gasket Temperatures with Different Cylinders)

The hatched areas in the diagram represent the temperature variations of inlet and outlet spark plug gaskets, the length of each section being a measure of the number of tests. Besides widely varying mean values the spread within each test series is clearly observed, probably caused by the insufficient accuracy of the temperature measurements at spark plug. The figure also shows that the cylinders differ greatly as far as the temperature distribution is concerned. No practical conclusion can be drawn from these facts as no connection exists between high temperatures and short running times or vice versa. These facts show that the difference in running times with Rotring oil on several cylinders could be caused by the different temperatures of the cylinders. It is therefore desirable to move the temperature elements nearer to the ring travel, that is to the level of the TDC, or to use piston temperature measurement if a suitable method is available for continuous operation.

The spread of results makes it difficult to study factors such as piston and ring clearance, ring position etc. To make these tests on one cylinder and piston only, then a whole test series is necessary to comprehend each single factor. Such extended tests are impracticable to-day, because of the great amount of time and labour involved. Results of a large number of tests indicate the following:

1) The piston clearance provided it remains circular, has practically no influence on the running time.

2) In the same way the effect of the ring groove width and consequently the ring side clearance is only slight. Too wide a groove however, causes a more or less great increase in running time.

A further point is to be made here. In individual runs the stuck section of this or that ring differs in size and position. It is therefore understandable that we tried to establish a relationship between the occurrence of the first stick and the ensuing running time until complete sticking. We analysed the results of several test series in this direction but no clear connection was found. Experience proves that in the great majority of cases sticking of the first ring starts on the inlet side and that the running time decreases if the ring gap is on the same side.

One of the most influential factors on the running time, as mentioned several times before, is the temperature of the cylinder. We have run several test series to establish the relation between temperature and running time Figure 1217 shows curves taken with a time interval of two years.

(Figure 1217 -Running Times and Temperatures with Injection and Carburation)

The curves agree well enough and show a continuous decline in running time with temperature increase.

Furthermore, following the reconstruction of the lubricant test engine to operate on a carburetter, we examined several cylinders as to effect of temperature behaviour on running time with carburetter operation. The results shown in Figure 1217 gave the following curious picture: the temperature running time curves are much steeper with carburetter than with injection pump. That is remarkable, because this was the first time we had curves similar in steepness to those found by DVL. I should like to point out that the DVL is the only place that ran N-cylinders with carburetters. From a further series of tests with higher specific consumption it becomes clear that with a carburetter the running time is very sensitive to the mixture regulation. We shall check these results and if they are verified we shall not recommend test runs with carburetter, since with such high temperature sensitivity the spread of running times is bound to increase. After these tests, which should preferably be carried out by some other test-station, the decision will have to be made whether the engine shall have an injection pump or a carburetter, As the DVL has the experience as well the necessary apparatus for runs with N-cylinders, it would probably be advisable to run the tests there.

Time does not allow to go into further detail on that point but I shall welcome a thorough discussion of this point after the lecture.

The spread of running times with Rotring reference oil is too great already, but the absolute spread is even greater with oils of longer running times e.g. mixtures with synthetic lubricants. Our experiences also show that the addition of fractions of a percent of additive often increase the running time by 50% or more. There is in many cases an optimum amount of additive which causes a maximum running time, greater or smaller amounts show an immediate and abrupt decrease. The determination of the optimum amount can only safely be done by control runs, as a single result might give an accidental maximum and so give a false picture.

Beside running time, and apart from sticking, the appearance of the engine after running especially the piston and cylinder is an additional means for the evaluation of an engine lubricant. It is therefore usual to examine the engine deposits after each ring sticking test. It will be understood that endeavours are made to correlate this information with the running time. At this test station the weight of the carbon residue on the piston crown and in the first and second ring grooves is determined after most of the runs. Results show that in Rotring runs the oil carbon in the first ring groove is near enough proportional to the running time, but the residue on the piston crown varies considerably. Rotring gives after 8 hours running about 2 gr. at the 1st ring whereas the weight on the piston crown varies from 0.7 to 1.5 gr.

The analysis of residues of oils with synthetic additives give results of great variety. Some oils shown even after a long running time a clear ring area, whilst the crown will have a considerable amount of residue and vice versa. From this may be concluded that the relationship between temperature and formation of residue is not fixed. A clear decision on that particular quality of the oil can only be made if the behaviour is known in other tests, e.g. evaporation test. It was also found that mineral oils with additives of greater strength than the normal inhibitor e.g. high sulphur content, do not present the normal residue picture. In such cases a complete analysis will often give the desired explanation.

We have now come to a further point, namely the relation between running time and analysis of the lubricant.

Comparing the different lubricants which, though from the same basic material, give different running time because of their further treatment, the analysis of the oils show only in the rarest instances any distinct characteristics. No relation at all could be established when the same oil was treated with inhibitors. Ageing tests also did not produce any differences greater than the test accuracy of the analysis and yet the running times of these oils varied often quite considerably.

The only test which gave near enough agreement was the Conradson test. Even here the conformity is limited to lubricants of a uniform base e.g. oil of paraffin base.

The analysis of the used oils is not much more encourging. Viscosity measurements permit conclusions on the expected thickening of the oil in the engine, but tests for sediment, saponification and asphalt content seldom show conformity with the ring sticking or running time. Yet these analytical data are necessary for the evaluation of the lubricant behaviour in aero-engines. Not only is the inclination to ring sticking of importance but also the cleanliness of the engine and its accessories, especially the formation of sludge. All these facts go to determine the suitability of a lubricant.

We reached now a factor in the stability behaviour of lubricants which I should like to mention, namely the general formation of residues.

Experience in residue formations shows only a limited agreement between cylinder and main engine. Lubricants which behave well in the single cylinder show only in the rarest of cases in the 100 hrs run of the main engine any residue on the pistons or rings. On the other hand it is quite possible and was frequently observed that lubricants with a short running time in the single cylinder show a favourable behaviour in the main engine. The cause of sludge formation in the main engine, especially in flight is not yet understood. A comprehensive investigation is precluded by the fact that sludging can seldom be observed on the test bed and never in the single cylinder. Investigations were carried out to define the conception of engine sludge. A complete analysis of engine sludge gives no criterion as to the nature of sludge or the components which are primarily responsible for its formation. Actual engine tests must therefore evaluate the sludging tendencies of the oil. Our tests showed an initial success in that we were able to observe sludge formation on the single cylinder engine.

The following illustration shows the result of a few of these tests :

(Figures 1226-Sludge formation of Two Oils)

Here the sludge is not separated by a centrifuge but simply by a fine filter. The ordinate of the graph shows the pressure loss in the filter caused by clogging and is graduated in mm Hg.

A synthetic lubricant under normal operating conditions gave the lower flat curve, above which the curve of the same oil under special operating conditions is shown. On the left is the third curve showing the course of a mineral oil run under the same conditions. The reproducibility of the curves was checked by a few control runs and seems to be satisfactory. A final evaluation can only be made by a comparison with practice. This will of course take some time.

Following this survey of our experiences, I should like to mention a few conditions which could possibly lead to a real improvement of the test accuracy.

Firstly the measuring of the actual ring groove temperature will improve the accuracy of the measurements as the cylinder temperature never gave a true picture or the temperature of the actual place where the oil carbon was formed. We are working in that direction at the moment, but I should like to recommend on this point the detailed and interesting report by Glaser.

The temperature in the region of the rings is partly determined by the oil cooling, that is by the amount of oil that reaches the rings. It is more important as it also determines the amount of substance which is being transformed to oil carbon on the rings. In this connection the exact determination and control to a constant amount of the spray oil in the crankcase. Our experience underlines the fact that with newly overhauled engines, where there is little play between crank-pin and connecting rod bearing or between connecting rod bearing and crank web, the first test runs reached long running times with very little residue. We surmise that there is an optimum amount of oil which gives a minimum running time i.e. just so much oil reaches the piston rings as can be transformed into oil carbon at the prevailing rate of decomposition. An increase of the amount should theoretically increase the cooling effect of the lubricant and therefore give a longer running time. A decrease of the oil amount would allow less oil to reach the rings than could be decomposed, which would also mean an increase in running time. We are working on such tests at the moment, but unable to give any results as the procedure is not yet satisfactory. It seems that particularly in this direction, a broadening of our knowledge is possible, especially as a number of other test stations are also working on this question and fruitful co-operation could be established.

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