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Observations and Thoughts on Horological Lubricants

Understanding Why they Work and Fail

Malcolm Pipes FBHI

Just over 70 years ago, in May 1953, the ascent to the summit of Mount Everest by Tenzing Norgay and Edmund Hillary was successfully achieved, and various watches, including Smiths and Rolex, were used for the expedition. Prior to the ascent, the demanding task of producing unique and special oils had to be undertaken to ensure the watches performed adequately in the hostile environment, where temperatures could fall to −30°C or lower.

Correct lubrication is of paramount importance in horology. In the eighteenth century the watchmaker Abraham-Louis Breguet famously said 'Give me the perfect oil and I will give you the perfect watch'. Despite enormous advances, horological lubrication continues to pose considerable challenges, and even today certain aspects of lubrication are not completely understood.

Tribology is the engineering and science of contacting moving surfaces, and the associated issues of wear, friction and lubrication. It is a complex topic, covering all manner of disciplines. In this article I wish only to relate my opinions based on the basic observations I have made over many years on some lubricants that can be used in clocks and watches.

'Classical' and 'Traditional' Lubricants

Oils and grease reduce friction, wear and corrosion, having been made for many centuries, and from many sources, including air, gas, water, animal fats such as sperm whale, vegetable, mineral oil (refined from crude oil), and other petroleum-based oils extracted from within the earth.

It is common for manufacturers to combine and blend several oils to produce a single oil with benefits from the constituents, and there may be many different lubricants produced from one manufacturer suitable for different applications. Such lubricants can be catorgorised as 'classical' or 'traditional'.

Vitally, and more recently, so-called 'synthetic' lubricants have been created. There is no universal definition of the word synthetic apart from indicating a man-made lubricant that includes chemical compounds. Synthetic lubricants, although still derived from crude oil, are made by chemical synthesis rather than the refinement of crude oil, but they are highly important and may differ considerably from the classical, traditional lubricants.

Many years ago, soon after I got involved with horology, I noticed a basic clock I had cleaned and serviced started to perform badly after just a few months. On dismantling again, I found one well-known classical lubricant in particular had visually degraded considerably, appearing green and spongy (not an official tribologist's term!). It had almost certainly completely lost its desired lubricant properties, see **Figure 1**, which motivated me to investigate further.

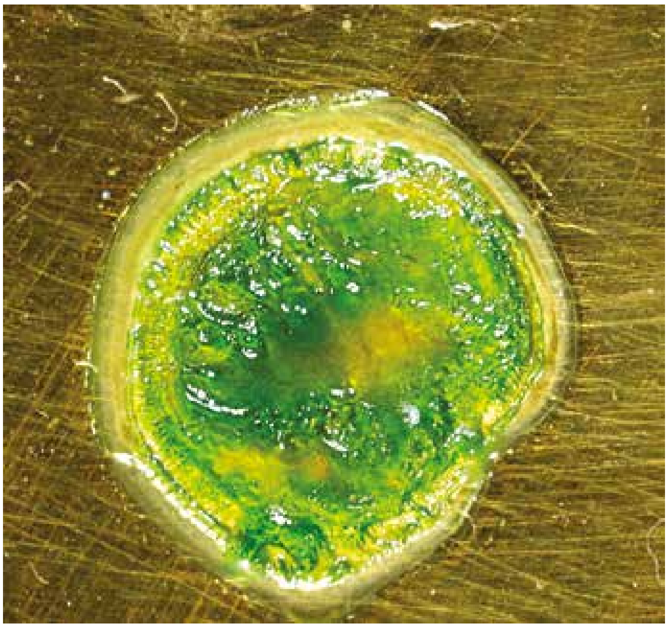

Figure 1. One well known 'classical' lubricant had visually degraded, appearing green and spongy.

Oils Put to the Test

Over the intervening years I have carried out further basic observations on lubricants using, for example, CZ120 brass discs (a free-machining brass with a 3% lead addition often used by horologists). After ultrasonically cleaning and drying the discs I applied spots of up to ten different horological oils – those I could readily find and purchase – and took an initial photograph, **Figure 2**. I then placed the plates under shallow glass domes in my workshop, and waited.

In this example the oils comprised two groups: 'A' traditional/classical oils and 'B' synthetic oils. I do not intend to identify all the classical oils individually in group 'A' as my observations cannot be considered scientifically controlled, but included are some well-known examples. Within the second group, 'B', on the same brass disc, are Moebius: 9010, 9020 and 941. All three are identified 'SYN' and are commonly used synthetic oils.

I noticed a rapid degradation of all the classical oils within a few months, **Figure 3**. All had degraded and/or spread to some degree, with two samples almost disappearing due to evaporation, and despite the sample plates being placed horizontally.

Also, importantly, some of these classical oils caused some minor corrosion on the brass plates, such that when the oil was eventually removed by cleaning, visual evidence of

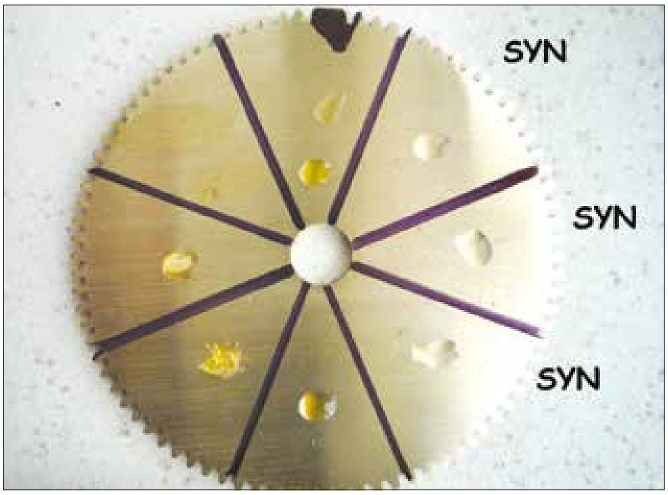

Figure 2. The start of the oil test.

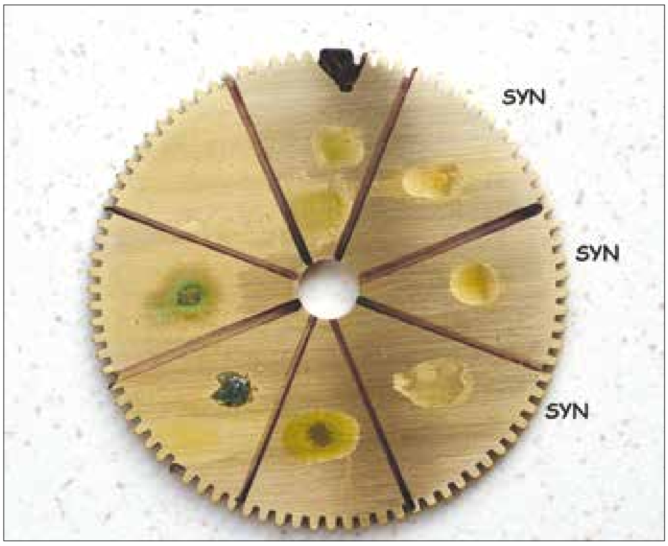

Figure 3. The end of the oil test after six months.

corrosion via the copper in brass was apparent. This could be removed on flat plates by fairly firm polishing, but obviously would be more difficult on engraved plates, **Figure 4**.

I have discussed my observations with other horologists. Several have noticed very similar degradation with some of these oils. It is noteworthy that the shelf life of classical oils is typically two years, compared with six years for synthetics, where I have noticed no visible degradation after many years when kept in their sealed containers.

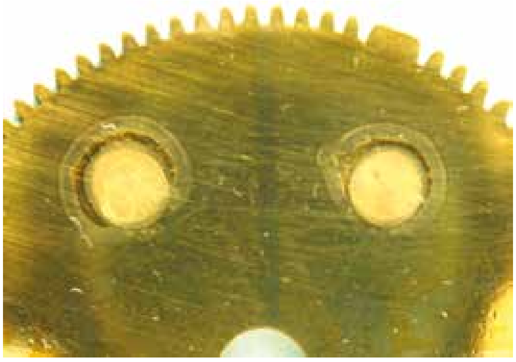

Figure 4. Visual evidence of corrosion on the brass plate was apparent.

The Moebius: 9010, 9020 and 941 synthetic oils appear to have performed far better than any of the classic oils, with only minor spreading exhibited by 9010 and 941. This is to be expected as both have a viscosity half that of 9020, which showed the least long-term degradation and spreading, with almost no visual change. 941 is an oil especially suitable for pallet jewels and is related to 9010 with similar viscosity, but with additives to increase its 'oiliness'.

'Oiliness' is an important parameter of oil but different from viscosity, which is a measure of the oil's internal friction. Two oils of the same viscosity can have different oiliness. A high value suggests lower surface friction and so better suitability for sliding surfaces, hence the recommended use of 941 for jewels and escape wheel teeth, for example. Regarding the classical oils, animal and vegetable oils are considered superior in oiliness to straight mineral oils.

It may be thought that oil viscosity is of absolutely paramount importance in a watch or clock, but most wheel pivots, for example, rotate very slowly, and so the frictional losses are usually small. However, the escape wheel teeth and balance pivots are fast moving and an exception – often discovered when an incorrect (high viscosity) oil has been applied to those locations, resulting in reduced balance amplitude and rate changes.

I have repeated the above brass plate observations many times finding identical results. The samples of classical oils placed in relatively high natural light positions exhibited more rapid degradation than those kept in the dark, even though there were three glass layers acting as ultra-violet protection. This might suggest caution when placing a French four glass clock on a south facing sunny window sill.

I also experimented using cleaned stainless steel plate, rather than brass. Here, all of the classical oils perform better on the stainless steel than they do on brass. This is because, when exposed to air, the copper content in the brass plate oxidizes, causing the surface to change gradually to a green colour, as observed.

Vitally, however, all the synthetic oils have shown no visible degradation, evaporation (indicating a high vapour pressure), or visible change over several years, and with little spreading. They exhibit first class performances in clocks and watches irrespective of the temperature or high ambient light levels, although an oil sourced from a Chinese auction site claimed as 'synthetic' did show significant spreading.

As a further experiment, I also carried out some observations on several fully synthetic motor engine oils, such as SAE 5W-40. It may be thought that a car engine oil is far more viscous than typical low viscosity horological oils, but at the same temperatures their viscosities are generally very similar. They do not degrade rapidly, but may spread slightly more than horological oils and so it may be tempting to use them due to their very low volume cost. However, the cost of mainstream horological oils is only a very small fraction of the cost of servicing and it may well be prudent to use them.

Limited Selection

Although oils of numerous specifications are available, I suggest for most horologists only a selection is necessary. Higher loaded components do need higher viscosity lubricants to reduce metal to metal contact, but increasing watch temperature by, say, a credible 50 °C (outdoor temperature to wrist temperature for example) can reduce viscosity by a factor of fifteen – a bigger effect than changing oil grade, which may only result in a reduction of viscosity by a factor of two at the same temperature. Hence the importance of developing special oils for use at very cold temperatures, such as high altitude expeditions or aircraft.

Levels of viscosity are normally given in stokes or centistokes (cSt), or sometimes poise or mm²/second.

In general, synthetic oils have a higher viscosity index than classical oils, meaning there is less viscosity change with temperature, and they are also less affected by change in humidity levels.

As mentioned previously, using oil of high oiliness, for example Moebius 941, is also strongly suggested on escape wheel teeth and pallet impulse faces of lever escapements, particularly those with fast beat balances. **Figure 5** shows a 'dirty' lever escape wheel teeth, as viewed through a microscope, and care is needed lubricating this area.

Maintaining correct lubrication of the lever escapement (excellent though the escapement is) may expose its Achilles' heel, as the varying amount and instability of lubrication in this area can cause rate variations. Many famous horologists, such as Breguet, Pratt, Nardin and Daniels, have, of course, designed and developed alternatives to the lever escapement.

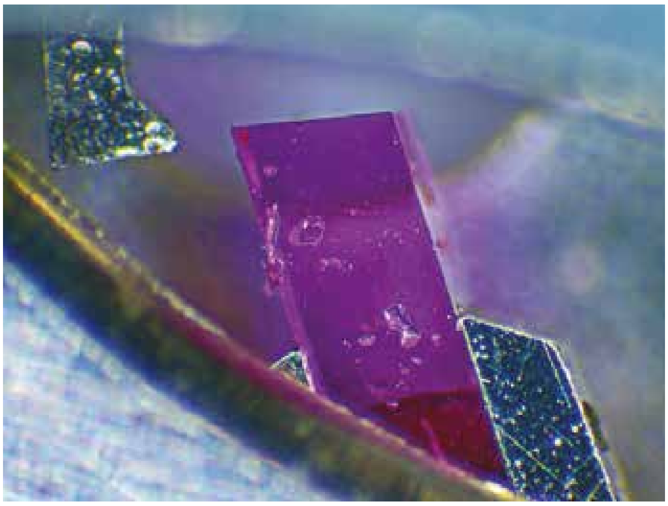

Figure 5. A 'dirty' lever escape wheel teeth, as viewed through a microscope.

Alternative materials are being considered too. Horologists are currently hoping to develop almost frictionless nano-coatings deposited onto horological parts using a sputtering process, which could possibly replace the need to use traditional oil-based lubricants in mechanical watches.

Correct Oil Spread

The shape of the oil sinks is important. A wide and shallow sink will allow oil to spread onto the clock plates and elsewhere, whereas a small-diameter, relatively deep sink can contain oil more effectively through surface tension and capillary action effects. The use of end stones, inside plate oil sinks and/or pivot shoulders should also be carefully considered to reduce oil migration and travelling elsewhere.

Despite the temptation many of us feel, I suggest the outer sink should only be partly filled with oil, as even a tiny amount will be encouraged to travel along the pivot length by capillary action and then easily find its way onto the clock plates and further.

Another route to reducing oil spread, which may be exacerbated by ultrasonically cleaned items, is the use of epilame treatments, which provide a very thin coating, acting like water 'beading' on a waxed car.

I have used stearic acid in a solvent solution as such a treatment with some success, but there are better commercial options, such as Moebius Fixodrop.

Probably one of the world's best-known supplier of horological lubricants is Moebius. In 1855 they were producing neatsfoot oil, seemingly oddly perhaps from the shin bones of cattle. Tribology has progressed enormously since then, with Moebius offering a wide range of lubricants, including, by 1952, its SYNT-A-LUBE synthetic oil and, more recently, the SYNT-HP, a group of oils and greases suited to high pressure applications and available in several viscosities.

The link *www.m-p.co.uk/muk/acrobat/hse/moebius-hs-sheets/moebius-specsbook.pdf* gives some useful Moebius lubrication specifications.

In Conclusion

Importantly, no one single oil of any manufacture is better than all others; the correct oil depends very much upon where it is to be used and its temperature and application. My advice is to peruse the manufacturers' data sheets and use the correct grade modern synthetic lubricants, particularly where brass is involved.

Using oil of high oiliness is also advocated on escape wheel teeth and pallet impulse faces, particularly those with fast beat balances. All parts should be cleaned thoroughly, simple re-oiling of 'dirty' parts will create a highly abrasive 'grinding paste', resulting in rapid wear.

For those intent on reducing clock friction and wear when designing their own clocks it is worth remembering the following points:

- The co-efficient of friction (a dimensionless number, the lower the better) varies according to the two surfaces involved, so, without lubrication: aluminium to aluminium 1.2, steel to steel 0.8, brass to steel 0.4, wood to metal 0.4, and steel to PTFE 0.1. When a lubricant is included these values can fall significantly.
- Using ball races (shielded not sealed, with grease flushed out) or anti-friction wheels (as Harrison) can reduce pivot friction enormously, utilising a rolling, not sliding, friction.
- However, the major loss of energy in a typical pendulum clock is not by metal-to-metal friction or incorrect viscosity oils, but by the clock's driving weight indirectly pushing the pendulum through the air.

As a result, designing a clock with a low pendulum amplitude (via a small impulse circle in the escapement geometry for example), a suitably shaped bob (not a vertical cylinder), and a rigid case and pendulum support, will allow a lighter driving weight to be used. This is coupled with lower resulting wear and friction in the train, hence longer intervals between servicing and benefits in the reduction of circular deviation effects.

There is a vast amount of material which can be read, studied and digested on tribology with considerable differences in opinions and test results. My own simple primary conclusion is: use synthetics!