Bird quill plectra, their performance and maintainance

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This paper describes the mechanism of wear of bird quill in a harpsichord. The aim of the research was to test the effectiveness of various methods the harpsichord technician uses to treat the quills. Although only swan feathers were systematically tested it is thought that the results will be valid for many other feathers. In any event, the results given here provide a useful guide until such time as testing of other feathers has been undertaken. The primary aim of this paper is to describe the testing and results, not to provide a succinct guide to quill maintainance; this is offered at another page on my website.

Introduction and summary of results

The touch with bird quills often suddenly becomes apparently stiffer or "harder", making playing difficult and requiring some intervention to restore normal performance. This feature is well known among harpsichords using bird quill and has led some to abandon their use in favour of Delrin plectra.

Testing of plectra made from swan feathers determined that the apparent "hardening" is due to an increase in roughness, and thereby increased friction, on the quill surface.

New wire strings were found to cause faster abrasion of quills than those which have been played for some time, an effect which has not been reported before.

A polishing procedure described by Tilman Skowroneck can usually restore a usable plucking strength immediately and at any time in the quill's life, albeit for a limited period.

The treatment methods which are effective or ineffective in maintaining an even plucking strength are described here, based on testing (begun in 2006) of oils and greases on both new and used quills from swan feathers.

Some oils, when applied only to the top surface of the quill, were found effective in maintaining a usable plucking strength as the quill was abraded, providing they are used from the outset with a new quill. Nevertheless, there was a noticeable variation in strength of pluck as abrasion of the quill took place. Greases (e.g. skin grease) were found to be less effective and olive oil was ineffective. Synta-A-Lube (a watch oil) not only prevented any increase in plucking strength but caused a decrease.

It was found that the most effective strategy is to apply oil (Ballistol) only to the underside of the quill and allow it to soak in for at least 45 minutes. Thereafter the quill showed no wear, even in plucking a new, and presumably more abrasive, string 2000 times, and no "hardening" during this period. This oiling procedure also "restored" an already "hardened" quill to the normal plucking strength. As far as I am aware, these effects have not previously been reported.

The performance of bird quill plectra

Untreated bird quill used with new strings wears steadily, starting at the initial voicing, even though its actual life may be several years.

Testing proceded by plucking a string 100 times, at about 120 beats per minute, then measuring the plucking strength with a weight, before playing in further steps of 100. A calibrated weight (of 15mm diameter brass rod, typically 115-120g) was used, the position on the keylever being noted where the weight just causes a pluck when lowered gently onto the key, with the string not vibrating. For a lighter touch the voicing weight has to be moved on the key, away from the player, a distance of being designated hereinafter as "-x mm", e.g. 3 mm to 6 mm away from the player = -3 to -6 mm. Although 3 mm might seem to be an insignificant amount, it can make the difference in the 8> register on an upper manual between a correct tonal balance with the lower manual <8, and one which is a shade too "bright". A sensitive player will also notice the difference in touch.

Quill is said not to "workharden" with use or age, which is one of its useful characteristics compared with Delrin. Thus, the nominal strength the voiced quill has been given will not increase with use, as does Delrin. However as the quill tip becomes polished with use the touch may become slightly lighter, as was observed in testing, and on the lower manual of a harpsichord after 5 months of use. There are also other phenomena concerning changes in plucking strength which will be described later.

With a new, untreated quill plucking new strings you will usually find that within 50-250 plucks the plectrum suddenly appears to be much stiffer, equivalent to moving the voicing weight towards the player by about 25-35 mm (designated hereinafter as "+x mm", e.g. +25 to +35 mm). This increase in plucking strength may be so large that the quill will not even pluck, and certainly the plucking stagger in a 2-register instrument will have been altered. This may also be accompanied by a "creaking" noise just before plucking as the quill bends under the string. The sound is much like opening a door, the hinge of which needs oiling. However, a creaking noise is not always correlated with a high plucking strength.

As for the "creaking" noise: inspecting the tip of the plectrum with a x3 jewellers' eyeglass shows that the string does not move evenly towards the tip during the plucking operation, but jumps in small discrete steps. This effect can be simulated in Delrin plectra with horizontal scratches so it is thereby clear that this is a mechanical problem with the quill.

At this stage, when the quill gives a higher plucking strength, visual examination with a x3 jewellers' eyeglass might show a slight matt area on the tip of the quill, but probably not a groove. In any event, the surface has become slightly abraded and apparently roughened (cf. Broekman, who correctly identifies the cause). Microscopy would no doubt show this effect clearly. A shallow groove will occur after considerable use, but does not necessarily cause a high plucking strength.

Regarding the apparently increased stiffness: if the top surface of the plectrum is cleaned x10 with a small antelope leather pad, with the motion of wiping towards you, it will be found that the quill will probably now be exactly at its original "strength" again. Even wiping the quill with a clean fingertip has some beneficial effect. A plausible explanation is that microscopic flakes of quill material were removed from the surface, which were causing additional friction. If you then operate this key again x10-x30 you will probably find that the resistance has again increased substantially, making playing of the key again difficult.

This increase in resistance is not the result of a defective quill; it is the result of wear leading to a rough surface. No doubt some quills might show more resistance than others. Replacing the quill would not solve the problem; it would only delay the next occurrence of such wear.

At this stage some people re-voice the plectrum in order to restore the original plucking strength. However, repeated tests have shown that this roughness can be a temporary phenomenon and that the original plucking strength can often be restored immediately by certain procedures, which will be described below. The quill might even restore itself, if one could carry on playing long enough (i.e. 400-700 plucks). However, the increased stiffness I refer to is so excessive that a harpsichordist would hardly wish to continue playing, thus I have not tested the suggestion that the "stiffness" might correct itself.

From extensive, controlled tests I have conducted it has been possible to determine the essential parameters in the wear of the plectrum. Usually within the first 10-400 plucks abrasion of the top surface of an untreated quill by a new string commences. By 1000 plucks a flat area is visible where the string makes contact with the quill. With x30 magnification, the difference between the orange-peel like surface of the quill and the flat area is obvious.

My tests have shown that once the surface of the quill starts to break up it is usually possible to restore the normal strength of pluck by "cleaning" the surface with a leather pad, or by "polishing" the surface with the edge of your fingernail, while supporting the quill on a voicing block. Tilman Skowroneck described this fingernail-polishing procedure (p. 17), which is one of the most significant techniques in quill maintainance, but may not yet be widely known. Almost always a reduction in the excessive plucking strength is possible with this method, and often the original strength can be attained. In other cases the strength returns to near the original position (i.e. with the weight +3 mm to +8 mm towards the player).

After cleaning with leather the quill may become hard again within about 30 plucks, but a fingernail-polished surface lasts longer. This "polishing" might be explained as the more effective removal of loose particles. Alternatively it might be explained by the compaction or compression of the keratin material of which the quill is composed. The actual effect remains to be investigated at a microscopic level.

After a further few hundred plucks (c.800 in continuous testing) the "polished" surface of an untreated quill breaks up again and can yet again be restored with the fingernail. There may be no limit to the number of times this cycle can be repeated, until the plectrum is too weak for further use. It appears that during the life of the untreated quill this breakup of the surface and consequent sudden "hardening" can occur at any time.

However, the initial phase (up to 1000 plucks) seems be the more difficult part of the quill's life. Tilman Skowroneck (p. 17) writes of the first few months being difficult. Initially I surmised that an external layer of the quill, perhaps of weaker material, was being eroded, until a more resistant inner core was reached. Thus, I thought that at this stage one might speak of the "running in" being completed, to borrow from the old automotive analogy, where piston rings were said to require running in, i.e. contacting surfaces were smoothed. In later testing it became apparent that it is the string itself which is rough when new, but becomes polished with continued plucking, as described below. This effect appears not to have been reported until now.

What has been observed in these tests of an untreated top surface is not an increase in stiffness or strength of the quill; it is merely that more effort is required to overcome the surface friction and thereby effect a pluck. For this reason it seems technically correct to speak of an increase in *plucking strength* although the cause is an increase in surface friction.

The harpsichord technician's task is to manage the breakup of the quill structure in a controlled fashion so that, if possible, the strength of pluck is neither weaker nor stronger.

Lubricating Quills

A lubricant could be used to overcome the friction of the excessive roughness, but this would also reduce the friction of the quill on the string and tend to nullify one of the positive characteristics of quills, namely that the player has more control during the plucking and thus a better sense of touch than with conventional Delrin plectra.

The application of a lubricating medium to the surface of a "hardened" quill immediately reduces the friction, thereby giving a reduced plucking strength. The lubricant holds the friction low until such time as it has been worn off. A microcrystalline wax (Cosmoloid) was found to wear off by 150 plucks although Klüber Montagepaste 46 MR 401 was still effective after 500 plucks. Synt-A-Lube, an expensive Swiss synthetic watch oil, was found to prevent any increase in stiffness during the first 1000 plucks and actually caused a decrease in plucking strength of -7 mm.

Oiling quills

It is a common practice to oil plectra, but the use of grease from one's own skin has also been recommended. My controlled tests have shown that oil on the top surface of the quill manages the initial abrasion of the quill-string interface better than a grease, but also that oils vary in their effectiveness. Friction-reducing lubrication is not the main effect of many oils or skin grease, nor (I contend) the explanation of the benefit which comes from using them.

Oil does not significantly penetrate the unworn upper surface of a quill since it can be seen as a liquid on the surface even days after application. It is not dispersed from the surface by 1000 plucks. Oil will penetrate the lower surface of the plectrum, and has been observed to soak in entirely within two hours, at the most. I therefore infer that oil will penetrate the top surface slightly at the area where the string wears away the quill.

The few published sources on quill maintainance do not always specify whether only the top surface of the quill (in contact with the string), alternatively the lower surface, or both surfaces should be oiled. Marc Vogel GmbH recommends the use of their Kielöl (quill oil) on the top surface. The procedure Tilman Skowroneck reports of soaking entire quills in olive oil obviously implies oiling both surfaces. The following remarks address the use of oil on the top surface.

Oiling the top surface

From the tests I have conducted I infer that oil applied to the top surface does not "care for" the quill in contact with the string, it probably does not soften it or "moisturise" it significantly. In fact, as already noted, oil applied to the top surface of an unused quill remains there for days and is apparently not absorbed.

Most oils do not prevent the breakup of the quill structure; they merely manage the abrasion in a controlled fashion. I think the correct analogy is that of sanding a painted surface with waterproof abrasive paper (so called "wet & dry" paper). If you sand dry, then the paper quickly clogs with paint particles. If you sand wet, then the particles are washed away from the sanding area and do not clump together. This analogy would explain why greases, (including Emu oil which has the viscosity nearer that of a grease), perform slightly worse in this process. Thus, the function of the oil is to aid the transport of abraded material away from the immediate contact area, not to lubricate, i.e. reduce friction.

When oil is applied to a new quill there is typically a noticeable increase in plucking strength within the first hundred plucks (+5 to +10 mm), but it may return to the original value after 400-700 plucks, depending on the type of oil. This seems to result from the surface abrading, becoming rougher, then being smoothed by further use. Undoubtedly the "hardening" effect is less pronounced when oil is used and this creates a manageable touch for the player, even though not a consistent one.

It has been said that when quills "harden", this is the time to apply oil. This observation is correct as regards timing. However, the inference that the quills have become "hard" and require "softening" with oil would (based on my observations) be incorrect. The "hardening" is evidence of the lack of controlled removal of particles during abrasion at the quill's top surface in contact with the string.

When oil is applied to a quill which has "run dry" and "hardened" to say +25 mm, tests have shown that there might be a measurable, immediate, and slight reduction (c. -8 mm) of plucking strength, but this will depend on the type of oil. The better oils give the least immediate effect. Even this slight reduction of friction leaves the quill strength at +17 mm in this hypothetical, but typical example. Playing is required in order to wear away the offending particles; it may take 500 plucks for the original plucking weight to be restored, although the improvement might be to +8 mm after only 50 plucks. That is, after 50 plucks the weight could be moved back 9 mm, so that the strength is now only +8 mm compared with the original strength: +17 mm - 9 mm = +8 mm.

Marc Vogel GmbH's Kielöl [quill oil] and Klever's Ballistol (see the Appendix for further details of oils and greases) were the most satisfactory oils in maintaining a playable plucking strength (i.e. an increase to +10 mm), although this obviously involves a substantial variation from the original voicing strength. Nevertheless these oils prevented a "hardening" of the pluck to +25 to +35 mm as would occur without treatment.

Skin grease was found to be a little worse than these oils in controlling the increase of plucking strength.

Olive oil was found ineffective in preventing "hardening" of the plucking strength. This is an interesting finding considering that it has the historical sanction of being recommended by Adlung (see Martin Skowroneck, p.93 in German, p. 227 in English). If olive oil is that which many harpsichordists have used for oiling quills, it would help to explain the poor reputation that quills have for an irregular touch.

An interesting exception was found in Synt-A-Lube, which prevented any increase in plucking strength of a new quill, but at the expense of reducing the plucking strength (as reported above). Somewhat curiously, it failed to ameliorate a quill, the plucking strength of which had already "hardened", which makes it unsuitable for "repair" purposes.

The source of the wear in quills

In 2006 when I voiced a 3-register harpsichord with quills made from swan feathers, I oiled the underside of the quills and gave my customer a recommendation to do the same. She was pleasantly surprised by the durability of the quills during the first year. In 2010, when I had the opportunity again to use bird quill in an instrument, I investigated in detail the apparently majority opinion that the top surface of the quill should be oiled, with the results reported above.

I then turned to an investigation of the oiling of the underside of the plectra. This led in turn to a line of enquiry, which it is convenient to report now.

After oiling the underside of the quill it appeared that this method would considerably extend the period before wear of the plectrum occurred. The question therefore arose, what would happen if a quill were left untreated and played until it "hardened", and only then oiled on the underside? This testing brought about unexpected results.

Two untreated quills were therefore tested up to 2000 plucks, with the surprising result that no increase in strength of pluck occurred. One of these quills was further tested to a total of 3000 plucks. Visual examination showed absolutely no signs of wear, whereas previous experience had shown obvious wear after only 1000 plucks, and a "hardening" by about 700 plucks at the latest.
On examination of the data it became evident that these untreated quills plucked a string which had already been used for several previous tests, i.e. for several thousand plucks. This gave rise to the hypothesis that it is the string itself which had become polished during the testing period and that this no longer abraded the quill. If this hypothesis is correct then it implies that we do not "run in" the quills, as I initially supposed (mentioned above), but rather the strings.

In order to test this hypothesis I then used an untreated quill on a new iron string with the result that the plectrum "hardened" between 600 and 700 plucks by + 20 mm; wear was also obvious on the top surface of the quill, just as previous testing had showed. I therefore conclude that new strings are likely to cause accelerated wear of quills, but that after a time the surface of the string becomes polished and causes less damage to the quill. This would explain Tilman Skowroneck's observation, that there is an initial phase of difficulty, as reported above.

My observation about the abrading effect of new metal strings appears not already to have been made in connection with quills, but it is hardly surprising when one recalls the surface finish of drawn metal strings, as shown by microscope photos. Thus, I do not imply that it is a fault of the wire drawing process; the surface imperfections are an inevitable consequence of wire drawing. All systematic testing was undertaken with iron wire strings (type A) made by Malcolm Rose.

I have not performed systematic tests using brass strings in order to determine if they are less likely to cause rapid wear of quills than iron strings. In any event I have observed "hardening" of plectra with some brass strings. It probably depends on the quality of surface finish of the material, which in turn may depend upon the die itself. Thus, it might be found that some gauges are more abrasive than others, depending on the state of the die when the wire was drawn.

It would further follow, if my hypothesis about strings abrading quills is correct, that replacement quills for already polished strings should not show any signs of "hardening" or wear in the early stages of their life, even if used without any oil.

Oiling the underside of the quill

It appears that oiling the underside of the quill, which oil then penetrates the material, provides a reservoir of oil in the quill, like a wick. One might ask whether this then "lubricates" the top surface? Quills in the treble of 8' registers are often only about 0.22 mm thick at the tip, so migration of oil from the underside to the top is not improbable.

After two applications of Ballistol over five hours, which achieved saturation of the quill, and before testing began, the plucking strength was found to have increased significantly (+6 mm). After 700 plucks the plucking strength diminished by 2 mm, and had returned to the original value after 1000 plucks.

It was found that it was not necessary to achieve saturation of the quill in order for there to be a significant oiling effect which "protects" the quill. When the quill was given a single, liberal application of Ballistol on the underside, this was found to have been absorbed within 45 minutes and produced an increase in plucking strength of only 3 mm. A small watercolour brush (no. 2; e.g. da vinci synthetics series 303) may be used. An "oiler" made from a small piece of wire, e.g. a paperclip, c. 0.8 mm diameter, also picks up the right amount of oil for one quill. The jack is then laid flat, with the quill pointing downwards. After this period any excess oil can be removed with a cotton bud or tissue paper.

Similar stiffening results were obtained with Kielöl and olive oil applied and left for 45 minutes. Almond oil and Emu oil, similarly applied, produced no change in plucking strength, perhaps due to a larger molecular size.

My hypothesis to explain this stiffening effect is that the interstital spaces in the quill had become filled with oil, which, being effectively incompressible, had increased the stiffness of the material. With playing, the excess oil appears to have been mechanically expelled so that the original stiffness is regained after 1000 plucks.

Testing of a new quill, which had been oiled on the underside with Ballistol, on a new iron string showed that no "hardening" had occurred after 2000 plucks. Thus, oiling the underside appears to confer the ability to resist abrasion, even with a new string, which is, from the evidence of the testing, apparently rougher than a used one.

This is a remarkable contrast to the situation where oil is applied to the top surface since there is typically an increase in plucking strength during the first 500 plucks while the surface of the quill is abraded.

The other notable effect of oiling the underside of the quill is that after 2000 plucks there was no sign of wear on the tip of the quill where it contacts the string, as was observed with a x3 jewellers' eyeglass. This was surprising considering the obvious wear observed with new strings when only the top of the quill was oiled, or when the quill was left untreated. My tests show that this occurs only when the underside of the quill is oiled. It therefore appears that reduced wear of the quill can be expected and therefore a longer quill life.

As a result, it seems that the best procedure is to oil only the underside: this confers the benefical protection and avoids any effect of oil on the top surface reducing the player's "feel" of the plucking action.

It has not been ascertained whether there are differences in the performance of oils or greases when applied to the underside of the quill which plucks a new iron string.

Restoring the original plucking strength through oiling the underside

Returning to the experiment of testing the effect of oiling the underside of a quill which has become "hardened" through playing: This same hardened quill was then liberally oiled with Ballistol (see the list of oils below for further details) on the underside and left for 45 minutes, after which period the under surface was wiped dry of oil with a cotton bud. The plectrum was found to have regained exactly its previous plucking strength. Furthermore, this strength did not change during a further 200 plucks, indicating that the improvement is longer lasting than merely polishing the quill.

This result is surprising considering that oiling the top surface has relatively little effect in restoring the prior plucking strength, as found during extensive testing reported above. Furthermore, the improvements possible with oiling the top surface were only gained after further playing. However, the practical implications are that oiling the underside will "restore" a quill to normal performance, albeit with a certain delay (45 minutes) until the oil has sufficiently penetrated the quill.

Why does oiling have an effect?

Although it is unnecessary for the harpsichord technician to know why his methods work, it is nevertheless of interest to understand the mechanism of oiling.

There are clearly different effects of oiling, depending on whether one applies it to the top surface or the underside. I have already suggested two explanations. In the case of oil applied to the top surface it seems as if the dispersal of abraded quill material is involved. When oil is applied to the underside it is readily absorbed, so it must fill cavities in the quill structure. For this reason I suggested that the oil being incompressible created additional stiffness from being being trapped in the cavities.

Why it should be that oiling the underside is so much more effective in preventing abrasion of a quill, even with a new wire, is not clear. Can it be that the oil being incompressible supports the interstitial cavities against collapse? It would be the task of further research to investigate this matter, probably at the microscopic level.

It is also unclear what caused the temporary increase in stiffness of a partly abraded quill when oiled on the top surface and left to relax a few hours. Could it be that "flakes" of quill material are caused to stand up by the partial absorption of oil, which in turn create a rougher surface for the string? It is a hypothesis which could be tested.

Requirements for oils

Two essential requirements for an oil, as applied to the underside, would be a non-drying quality and long life since the oil will be absorbed by the quill structure and presumably remain there (at least in part) as long as the quill is in use.

Since Ballistol is considered to meet the requirements of non- drying, long shelf life, and minimum deterioration in use, there was no practical purpose for me in rigorous testing of less suitable oils.

Vogel's Kielöl and almond oil may in practice be equivalent to Ballistol for oiling the underside, but I have not tested this. I have found the shelf life of Kielöl is apparently longer than stated (1 year). I have no reports that the three-register harpsichord I quilled in 2006, which quills were oiled with Kielöl on the underside, has given an unsatisfactory performance.

Almond oil is commonly classified as a "non-drying" oil. I can confirm that almond oil does not show any tendency to "dry" even after a month, when spread as a thin film, but after 5 months exposure to the air the oil becomes noticeably more viscous and sticky.

For quills one preferably requires the assurance that an oil will not harden after longer periods. The watch industry changed from "natural" oils (e.g. neatsfoot oil, of animal origin) to "synthetic" ones (paraffin based) in order to reduce the gumming effects of oil over time. Frei reports that this changed the maintainance period for watches from about 18 months to 5-7 years; good for the watches, but bad for the watch cleaning business.

These considerations on oils might appear overly cautious to the harpsichordist, but for instruments which are used professionally, the long-term use of unsuitable materials or procedures will eventually cause higher maintainance costs.

The life of quills

I have not tested whether oiling the underside extends the life of the plectrum, although the indications are that wear is significantly reduced by this procedure. It would be necessary to define what one means by "life". Marc Vogel GmbH claims an "extended life" of the quill through the use of their Kielöl, although their recommendation is to oil the top surface. Tilman Skowroneck (p. 17-18) is sceptical that quills soaked in oil last longer.

It is apparent from the results I have reported that in order to decide such an issue one would have to design the tests so as to compare quills oiled on the top (or on the underside) with untreated quills. Would one use a "brute force" playing method which continued plucking an untreated or treated quill, even if it showed "hardening"? Obviously, in the real harpsichord world one would ensure, in one way or another, that the plucking strength remained relatively constant. Presumably the "reference quill", i.e. the one not oiled, would just be re-voiced when it hardened and tested again "dry". However, this regime of use could be said to provide an unrealistic and unnatural loading of the quill. It is, therefore, not self-evident how one should compare an untreated quill with a treated one. Furthermore, a testing machine for this purpose would need to have the quill pluck a string with a suitable force. It should also be able to recognise the onset of "hardening" in order to then halt the testing so that some intervention could take place. It would also have to recognise when a quill had weakened substantially and then halt the testing, since quills often fail by becoming weak or developing a split. Would one use a new string for the test or one which had been "run in"? If a number of quills were tested in this fashion and the testing parameters were carefully controlled it should be possible to produce results which reflect the use of quills in a harpsichord and which are statistically significant to a specified level of confidence. However, it will be clear from this brief assessment that the testing required is not a trivial undertaking in order for any statistically-significant results to be determined.

Creaking noises

A "creaking" noise is an inevitable phenomenon of quills and often increases just after oiling, possibly due to the (hypothetical) "scales" standing up. I have only removed it temporarily using lubricants, although it may sometimes be lessened by oils or greases. Polishing with the root of a swan feather was ineffective. It can be transitory and appears to depend on large, local disturbances in the surface of the quill structure. Presumably as the quill is worn away the "creaking" may also disappear.

Other "stiffening" effects

Testing showed that an increase in plucking strength occurs (typically +8 mm) with quills which have been oiled or greased on the top surface and then left a few hours to "relax". This phenomenon appears not to have been reported until now and controlled testing with a weight is necessary to reveal it. After 10 plucks the extra strength is usually reduced to near the previous value. Thus, one might speak of a "waking up" period, when the quill quickly loses the additional "stiffness" on being played a few times. The sensitive player will feel these variations, but might never have measured them. Thus, the "real world" situation for quills oiled on the top surface is probably one of continuously-changing plucking strength, perhaps held within a range of 8 mm (i.e. +/- 4 mm). This may be part of the explanation for the reputation quills have for being variable in touch.

A slight increase (c.+6 to +8 mm) in plucking strength also occurs if one applies oil (or grease) to the top surface of a quill which has been in continuous use. The fact that the increase in plucking strength does not necessarily occur immediately when oiled, but requires 10 plucks to develop the additional "stiffness", suggests that the oil or grease has to be absorbed by the quill. The experience of oiling the underside of the plectra, which caused an increase in stiffness without plucking having occurred, is perhaps evidence of a similar mechanism of oil absorbtion.

Humidity and temperature effects

It is often reported that quill (e.g. turkey) is sensitive to humidity and temperature. Tests I conducted in 2006 on a few voiced swan quills showed no measurable change due to a large increase in humidity over about 12 hours. Only one plectrum in 20 samples showed a change following a decrease of humidity (with an attendant increase in temperature). These tests were conducted on relatively unworn plectra, which were probably mostly untreated with oil. Having discovered the stiffening effect which occurs with quills that have been oiled on the top surface and left to relax, there is yet another factor to consider. The practical testing problem would be in separating effects due to humidity change and those due to stiffening following relaxation since it would be necessary to wait some time for humidity to penetrate the quill and in this period the stiffening effect could take place. It may be supposed that the stiffening effect I have observed could have been attributed by others to temperature or humidity effects. Only systematic testing along the lines I have indicated here would show what the causes might be. My testing has been conducted solely with swan quills, which material was chosen following Martin Skowroneck's recommendation of their durability (German p. 92; English p. 226). He also recommends seagull heron and condor feathers (ibid.). Other feathers apparently yield poorer results: turkey quills reportedly give difficulty with high and low humidity.

I have not yet conducted any humidity and temperature tests on plectra which were oiled on the underside, but no stiffening effect following relaxation was noticed in a working instrument over several weeks.

Conclusions

The primary findings are as follows:

1. The "hardening" effect in bird quill used as plectra is due to roughness on the surface, leading to increased friction, thereby requiring more effort to effect a pluck. Only Broekman appears to have reported this until now.

2. Abrasion of the surface of an untreated quill is rapid with new strings, presumably being due to the microscopic surface structure of the drawn wire. This finding has not been previously reported.

3. Oiling the top surface of the quill with Kielöl (Vogel's quill oil) or Ballistol, is only moderately effective in controlling the abrasion produced by the string and thereby keeping changes of plucking strength within a playable range. Skin grease is worse than these oils. The traditional olive oil is a poor performer in this respect. Only Synt-A-Lube was found to prevent "hardening" of the touch.

4. An effective treatment for quills which both reduces abrasion of the surface and restores the mechanical performance of abraded quills is to soak the underside of the quill with a suitable oil. This finding is believed to be new. Ballistol has been found satisfactory for the purpose. At the time of writing a 3-register instrument has experienced no "hardening" of any quills over a period of 6 months indicating the success of the strategy.

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APPENDIX

Oils and lubricants in comparison, used on the top surface of quills

The following comments relate to the treatment of only the top surface of quills on a newly-strung instrument. They became less relevent after the benefit of oiling the underside had been established. However, this information may have some value for those who have oiled the top surface and wish to understand the effects of different oils. It also gives some indication of the extent of my testing.

The reader is reminded that without any treatment a new quill plucking a new string would probably show an increase in plucking strength, measured with a voicing weight of +25 mm (nearer the player), which is colloquially referred to as a "hardening" of the touch.

The tests performed using these oils were on new and used quills, but some oils have been tested only once, although usually up to 1000 plucks. It would be necessary to test several quills with each material in order to give a statistically-reliable, quantitative description, i.e. how large the effect is. However, the descriptions below are believed to be qualitatively correct, i.e. in describing the type of performance involved.

Klever's "Ballistol" and Marc Vogel GmbH's "Kielöl" [= quill oil] are both suitable for new quills and treating those which show signs of "hardening", i.e. where the surface has become abraded and is rough. On new quills with new strings the initial roughness is often overcome with Ballistol or Kielöl after 400 plucks with an increase in plucking strength of +3 to +10 mm in this period. On already "hardened" quills (i.e. c. +25 mm) these oils produce an immediate improvement of about -10 to -15 mm, and after c.150-300 plucks the voicing weight might be only +3 mm from the original position. Kielöl might be the better of the two oils for new plectra, but it might also be a slightly better lubricant, which can be interpreted as a worse oil from the point of view of touch. Further tests would be required to establish if there is any significant difference between the two since the characteristics of quill vary widely. No quill ever became "hard" (i.e. + 25 mm) during testing when there was still Kielöl or Ballistol on the top surface, although there was an increase in plucking strength.

Ballistol is mostly a paraffin oil of medicinal quality, and is thus a "synthetic oil". It was originally formulated as an oil for guns and the shelf life is said to be several decades. It is relatively inexpensive (50ml currently costs € 2.67 + sales tax from www.conrad.de). This oil thus represents the best value and should have shelflife of several years, if not decades (according to manufacturer's information).

Marc Vogel's Kielöl is stated to have a shelflife of c. 1 year. The composition has not been disclosed but is stated (private communication) to contain vegetable matter. 30ml currently costs € 8.70 + sales tax.

Olive oil (good quality, cold pressed, extra vergine) was found to give a high initial plucking strength (+20) on new quill, +12 by x50 plucks, reduced to +6 by x400 plucks, thereafter returning to +11 by 1000 plucks. It was ineffective on quills which were already "hard". Even a quill which had already been plucked 2300 times ran "hard" while coated with olive oil, suggesting that its usefulness is limited. Olive oil might also become sticky with time and is therefore not to be recommended.

Moebius Synt-A-Lube 9010 is an expensive synthetic Swiss watch oil, € 19.50 + sales tax for 2ml, with a stated shelflife of 6 years. It was the only oil tested which prevented "hardening" of the touch (when used on the top surface). On one test it had the effect of lightening the touch of new quill within the first 1000 plucks (-3 mm immediately, -5 mm after 100 plucks, -7 mm after 700 plucks), so it is obviously effective as a lubricant and therefore less useful for quills when we would like our adjusted voicing to remain as it is. Somewhat surprisingly, given this good performance (and as with olive oil), Synt-A-Lube was ineffective on abraded quills which were already "hard".

Klüber Montagepaste [assembly grease] 46 MR 401 is a white synthetic grease, with a viscosity not much more than olive oil. It has the effect of reducing a "hard" quill from +35 mm to only +10 mm immediately and to +5 mm (or possibly to the original value) after 10 plucks. After 500 plucks the quill was still working normally. The disadvantage is that it removes some of the "feel" of a quill plucking the string by reducing the friction. It could find use where it is desired to restore the original plucking strength quickly and with the minimum of work, for example in an entire register of quills, which has uncertain and variable performance and must be brought quickly to a playable state. It has not yet been tested on new quills.

Skin grease has little immediate lubricating effect in reducing the plucking strength of an already rough quill. On a new quill a gradual increase in plucking strength up to +14 mm at 600-800 plucks was observed and by 1000 plucks the plucking strength was still at +12 mm. Thus, skin grease has a relatively poor performance when used on new quills for "running them in", although it will keep them in a playable state. When the quill has already been well used (i.e. after 1000 plucks), skin grease was found to be effective in keeping one quill at its normal strength over 1800 plucks (at which point the testing was stopped). In retrospect it must be questioned whether the effect was due to the grease or that the string had become polished by this stage. These findings revise previously published opinions about the effectiveness of skin grease.

Petroleum jelly (Vaseline) has a slight and immediate lubricating effect (-10 mm) when used on a "hardened" quill, but the strength of pluck was still +10 mm after 500 plucks so this material is comparable with skin grease in effectiveness.

Emu oil has been described by Keith Hill. Although usually called an oil, has the viscosity of a light grease (which may vary with temperature). When used on a new quill it showed an immediate increase in plucking strength (+11 mm), leading to a significantly greater plucking strength (i.e. "hardening") of +22 mm after only 10 plucks, which was reduced to +2 mm by 400 plucks, but had not reached the original value until 600 plucks. Thus, it appears to be worse than Kielöl or Ballistol, but may be slightly more effective than skin grease. Since it is from the emu bird it will, like other animal or vegetable oils, deteriorate with time and may be subject to bacterial attack. It is usually sold without a preservative and said to have a shelf life (unopened) of 6 months to 3 years. Prices are around € 18 for 55ml (+ sales tax).