CLOCK LINES – 3

Significance of creep and concluding remarks

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Significance of creep – longcase clocks

A typical 8-day 2-fall longcase clock driving a barrel of 50 mm diameter has a line length of 2.4 metres. Using the measured data and extrapolated creep rates of natural gut and nylon-6, we can obtain the results in Table 3. These figures and the writer's conclusions therefrom must be treated as indicative only as the actual creep rate will be determined by line length and diameter, driving weight, number of falls and probably several other factors as well.

Longcase clock (2.4 m 2-fall line)	Natural gut	Nylon-6
Elastic extension	0.7%	1.6%
Initial elastic extension fall of weight (2-fall)	8 mm	19 mm
Stage 1 creep over 10 days (workshop testing)	1.0%	1.0%
Creep fall of weight after 10 days	12 mm	12 mm
Creep additional barrel turns (50 mm dia.) (approx.)	+ $^{1}/_{12}$ turn	+ $^{1}/_{12}$ turn
Stage 1 + 2 creep over 7000 days (20 years)	3.4%	3.8%
Creep fall of weight after 7000 days	40 mm	45 mm
Creep additional barrel turns (50 mm dia.) (approx.)	+ $^{1}/_{4}$ turn	+ $^{1}/_{4}$ turn

Table 3: Significance of creep in a longcase clock (20 MPa)

Table 3 is divided into three sections:

- Initial elastic extension. This will (or should) be eliminated during the initial set-up of the driving weights and final adjustment and/or tying-off of the line to length,
- Stage 1 creep over 10 days representative of the time the clock is under set-up and test in the horologist's workshop,
- Stage 1 + 2 creep after 7000 days (20 years) use.

Over 7000 days (20 years), both the additional fall of weight and number of barrel turns are unlikely to be worrying for a longcase clock whether natural gut or synthetic gut. If very unlucky the worst case scenario is either up to ¼ riding turn on a grooved barrel or, if the 40 or 45 mm creep allows the weight to rest on the bottom of the case, a run time reduced by up to 3 hours. If up-stopwork is fitted as in a regulator clock, no riding turn could develop.

Significance of creep – fusee clocks

With fusee clocks the situation is more confused as the line tension reduces as the mainspring unwinds.

Assuming the fusee is perfectly matched to the mainspring characteristics and is initially set-up perfectly, line creep will effectively cause the fusee shape to be increasingly mismatched to the mainspring. This is because the line extension will result in the mainspring being less fully wound than it was before creep set in, and this reduction in line tension will vary from fully wound to fully unwound. These effects are complicated to assess quantitatively and is something the writer shall not attempt.

Stripped down to the basic but pessimistic assumption of a constant 60 MPa stress from a 55 mm diameter barrel and noting a typical English fusee bracket clock has a line length of 1.4 metres, the significance of the creep is tabulated in Table 4. And as in the significance of creep in weight-driven clocks (above), these figures and the writer's conclusions therefrom must be treated as indicative only.

Fusee clock (1.4 m line)	Natural gut	Nylon-6
Elastic extension	3% (42 mm)	5.5% (77 mm)
Decrease in barrel turns (55 mm dia)	+$^{1}/_{4}$ turn	+$^{1}/_{2}$ turn
Stage 1 creep over 10 days	1.7%	5.2%
Line extension	24 mm	73 mm
Decrease in barrel turns (55 mm dia) (approx.)	+$^{1}/_{8}$ turn	+$^{7}/_{16}$ turn
Stage 1 + 2 creep over 7000 days (20 years)	6.0%	8.0%
Line extension	84 mm	112 mm
Decrease in barrel turns (55 mm dia) (approx.)	+ $^{1}/_{2}$ turn	+ $^{5}/_{8}$ turn

Table 4: Significance of creep in a fusee clock (60 MPa)

As in Table 3, Table 4 is divided into three sections:

- Initial elastic extension. This will (or should) be eliminated during the initial set-up of the fusee,
- Stage 1 creep over 10 days representative of the time the clock is under set-up and test in the horologist's workshop,
- Stage 1 + 2 creep after 7000 days (20 years) use.

However, there are several differences; the fusee always has up-stopwork so any line creep always results in a reduction in the mainspring torque. The above figures are also pessimistic because the delivered mainspring torque and hence line tension typically falls to as little as 40% or less of the fully wound tension by the end of the going period.

In addition, mainspring 'set-up' will be affected, set-up being typically between ¾ to 1¼ turns. The full elastic stretch will not take place until the mainspring is fully wound for the first time, and during first unwinding Stage 1 creep will commence as well as the elastic stretch slightly reduce throughout the going period. For natural gut, elastic stretch plus Stage 1 creep taken together will result in the loss of something approaching ½ barrel turn of set-up, while for nylon-6 most, if not all the set-up will be lost.

What this implies is that, especially with a nylon-6 line with its initially high Stage 1 creep, this set-up must be restored after the first few weeks of testing before the fusee clock is released for use. That this set-up is restored is even more important when one sees the further reduction in set-up by Stage 2 creep over the next 20 years.

Even if Stage 1 creep is eliminated and one somehow has the ability to match fusee to mainspring after including creep effects, Stage 2 creep throughout the clock's working life will contribute to a mismatch between fusee shape and mainspring characteristics, making constant torque less achievable.

Superficially, while the combined 7000 day Stage 1 and 2 creep of natural gut (6%) may seem lower than that for nylon-6 (8%) natural gut, the reverse is actually true if Stage 1 creep is eliminated during initial testing and set-up. From Table 4 ,Stage 2 creep alone for natural gut is 4.3% and for nylon-6 is 2.8%. As natural gut was used by 18th and 19th Century clockmakers for domestic fusee clocks, on this basis it is difficult to argue against the use of synthetic line as an alternative.

General comments

Conservation or replacement?

The engineer would always see a driving line as an item with a finite life requiring periodic replacement. Inspection is always required at all service intervals, checks being made for cuts or fraying at sharp bends and where the line might rub over any stopwork levers, etc. At any sign of fraying, replacement should be mandatory. In practical terms, cutting out damage and splicing is not an option.

Conservationists, who by and large would regard a stranded steel or brass/bronze line, or a nylon-6 line as not falling within their purview, may argue that natural gut should not be replaced, but that would generally require that the clock become a merely static ornament. Others might argue that natural gut should be replaced with natural gut, though why replacement of an earlier (probably not original) natural gut line with a modern natural gut line should be regarded as conservation the writer is unclear.

Replacing a gut line with a steel line is sometimes frowned upon by horologists as it might damage (mark) the barrel or fusee. It is an interesting comment, the writer being unclear why a steel line will cause more damage than, say, the links of a steel fusee chain and the higher localised pressures associate with the link edges.

Failure of a line, particularly of a spring-driven fusee clock line, will not infrequently result in damage to the great wheel gear teeth due to the explosive release of mainspring energy. It is a balance between relatively short-term conservation of the existing natural gut and damage that is decidedly not conserving other parts of the movement. All in all, it is a difficult subject, to which the answer generally seems to be in the eye of the beholder or, perhaps more importantly, the owner of the clock. And at this point the writer shall desist from further comment.

Life

From enquiries made by the writer, it is probable that an 18th or 19th Century owner would expect to have his or her clock serviced every five to ten years, at which time the natural gut line would be replaced (other types of line were, of course, not available). This is probably a good life for a mammalian collagen/protein mix which is essentially what natural gut is, and one only has to look at the life expectancy of leather not regularly nourished to see how a heavily-stressed gut line might age. Even with the improved natural gut available today from manufacturers such as Babolat of Lyon (France), 20 years is probably the most that one should expect, though the writer's experience suggests a life of 40 years is quite possible.

Subject to the avoidance of fatigue damage resulting from repeated sharp bending, the life of steel or brass/bronze lines is probably greater than natural gut while, in the absence of ageing tests on nylon-6 lines, prudence would suggest 20 years should be seen as their replacement interval.

Concluding remarks

In summary, the writer fully acknowledges that further work is needed, but his tentative conclusions from this paper are:

- 7 x 19 stranded 316 stainless steel line is, in the writer's view, the most suitable material for clock lines of all types,
- Brass/bronze lines are to be avoided, and are not recommended for fusee clocks or weight-driven clocks where down stopwork is not fitted. If a brass/bronze colour is required, consideration should be given to using plated steel lines,
- Both high-quality natural gut and Nylon-6 ('Perlon') are very satisfactory for weight-driven clocks,
- Subject to set-up adjustment after the first 10 day trial period, high-quality natural gut and Nylon-6 (Perlon) would seem equally suitable for domestic spring-driven fusee clocks,
- Only stranded steel lines (or fusee chains) should be considered for precision spring-driven fusee timekeepers.

And finally

While freely acknowledging the engineering logic is highly flawed, a few thoughts are offered as aide memoires:

- On the suitability of brass/bronze for fusee lines: Would you make a fusee chain out of brass?
- On the life of natural gut: Perhaps 20 years, which is the design life selected by the Original Creator of the donor animal?
- On marine chronometers: Would you trust the precision of your navigation to a creeping fusee line?
