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Breguet Hands on Watches and Clocks

Ideas for a Condliff-Inspired Skeleton Clock

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Motivation

The current Sydney Clockmakers Society (SCS) project on Condliff's skeleton clocks has sparked various debates on methods and styles in many areas of clockmaking.[1] I have already reported on the radial surrerwerk strike mechanism that was developed in this project.[2,3] Here I report on my slant on the clock hands.

CNC was to be used by several of us, so the need arose to specify the coordinates for the automatic cutting. The hands used by Condliff are often quite elaborate, and while these are not beyond being made by us with CNC milling, it was thought that there might be a more elegant solution. 'Breguet hands' sprang to mind; indeed, such use on a contemporary Condliff-inspired skeleton clock was recently reported in the *HJ*.[4–6]

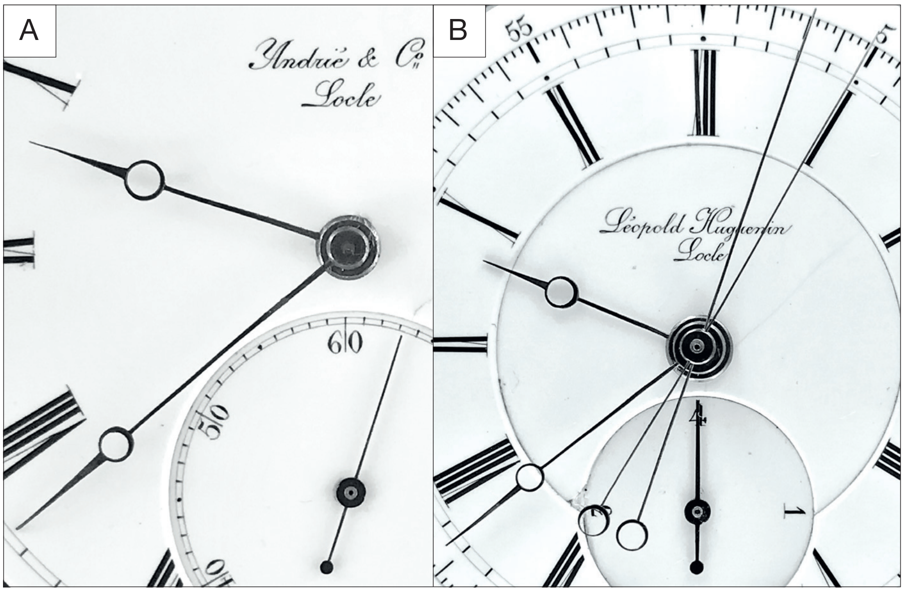
As with the question of the most aesthetically pleasing form of wheel crossings, the next problem was to define the shape of the hands in a way that would be readily programmed in the CNC computer.[7–9]

Examples

Provided there is overall 'sympathy' with the style of the clock, or watch, Breguet hands seem to be regarded as 'indisputably elegant'. What, though, constitutes the 'best' proportions of these, since they invariably differ from one manufacturer to another? Even for Breguet himself, there were variations of his basic style over many years.[10] Two examples with this style of hands on nineteenth-century Swiss pocket watches, from my own collection, are shown here, **Figure 1**; everyone I know declares these (interpreted generally) to have 'a certain bewitching something' or, in French, some *je ne sais quoi*!

The outer circle or 'head' is described as a 'hollow apple or a crescent moon' because it has an eccentric circular hole, which helps give these illusions.[11] Another obvious feature is that the base of the triangular tip is wider than the far end of the long trapezoidal arm (the body of the hand), and in many cases, it is wider than the base of this arm.

Despite these 'design constraints' there is still a lot of scope for variations on the theme, and manufacturers have certainly taken the liberty to make adjustments. The success or otherwise of achieving pleasing outcomes can be seen during a horological museum visit, or from searching the Internet; **Figure 2** is an image of one such collection.



Figures 1. Breguet hands on two high-quality nineteenth-century Swiss watches by Andrié (A), and Huguenin (B) of Le Locle.

Geometry

At a geometrical level a Breguet hand could be described as simply 'a circle, joined to a trapezium, joined to a circle, joined to a triangle'! How does this become transformed into something that is aesthetically pleasing? To help the discussion, **Figure 3** shows the various parts of a Breguet minute hand.

Mathematical Specification

The translation of style into numbers is best done with a graphics computer program, so the visual effects of making changes in proportions (in the present case of clock hands) can be effortlessly inspected and repeated. With this in mind I wrote a program in *Mathematica* that required the assignment of numbers to the various features shown in **Figure 3**.[12]

Specifically, the span must be specified, as for a minute hand this is typically the distance between the centre of the minute arbor and the inner circle of the chapter ring on the dial. The inside diameter (ID) of the hub of the hand depends on the diameter of the minute arbor, or the ferrule that fits on to this arbor. Likewise, the outside diameter (OD) of the hub is chosen to give the hub sufficient strength, and yet it should be unobtrusive on the dial. The outside diameter of the head is typically a little less than that of the hub for the minute hand and the sweep-seconds hand, but not for the hour hand. The arm is tapered and its widths at the hub and head must be specified by the designer.

Minute Hand

In the particular example shown below, the minute hand was specified as follows (in mm): span, 69; hub ID, 6; hub OD, 9; huW (width of arm at the hub), 1.5; ζ (ratio of the width of the arm at the head to that at the hub), 0.7; head OD, 7; α (ratio of the diameter of the hole in the head to the OD of the head), 0.7; β (relative offset, eccentricity, of the circular hole in the head relative to the outside circle of the head), 4; ξ (ratio of the width of the base of the tip at the head to that of the outer end of the arm at the head), 1.4; ϕ (ratio of the arm length that is the sum of the head length and the tip length), set to 0.6. These parameter values were used in the *Mathematica* program that generated several intermediate values that were needed for drawing the hand; specifically, with the centre of the hub set at the x, y co-ordinates of (0,0) the centre of the head-circle was at (48.25,0) while that of the eccentric hole was at (48.88,0).

Figure 2. Breguet clock hands showing straight and curved (leaf-shaped) arms, and non-triangular tips; while the majority have sharp acute-angle tips. The extent of eccentricity of the hole in the head, viz the ratio of the thickness of the base of the head to that opposite it, varies from 1 to ~5.

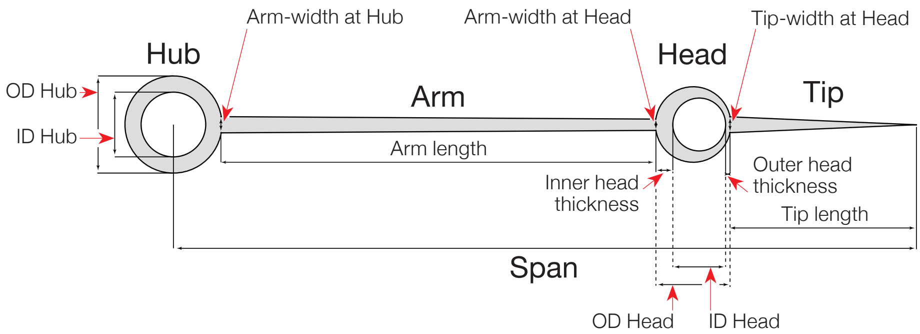


Figure 3. Features and key dimensions of a Breguet minute hand.

Hour Hand

The hour hand was specified as follows (in mm): span, 59; hub ID, 9; hub OD, 12; huW, 1.9; ζ, α, β , ξ were all the same as for the minute hand thus using the same relative proportions in both hands; but unlike the minute hand, ϕ (fraction of the arm length that is the sum of the head length and the tip length) was set to the smaller value of 0.42. Again, these parameter values were used in the *Mathematica* program that generated several intermediate values that were needed to draw the hand; specifically, with the centre of the hub set at the x, y co-ordinates of (0,0) the centre of the head-circle was at (38.85,0) while that of the eccentric hole was at (39.67,0).

Sweep-seconds Hand

This required special consideration of balance of the hand; thus, the first moment of the hand on either side of the centre arbor should be the same. The tail arm length was 33.6 mm. This value was calculated in the *Mathematica* program, in which I used the following specification parameters (mm): span, 70; hub ID, 3; hub OD, 7; maximum tip width, 1; tail head OD, 10; α and β were the same as for the minute and hour hands, *viz* 0.7 and 0.4, respectively. With the centre of the hub at (0,0), the centre of the tail circle would be at (−42.1,0) while that of the eccentric hole is at (−43,0).

CNC Results

Figure 4 shows a three-dimensional rendition of the hands drawn in SketchUp. A computer aided design (CAD) drawing was made of the hands as specified by the *Mathematica* program; and SheetCam was used to convert this drawing into the cutter path for the CNC mill. A strip of 0.7 mm carbon steel plate was clamped on to an MDF base board on the x-y table, and the cutting was done with a 3 mm solid tungsten carbide slot drill.

The hands were finished by hand filing, then polished with 1200 and then 3000 grit Emery paper (wet-and-dry), and buffed using Dialux white compound. The hands were blued by using a paint stripper heat 'gun'

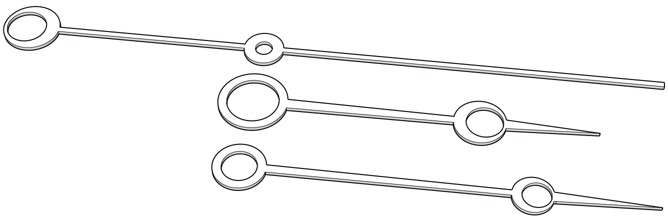


Figure 4. SketchUp renditions of Breguet hands used on the Condliff-inspired skeleton clock as calculated with Mathematica, and used for the CNC mill.

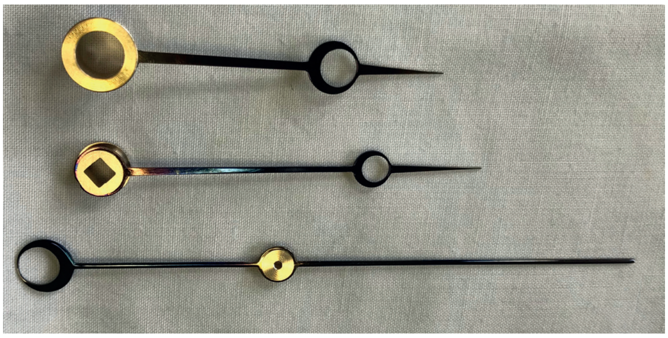


Figure 5. Breguet hands cut from high-carbon spring-steel by using a 3 mm tungsten carbide cutter in the CNC mill. The co-ordinates were specified by the Mathematica program and given above. The hands were fitted to the Condliff-inspired clock shown in Figure 6.

applied interactively to obtain uniform colouring. **Figure 5** shows the results after adding the brass ferrules to the hubs.

In Situ

The hands were installed on my Condliff-inspired skeleton clock, as shown in **Figure 6**. While they are slender they are, perhaps surprisingly, robust because of the hard steel from which they are made and yet, as noted above, this style of hand is weakest at the connection between the head and the tip. It is prudent not to set the time by moving the minute hand directly, hence this should be facilitated by a separate setting system. Their blue colour ensures that the hands stand out against the French-silvered chapter ring, and also against the 'cacophony' of brass wheels visible through the centre of the ring.

Figure 6. Condliff-inspired skeleton clock with Breguet hands.

Conclusions

Breguet hands on watches are typically more 'spidery' than on clocks (compare **Figures 1 and 2**) so the proportions used on watches did not seem to be appropriate for the Condliff-inspired clock. In addition, the minute hands on watches are susceptible to breakage because of the relatively thin outer edge of the head. Therefore, the style used in my clock was more in keeping with that used by Breguet in his clocks.[13]

A few 'ground rules' seemed to be obvious from the literature (and museum examples) and were used here:

1. The hole in the head of the hand (or tail of the seconds hand) should be placed eccentrically, and should be of such an extent that it gives the illusion of a crescent moon (or, less convincingly, of an apple with its stalk being the tip and the eccentric hole being the illusory shine off its spherical surface).
2. The base of the tip is almost always wider than the outer end of the arm.
3. The arm is almost always tapered and most often is straight sided making it an isosceles trapezium. This is confirmed in **Figure 2** (while it is acknowledged that this not a truly representative sample) that shows there to be one hand (top left) with a straight-sided arm, two have leaf-shaped arms, and nine have arms that are tapered (trapeziums).
4. The head of the hour hand has a larger OD than the minute hand; and
5. The tip is shorter on the hour hand than on the minute hand.
6. The arm on the hour hand is shorter (of course) than that of the minute hand, but it is wider overall. Whether the total area of the hour hand is the same as that of the minute hand is moot. I could have built this constraint into the *Mathematica* program but

> I decided it would be one step too close to 'gilding refined gold and painting the lily'!

I sought insights on the design of Breguet hands from the Swiss watch industry. Despite some promising sounding early email exchanges, no information on design principles used by the modern makers of these hands emerged. I gained the impression that the design, while done with computer graphics, is still 'non-formulaic' or 'intuitive', and the drawing task lies with designers rather than those with an academic (mathematical) interest in quantifying the 'elements of style'.

Ultimately, it is for you the viewer, or purchaser, of a clock or watch to decide what most attracts you about the Breguet hands (if it has them). I hope this discussion has raised your critical awareness of which parameter-values define the geometry that makes you decide that a set of Breguet hands is elegant or not.

Acknowledgements

Thanks go to Rex Swensen, with whom I conducted key aspects of the Condliff skeleton-clock project. His breadth of knowledge on constant torque springs, miniature ball races and CNC milling etc is highly valued and, in the context of this article, he is thanked for crossing out the hands on his CNC mill. I now have my own mill with many thanks to Lindsay Drabsch for this. Martin Foster is thanked for providing contacts within the Swiss horological industry regarding the design and manufacturing principles for Breguet watch hands.

ENDNOTES

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12. S. Wolfram, *Mathematica* V11.2.0.0 (Champaign, ILL: Wolfram Research Inc.).
13. Daniels, op cit.