Worcester Cathedral
Guild of Bellringers

GETTING THE HANDSTROKES RIGHT

Summary

During 2018 the garter hole and in some cases the pulley position of various bells were changed to get a longer handstroke pull, in order to make them easier to ring. This paper details the work done and the reasoning behind it.

Background

Some of the Cathedral bells have always seemed much more difficult than others to move around accurately in changes, particularly the middle bells. Their turning dynamics, attributable to their hanging, may be the key factor and that is not something the Steeplekeeper can do much about. But a contributory factor is how well the ringer can cope with any difficulties he is faced with and for this he needs a sensible amount of handstroke reaction time and pull. It certainly seemed worth investigating whether the situation could be improved.

The relationship between the handstroke and backstroke pull depends on the positioning of the garter hole relative to the main pulley. **In theory it should be the same for all bells rung to the balance** (bells 1-8 at Worcester in Cinques and Maximus) but it was not obvious what was most practical for bells rung below the balance. A complicating factor is that the some of the bells, particularly 6, 7 and 8, are rung in a different style (below the balance) when used in the Harmonic Minor Ten or the Clare Ten than when rung in the twelve.

Rather than calculate the exact amount of handstroke pull for each bell it struck me that **the key point was the ratio of backstroke:handstroke and that this could be represented by how far the garter hole was from the pulley in each direction** (Long way round and Short way round) along the circumference of the wheel. The greater the ratio of Long:Short the more handstroke the ringer has. It is not necessary to know the diameter or the circumference of the wheel and the absolute position of the pulley is irrelevant because it is part of the measurement (See Maths note at end). The measurements made in March 2018 are shown below (all in inches). The ratios shown in **blue** are the bells which ringers felt most comfortable with and were therefore felt to be ‘about right’.

	Long	Short	Ratio		Long	Short	Ratio
Treble	156	57	**2.74**				
2nd	157	58	**2.71**	*Sharp 2nd*	157	58	**2.71**
3rd	159	59	**2.70**				

4th	163	59	**2.76**				
5th	169	62	**2.73**	*Sharp 5th*	165	62	**2.66**
6th	168	65	**2.59**	*Flat 6th*	172	63	**2.73**
7th	179	67	**2.67**				
8th	186	66	**2.82**				
9th	202	70	**2.89**	*Sharp 9th*	194	70	**2.77**
10th	208	72	**2.89**				
11th	223	80	**2.79**				
Tenor	243	88	**2.76**				

What was immediately obvious was that the figures represented neither a uniform level nor a pattern either decreasing or increasing. The back and middle bells, particularly the 6th and tenors, had rather low ratios and hence short handstrokes.

Before making any changes though, we needed to know what ratio the bells should have.

What is an ideal ratio?

I looked at three comparisons – what I labelled the Bellhangers Default, the Declared Ideal (mentioned in various studies) and our own Dumb Bells in the Teaching centre which were set up to be 'perfect' when installed in 2007-8.

Note - the rope goes round the circumference (C) of the wheel – expressing this as multiples of the diameter (D) is useful so half of C is 1.5708 D and quarter of C is 0.7854 D. (Since C = D x pi)

The **Bellhanger's Default** is 45 degrees from the top, so g = 0.3927
Short = D/2 + C/4 - 0.3927D = D (0.5 + 0.7854 - 0.3927) = 0.8927 D
Long = D/2 + C/2 + 0.3927D = D (0.5 + 1.5708 + 0.3927) = 2.4635 D
Ratio = 2.4635 / 0.8927 = **2.76**

This usually gives reasonably adequate handstrokes but when it has to be modified to avoid a spoke the hole invariably goes higher not lower on the wheel so in practice they often end up short.

The **Declared Ideal** is for g = 0.4188, an angle of 48 degrees
Short = D/2 + C/4 - 0.4188D = D (0.5 + 0.7854 - 0.4188) = 0.8666 D
Long = D/2 + C/2 + 0.4188D = D (0.5 + 1.5708 + 0.4188) = 2.4896 D
Ratio = 2.4896 / 0.8666 = **2.87**

The **Dumb Bells** have an angle of 46 degrees so g = 0.4014 D
Short = D/2 + C/4 - 0.4014D = D (0.5 + 0.7854 - 0.4014) = 0.8840 D
Long = D/2 + C/2 + 0.4014D = D (0.5 + 1.5708 + 0.4014) = 2.4722 D
Ratio = 2.4722 / 0.8840 = **2.80**
Actual measurements of 149/53 = **2.81** pretty much confirm this

Given that it is not possible to avoid the spoke on every bell (particularly 2#, 2, 3, 6, 7, 8, 9#, 11) I would suggest that any measurement between 2.76 and 2.87 would be satisfactory, with a **target around the average** **2.81** a sensible compromise. Where the spoke gets in the way it is probably better to err on the positive side – being below rather than above - having more rather than less handstroke.

Phase One

Some experimental moves were made in April 2018, deliberately on a mix of front, middle and back bells, six being chosen. By necessity some of these changes had to be greater than I wanted because the existing wooden fillets are quite long, spreading 4" each way from the garter hole and at that stage I didn't want to remove them or drill into them. They have 6-8 fixing screws, dating back to 1928 and completely resistant to my efforts. The tenor required no drilling, just a move back to the original hole (it had been moved to give a shorter handstroke, for reasons which are not clear. This seems to have occurred sometime in 2008).

	Long	Short	Ratio	Move			New ratio
3rd	159	59	**2.69**	**5"**	164	54	**3.04**
Sharp 5th	165	62	**2.66**	**5"**	170	57	**2.98**
6th	168	65	**2.59**	**6"**	174	59	**2.95**
7th	179	67	**2.67**	**5"**	184	62	**2.97**
11th	223	80	**2.79**	**6"**	229	74	**3.09**
Tenor	243	88	**2.76**	**7"**	250	81	**3.08**

The results were quite startling. For the tenor everyone said how much easier it was to ring. Most liked the 11th too, which suggests that **the ratio for the back two bells could usefully be higher than the 2.89 of the 9th and 10th.** For the other bells the consensus was that the changes were good but too much. I rang a peal on the 3rd and liked the way it handled but others didn't so I moved it back to the original hole after a few weeks. No-one commented on the sharp 5th, probably because people had less experience of it. The balance of opinion was favourable for the 6th and 7th. So I concluded that the **middle bells needed to be somewhere around the level of the unchanged 8th, at 2.85** and that **the front bells could comfortably be less than this,** the main evidence being that the 4th was acceptable as it was.

Phase Two

To get a better result on the six bells already changed we removed the fillets (requiring careful drilling out of the screws), drilled the new garter holes where they should be and re-installed the fillets with modern posidrive screws. That way the whole job could be easily reversed if required. It would have been much quicker to break the fillets off and replace them with modern 'bobbins' but they are part of the 1928 heritage and we thought it appropriate to keep what we can. Each one took about 1.5 hours.

We then changed the handstrokes of two further bells (5, 6b).

Phase Three

We tidied up any holes in the wheels no longer needed with wood-filler. The original garter holes were left untouched so that the work is reversible.
Five of the bells were further modified when their pulley position was altered as part of the re-roping exercise - double pulleys were replaced by re-sited singles for 5th, 5# and 6b, and re-siting of the main double pulley enabled the handstroke of the 9# to be longer. The 7th also had its pulley re-sited but this was counteracted by a further change in the garter hole so that the ratio was unchanged. Repositioning the tenor pulley meant the handstroke of the tenor became marginally shorter.

Phase Four

The 5# and 6b were re-worked when they were rehung in new pits, Aug/Sep 2020.

In total the handstrokes have been changed for 9 of the 16 bells.

The current position is -

	Long	Short	Ratio	
Treble	156	57	**2.74**	unchanged
Sharp 2nd	157	58	**2.71**	unchanged - spoke in way of the optimal 2” move
2nd	157	58	**2.71**	unchanged - spoke in way of the optimal 2” move
3rd	161	57	**2.82**	moved 1.5”
4th	163	59	**2.76**	unchanged
5th	169	59	**2.85**	changed when single main pulley replaced double
Sharp 5th	167	59	**2.83**	After rehanging in pit of Flat 6th, Aug 2020
6th	173	61	**2.84**	moved 4” to just below spoke
Flat 6th	177	62	**2.85**	After rehanging in new framework Sep 2020
7th	182	64	**2.84**	moved 3” to just below spoke, changed again when pulley moved
8th	186	66	**2.82**	unchanged - spoke in way of optimal 1” move
Sharp 9th	186	65	**2.86**	moved 4” when new pulley put in
9th	202	70	**2.89**	unchanged
10th	208	72	**2.89**	unchanged
11th	227	76	**2.99**	moved 4” to just below spoke
Tenor	248	83	**2.99**	moved 7” to previous garter hole

Bernard Taylor (Oct 2019 plus Sep 2020 work)
Steeplekeeper

Relevant maths

The rope goes round the circumference (C) of the wheel – expressing this as multiples of the diameter (D) is useful so half of C is 1.5708 D and quarter of C is 0.7854 D. (Since C = pi x D)

The position of the garter hole from the top dead centre of the wheel is referred to either by the number of degrees from vertical or as a proportion of the diameter of the wheel. Let us call this 'g'.
Example - hole at 48 degrees, g = 48/360 x 3.141592654 ('pi') = **0.4188 D**

With the pulley placed in the normal position in line with the wheel vertically and horizontally, once the bell is on the balance the handstroke and backstroke distances are easy enough to calculate -

H = D/2 + 0.4188 D = 0.9188 D
B = D/2 +3C/4 – 0.4188 D = (0.5 + 2.3562 - 0.4188) D = 2.4374 D
Hand as percentage of back = **37.7%**

So the ratio of the backstroke:handstroke **pull** is 2.4374 / 0.9188 = **2.65**
Note that this actually measures the movement of the rope for the handstroke and backstroke which in practice is not quite the same as the pull distance available to the ringer. Generally the ringer tends to end his/her pull as soon as the bell is accelerating away from the balance point. How quickly that point is reached depends on the swing dynamics of the headstock-bell combination.

Whilst this can be calculated for each bell it is much more practical just to measure the distance of garter hole from pulley in both directions and look at the ratio of the two. For the 'ideal' bell illustrated above the maths of this is

Long Distance/Short Distance - Garter Hole to Pulley = **2.87** calculated :
Short = D/2 + C/4 - 0.4188D = D (0.5 + 0.7854 - 0.4188) = 0.8666 D
Long = D/2 + C/2 + 0.4188D = D (0.5 + 1.5708 + 0.4188) = 2.4896 D
Ratio = 2.4896 / 0.8666 = **2.87**

Using this ratio is much more practical because it is easy to measure and easy to work out the effect of moving either garter hole or pulley.