Jim Wheeler's remarkable wooden clapper.

On Christmas Day 2004, just after 10 o'clock while we were ringing for the Cathedral's main service, we heard the dreaded crash and the tenor was silent. It is a sound familiar to lots of towers with heavy bells. The tenor clapper had broken just three years previously and soon after that a gudgeon on the eleventh had to be replaced. The bells being out of action was inconvenient as the Cathedral's bells are now rung more as part of Cathedral and civic life. Eyre and Smith moved quickly and the tenor clapper was replaced under their guarantee and arrived in February. However, we *were* able to ring the tenor again the next day.

Losing the tenor's clapper would normally have meant that we could not ring the 12 bells open on New Year's Day. However, a few months earlier Jim Wheeler had welded an old, broken, cast iron (SG) tenor clapper as a precaution. We don't like the bells to be out of action. This was the beginning of his experiments with clappers and Jim's eventual solution: a tenor clapper with a wooden shaft. We put the welded clapper in the tenor thinking we might get a few rounds and then hear the dreaded crash again. What happened was remarkable. First the clapper didn't break. It lasted until Eyre and Smiths' remodelled and significantly better replacement arrived in February, and it was rung for over 6000 changes, including a quarter peal. Not only did the clapper work, the bell sounded different. Ringers who could remember the last wrought iron (WI) clapper appreciated the hum from this wonderful bell, something that our recent SG clappers could not reproduce. Or so we thought. Jim had obviously done something special and we had to work out what was different…

Current opinion suggests that WI clappers are better than SG clappers. Some pundits think the materials produce a different sound, others, having thought about it, think that the shape of the clapper is more important than its composition. Clappers with thick shafts, over engineered for safety and strength, strike the bell much harder. The bigger the bell, the bigger the clapper and more energy is transferred through the shaft, and the greater the danger of a break. Thick shafts invariably mean that the centre of gravity and percussion (CP) is higher up the shaft towards the pivot. SG clappers are much bigger than their old WI counterparts and they will hit the bell much harder, whilst still accelerating. They do not bounce on impact deadening the sound of the bell. The mass and distribution of metal in a clapper has a significant effect on its dynamics. If the CP is moved away from the staple, in theory, the clapper should bounce, allowing the bell to hum. Just fractions of seconds mean the bell sounds dead or it double clappers. As large bells only rotate 340 to 350 degrees or so in changes (less at Bow), the likelihood of double clappering is reduced. An example of this is the tenor at St Paul's Cathedral which clappers well in changes though will double clapper when rung to the balance. Compared with our new SG clapper the welded SG clapper had a CP which was nearer to the staple. (Where does all this come from and why do you say this. Is the clapper significantly different after welding or did Jim also remove the counterbalance. Is the new clapper a totally different design?) We were not comparing like with like though the indicators were useful. Also, noone had thought welded SG clappers would last for any acceptable period of time. There is no evidence of the weld fracturing in the clapper, so we can deduce, so far, that welding SG clappers can work.

The band was excited and keen to experiment more. Sources of wrought iron were found in Italy and Belarus. Our engineers made 3D designs based on old clappers for wrought iron, SG iron and steel. Visits were made to St Mary, Redcliffe and measurements were taken of other clappers in other large bells.

…Jim then said,

“Why do you think sledge hammers and pick axes have wooded handles?” And then “What would happen to your arms if they had iron handles?”

So Jim argued why not use a wooded shaft in a clapper? Again, current thinking said that this idea would not work especially the issue of joining dissimilar materials. We were keen to find out and the only way to find out was to do it. Jim then took away an old SG clapper and thought of how to replace the shaft with a piece of ash. We were also aware of how important the CP was to the sound of the bell So we………………..Clearly, the welded SG clapper had a CP which was conducive for it just to bounce off the bell at the point of impact just enough for the bell to hum. The new Eyre and Smith clapper performed well in the bell but was of a different profile from earlier designs with a thinner shaft and different distribution of metal throughout the clapper. A thinner shaft and a CP closer to the bottom of the clapper will make a difference to how the bell rings, strikes and sounds. An example of this is the tenor clapper at Exeter. After its shaft had been turned down it made the bell sound different and it also made the bell far easier to ring. (By turning down the shaft the centre of gravity and percussion moves down towards the ball, and makes the whole assembly lighter).

Jim’s redesigned clapper is constructed using the top and bottom ends of an old SG clapper. The metal ends have been cut into a “V” which is joined to an Ash shaft with five Nylock nuts and bolts. The ash shaft is octagonal in shape (is it?) measuring (XXX). This will vary from bell to bell and is determined by the original dimensions of the clapper. A metal plate is placed over the ash shaft. Another innovation was replacing the traditional bush with two sets of double race ball bearings in the staple unit. Jim’s drawing explains how this works. The clapper was made at NDS Engineering at Clifton upon Teme where Neil Sparey supplied the bearings and the workshop premises and Clint Fry did the necessary turning and also fitted the bearings.

Jim’s new clapper has proved a great success and after five months it is bedded in and the sound is superb. The bell also seems easier to handle. Four peals and over 60,000 changes already rung since installation indicate a successful experiment. The ash shaft probably reduces the vibrations and stresses which are produced when the clapper hits the bell. The ten Nylock nuts and bolts which hold the unit together have remained tight and are checked every week.

The potential for further change and improvement are enormous. Other materials may be used for the shaft of the clapperand clappers can be replaced with a spare wooden (or a new material) shaft. So if a break did happen the clapper can be repaired immediately. What Jim appears to have achieved is a successful jointing mechanism to allow the use of dissimilar materials for ball, shaft and pivot in clapper construction. Equally, towers now have the possibility of effecting in-house repairs when clappers fail.

Have we solved the problem? Well we think we've made lots of progress and Jim's experiment seems to be working for the tenor at Worcester Cathedral. The clapper will stay in the bell. Jim's experiment gave these findings:

- the CP of the clapper seems to be important in producing a good sound; the design and distribution of mass in the clapper needs more careful investigation;
- dissimilar materials can be joined together successfully; the debate over materials, SG v WI, ceases to be a key issue.

Of the 26 bells over 40 cwt only one (I think) still has a WI clapper. It is these bells with SG clappers especially where considerations of tonal quality and clappering have been subject to debate. The difference in sound at St Paul's Cathedral with WI (thinner shafts) and SG (thicker shafts) clappers is remarkable. Renewals and repairs to big clappers are extremely costly and take time. It is unlikely that the metal parts of a composite clapper will break as the wooden shaft absorbs most of the stresses of impact and there is less likelihood of a casting flaw in the shaft. If the wooden shaft does break then a repair (if a spare is available) can be accomplished in minutes. Clappers of all sizes of bells could be designed and made to this formula, though it may only make commercial sense for bigger bells.

Worcester Cathedral's tenor has a new clapper which produces a richer sound. Problem solved.

The Worcester Clapper

Sir, - I would like to respond to Bob Smith's excellent treatise on the history of clapper design since the early 1970's. (RW4948; p.171). I must confess to being slightly amused to learn that after consulting with the BCIRA (British Cast Iron Research Assoc.) Whitechapel was advised to use a "cast iron" material, namely SG iron. Just shows how prejudiced metallurgists can be! I wonder what suggestions would have come from a consultant at BISRA (steel orientated) and hence where we might have been today!

Bob tells us that early experiments with fabricated steel clappers were a disaster and that they always failed at the welds. I guess this was predictable unless suitable materials and welding procedures had been used, followed by full heat-treatment (normalising) to eliminate any heat affected zone. Even so, this could still have left stress raisers at the changes of cross-section. It's a pity the experiments stopped here. Perhaps it would be worthwhile re-visiting this option in conjunction with The Welding Institute (TWI).

I agree that machining from solid round bar could be costly and very wasteful of material, but a piece of the same round bar forged roughly to shape using the equipment used to make WI clappers, and then machined to size and heat-treated, would most likely have worked. It was around this time that we replaced the 11th clapper at St Martin's, Birmingham with a forged and heat-treated steel unit that as far as I know was a complete success.

I'm surprised that no one ever considered **cast steel** as an option, given the vast range of compositions and heat treatments that could have been used. Perhaps the bell founders would like to comment.

If clapper failure is mainly restricted to larger bells (>30 cwt) then the extra cost of producing a forged steel clapper for these bells shouldn't be in issue: SG iron could be used for everything else.

As far as centre-of-gravity and centre-of-percussion are concerned, having read Bob's comments I suspect the result of using a lightweight Ash shaft has been to bring the c.o.p. closer to the point of impact. Certainly there seems to be general agreement amongst those who ring the tenor at Worcester regularly that it is easier to ring.

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The Worcester Clapper

We would like to thank Neil Lomas for his letter (RW page 127) explaining "centre of percussion". However, we're not quite sure what we've done with the new tenor clapper at Worcester Cathedral with the Ash shaft, other than having moved the centre of gravity about 2" closer to the ball end. One thought was to remove part of the counter balance, drill and tap the end of the clapper, and produce a removable section that could be varied in size before being screwed back into place. Because the current design seems to work, and six peals have now been rung without incident, we will probably leave things be for the time being. One positive effect now means that the bell can be raised single-handed with the clapper on the "right" side.

Neil's suggestion of experimenting with a tapered shaft like an axe handle we believe misses one of the key conclusions from this experiment. Although the original idea was just to replace the cast iron shaft with a piece of Ash, what Jim Wheeler's team have actually developed is an innovative jointing mechanism allowing the use of vastly dissimilar materials, in which the use of wood on this occasion has become almost incidental. The concept of a tapered shaft was discounted early on as it was felt that the ball-to-shaft joint may not be secure and undesirable stress raisers might be introduced which could cause premature failure. It might be worth pursuing further but would suggest this is work for another team.

The jointing mechanism of the Worcester clapper provides a number of future options and advantages.

- Various materials for the replaceable shaft section could be tried including other hard woods, plastic, Carbon fibre, Aluminium, steel, etc. One of the disadvantages of using wood is quality consistency that could seriously affect service life.
- The ability to replace the centre section means that a broken clapper can be repaired and returned to service almost as easily as replacing a broken stay, and without the delays of sending it back to the manufacturer for replacement or repair.
- Clapper manufacture for larger bells could be simplified with small castings or forgings for the ball & flight and pivot ends produced separately and in almost any material of choice.
- In the future, clapper design would no longer be dictated by available materials and process considerations, i.e. cast iron vs. wrought iron or forged steel.
- It is now feasible to produce composite clappers with specific materials for ball, shaft and pivot sections, optimised for performance in each instance.
- Worn clapper balls can be replaced as necessary without buying a complete new clapper.

We hope our experiments continue to be of interest to your readers and would welcome as much feedback and constructive comment as possible. There has already been considerable interest shown by some of the country's leading towers, and from the bell founders, so watch this space!

Steve Barton
Jim Wheeler
Mark Regan
Worcester Cathedral.

Wrought Iron vs. SG Cast Iron Clappers.

Sir, - Taking up Kenneth Brown's point in his recent letter (RW 2005, 4916.0667) and hopefully adding constructively to the various correspondence (Paul Cattermole, Alan Hughes & David Beacham), I would like to offer the following for your readers' consideration.

Kenneth is quite correct in his description of "wrought iron": a term derived from the early methods of iron manufacture. Prior to modern steelmaking, our ancestors had only a limited choice of materials for clappers; cast iron which was very brittle and wrought iron which was soft and malleable. The latter could be forged into shape by a blacksmith while the former could not. Commercial steelmaking only commenced in 1856 and SG (spheroidal graphite) irons were only developed post-WW2.

Wrought iron is produced by refining molten "pig/cast" iron in a furnace, whereby almost all of the carbon (some 3% or more) is removed, together with most of the silicon and manganese. If the ironmaker had used low sulphur and phosphorus pig iron in the first place, these elements, together with the residual carbon, silicon and manganese, would constitute the "other elements" referred to by Kenneth in the resulting almost pure iron: impurities usually < 0.2% in total. Unfortunately for the iron founder, as the refining process proceeded the melting point of the liquid in the furnace would rise until it began to freeze, and the lump (bloom) of refined iron inter-mixed with non-metallic "slag" materials (iron silicates mainly) had to be taken out of the furnace with tongs. This white-hot lump of iron was then hammered, folded and hammered repeatedly in an attempt to eliminate as much of the slag as possible; the more hammering and folding producing increasingly better quality "wrought" iron. Looking through a microscope at a transverse section of the finished product would reveal a rather fibrous structure: slag stringers running in one direction through the almost pure, soft iron, not unlike Blackpool rock.

Given the above scenario faced by the old bellfounders, it's not surprising that wrought iron was the traditional material of choice for clappers: there really was nothing else. This cannot be true today. There are many modern materials from which to choose, particularly steels, but what is missing today is the historic proliferation of blacksmiths and forgemasters capable of making clappers. The alternative method of manufacture is to use a simple mould and cast the clapper to its final shape, a skill which is still available and significantly enhanced today. The choice for the modern bellfounder would therefore seem to be simply practical and commercial.

David Beacham makes the point that the centre of percussion (CP) of the clapper is very important to the sounding of the bell, and how this is affected by the design of the clapper is explained well. He refers to SG iron clappers having their shafts machined to reduce the thickness, thereby lowering the CP and improving the sound produced, effectively mimicking the design of the traditional wrought iron clapper. Reading between the lines, I suspect that SG iron clappers have to be made with thicker shafts to facilitate the casting process, and the design may have been compromised unwittingly. Alternatively, the thicker shaft may be required for added strength and service life.

If the former observation is valid we seem to have a "tail wagging the dog" situation. If David is correct and the clapper shape and position of the CP is critical, then the material and method of manufacture should be chosen to allow the correct design dimensions to be achieved. The design should not be changed to suit the manufacturing process and material of construction if that design change is going to affect the final sound. This might rule out casting as a process, or SG iron as a material for making clappers, if thin shafts are important to correctly position the CP within the clapper ball.

If forging to shape is to be preferred to casting, then facilities capable of this type of work need to be identified. Inevitably, costs could well be higher but this may be justified in some situations. It would be interesting to do a cost comparison between a forged and heat-treated steel clapper and one made of SG iron. The difference spread over a life of say 200 years, might not be such a problem.

In an earlier article (RW 1986, 3931.0756) I referred to a replacement clapper for the 11th bell at Birmingham, St Martin's which John Anderson and I had forged and heat-treated from a carbon-manganese steel similar to En14B (as was), back in the early 1970's. All the dimensions were as per the old, much-repaired, wrought iron clapper, and as far as I remember it sounded fine and didn't break again. Given this, then perhaps the dimensions/design we copied were more important than the choice of modern material. I suspect the clapper went with the old bells to Escrick and may well still be in use today (?).

I hope the above contributes to the debate without being either overly technical or demeaning, and it would be very interesting to hear the bellfounders' views especially on life-time costs for clappers based on modern materials and processes.

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