TANDEM RIGGING FOR ROWING EIGHTS AND FOURS

Originated by Graeme Cohen

INTRODUCTION

This vignette shows how some old mathematics, classical Newtonian mechanics, in fact, was used in the mid-1970s to explain why there are better ways to arrange the oars on racing eights and fours. These new ways ('tandem rigging') are particularly useful when the boats have no cox (or coxswain), but it is not always easy to convince the traditionalists to change their methods.

TANDEM RIGGING

The standard arrangement of oars on a rowing eight is indicated in Figure 1. The direction of motion is shown, so that we may think of the rudder as being at O.

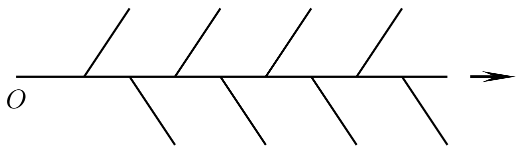

FIGURE 1. Standard rigging for a rowing eight.

Other arrangements are possible. The German and Italian riggings of Figure 2 have been used in various events at various levels, and with some success. Variations such as these are known generally as *tandem* riggings.

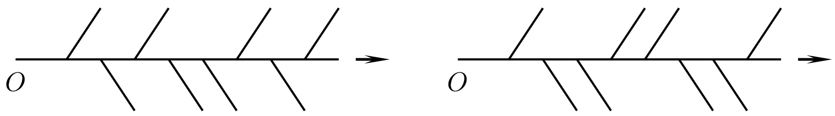

FIGURE 2. German and Italian riggings, respectively, for a rowing eight.

We will describe the sense in which better results might be anticipated if the German or Italian rigging is used. Rowers themselves, and their coaches, are often unaware of the scientific principles behind these variations, as the following quotation from *Australia in World Rowing*[1] demonstrates. It refers to the Victorian eight preparing for the prestigious King's Cup event in Brisbane, Queensland, in 1963.

> On arriving at Brisbane for training we learnt that the new boat ordered from George Towns & Sons for the occasion had been smashed and would not be delivered. We therefore borrowed a boat from Queensland University. It had been set up with tandem rigging. Numbers 'four' and 'five' were on bow side, and 'bow' rowed as number 'two' while 'two' rowed as 'bow'. It sounds and felt rather complicated and *without logical purpose*, and it took some time to become accustomed to the different positions.

We have added the italics. The author goes on to say that the crew won in this borrowed boat, but does not give any credit to the tandem rigging (or German rigging, in this case). Much more recently, German rigging was used by the gold medal winning eight, from Canada, at the Beijing Olympics in 2008. (More on this later.)

[1] A. N Jacobsen, *Australia in World Rowing*, Hill of Content, Melbourne (1984).

Italian rigging is possible also on a four (see Figure 3), and was noticeably predominant among finalists in the 2000 Sydney Olympic Games (to this author, living in Sydney!). Nick Baxter, an Australian Olympic rower, has some idea of the benefits as evidenced in the following question and answer from a local website:[2]

> **Q** You are racing your four tandem-rigged i.e., two bowsiders in the middle. For those who have less experience in fours, how is this different to row?
> **A** The tandem is essentially the same when it comes to boat feel. However, there are some advantages in the timing between the 2 and 3 seat and the way the boat runs. The tandem shifts the forces in the boat so it naturally runs a little straighter and the bow man is more able to apply more force without turning the boat, thus resulting in a little more boat speed (hopefully).

An analysis of tandem rigging for fours, based on what we are about to do for eights, and fully explaining Baxter's comments, is left as an exercise.

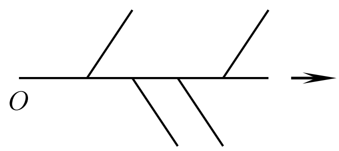

FIGURE 3. Italian rigging for a rowing four.

The standard arrangement of rigging in Figure 1 necessarily leads to a 'fish-tail' swerving, or wiggle or yaw, of the boat, in which with each stroke it veers alternately to the left, then to the right. This movement must be compensated for by efficient use of the rudder (handled most easily by having a cox), all of which implies resistance to the forward motion of the boat, and some loss of speed. We will see that this is not the case with either the German or Italian rigging (which is why, if there is no cox, these will be more efficient).

THE ANALYSIS

To compare the different arrangements, we will first consider a single oar during a 'power' stroke. Let F be the force which the oar exerts on the boat through its point of contact at the rowlock, and let Q and R be the components of F in directions parallel to and perpendicular to the boat's axis, respectively. These are indicated in Figure 4. The figures show the force F as being perpendicular to the oar, but this is not necessary for our analysis. What is important is that the perpendicular component R reverses its direction as the angle θ between oar and boat passes from less than 90°, in the first part of the stroke, to more than 90°, in the latter part of the stroke. We will assume that the force F is the same for all oars (that is, we are assuming the different oarsmen to be identical in their pulling power).

Now we will calculate the moments of the various components about some point on the axis of the boat, such as the rudder O. The moment of a force about a point is the product of the force and the signed distance (positive or negative) from its line of action to the point. The combined moment of a number of forces about the same point is simply the sum of their separate moments.

For all three arrangements in Figures 1 and 2, the components Q each have their line of action through the rowlock (although it was not convenient to show this in Figure 4). If this is distant d from one side of the boat to its axis, then it is distant $-d$ from the other side. The total moment about O over all eight oars is therefore

[2] www.rowingnsw.asn.au/news/athletes07/nick-baxter.html

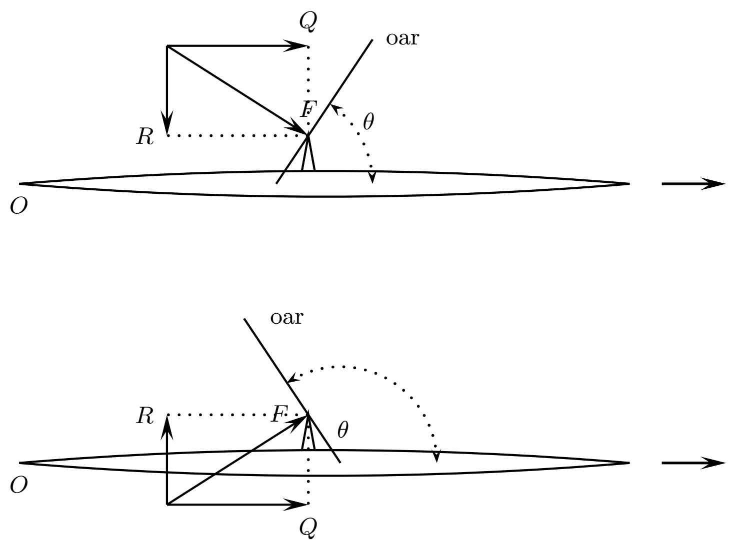

FIGURE 4. Forces at the rowlock, in the early and late parts of the stroke, respectively.

zero, since for four of the oars the moment of Q is Qd, for each one, and for the other four it is $-Qd$, for each one.

The situation is not as simple for the components R. Consider the standard rigging first, with the oars in the first position of Figure 4. Label the R's as R_1, R_2, …, R_8, directed into the rowlocks so that their lines of action are at distances d_1, d_2, …, d_8 from O. See Figure 5. Assume the rowlocks are evenly spaced, with l the distance between them.

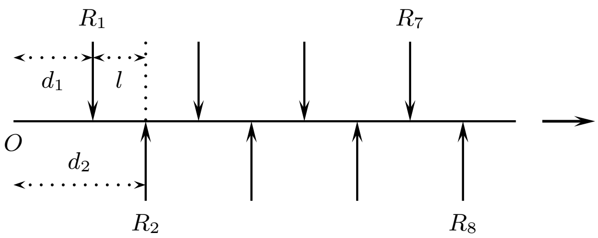

FIGURE 5. Perpendicular forces at the rowlocks, standard rigging.

For convenience, we may take

$$R_1 = R_3 = R_5 = R_7 = -R, \quad R_2 = R_4 = R_6 = R_8 = R,$$

and $d_1 = d$, $d_2 = d + l$, $d_3 = d + 2l$, …, $d_8 = d + 7l$. Then the total moment of R_1, …, R_8 about O is

$$\begin{aligned} &- Rd + R(d + l) - R(d + 2l) + R(d + 3l) - R(d + 4l) + R(d + 5l) \\ &\qquad - R(d + 6l) + R(d + 7l) \\ &= Rl(1 - 2 + 3 - 4 + 5 - 6 + 7) = 4Rl. \end{aligned}$$

This has the same sign as R_2 so that the effect of this combined moment is to turn the boat to the left. In the latter part of the stroke the directions of the forces R_1, …, R_8 are reversed, so the total moment has the opposite sign and the boat veers to the right. This explains the fish-tail motion mentioned before.

Now consider the German rigging in Figure 2. Corresponding to Figure 5,we have Figure 6, but this time, when we calculate the combined moment of the components $R_1, \ldots, R_8$, we obtain

$$\begin{aligned} & -Rd + R(d+l) - R(d+2l) + R(d+3l) + R(d+4l) - R(d+5l) \\ & \qquad + R(d+6l) - R(d+7l) \\ & = Rl(1-2+3+4-5+6-7) = 0. \end{aligned}$$

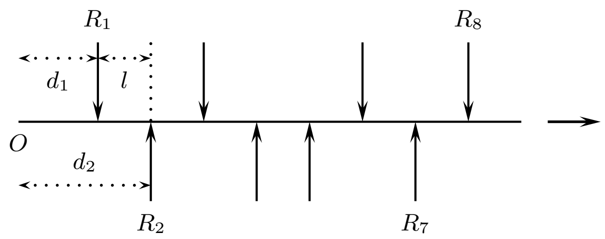

FIGURE 6. Perpendicular forces at the rowlocks, German rigging.

This sum will be zero in the latter part of the stroke, as well.

Thus the German rigging is such that there is no turning moment at any stage of the stroke, so this must be more efficient than the standard rigging. Calculations for the Italian rigging lead to the same result.

CONCLUSION

The ideas in this note were first described by the Australian mathematician, Maurice Brearley.[3] There was some further work in the same direction by John Barrow,[4] a mathematical physicist at the University of Cambridge. The *Washington Post*[5] wrote about Baxter's work in the light of Canada's winning the gold medal in Beijing in 2008 with German rigging. The article ended with the following comment:

> So why did the Canadian rowers use the German rig in Beijing? It turns out this had little to do with turbulence or Barrow's moment analysis. According to Nolte [Volker Nolte, professor of biomechanics at the University of Western Ontario and former coach of the Canadian national rowing team], the Canadians chose this rig because, when everything else had been taken into account, it allowed the team's lighter rowers to sit nearer the bow. This made the bow lift out of the water, causing the boat to 'surf' along when traveling at speed, thus reducing friction with the water. So much for moments of force.

But this is still something of a triumph for mathematics (or physics, if you like, since these are much the same thing at this level). The point of this vignette is to show that old mathematics is still good mathematics, and new applications are continually appearing.

[3] M. N. Brearley, 'Oar arrangements in rowing eights', in *Optimal Strategies in Sports*, S. P. Ladany and R. E. Machol (editors), North-Holland (1977), 184–185. See also M. S. Townend, *Mathematics in Sport*, Ellis Horwood, Chichester (1984), and G. Cohen and N. de Mestre, *Figuring Sport*, MathSport (2007), both of which reproduced the idea with acknowledgment.

[4] 'Rowing and the same-sum problem have their moments', arXiv:0911.3551v3 [physics.pop-ph] (16 Aug 2010).

[5] www.washingtonpost.com/wp-dyn/content/article/2010/08/23/AR2010082303569.html