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Gearing ratio

The standard definition of the gearing is the ratio of the **velocities** at output to input. Higher, heavier gearing, say, in cycling or cars, means higher vehicle velocity at lower engine rotation speed, but lower propulsive force, and vice versa. In rowing, the total gearing could be defined as the ratio of the boat velocity V_{boat} relative to the water to the rower's velocity V_{row} relative to the boat (Fig.1).

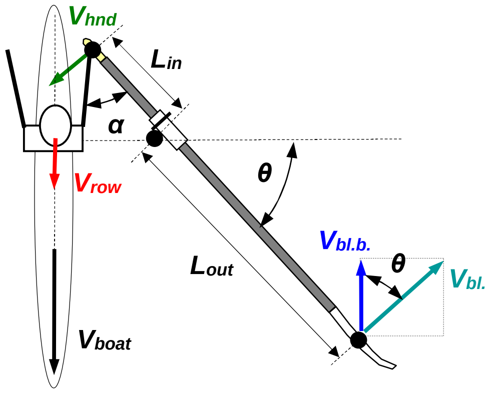

Fig.1

The total gearing could be determined as a product of the following four factors:

1. Static oar gearing is the ratio of the actual outboard L_{out} to inboard L_{in} (RBN 2006/11). This factor defines the ratio of the velocities at the blade to the handle, and ranges from 2.0 in small boats up to 2.3 in big boats. However, the direction and magnitude of the blade velocity is different from the boat velocity, so there are three other factors below affecting the total gearing.
2. Blade slip in the water increases blade V_{bl} and handle V_{hnd} velocities at the same boat velocity V_{boat}, so it makes gearing lighter, but decreases the blade efficiency E_{bl} (RBN 2007/12, 2012/06). As E_{bl} ranges from 70% to 90%, this factor makes the gearing lighter by similar amount. Bigger blade area and its deeper placement in the water decreases slip and makes gearing heavier for rower, but increases the propulsion efficiency.
3. Oar angle gearing is defined by the ratio between the total blade velocity V_{bl} and its backwards component $V_{bl.b}$, (=1/cos(oar angle θ), RBN 2007/03). This makes the gearing heavier by the factor, which varies during the drive from 3 at catch angle 70° down to zero at the perpendicular oar position, then it increases again at the finish.
4. Span gearing. The biggest rower's segments: legs and trunk, usually move parallel to the boat, but the handle path is circular. Therefore, the handle velocity V_{hnd} is higher, than rower's shoulders velocity V_{row}, which means heavier gearing (by 13.3% at A=60°). The force vector from legs and trunk is transferred to the handle at an angle to the shaft α (RBN 2012/08), which is variable during the drive and affected by the spread/span (RBN 2006/12), so, it was used in earlier gearing definition.

As the total gearing is a product of all four factors above, it vary from 6-7 at catch down to 1.7-2 at the middle of the drive, then increases again up to 3-4 at finish. Only the first gearing factor is fixed to the oar dimensions. The blade slip and span factors are partially fixed with the blade size and rigging, but also have a variable component depending on the blade work (shallower or deeper) and oar angles. The third factor completely depends on the stroke length - oar angles. Therefore, **rowers have a limited ability to change the gearing ratio during the race and training by means of varying the stroke length**: a shorter stroke makes the gearing lighter, which is used at the start and during the final push for rapid acceleration; a longer stroke makes it heavier and is used at cruising speed.

At a given boat speed, the gearing affects average handle speed, drive time and stroke rate. For example, lighter gearing makes the drive faster and stroke rate higher, without necessity to change rhythm – "to rush on recovery". The most important practical questions are: how to measure the actual gearing, and how to find its optimal value?

The simplest practical method is a step test (1), which detects the maximal stroke rate that could be achieved without significant change of the stroke length and rhythm. The stroke length should be controlled during this test, because a shorter stroke affects the stroke rate double fold: it makes the gearing lighter and also shortens the drive time directly. The question with this test is: what is the "optimal" stroke rate for each specific crew?

No doubts, the main criterion of the gearing optimization should be the maximal rowing speed, which is directly proportional to rowing power. The maximal power of muscle contraction is defined by the Hill law (RBN 2007/09), which determines it at about one third of maximal unloaded contraction velocity and one third of maximal static force. In attempt to build an optimisation model based on this law, many other factors should be added, such as: 5) joint angles: acute knee angle makes contraction of quad muscles slower and "gearing" for them heavier; 6) coordination of the muscle groups: a rowing style with simultaneous activation of trunk and legs makes their muscles contraction velocity slower and "gearing" heavier, compare to consecutive rowing style (The model could be simplified if the rowing style is considered as constant); 7) individual specifics of the Hill curve for muscles (fast/slow twitch fibres) and rowers, which require expensive testing at a range of contraction velocities.

8) The endurance factor (RBN 2012/01) should be considered: the higher stroke rate at lighter gearing may produce higher power and speed, but can't be maintained for a long time. Also, 9) inertial losses grow with the stroke rate (RBN 2010/05), so "42-44 str/min could be an inertial limit of the stroke rate". Therefore, the most effective gearing appeared to be quite a complicated and individualized model, which was never implemented to our knowledge.

Our simplified general model takes into account factors 1-4 above (static oar gearing, blade area, span/spread and oar angles) and relates them to the stroke rate and power/speed to keep average handle speed constant (2, RBN 2010/01). This model could be helpful to adjust gearing to various conditions, say for a different boat type/speed and stroke rate. Having sensors, Handle Drag Factor HDF (RBN 2011/01, 06) could be used for evaluation of a "burden factor" related to gearing, e.g. **rowing half-slide in a single decreases HDF from 110 down to 90, which is similar to shortening the oar length by 15cm at the same inboard**.

References

1. *O'Neil, T. 2014. Oarsport Rigging Guide.*
2. *Kleshnev V. 2010. Boat Speed and Rigging Chart*