BIOROW
BIOMECHANICS OF ROWING

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Blade efficiency and effectiveness

The blade specific impulse introduced in the previous newsletter could be considered as a measure of its effectiveness (performance), which is often differently directed to efficiency (RBN 2011/10). Similar opposition can be seen in aircrafts, where efficiency increases with the speed, but performance decreases (Fig.1), so the design of the engine is defined by both cruising speed and takeoff requirements.

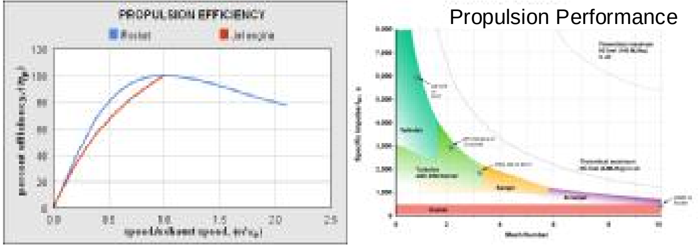
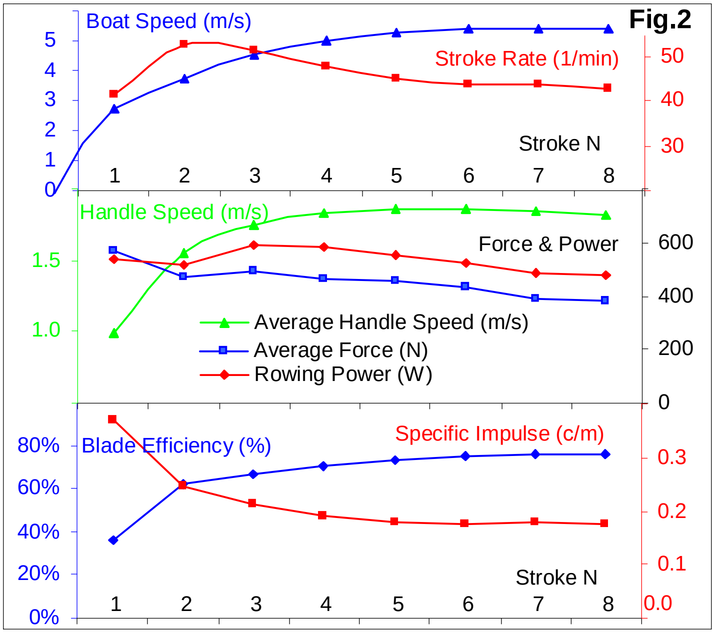


Fig.1. From http://en.wikipedia.org/wiki/Jet_engine

We have done similar analysis for the first eight strokes at the standing start in LM1x (Fig.2):

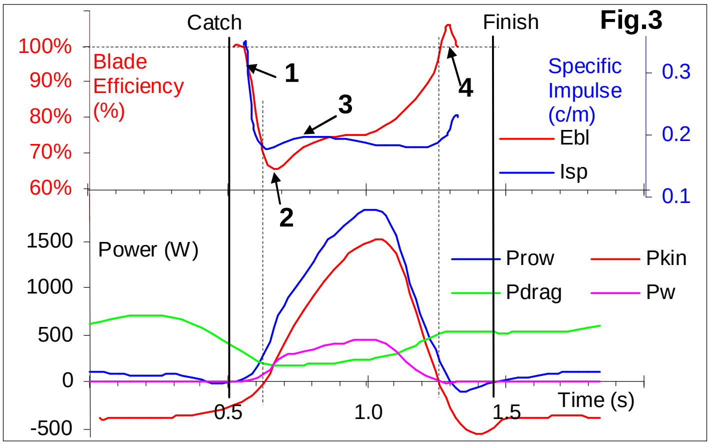


After the first stroke, boat speed increases up to about half of those at cruising speed; blade efficiency has the lowest value 36% only, but specific impulse has the highest value 0.37 s/m. Then, boat speed increases and achieves its constant level after the sixth stroke; but average handle force drops down by 33%, which could be explained by Hill's law of muscle contraction (RBN 2007/09). Work per stroke and rowing power ***Prow*** remains nearly constant, because lower force is compensated by longer stroke length and higher handle velocity. Blade efficiency ***Ebl*** increases more than two times up to 76%, because it depends on propulsive power ***Pprop***, which is proportional to the velocity of the system CM V_{CM}:

$$Ebl = Pprop / Prow = Fprop\, V_{CM} / Prow \qquad (1)$$

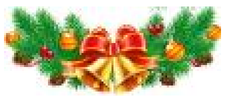
After six strokes, specific impulse ***Isp*** decreases two times down to 0.18 s/m, because propulsive force ***Fprop*** decreases and handle velocity increases (the last is reversely proportional to ***Isp***, Eq.7 in RBN 2013/11), so the rower has to spend more power to provide less thrust.

Similar things happen during the stroke cycle, when velocities of the boat and CM of the rower-boat system vary. Fig.3 shows blade efficiency and effectiveness (***Isp***) of LM1x at stroke rate 32 1/min. The bottom chart shows power ***Prow*** produced by the rower, power transferred into kinetic energy of the system ***Pkin***, power spent on drag at the hull ***Pdrag*** and waste power ***Pw*** of the blade slippage in the water.



At the catch (1), both blade efficiency and effectiveness are high because the power production ***Prow*** is less than drag power ***Pdrag*** and ***Pkin*** is negative, so kinetic energy of the system is spent on overcoming the drag and, partly, on moving the blade forward through the water together with the boat. As power production starts increasing, but the system CM velocity is still close to its minimum, the blade efficiency has its lowest value (2). During the drive, it increases together with the system velocity and ***Pkin***. Contrarily, the specific impulse is quite constant during the drive and has only a small maximum (3) at the **oar angle -40-45° at catch**, which **could be considered as the most effective position for the force application**.

At the finish, the velocities of the boat and system CM increase together with drag power, but rower's power production decreases. At a +30-35° oar angle ***Prow*** becomes lower than drag power ***Pdrag*** (4), the system starts decelerating and ***Pkin*** becomes negative. This means kinetic energy of the system is spent on moving the boat forward together with the blade, while there is still some backwards force at it. It could probably be explained by the hydro lift effect. Product of this forward blade velocity (with the boat) and backward force creates negative "waste power" ***Pw*** and ***Ebl***>100%. **At the finish, the blade efficiency becomes higher than 100%, but this doesn't indicate effective blade work.** Similar to a jet plane, if it suddenly puts engines to low power and exhaust gases become slower than the plane speed, then the efficiency of the jet engines will be more than 100% (Eq.3 in RBN 2013/11), but the thrust became lower than drag, so the plane can't sustain flight very long.



Best wishes for the Christmas and New Year 2014!