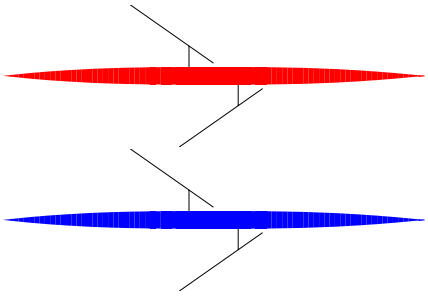
FREE INTERNET ROWING MODEL (FIRM)

EXAMPLES: Pairs

March 25, 2015



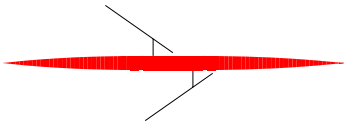
FIRM IS RESEARCH CODE!

Please check all estimates generated by the program against experimental results before committing any time or funds to your project as no liability can be accepted by Cyberiad.

Contents

1 INTRODUCTION

Two pairs examples are included in this version of FIRM. More will be added in future versions.



2 W2-: Women's Pairs

The on-water trial for these two heavyweight female rowers, "Gigi" and "Qing", was conducted over 2000m on a summer morning. Air and water temperatures were not recorded: they were estimated as 15°C and 23°C respectively. Measured values of rigging details, oar angles, gate normal forces, and their anthropometry were used as input to FIRM. Body angle regimes were not recorded but were estimated by the author using a complicated fitting process.

Table 1: Summary of experimental results for this simulation: number of strokes, stroke rate, non-dimensional pull phase duration (t_p/t_s), minimum hull velocity (U_{min}), maximum hull velocity (U_{max}), and mean hull velocity ($\overline{U}$).

Item	Value
Nstrokes	41
Rate (spm)	35.968 ±0.315
t_p/t_s	0.543 ±0.010
U_{min} (ms^{-1})	3.363 ±0.046
U_{max} (ms^{-1})	5.760 ±0.068
$\overline{U}$ (ms^{-1})	4.803 ±0.055

Table 1 summarises the main quantities relating to the simulation for this crew. Values are given ± one standard deviation.

Table 2: Experimental oar-related values for this simulation: Minimum and maximum oar angles, and maximum gate normal force.

Name	Port Oar			Starboard Oar		
	Min. Angle (degrees)	Max. Angle (degrees)	Max. F_{Gn} (N)	Min. Angle (degrees)	Max. Angle (degrees)	Max. F_{Gn} (N)
Gigi				-52.9±0.40	32.8±0.75	733.3±59.6
Qing	-52.9±0.42	30.5±0.55	722.9±24.5			

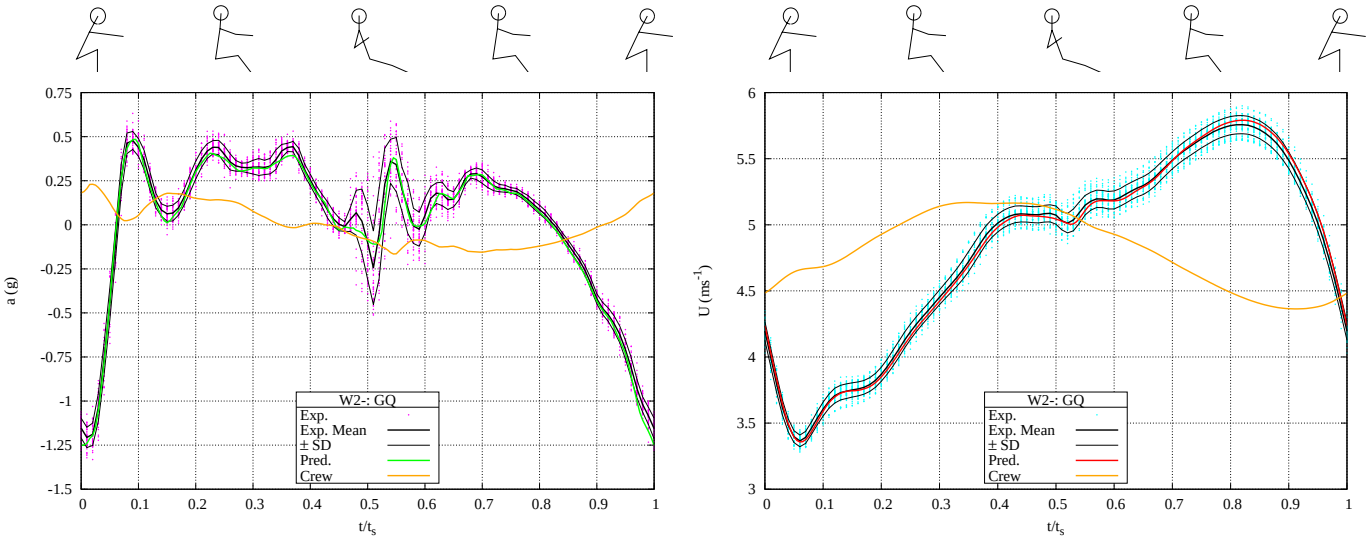


Figure 1: Hull propulsive acceleration and crew cg acceleration (left); hull velocity and crew cg velocity (right).

The hull propulsive acceleration is shown in the left panel of Fig. 1. Experimental data is shown as pink dots; the thick black curve is the mean of the measured values and the thin lines are one standard deviation (SD) either side of the mean curve. The green curve is FIRM's prediction.

Hull propulsive velocity and the speed of the crew CG is shown in the plot at the right of Fig. 1.

The forces in the equations of motion are shown in the left panel of Fig. 2. Drag components during the stroke are in the panel at the right.

Experimental oar azimuth angles and values used as input to FIRM are shown at the left of Fig. 3. Gate normal forces are at the right of the figure.

Blade propulsive forces are shown at the left of Fig. 4. Dynamic oar lever ratios shown at the right of the figure include the effect of variations in the location of the OBCP during the stroke.

Body angle regimes are shown in the two parts of Fig. 5. The angles are the same for both crew members in this simulation.

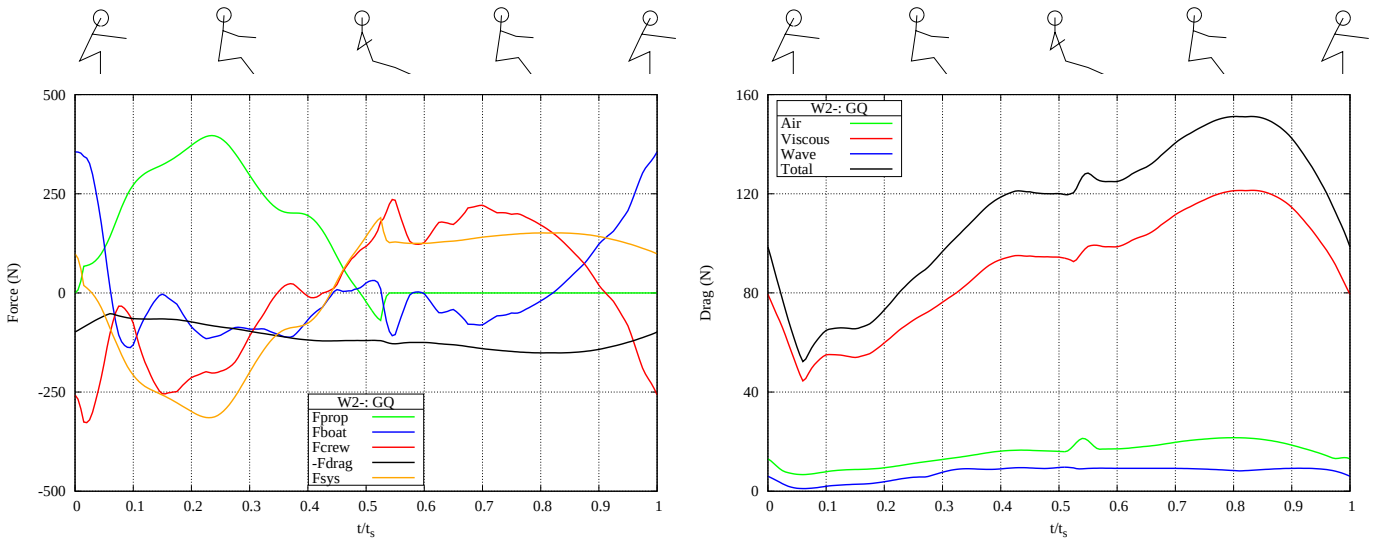


Figure 2: Equation of motion forces (left) and drag components (right).

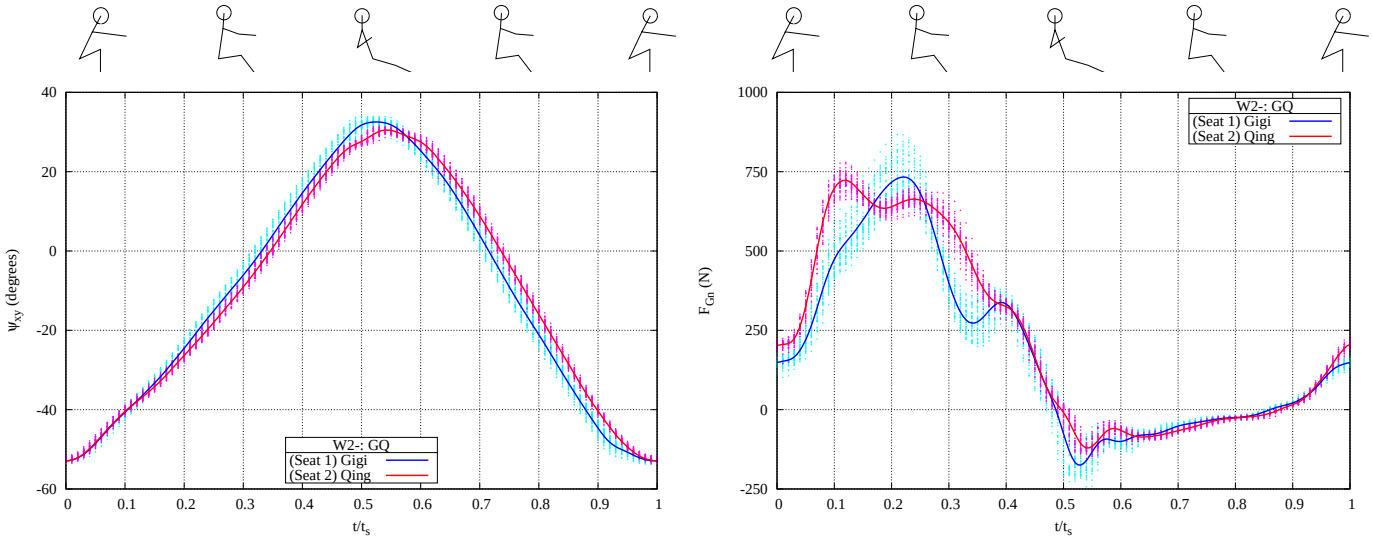


Figure 3: Oar azimuth angles Ψ_{xy} (left); gate normal forces F_{Gn} (right).

Yawing moment lever arms and yawing moments are shown in the two parts of Fig. 6.

The OBCP trajectories in Fig. 7 have been plotted on the same side of the hull for clarity and comparison.

The OBCP trajectories in the yz-plane are shown in Fig. 8. For the purposes of this plot, the OBCP is assumed to be at the geometric centre of the blade when it is out of the water.

The OBCP is below the water from about $t/t_s = 0.01$ to $t/t_s \approx 0.47$. The latter value is the value entered in the main input file.

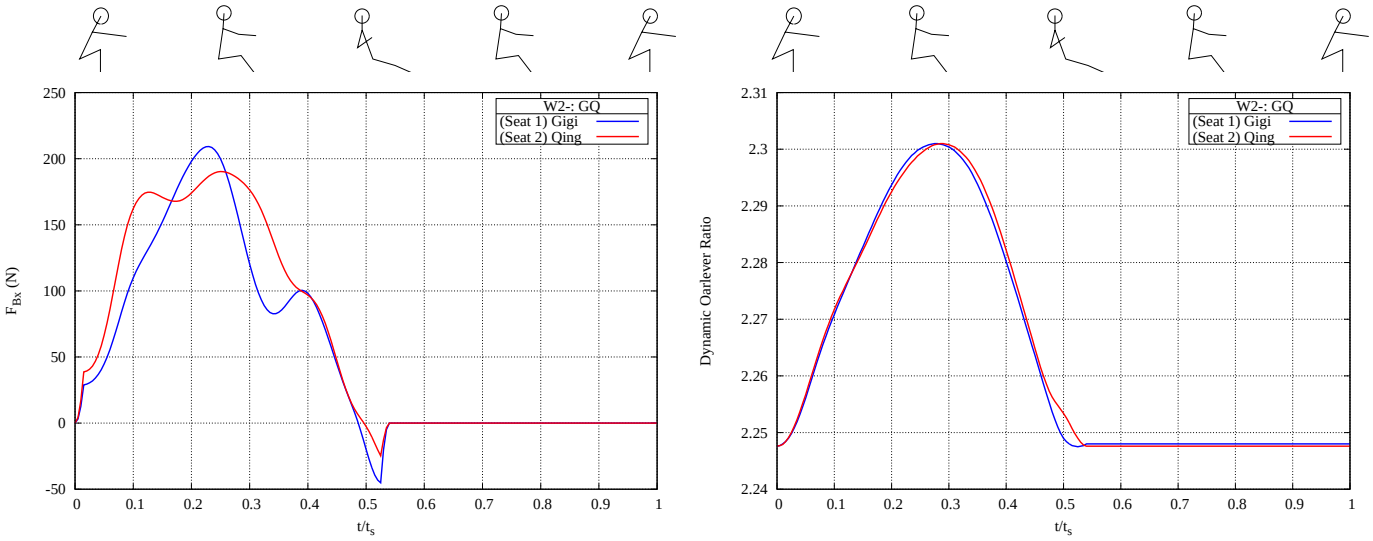


Figure 4: Blade propulsive forces F_{Bx} (left); dynamic oar lever ratios (right).

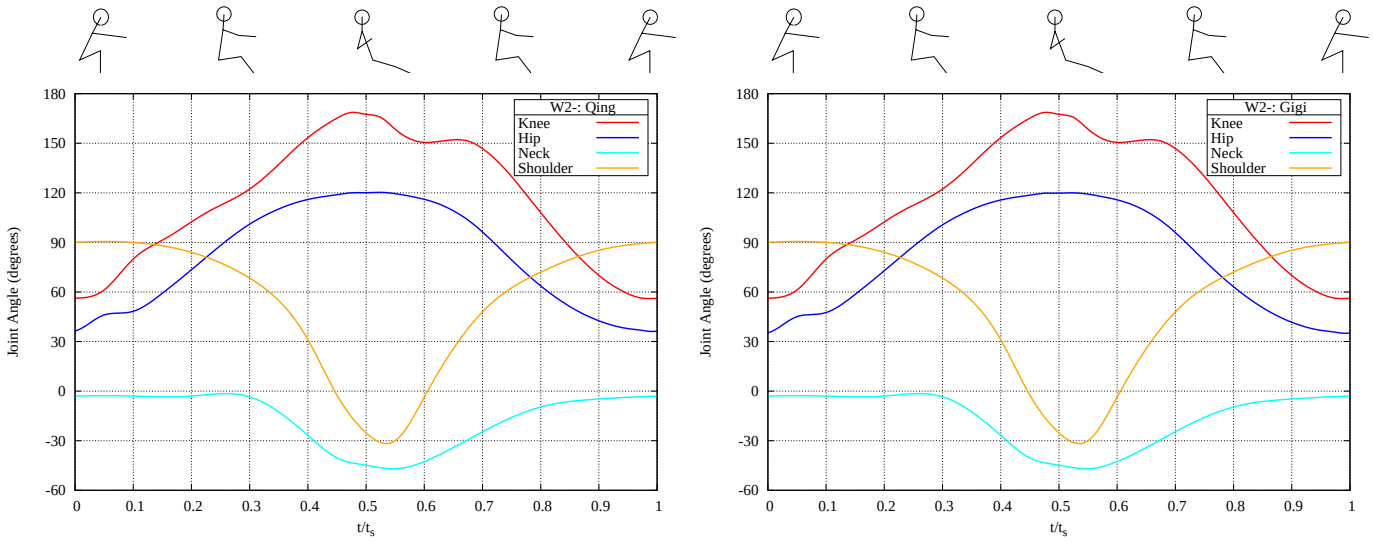


Figure 5: Joint angles: Seat 2 (left): Seat 1 (right).

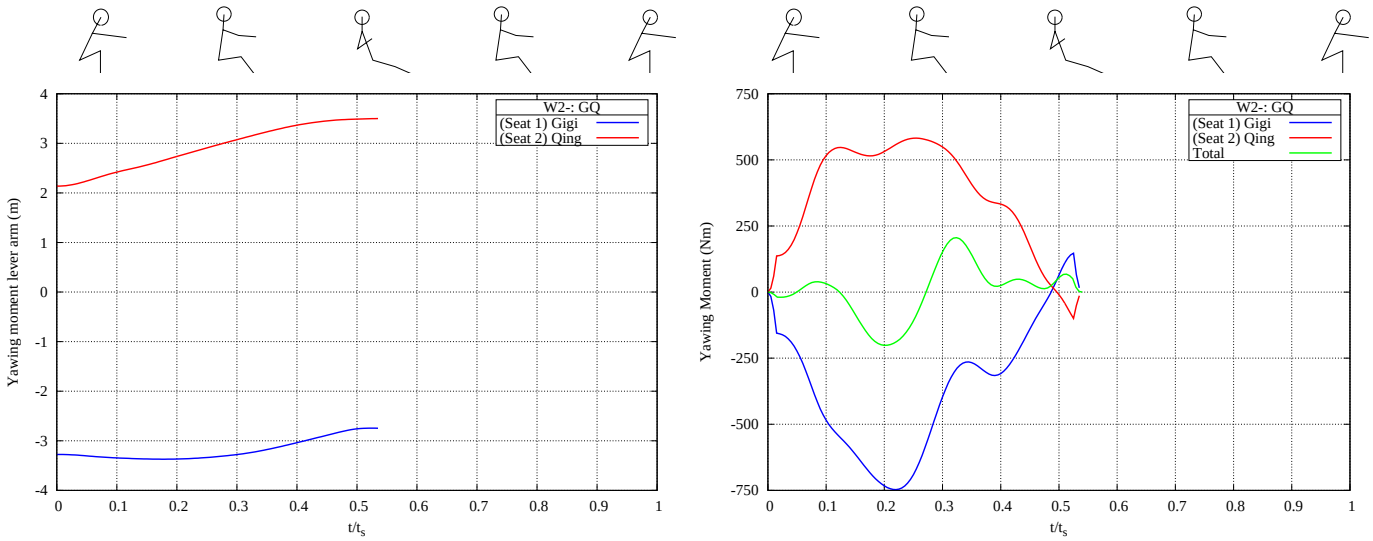


Figure 6: Yawing moment lever arms L_{yaw} (left); yawing moments M_{yaw} (right).

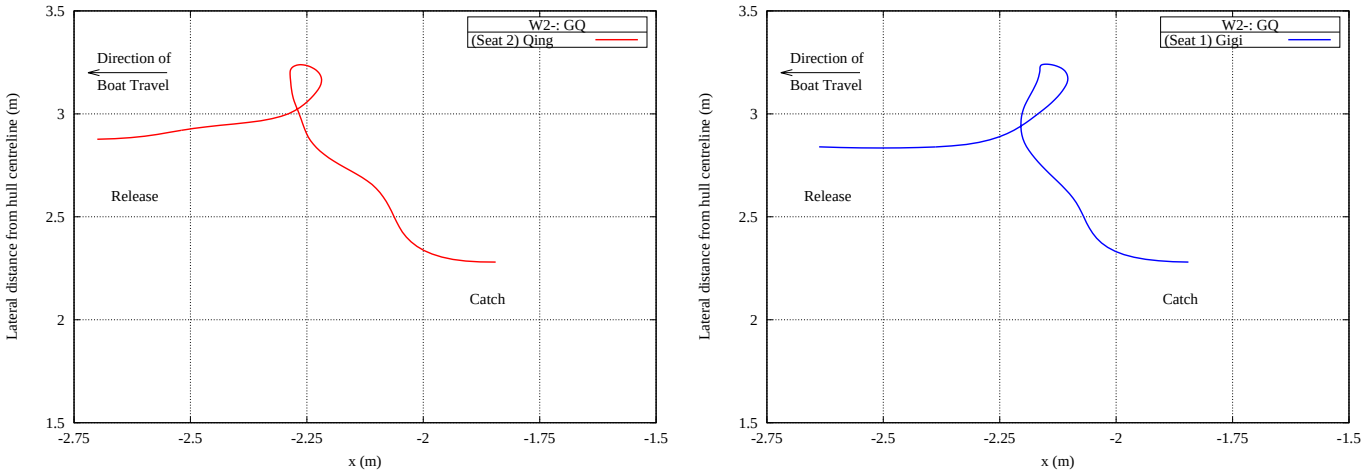


Figure 7: OBCP trajectories in the xy-plane: Port side (left); Starboard side (right).

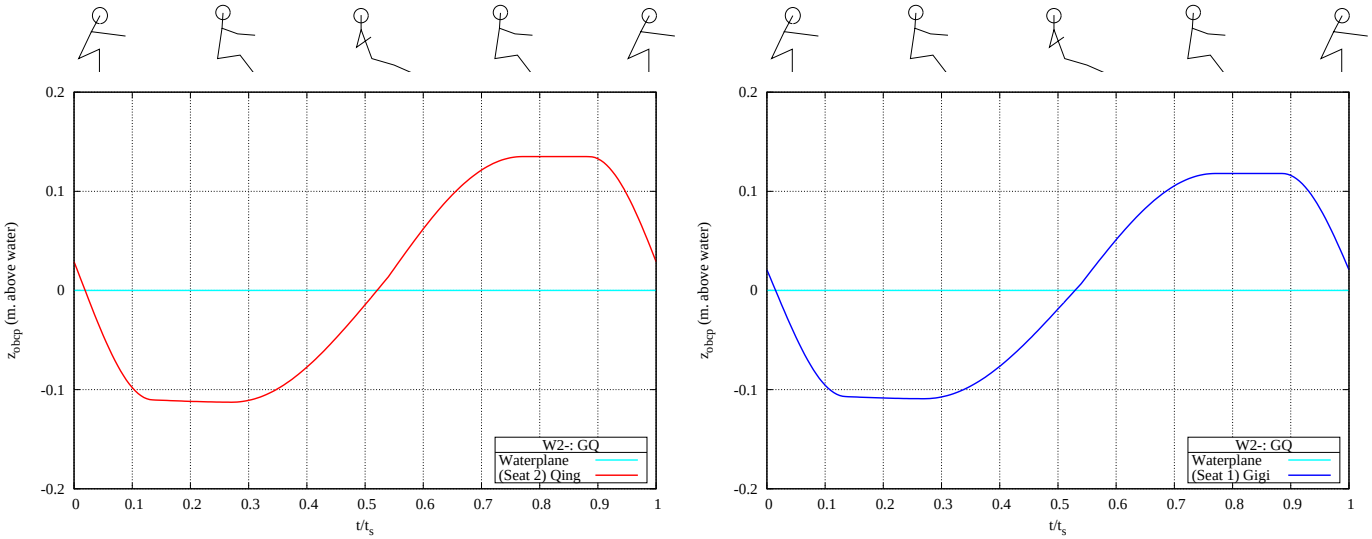


Figure 8: OBCP trajectories in the yz-plane: Port side (left); Starboard side (right).

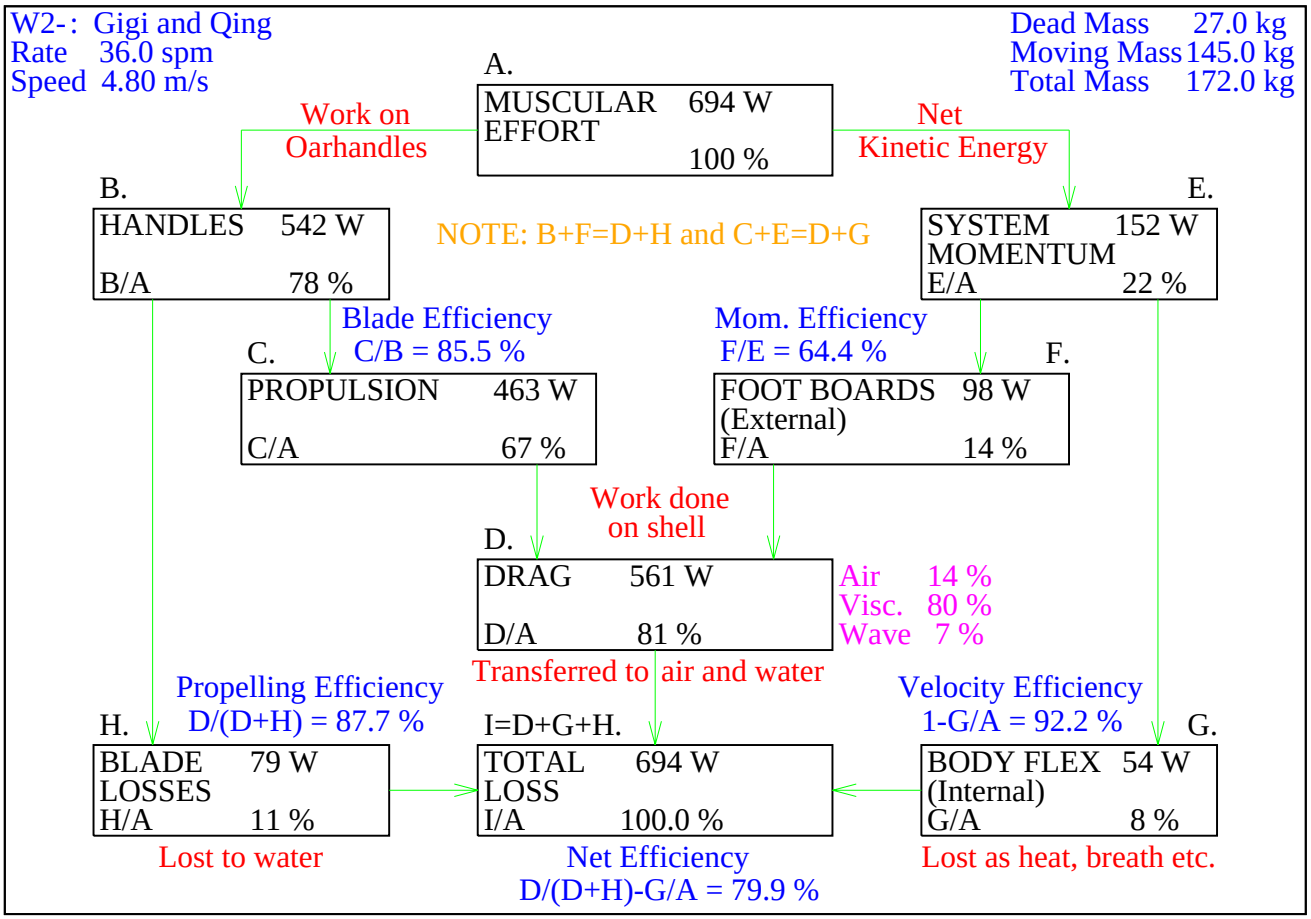


Figure 9: Power flow chart.

3 M2-: Men's Pairs

The on-water trial for these two heavyweight male rowers, "Dazza" and "Robbo", was conducted over 500m on a cold winter morning. Air and water temperatures were not recorded: they were estimated as 9°C and 9°C respectively. Measured values of rigging details, oar angles, gate normal forces, and their anthropometry were used as input to FIRM. Body angle regimes were not recorded but were estimated by the author using a complicated fitting process.

Table 3: Summary of experimental results for this simulation: number of strokes, stroke rate, non-dimensional pull phase duration (t_p/t_s), minimum hull velocity (U_{min}), maximum hull velocity (U_{max}), and mean hull velocity ($\overline{U}$).

Item	Value
Nstrokes	18
Rate (spm)	36.002 ±0.296
t_p/t_s	0.476 ±0.008
U_{min} (ms^{-1})	3.660 ±0.090
U_{max} (ms^{-1})	6.487 ±0.066
$\overline{U}$ (ms^{-1})	5.330 ±0.074

Table 3 summarises the main quantities relating to the simulation for this crew. Values are given ± one standard deviation.

Table 4: Experimental oar-related values for this simulation: Minimum and maximum oar angles, and maximum gate normal force.

Name	Port Oar			Starboard Oar		
	Min. Angle (degrees)	Max. Angle (degrees)	Max. F_{Gn} (N)	Min. Angle (degrees)	Max. Angle (degrees)	Max. F_{Gn} (N)
Dazza				-57.1±0.60	30.8±0.38	1138.3±27.5
Robbo	-50.7±0.67	32.4±0.33	1351.4±37.7			

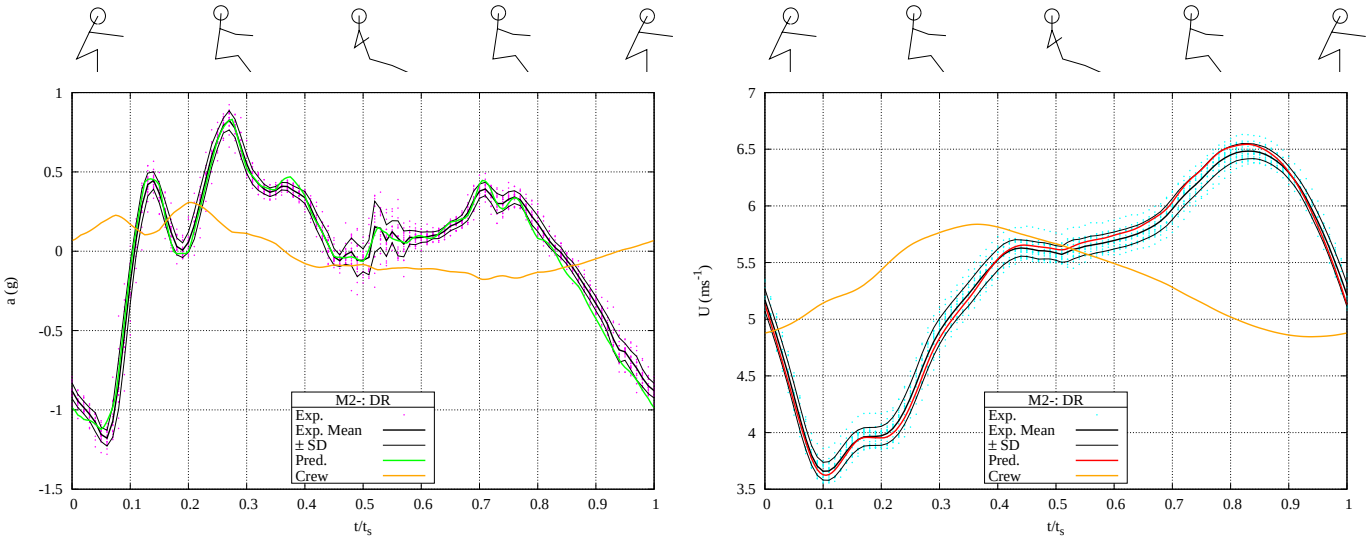


Figure 10: Hull propulsive acceleration and crew cg acceleration (left); hull velocity and crew cg velocity (right).

The hull propulsive acceleration is shown in the left panel of Fig. 10. Experimental data is shown as pink dots; the thick black curve is the mean of the measured values and the thin lines are one standard deviation (SD) either side of the mean curve. The green curve is FIRM's prediction.

Hull propulsive velocity and the speed of the crew CG is shown in the plot at the right of Fig. 10.

The forces in the equations of motion are shown in the left panel of Fig. 11. Drag components during the stroke are in the panel at the right.

Experimental oar azimuth angles and values used as input to FIRM are shown at the left of Fig. 12. Gate normal forces are at the right of the figure.

Blade propulsive forces are shown at the left of Fig. 13. Dynamic oar lever ratios shown at the right of the figure include the effect of variations in the location of the OBCP during the stroke.

Body angle regimes are shown in the two parts of Fig. 14. The angles are the same for both crew members in this simulation.

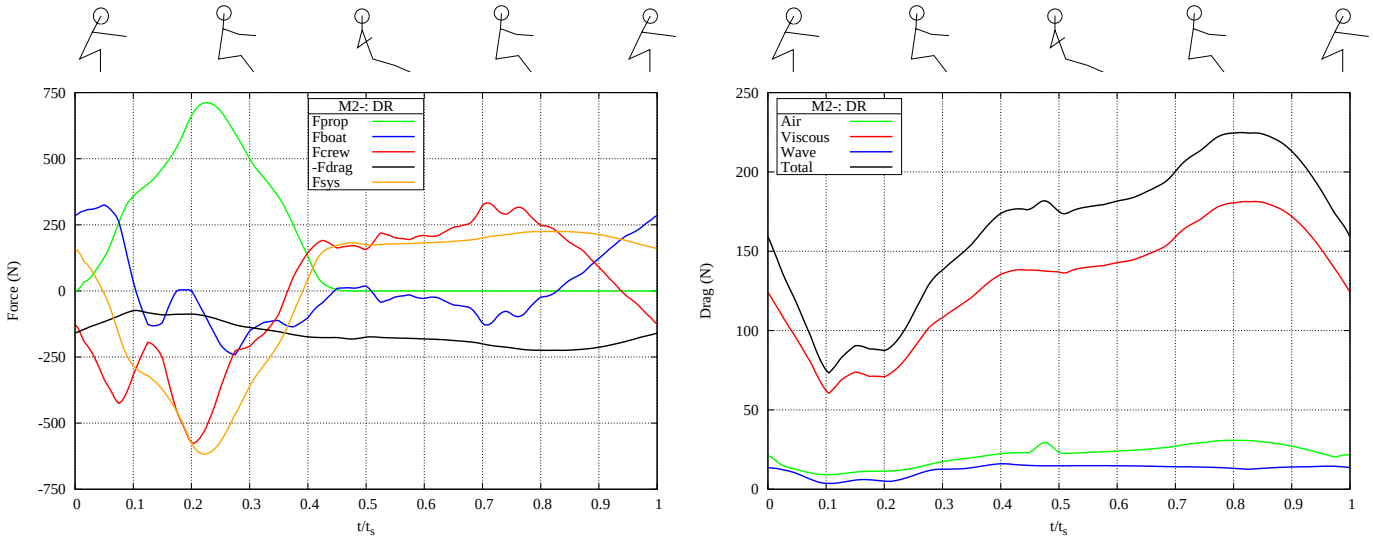


Figure 11: Equation of motion forces (left) and drag components (right).

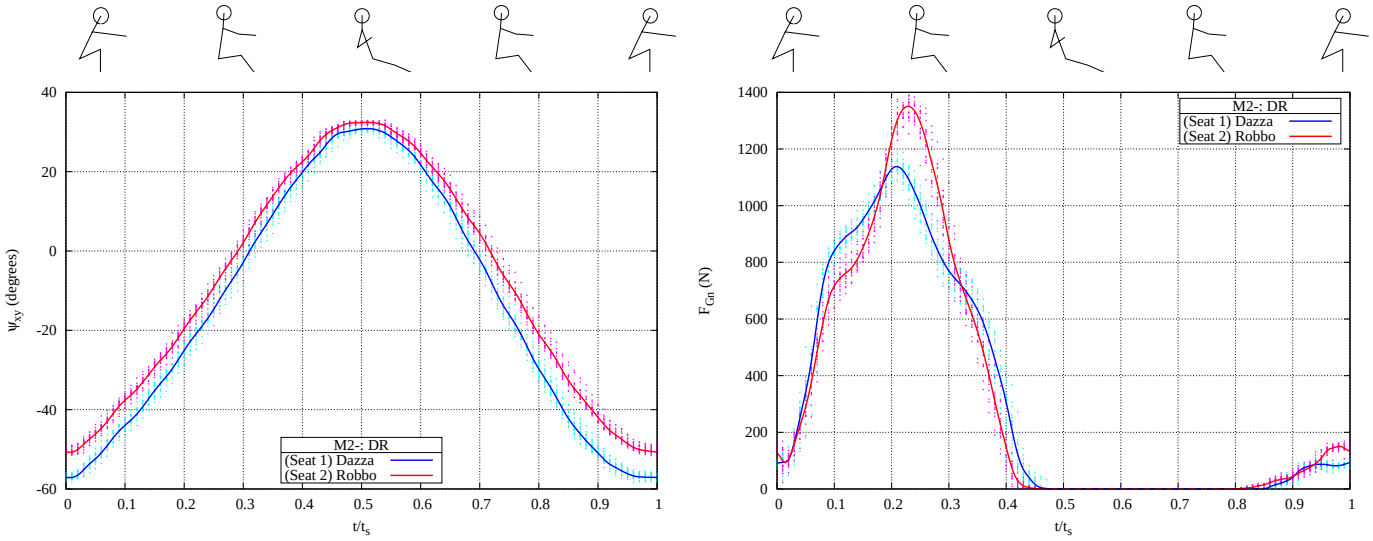


Figure 12: Oar azimuth angles Ψ_{xy} (left); gate normal forces F_{Gn} (right).

Yawing moment lever arms and yawing moments are shown in the two parts of Fig. 15.

The OBCP trajectories in Fig. 16 have been plotted on the same side of the hull for clarity and comparison.

The OBCP trajectories in the yz-plane are shown in Fig. 17. For the purposes of this plot, the OBCP is assumed to be at the geometric centre of the blade when it is out of the water.

The OBCP is below the water from about $t/t_s = 0.01$ to $t/t_s \approx 0.47$. The latter value is the value entered in the main input file.

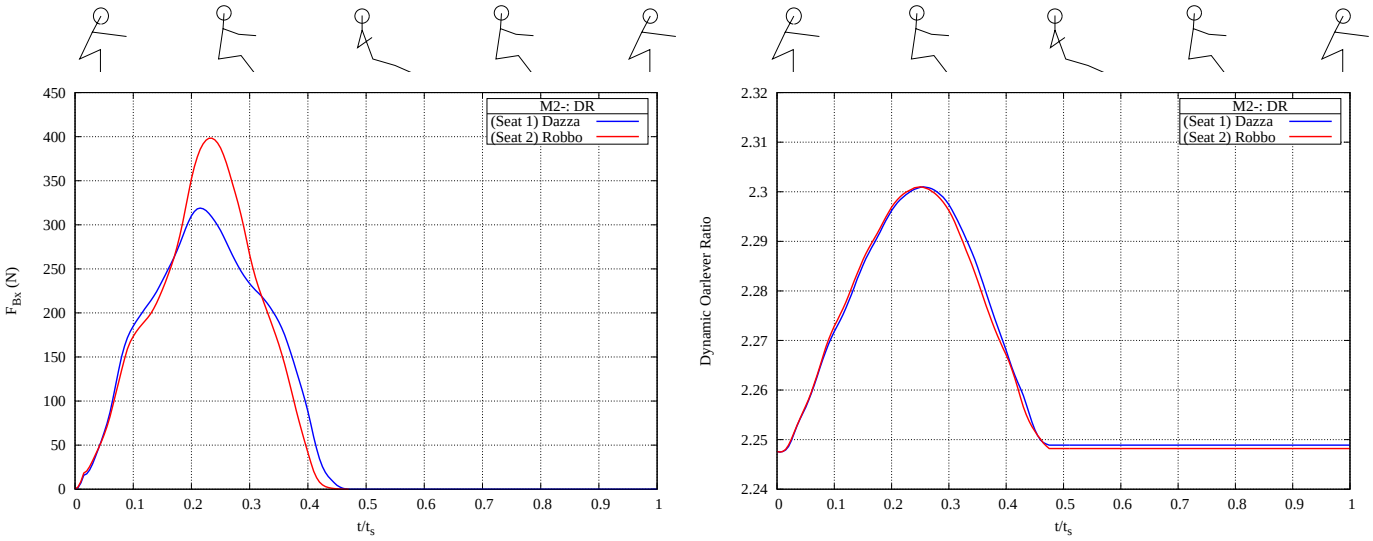


Figure 13: Blade propulsive forces F_{Bx} (left); dynamic oar lever ratios (right).

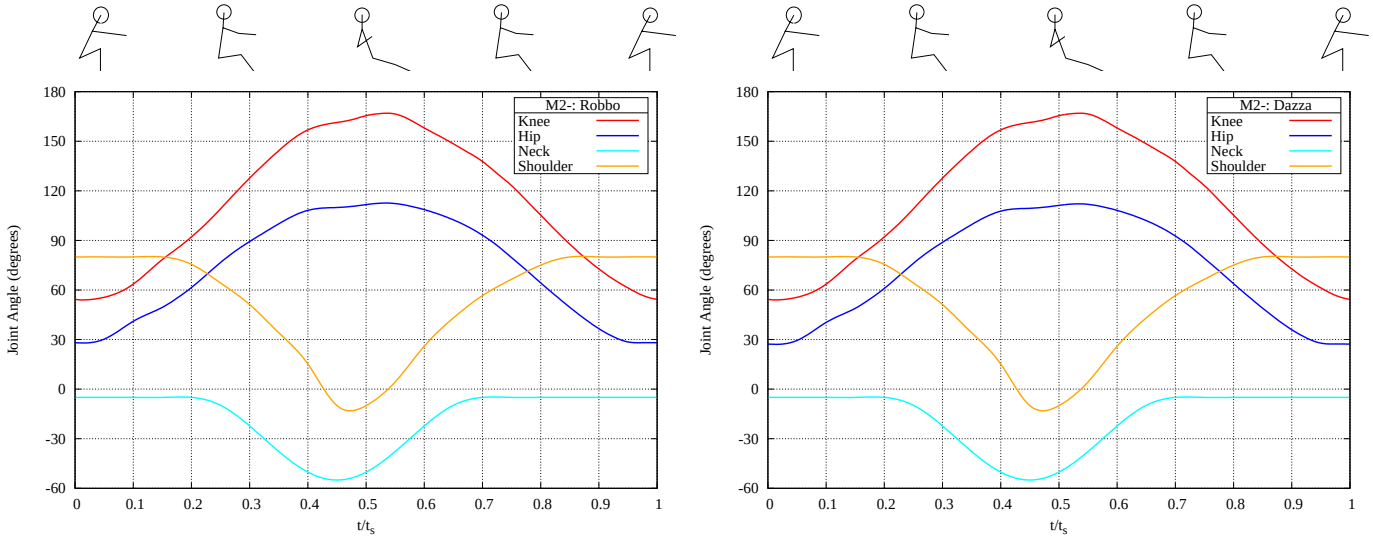


Figure 14: Joint angles: Seat 2 (left): Seat 1 (right).

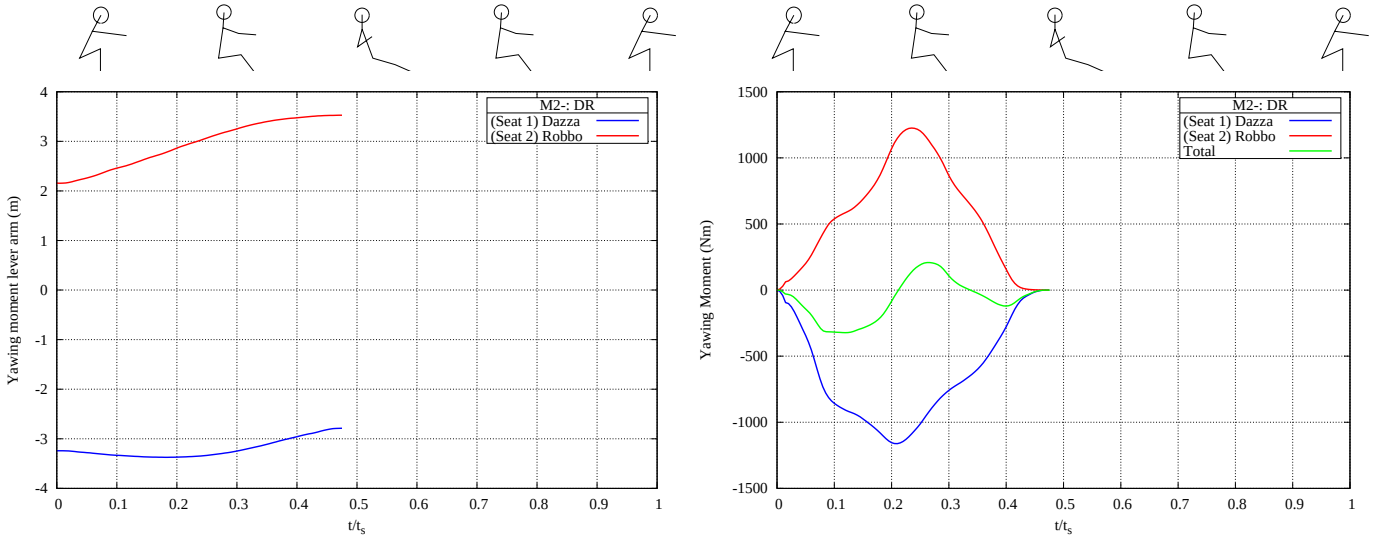


Figure 15: Yawing moment lever arms L_{yaw} (left); yawing moments M_{yaw} (right).

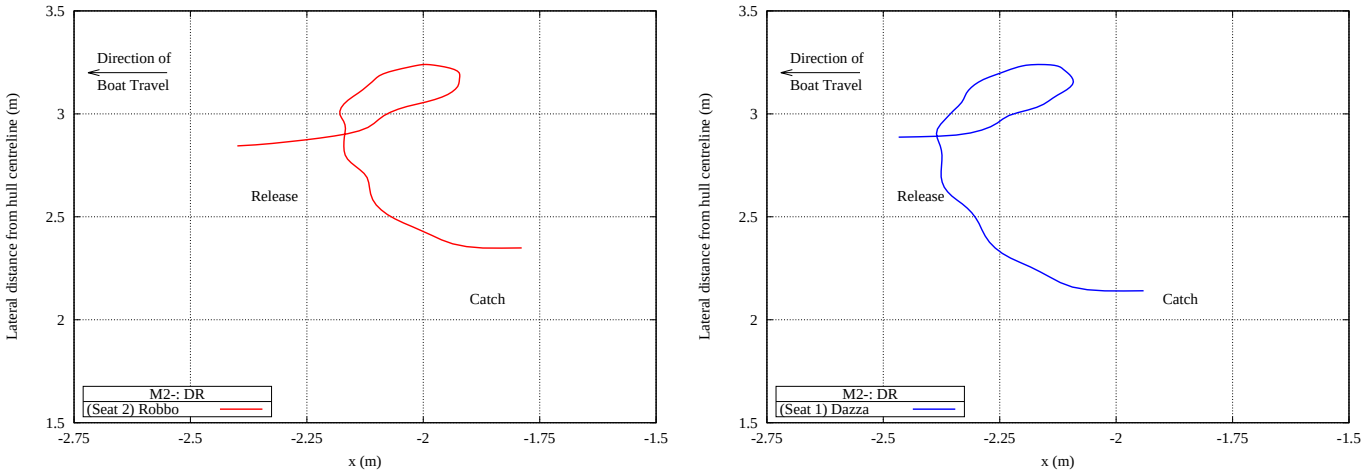


Figure 16: OBCP trajectories in the xy-plane: Port side (left); Starboard side (right).

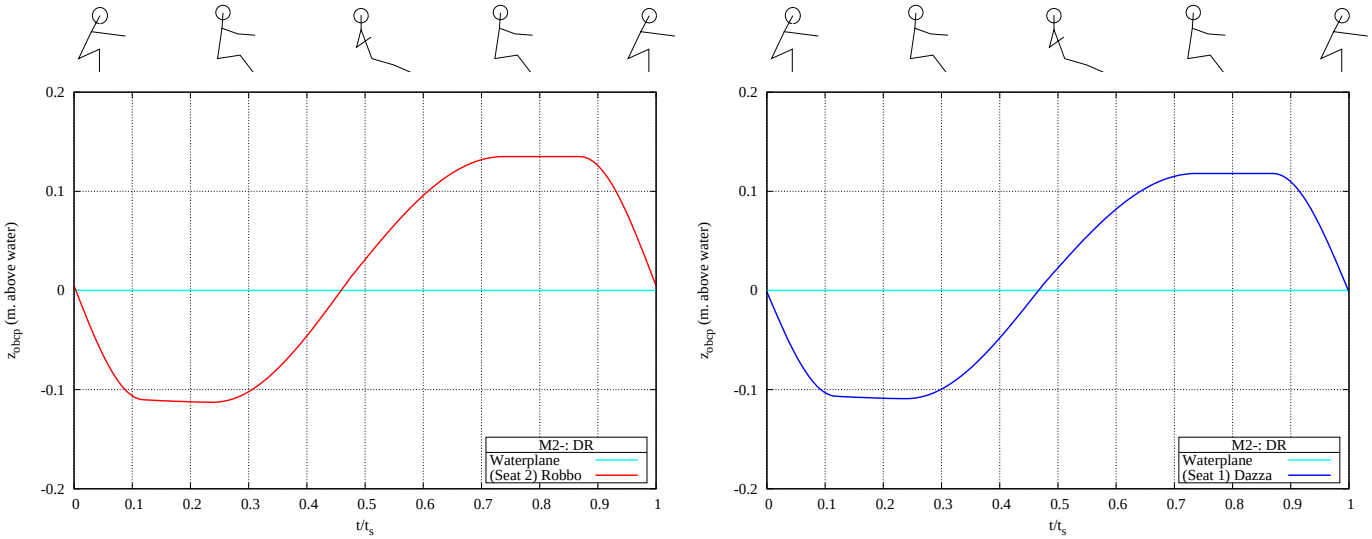


Figure 17: OBCP trajectories in the yz-plane: Port side (left); Starboard side (right).

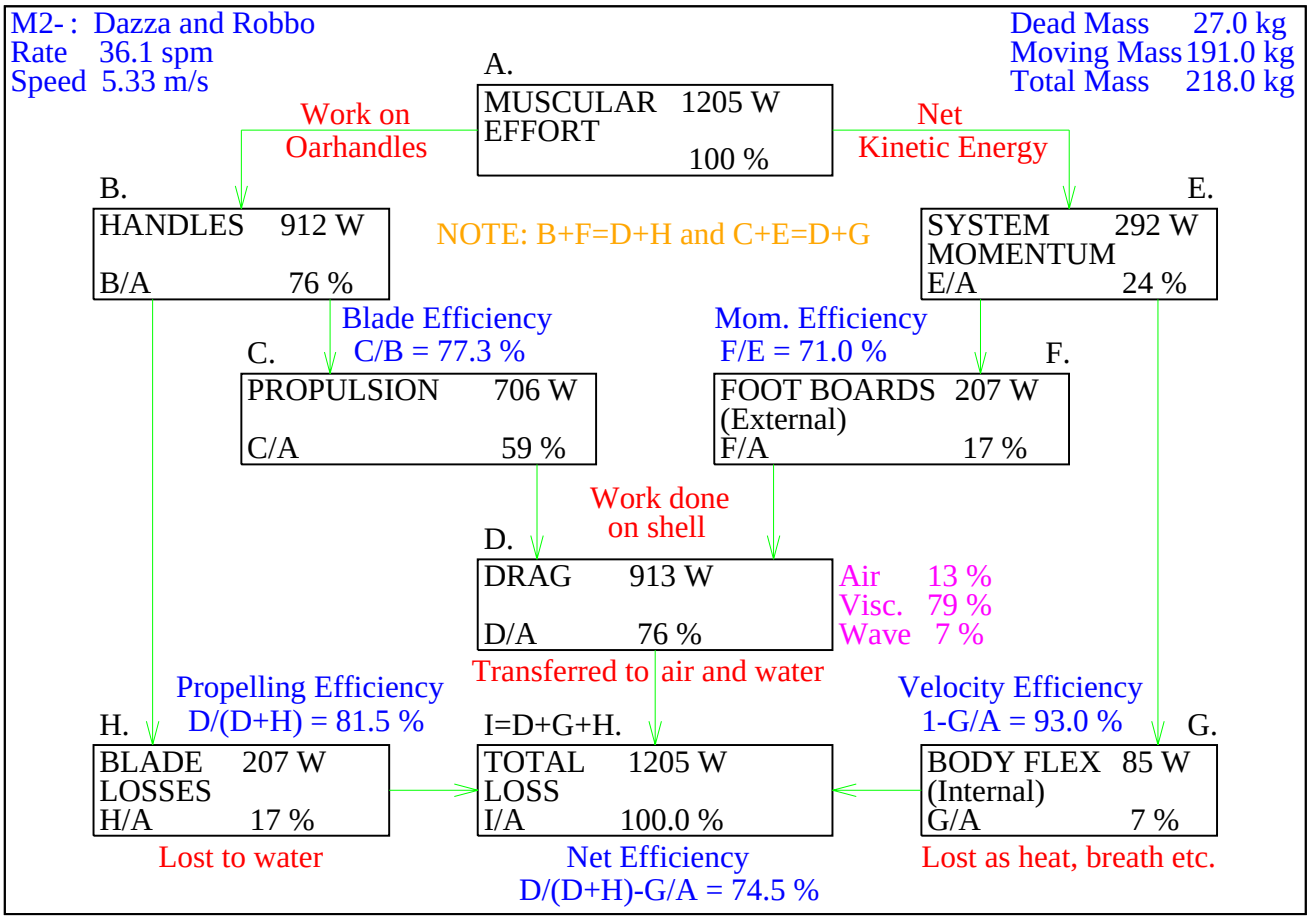


Figure 18: Power flow chart.