Estimation of vessel power and energy consumption, in calm waters

Foreword

This program allows an estimation of squat, resistance and power for vessels (sea ships and riverboats) in different configurations of channel sections (unrestricted channel, restricted channel, canal).
For riverboats, it provides also an estimation of energy consumption, fuel use and emission rates of CO2, PM10, NOX.
This program takes part of one module of the OpenTNSim software (Copyright (c) 2018 TUDelft / CITG-Ports and Waterways, see https://github.com/TUDelft-CITG/OpenTNSim)

References:

- [1]: MAN Energy Solutions: ”Basic principles of ship propulsion”
- [2]: PIANC, " Harbour approach channels design guidelines", Report n°121, Maritime Navigation Commission, 2014
- [3]: Gkioka D. " Investigation of the power estimation of inland barges", TUDelft, June 2023 http://resolver.tudelft.nl/uuid:a78922f9-beee-48bf-8a17-35baa138ad63
- [4]: Holtrop J. and Mennen G.G.J. , “An approximate power prediction method”, International Shipbuilding Progress, 29, 1982
- [5]: Holtrop J., “Statistical reanalysis of resistance and propulsion data”, International Shipbuilding Progress, 31, 1984
- [6]: Lützen M. and Kristensen H.O., "Prediction of resistance and propulsion power of ships“, DTU-USD, Project n°2010-56, Report n°04, 2012

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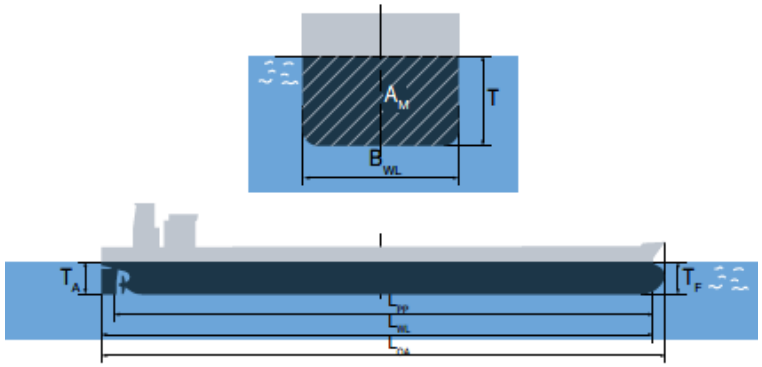
INPUT DATA

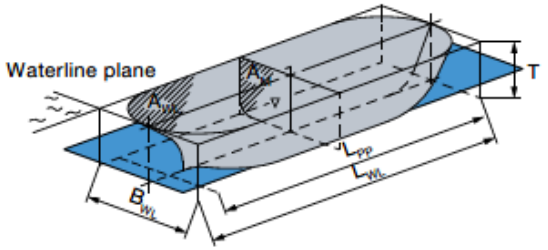
Input data

Input data for vessel and channel properties:

- "type": can contain info on vessel type
- "L": vessel length between perpendiculars (m)
- "B": vessel width (m)
- "Tb": forward draught (m)
- "Ts": aft draught (m)
- "Displ": load displacement (t)
- "C_WP": waterplane coefficient (If none, calculated)
- "C_M": midship section coefficient (If none, calculate
- "Npro": number of propellers
- "bulbous_bow": False/True
- "transom_stern": False/True



Length between perpendiculars:	L_{PP}
Length on waterline:	L_{WL}
Length overall:	L_{OA}
Breadth on waterline	B_{WL}
Draught:	$T = ½ (T_F + T_A)$
Midship section area:	A_M



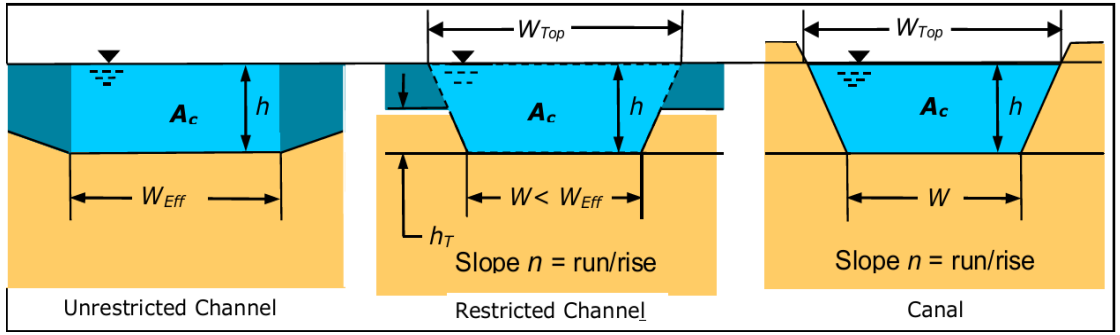
Volume of displacement	: ∇	
Waterline area	: A_{WL}	
Block coefficient, L_{WL} based	: $C_{B,WL}$ =	$\frac{\nabla}{L_{WL} \times B_{WL} \times T}$
Midship section coefficient	: C_M =	$\frac{A_M}{B_{WL} \times T}$
Longitudinal prismatic coefficient	: C_P =	$\frac{\nabla}{A_M \times L_{WL}}$
Waterplane area coefficient	: C_{WL} =	$\frac{A_{WL}}{L_{WL} \times B_{WL}}$

Hull dimensions and coefficients (from ref.[1])

Input data

Input data for vessel and channel properties:

- "rho": density of the surrounding water (t/m^3)
- "Dwl": design water level (m)
- "h0": water depth (m)
- "hT": height of trench (m)
- "W": channel width (m)
- "Nb": inverse bank slope (m/m)
- "safety_margin": the water area above the waterway bed reserved to prevent ship grounding due to ship squatting during sailing



Channel configurations (from ref.[2])

Weff: effective width (calculated by the program)

For an unrestricted channel: height hT = 0; slope Nb = 0; width W >= Weff

For a restricted channel: W < Weff; height 0< hT < h0+Dwl; slope Nb >=0

For a canal: W < Weff; height hT = h0+Dwl; slope Nb>=0)

Input data

Input data for resistance and power calculation:

- "P_installed": installed engine power [kW]
- "L_w": weight class of the ship (depending on carrying capacity) (classes: L1 (=1), L2 (=2), L3 (=3))
- "C_year": construction year of the engine [y]
- "P_hotel": power for systems on board [kW] (If none, calculated with P_hotel_perc)
- "P_hotel_perc": percentage of P_installed for P_hotel (default value:0.05)
- "nu": kinematic viscosity [m^2/s] (default value:1 * 10 ** (-6))
- "g": gravitational accelleration [m/s^2] (default value: 9.81)
- "eta_o": open water efficiency of propeller [-] (default value: 0.4)
- "eta_r": relative rotative efficiency [-] (default value: 1.0)
- "eta_t": transmission efficiency [-] (default value: 0.98)
- "eta_g": gearing efficiency [-] (default value: 0.96)
- "c_stern": determines shape of the afterbody [-] (default value: 0.0)
- "C_BB": breadth coefficient of bulbous_bow, set to 0.2 according to the paper of Kracht (1970), https://doi.org/10.5957/jsr.1970.14.1.1

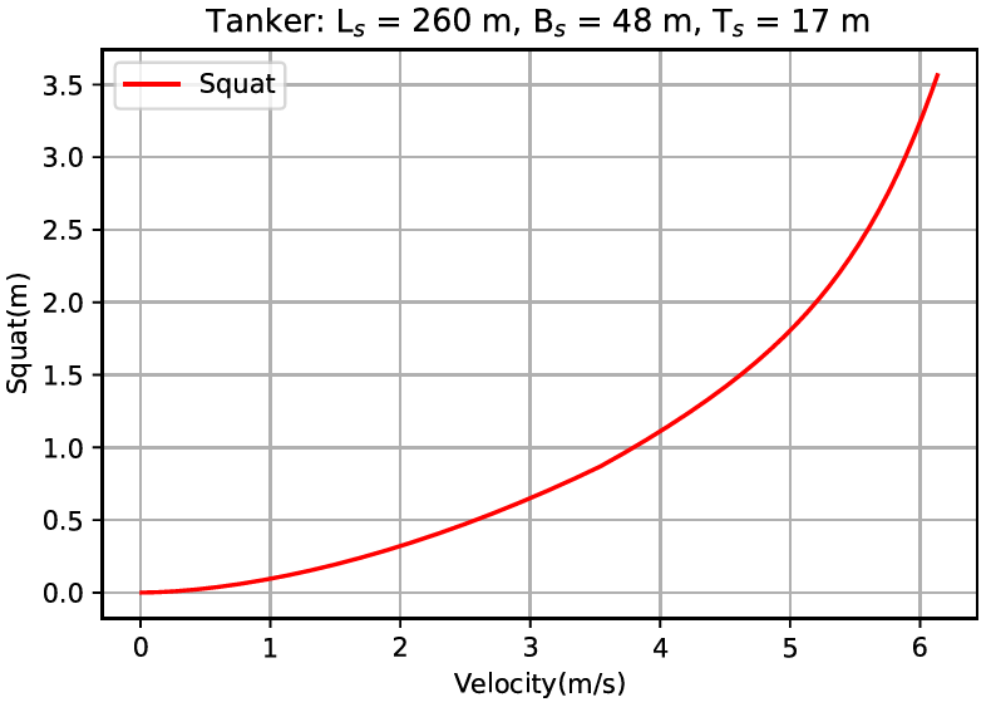
Input data

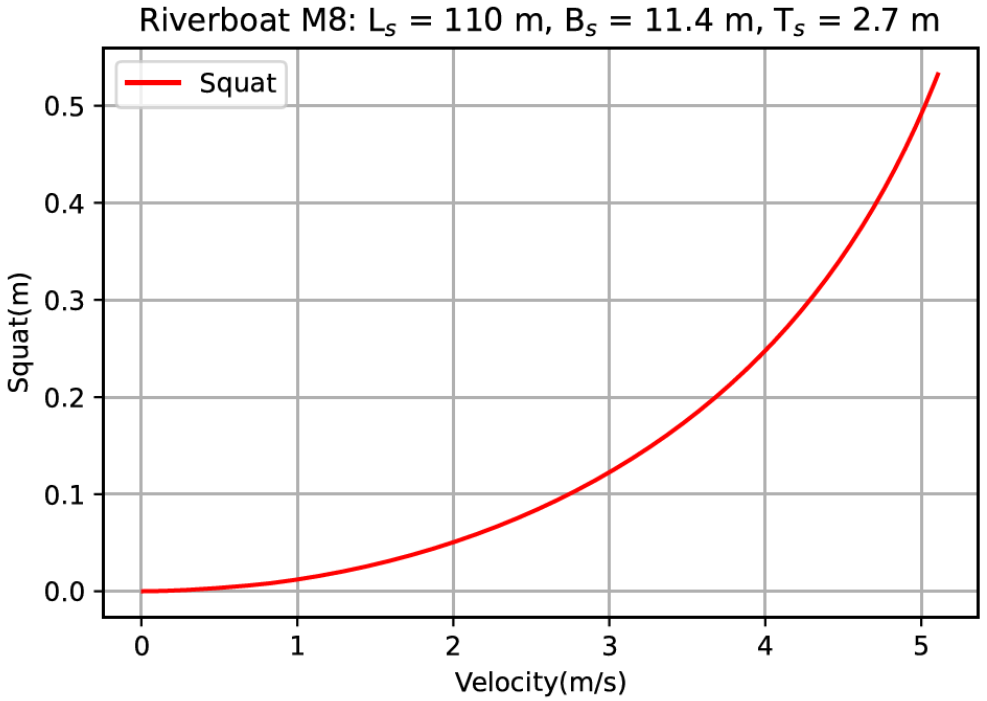
Input data for resistance and power calculation:

- "one_k2": appendage resistance factor (1+k2) [-] (default value: 2.5)
- "Typvessel": type of vessel for calculation of propulsion power (default value: 'Inland'):
  - ✓ 'Inland' for riverboat,
  - ✓ 'Tanker' for tankers and bulkcarriers
  - ✓ 'Container' for containerships
  - ✓ 'RoRo' for RoRo ships
- "S_APP1": wetted area of appendages in percentage of hull wetted area (default value: 0.05)
- "h_B1": Position of the centre of the bulb transverse area in percentage of mean draught (default value: 0.2)
- "A_T1": Transverse area of the transom in percentage of B*T (default value: 0.2)
- "D_s": Propeller diameter (If none, calculated)

Output Data

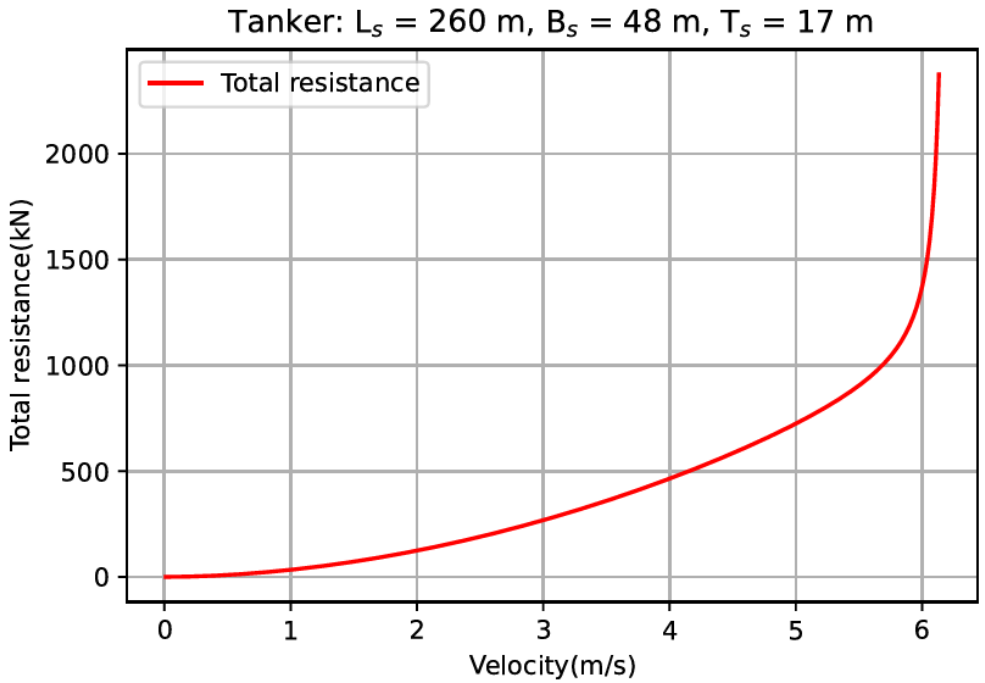
Estimation of squat (m), total resistance (kN) and power (kW) as a function of ship speed over water (m/s)

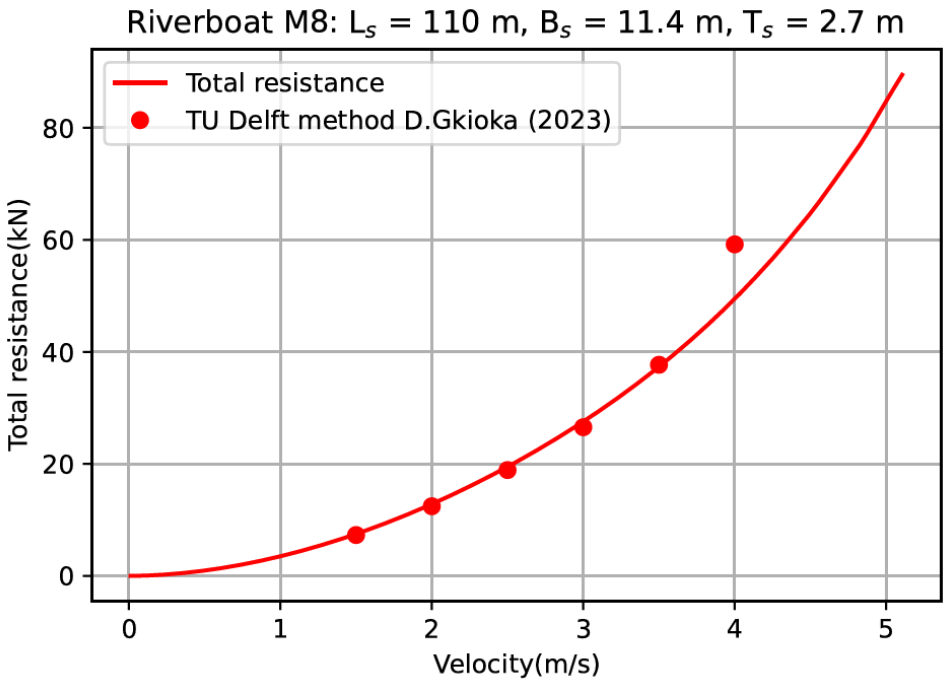




Squat estimation (in m)

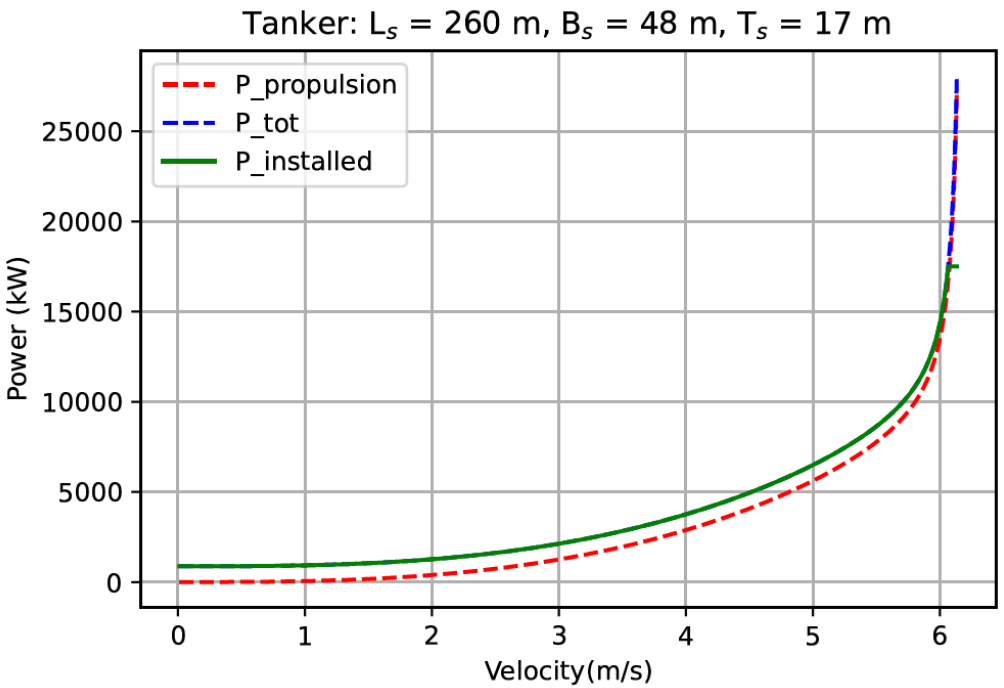
ESTIMATION OF SQUAT (M), TOTAL RESISTANCE (KN) AND POWER (KW) AS A FUNCTION OF SHIP SPEED OVER WATER (M/S)

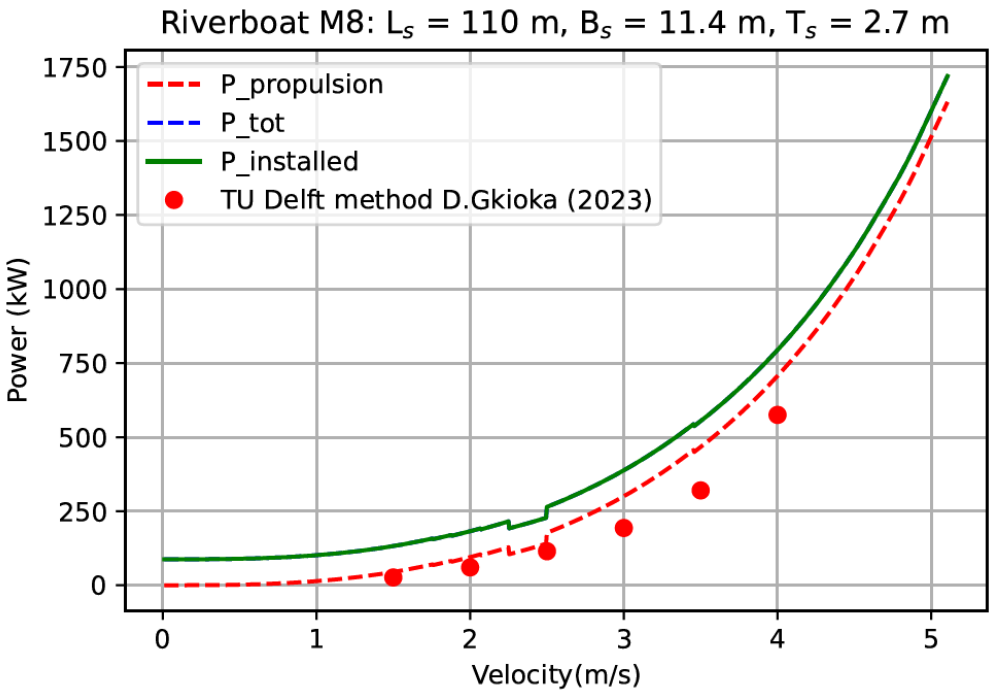




TOTAL RESISTANCE ESTIMATION (IN KN)

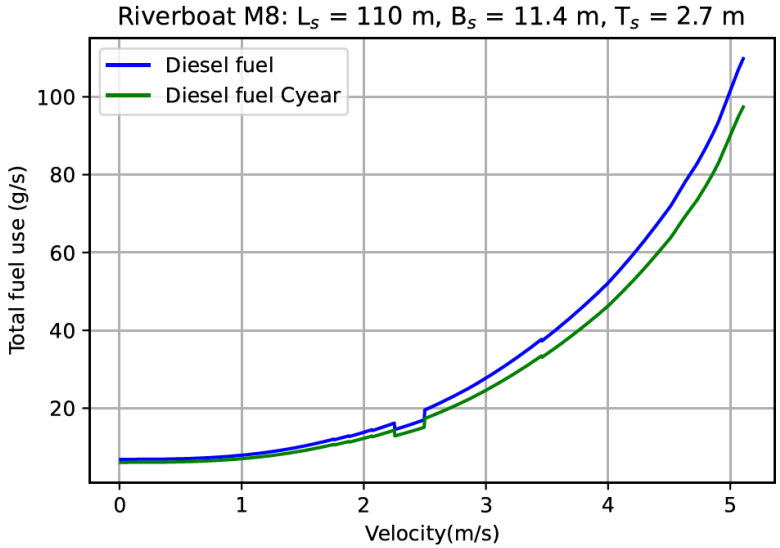
Estimation of squat (m), total resistance (kN) and power (kW) as a function of ship speed over water (m/s)

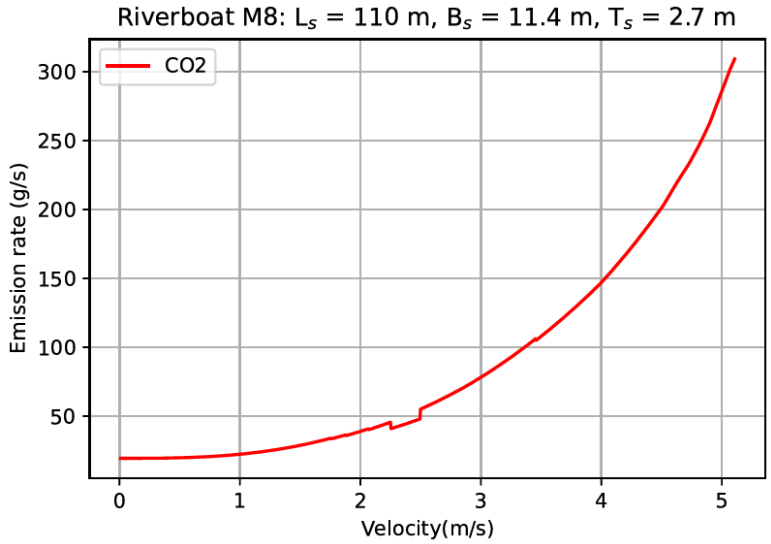


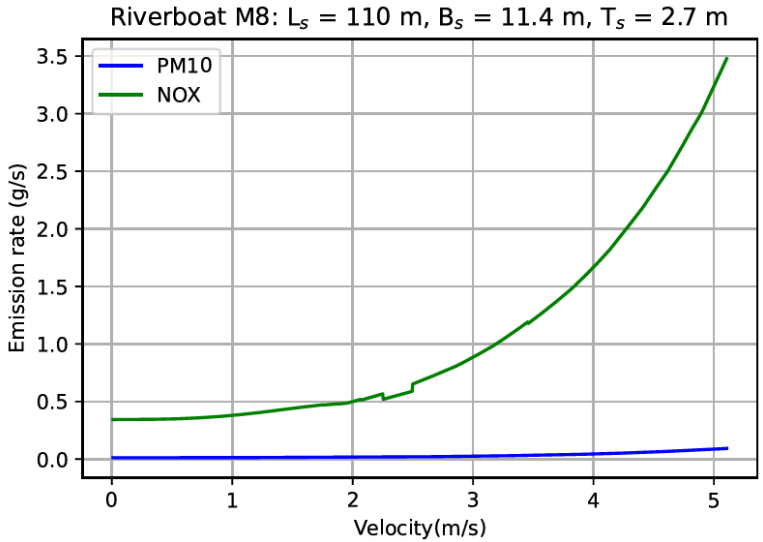


Power estimation (in kW)

For riverboats, estimation of energy consumption, fuel use and emission rates of CO2, PM10, NOX as a function of ship speed over water (m/s)





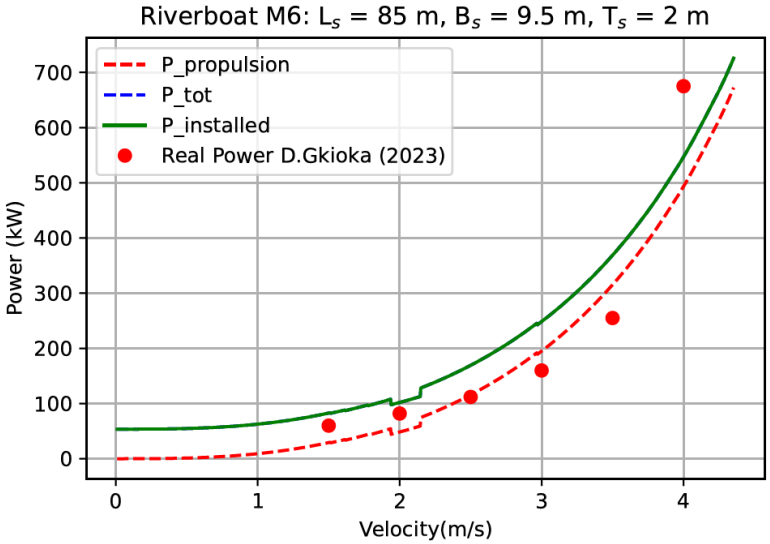


Fuel use and CO2, PM10, NOX emission rate estimation (in g/s)

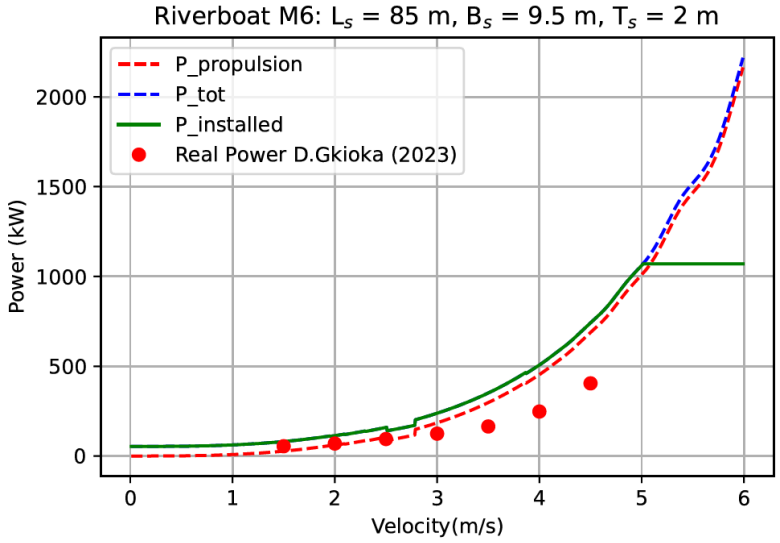
Comparison with published results

(Note: The comparison is always a challenge insofar as when going into the details of things, we realize that some parameters may be missing or are known with a certain approximation. This comparison, even imperfect, however makes it possible to ensure that the numerical model gives results with good orders of magnitude.)

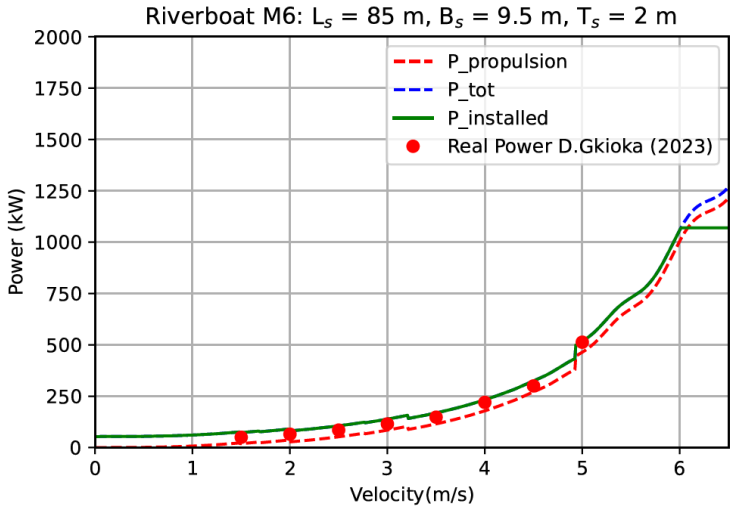
COMPARISON WITH REAL POWER DATA OF A RIVERBOAT IN AN UNRESTRICTED CHANNEL OF DIFFERENT WATER DEPTHS (H0 = 3M, 5M AND 10 M) (SEE REF. [3] FOR FURTHER DETAILS)



H0 = 3M

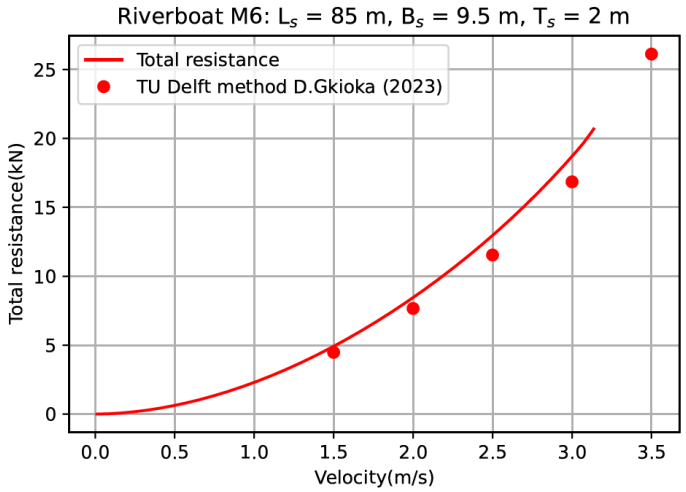


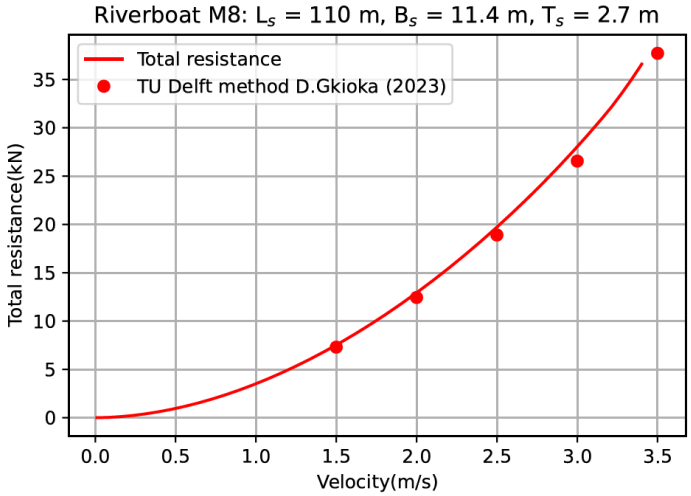
H0 = 5M



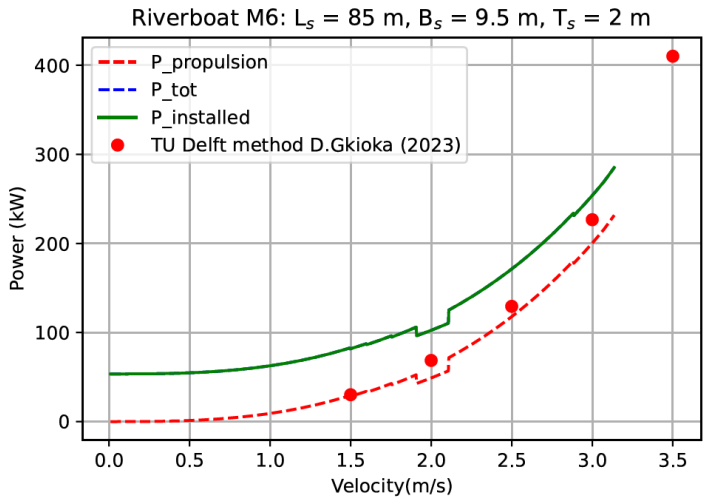
H0 = 10M

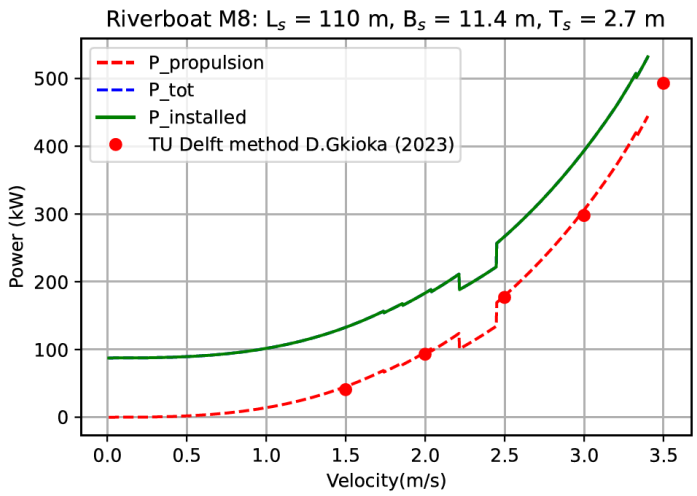
Comparison with TU Delft method results for two riverboats in a canal (W=50m; h0/T = 1.5) (see ref. [3] for further details)





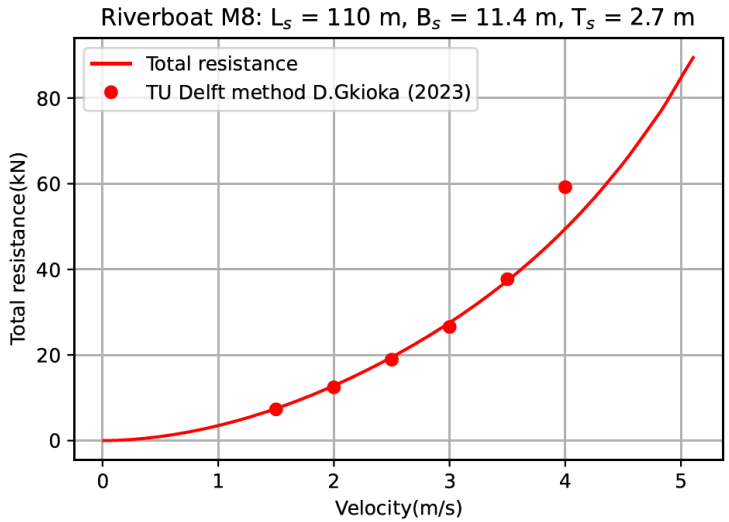
Total resistance (in kN)



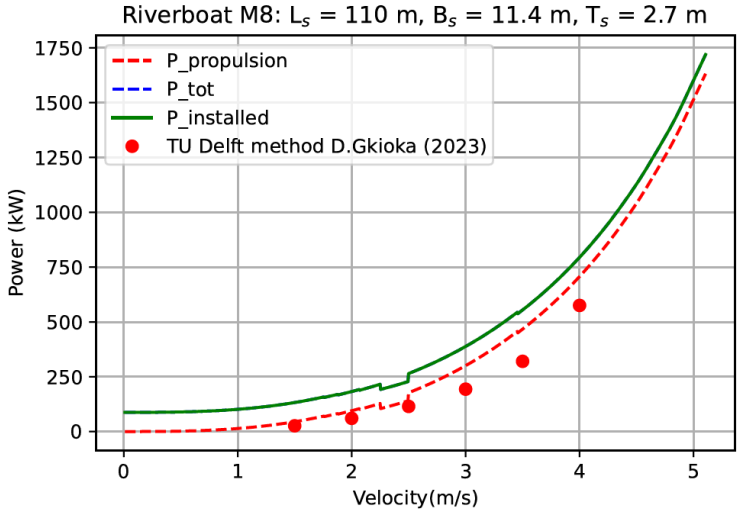


Power (in kW)

COMPARISON WITH TU DELFT METHOD RESULTS FOR A RIVERBOAT IN AN UNRESTRICTED CHANNEL (W=150M; H0/T = 1.5) (SEE REF. [3] FOR FURTHER DETAILS)

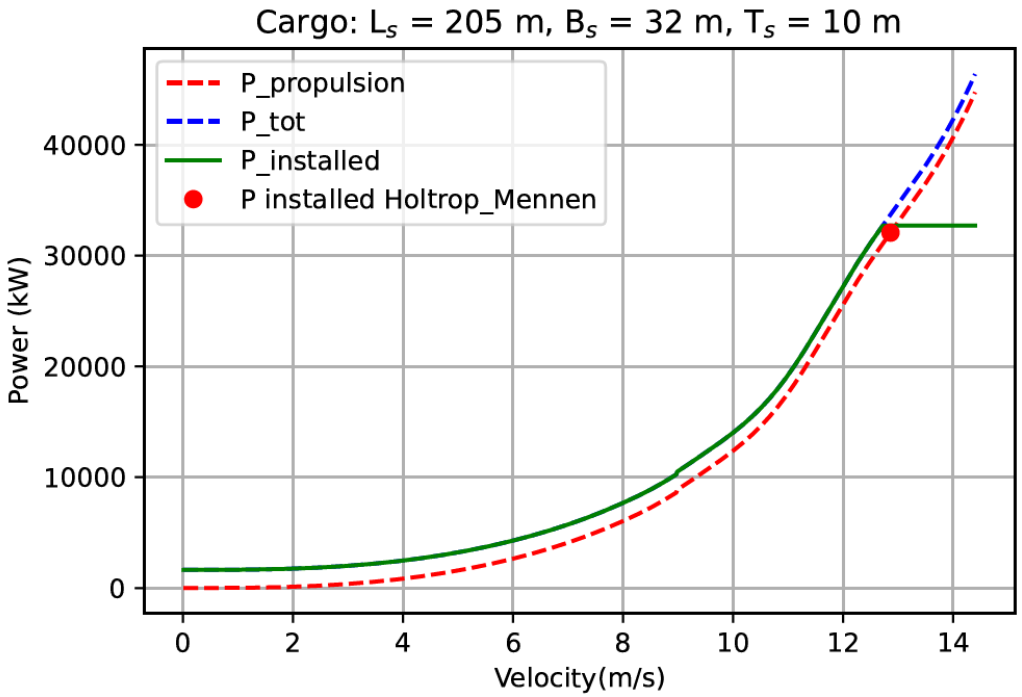


TOTAL RESISTANCE (IN KN)



POWER (IN KW)

COMPARISON WITH PUBLISHED RESULTS FOR A CARGO IN A DEEP AND UNRESTRICTED CHANNEL (SEE REF. [4] FOR FURTHER DETAILS)



POWER (IN KW)