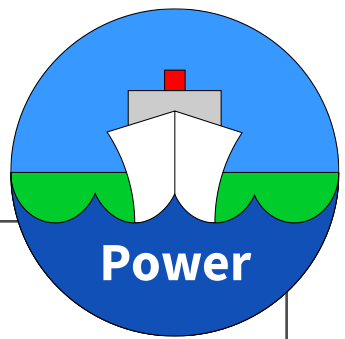# ShipPowerModel: : CHEAT SHEET

Power

Load Factor Models

Load factor models estimate power by comparing vessel operating conditions against a set reference conditions and a reference power. These models require a limited set of inputs and are easy to calculate by hand if needed. The default reference speed for both models is the ship's service speed.

Propeller Law

The propeller law is the simplest power model. It only requires knowing a reference speed and power for the vessel. The propeller law equation is:

$$P = P_{ref} \left(\frac{V}{V_{ref}} \right)^3$$

V = Ship speed
V_{ref} = Reference speed
P_{ref} = Power at reference speed

```
calcPropPwr(totalInstalledPwr,
        shipSpeed,
        refSpeed)
```

Admiralty Formula

The admiralty formula adds a term to account for the draft of the vessel. Operating at a deeper draft increases the required propulsive power. When the operating draft is the same as the reference draft the admiralty formula is the same as the propeller law. The admiralty formula equation is:

$$P = P_{ref} \left(\frac{V}{V_{ref}} \right)^3 \left(\frac{D}{D_{ref}} \right)^{\frac{2}{3}}$$

V = Ship speed
V_{ref} = Reference speed
D = Ship draft
D_{ref} = Reference draft
P_{ref} = Power at reference speed and draft

```
calcAdmPwr(totalInstalledPwr,
        shipSpeed,
        refSpeed,
        actualDraft,
        maxDraft)
```

Resistance-Based Models

Resistance-based models use vessel characteristics and operating conditions to estimate the power required to overcome air and water resistance against the vessel's hull. These models also estimate the vessel's efficiency for converting engine power into forward thrust. While these models require more detailed information about each ship than the load factor models, they allow more granular modeling of a vessel's power usage based on its specific design. The general form for these models is:

$$P = \frac{\rho C_T S V^3}{2 \eta_T}$$

ρ = Water density
C_T = Total resistance coefficient
S = Wetted surface area
V = Ship speed
η_T = Total efficiency

Holtrop & Mennen Model

The Holtrop & Mennen model is one of the first resistance-based models. It was created in 1982 and is based on regression analysis of tank towing data from the Netherlands Ship Model Basin. This model is widely cited in maritime literature. The Holtrop & Mennen model, as implemented by this package, was used by the U.S. EPA to estimate Category 3 commercial marine vessel emissions for the 2017 NEI and the 2016 emissions modeling platform.

```
calcHMPwr(totalInstalledPwr,
        shipSpeed,
        actualDraft,
        maxDraft,
        shipType,
        lwl,
        breadth,
        maxDisplacement,
        Cb,
        nProp)
```

Kristensen Model

Kristensen's SHIP DESMO model is based on Harvald's 1982 tank towing regression analysis. This method shares several of underlying functions with the Holtrop & Mennen model. A stand-alone version of SIP DESMO along with its documentation is hosted and maintained at https://gitlab.gbar.dtu.dk/oceanwave3d/Ship-Desmo.

```
calcKristPwr(totalInstalledPwr,
        shipSpeed,
        actualDraft,
        maxDraft,
        shipType,
        lwl,
        breadth,
        maxDisplacement,
        Cb,
        nProp,
        dwt)
```

Auxiliary and Boiler loads

A vessel's speed does not provide any direct information about how its auxiliary engines are used. Instead, auxiliary engine and boiler energy consumption must be estimated based on the type of ship, and assumptions about its operating conditions. Here the subType indicates the size class of the ship, and operating mode indicates the likely activity it is engaged in: Berth, Anchorage, Maneuvering, Transit.

```
calcOperatingMode(shipSpeed,
        loadFactor)
```

```
calcAuxBoilerLoad(opMode,
        shipType,
        subType,
        method = "imo",
        output = "aux")
```

ShipPowerModel: : CHEAT SHEET
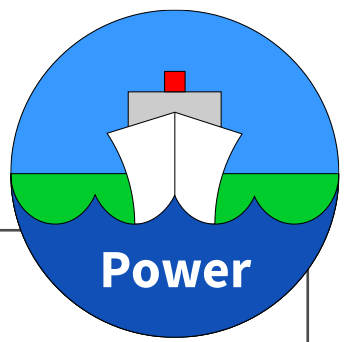
Power

ShipType and SubType

shipType: Ship type is used to make assumptions about both the design and operation of a ship when estimating its power consumption. The categories of ship used in this model are:

- "container.ship": ships that carry containerized cargo

- "bulk.carrier": ships that carry loose bulk cargo like stone, or ore.

- "tanker": ships that carry bulk liquid cargos

- "general.cargo": ships that can carry a wide range of non-containerized cargos

- "vehicle.carrier": ships designed to transport vehicles

- "reefer": ships that carry refrigerated cargos

- "ro.ro": ships that have facilities to drive vehicles directly into the cargo area

- "passenger": ships that primarily transport passengers

- "tug": tugboats and push boats

- "misc": other vessels not otherwise specified

calcShipType helps standardize model inputs by assigning a wide variety of potential input vessel types to one of the ship types listed on the left.

calcSubType assigns a size subclass to ships of a given type. Subtype is used when estimating auxiliary and boiler power consumption.

Both of functions can accept alternate ship type mappings via an input *.csv file.

calcShipType(vesselType,
            method ="imo")

calcSubType(shipType,
            DWT,
            GT,
            TEU,
            method = "imo")

Vessel Characteristics

**calclwl** estimates the waterline length of a ship based on its length between perpendiculars and its ship type

calclwl(shipType, lbp)

calcCb estimates block coefficient based on the ship's waterline length, breadth, and maximum draft

calcCb(maxDisplacement,
       lwl,
       breadth,
       maxDraft)

calcPropNum estimates the number of propellers that a ship has based on its type.

calcPropNum(shipType)

breadth

draft

Length Between Perpendiculars (lbp)

Waterline Length (lwl)
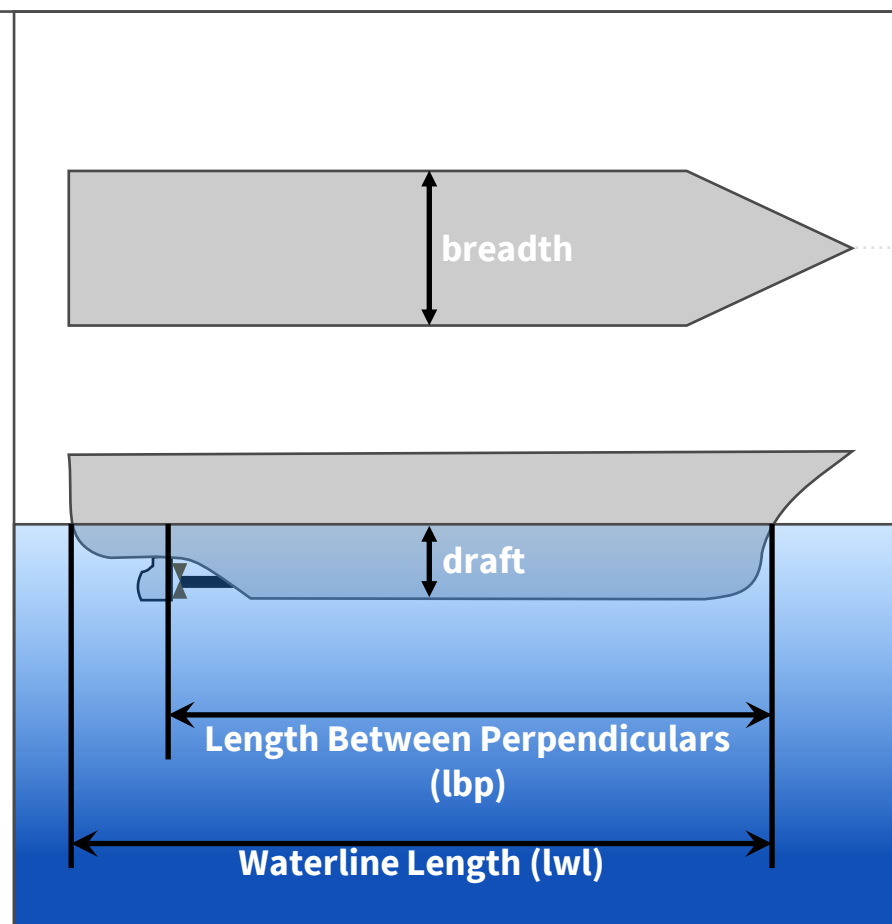
Variable Definitions

totalInstalledPwr: Total installed main engine power input in kilowatts (kW). This is also called the maximum continuous rated power (MCR) of the ship.

shipSpeed: A ship's actual speed (m/s) corresponding to the modeled main engine power.

refSpeed: Reference speed of the ship (m/s).

- *service speed*: The intended operating speed of the ship

- *maximum speed*: The maximum speed that the ship can achieve in calm waters

actualDraft: The operating draft of the of the ship corresponding to the modeled main engine power.

maxDraft: Maximum summer load line draft (m).

lbp: Length between perpendiculars (m). This is the distance between the rudder post, and the point where the bow meets the waterline .

lwl: Waterline length (m). This is the length of the entire hull along the line where it meets the water.

breadth: The widest breadth of the ship (m).

maxDisplacement: Maximum ship displacement (m^3). This is the maximum volume of water that the ship displaces when at sea.

Cb: Maximum block coefficient (dimensionless). This coefficient describes the relationship between how much water is displaced by the hull, relative to it overall submerged dimensions (length, width, draft).

nProp: Number of propellers used to move the ship under normal cruising operations.

dwt: Ship maximum deadweight tonnage (tonnes). This is the total carrying capacity of the ship including cargo, fuel, crew, passengers, and food.

GT: Gross Tonnage. A measure of a ship's total internal volume (tonnes)

TEU: Twenty-foot Equivalent Units. This is the number of standard containers a containership can carry.

nPassengers : The maximum number of passengers the ship can carry.

opMode: The type of activity the ship is engaged in

- "Berth": not moving at a berth in a port

- "Anchorage": floating at anchor

- "Maneuvering": moving at low speed within a port area

- "Transit": traveling in open water

loadFactor: The fractional portion of a main engine's total installed power that is being used.