Hercules Tug Power Requirements and Range

Curve fit to Glen-L data

Reference: Hull_Analyses_Displacement.xlsx

The Glen-L web site reports the following cruise power and speed conditions for the Hercules trawler yacht:

7 knots at 10 hp
9 knots at 25 hp

Hull drag comprises wave-generating drag and skin-friction drag. Wave drag is a cubic function of speed and skin-friction drag is a linear function of speed. Therefore, drag can be expressed as:

$$f_d := k_w \cdot v^3 + k_s \cdot v$$

where:

k_w is the wave-drag coefficient

k_s is the skin-friction coefficient

Therefore, drag power would be:

$$P_d(v) := k_w \cdot v^4 + k_s \cdot v^2$$

By fitting this curve to the Glen-L data, in Excel, we get the following values (with and without units):

$Parameters := \text{importData}_{XLSX}($"C:\Users\micro\Documents\Marine\Boat_Designs\Hull_Analyses_Displacement.

$$k_{wH} := Parameters_{3\,3} \cdot \frac{\text{kW}}{\left(\frac{\text{m}}{\text{s}}\right)^4} = 9.54 \; \frac{\text{kg s}}{\text{m}^2}$$

$$k_{sH} := Parameters_{3\,4} \cdot \frac{\text{kW}}{\left(\frac{\text{m}}{\text{s}}\right)^2} = 452 \; \frac{\text{kg}}{\text{s}}$$

$$k_{wH} = 20000 \; \frac{\text{lbm hr}}{\text{nmi}^2}$$

$$k_{sH} = 3.59 \cdot 10^6 \; \frac{\text{lbm}}{\text{hr}}$$

$$P(v) := k_{wH} \cdot v^4 + k_{sH} \cdot v^2$$

Sanity check:

$$P(7\ \text{kn}) = 10.0115\ \text{hp}$$

$$P(9\ \text{kn}) = 18.8722\ \text{hp}$$

$$P(10\ \text{kn}) = 25\ \text{hp}$$

Range With Electric Drive

$\eta := 0.9$ "Motor efficiency"

$C_b := 80\ \text{kW hr}$ "Battery capacity"

$A_s := 6\ \text{m}^2$ "Solar panel area"

$q_s := 0.2\ \frac{\text{kW}}{\text{m}^2}$ "Solar cell effective charge rate"

Range:

$$R_{et}(v) := \frac{C_b + \frac{A_s \cdot q_s \cdot C_b}{P(v)}}{P(v)} \cdot v$$

$R_{et}(3\ \text{knot}) = 438\ \text{nmi}$

$R_{et}(4\ \text{knot}) = 242\ \text{nmi}$

$R_{et}(5\ \text{knot}) = 159\ \text{nmi}$

$R_{et}(6\ \text{knot}) = 114\ \text{nmi}$

$R_{et}(7\ \text{knot}) = 87\ \text{nmi}$

Specific range:

$$S_{et}(v) := \frac{v}{P(v)}$$

$S_{et}(3\ \text{knot}) = 2.7\ \frac{\text{nmi}}{\text{kW hr}}$

$S_{et}(4\ \text{knot}) = 1.9\ \frac{\text{nmi}}{\text{kW hr}}$

$S_{et}(5\ \text{knot}) = 1.5\ \frac{\text{nmi}}{\text{kW hr}}$

$S_{et}(6\ \text{knot}) = 1.2\ \frac{\text{nmi}}{\text{kW hr}}$

$S_{et}(7\ \text{knot}) = 0.9\ \frac{\text{nmi}}{\text{kW hr}}$

Solar panel break-even point (charging rate equals drag power):

$$A_b(v) := \frac{P(v)}{q_s}$$

$A_b(5\ \text{knot}) = 17.0403\ \text{m}^2$

$A_b(4\ \text{knot}) = 10.4247\ \text{m}^2$

Why don't these numbers jive?

$A_b(3\ \text{knot}) = 5.6534\ \text{m}^2$

Specific range versus speed

Ref: http://www.kubotaengine.com/assets/documents/15_v1505t_30.pdf

$\rho := 0.832\ \frac{kg}{L}$	"Diesel fuel density"	"Wikipedia"
$Q_s := 250\ \frac{g}{kW\ hr}$	"Kubota Diesel BSFC"	"Reference"
$gal_{imp} := 1.2\ gal$	"Imperial Gallon"	"Wikipedia"
$\eta := 0.9$	"Motor Efficiency (est.)"	"Wikipedia"

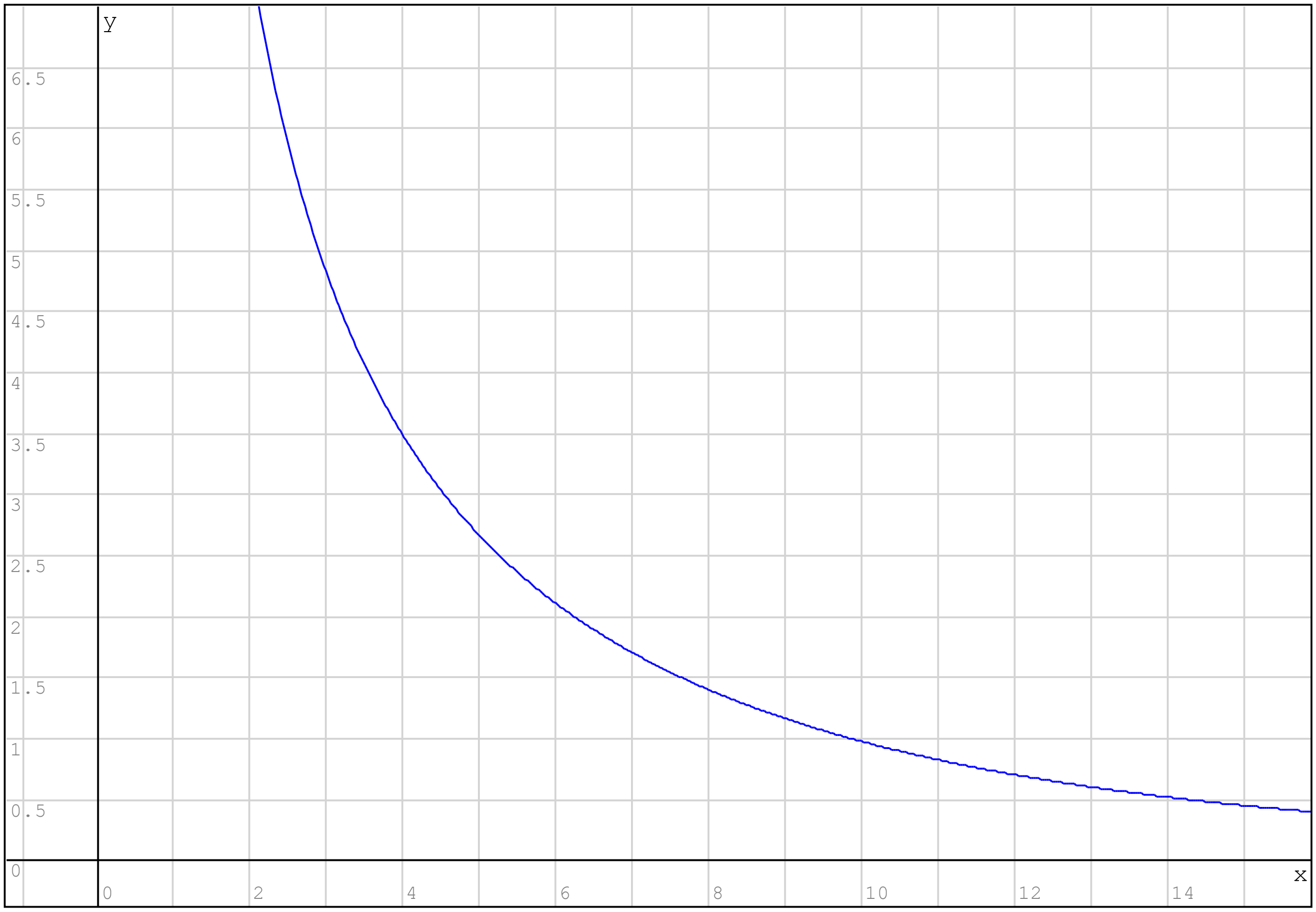
Equation:

$$R_s(v) := \frac{v}{Q_s \cdot P(v)}$$

$$Q_s = 0.411\ \frac{lbm}{hp\ hr}$$

$$R_s(7\ kn) = 1.7012\ \frac{nmi}{lbm}$$

Specific Range (nmi/lbm) versus speed (kn)



if $x \geq 0$

$R_s(x\ kn)\ \frac{lbm}{nmi}$

else

"null"