Using K_T and K_Q for design

these notes are landscape as plots are usually shown in that mode

we have seen in general the development of the Wageningen B series. The performance curves are available either in chart form or can be generated from polynomials:

▸ regression coeff. Re=2*10^6

▸ polynomial representation

use in design

A typical design problem calls for designing a propeller that will provide the required thrust at a given speed of advance. These parameters result from applying thrust deduction and wake fraction to resistance and ship velocity respectively. Design will imply selecting a P/D from a B-series plot that will maximize open water efficiency.

For now we will arbitrarily pick a number of blades and expanded area ratio. Later we will address the criteria in their selection. Reviewing the non-dimensional forms of the parameters associated with thrust and speed:

$$K_T = \frac{T}{\rho \cdot n^2 \cdot D^4} \qquad J = \frac{V_A}{n \cdot D}$$

we have independent variables n and D. Normally one of these is determined by other criteria, e.g. maximum diameter by hull form, or n by the propulsion train design, so we will look at two cases, one in which D is fixed - determine n, and the other where n is fixed determine D

<u>case 1</u> given: V_A, T, D find n and P/D for maximum efficiency

only thing unknown is n, eliminate ... from ratio of K_T and J

$$\frac{K_t}{J^2} = \frac{T}{\rho \cdot n^2 \cdot D^4} \cdot \frac{n^2 \cdot D^2}{{V_A}^2} = \frac{T}{\rho \cdot D^2 \cdot {V_A}^2}$$

this says that propeller (full scale and model) must match this ratio which is a constant determined by T, V_A, D and ρ

$$Kt\_over\_J\_sq := \frac{T}{\rho \cdot D^2 \cdot {V_A}^2}$$

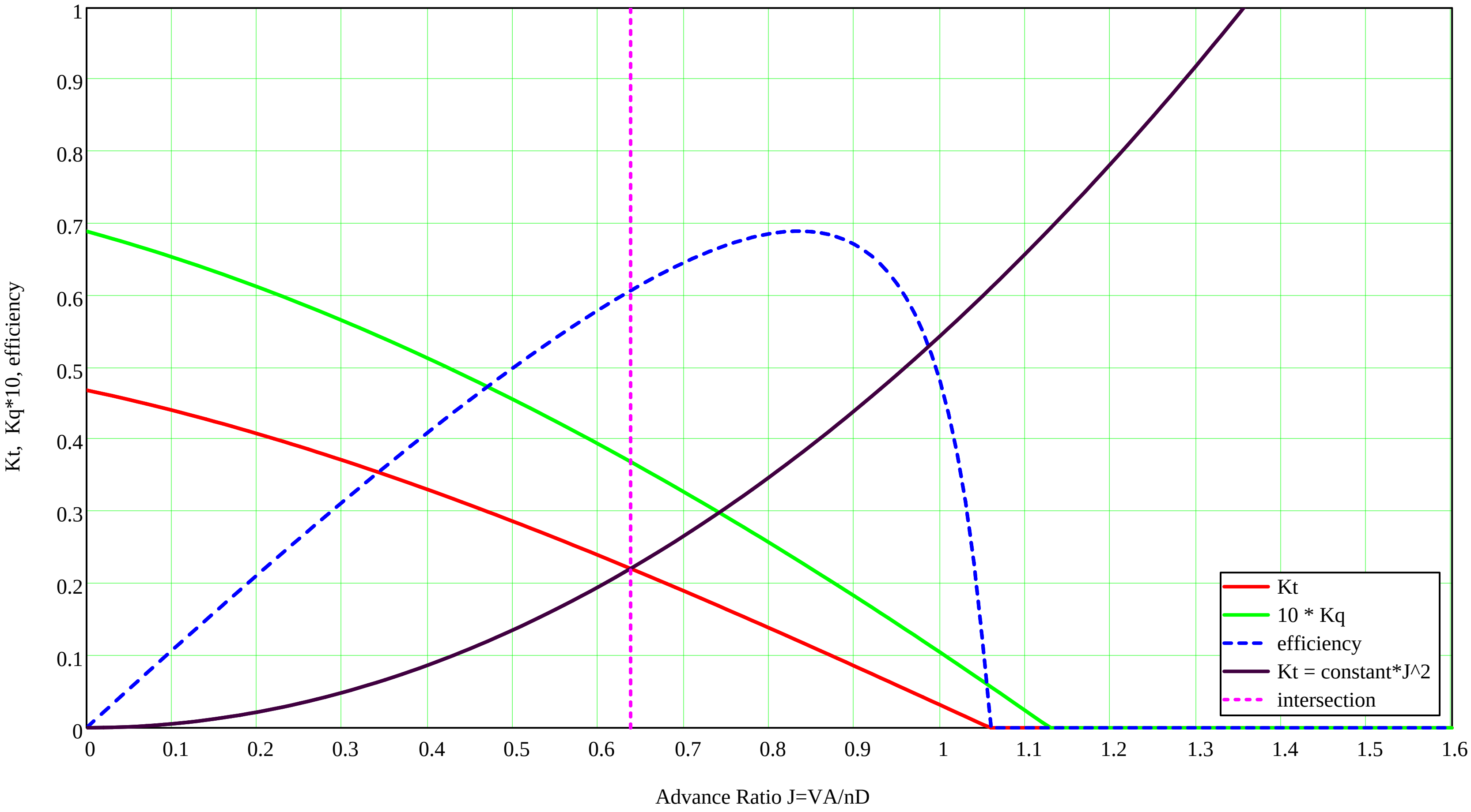
we can plot a curve of K_T vs J^2 and determine the points (values of J) for which K_T vs J for a given P/D match.

the design point for a particular propeller (B.n.nn) i.e. n is determined from the value of J that satisfies: $Kt(J) = constant \cdot J^2$

for example, let $Kt\_over\_J\_sq := 0.544$ what n i.e. J will satisfy the relationship for a B 5.75 propeller with P/D -1.0

$Kt\_design(J) := Kt\_over\_J\_sq \cdot J^2$ select using B_series $z := 5$ $EAR := 0.75$ $P\_over\_D := 1.0$

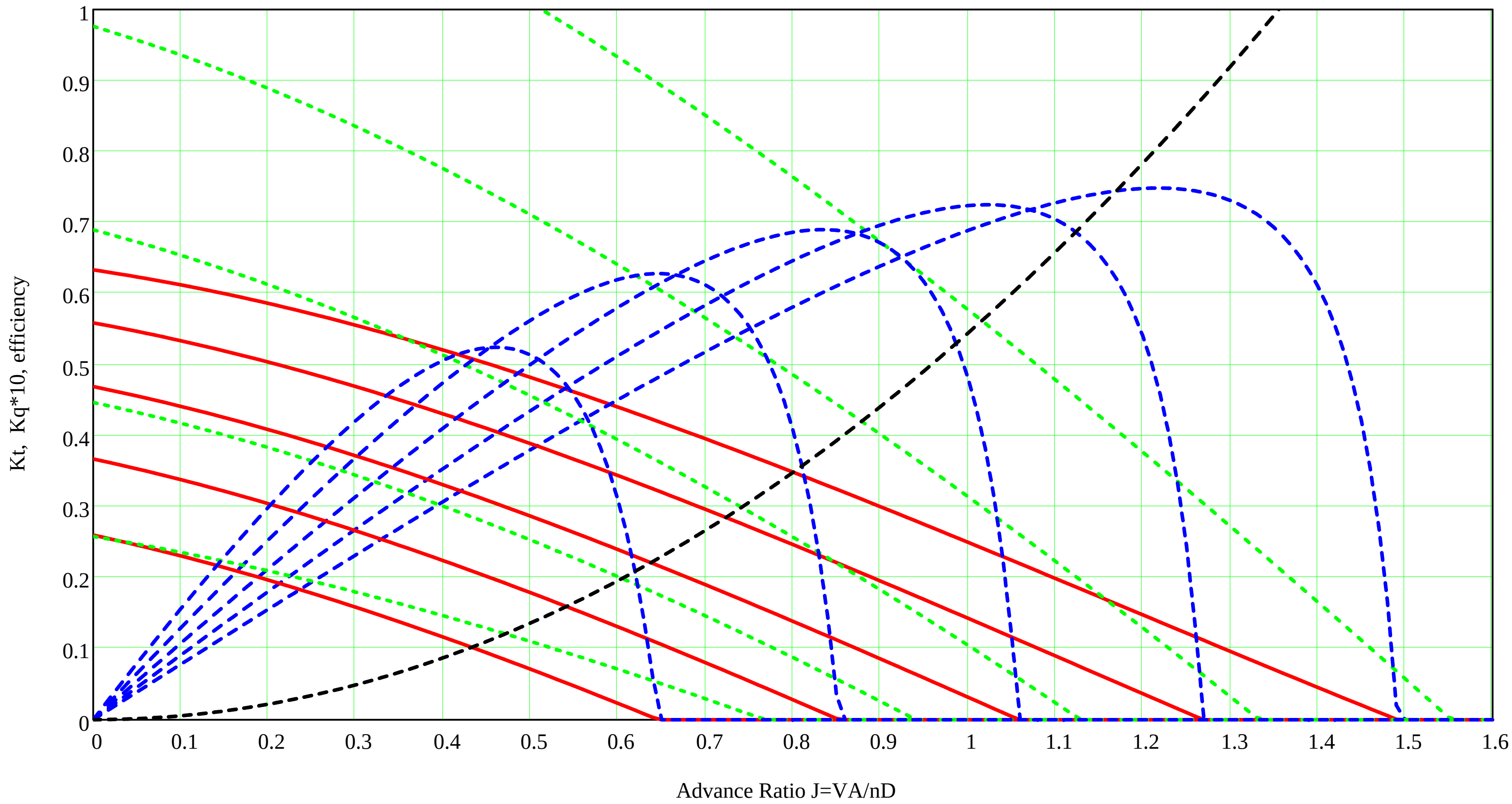
determine intersection



intersection occurs at $JJ = 0.64$ so ... $n = \frac{V_A}{JJ \cdot D}$ where V_A and D are known as described above selection of the optimum n for this B z.EAR propeller is a matter of comparing similar curves for a range of P/D and choosing the maximum open water efficiency η_o

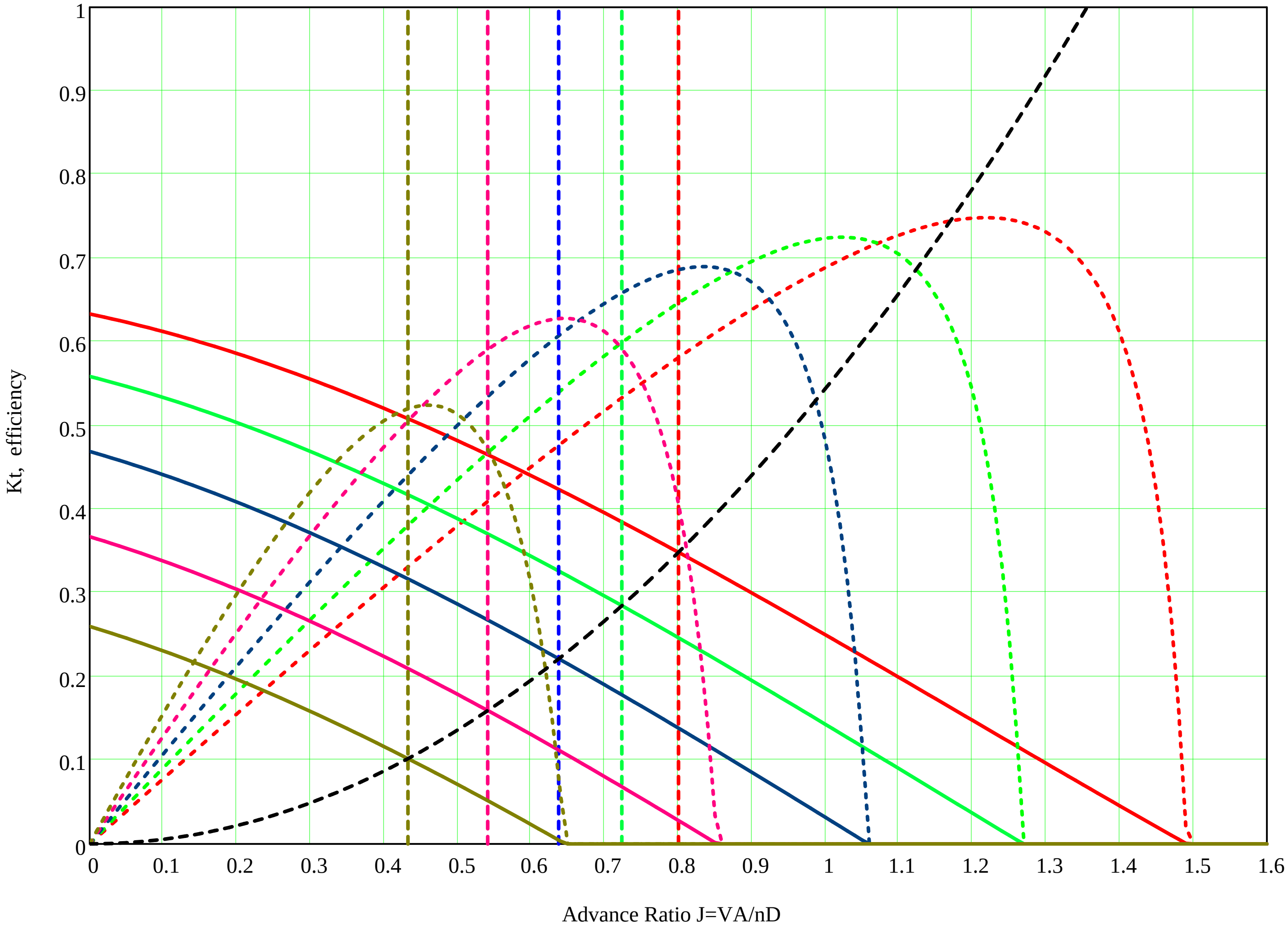
B series $z = 5$ $EAR = 0.75$

say .... $P\_over\_D := \begin{pmatrix} 1.4 \\ 1.2 \\ 1.0 \\ 0.8 \\ 0.6 \end{pmatrix}$



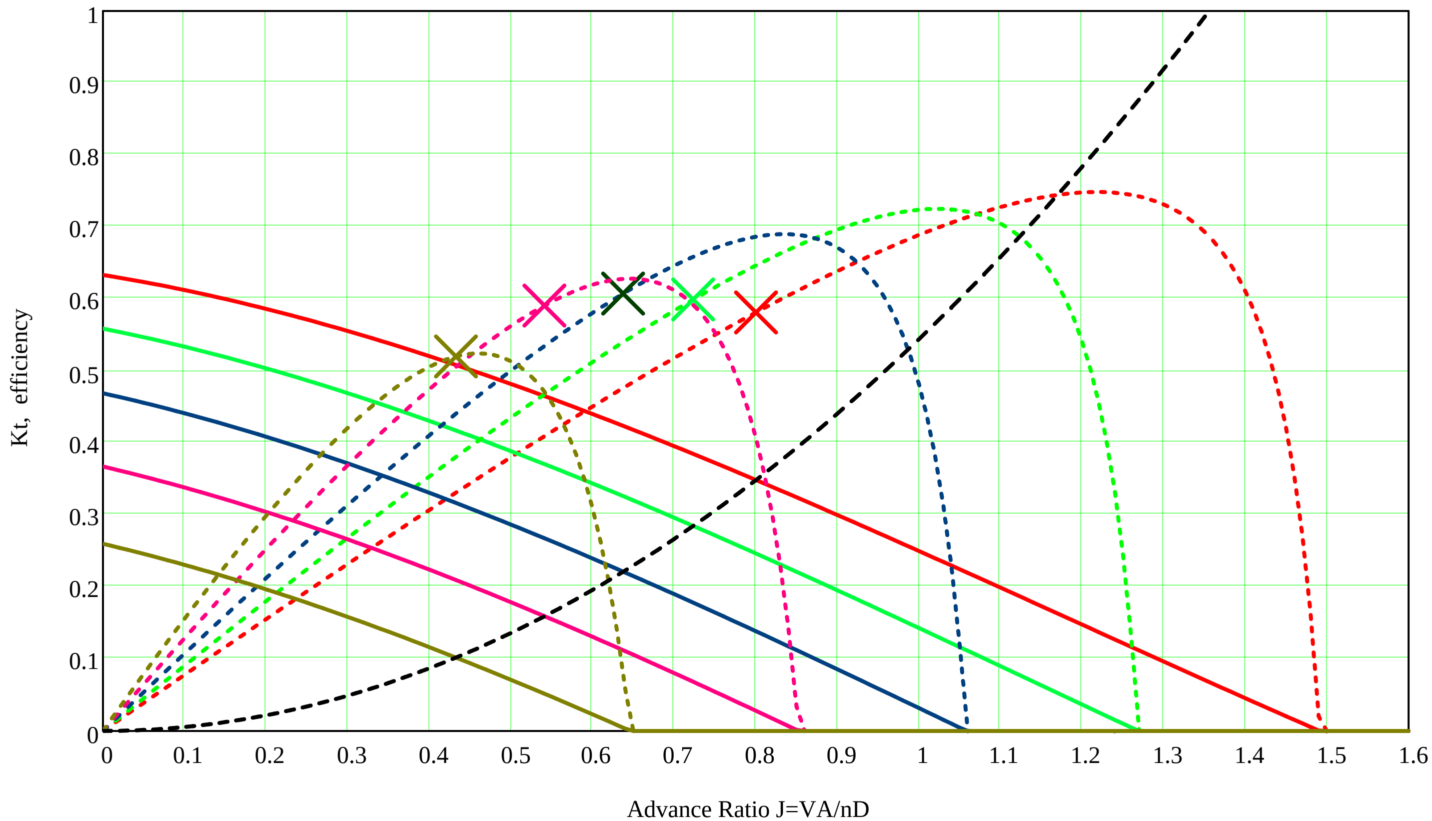
busy plot of Kt, Kq, η_o and Kt = constant * J^2. see breakdown below. P/D not labeled but ~ J at Kt = 0 intersection solution

plot with only Kt but vertical lines at J for Kt/J^2 = Kt to show points which satisfy the design requirements



P/D = 0.6 P/D = 0.8 P/D = 1.0 P/D = 1.2 P/D = 1.4

note the η_o at each J intersection and select the maximum (P/D curves not well labeled, P/D ~ = J at K_T=0. left to right lowest to highest



Plot for P/D = $P\_over\_D^T = (1.4 \ \ 1.2 \ \ 1 \ \ 0.8 \ \ 0.6)$ calculated using regression relationships

this case appears to have maximum at $J\_ans = 0.64$ $P\_over\_D\_ans = 1$ $\eta(J\_ans, EAR, z, P\_over\_D\_ans) = 0.61$

so ... $n = \frac{V_A}{J\_ans \cdot D}$ where V_A and D are known as described above

case 2 given: V_A, T, n find P/D and D for maximum efficiency

only thing unknown is D, eliminate ... from ratio of K_T and J

$$\frac{K_t}{J^4} = \frac{T}{\rho \cdot n^2 \cdot D^4} \cdot \frac{n^4 \cdot D^4}{V_A^{\ 4}} = \frac{T}{\rho} \cdot \frac{n^2}{V_A^{\ 4}}$$

this says that propeller (full scale and model) must match this ratio which is a constant determined by T, V_A, n and ρ

$$Kt\_over\_J\_4 := \frac{T}{\rho \cdot D^2 \cdot V_A^{\ 2}}$$

we can plot a curve of K_T vs J^4 and determine the points (values of J) for which K_T vs J for a given P/D match.

for example, let $Kt\_over\_J\_4 := 0.544$

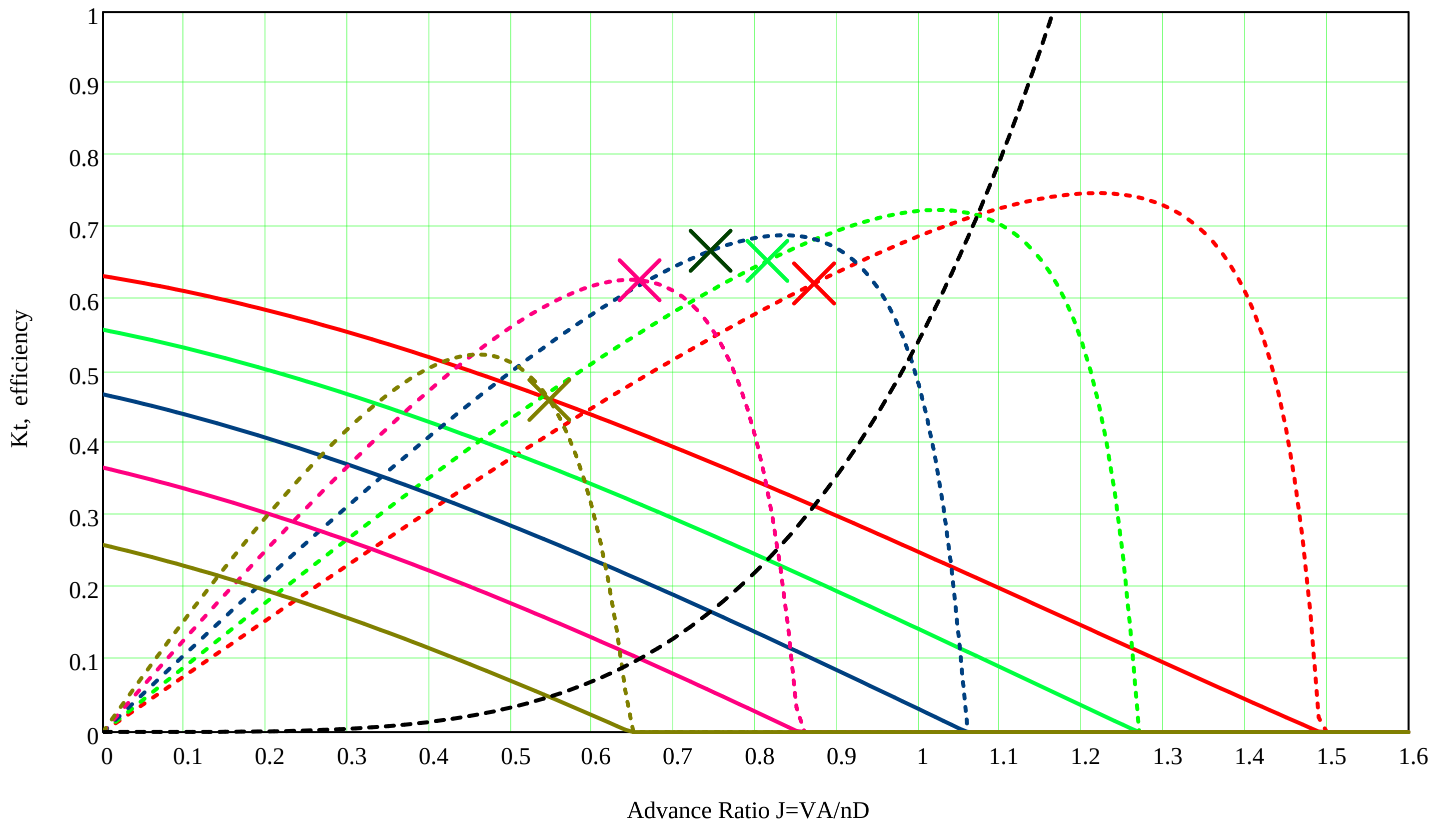
$Kt\_design(J) := Kt\_over\_J\_4 \cdot J^4$ select using B_series $z := 5$ $EAR := 0.75$

the design point for a particular propeller (B.n.nn) i.e. n is determined from the value of J that satisfies: $Kt(J) = constant \cdot J^4$

since the process is identical to case 1, only the final result is shown

intersection solution

note the η_o at each J intersection and select the maximum (P/D curves not well labeled, P/D ~ = J at K_T=0. left to right lowest to highest)



Plot for P/D = $P\_over\_D^T = (1.4 \ \ 1.2 \ \ 1 \ \ 0.8 \ \ 0.6)$ calculated using regression relationships

this case appears to have maximum at $J\_ans = 0.74$ $P\_over\_D\_ans = 1$ $\eta(J\_ans, EAR, z, P\_over\_D\_ans) = 0.67$

and ... $D = \frac{V_A}{J\_ans \cdot n}$ where V_A and n are known as described above