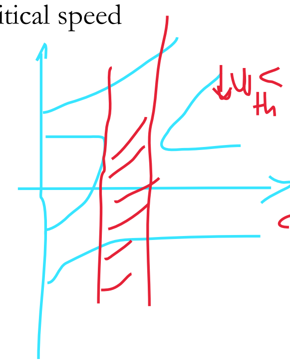
THEORY EXERCISES ON ROTORDYNAMICS AND TORSIONAL DYNAMICS OF CRANKSHAFTS

Choose the correct answer. Briefly explain in few lines, eventually resorting to graphs, schemes or formulas, the reason of your choice and exclusion of the other possible answers.

1. The inversion of the direction of whirling in the unbalance response of a rotor
   [A] Happens in the case of anisotropy of the stator, for spin speeds between the two critical speeds
   [B] Happens in case of anisotropy of the rotor, for spin speeds between the two critical speeds
   [C] Happens in case of anisotropy of the stator, for spin speeds above the second critical speed

2. The presence of a field of instability between the two critical speeds can happen
   [A] In case of a rotor on anisotropic supports
   [B] In case of an anisotropic rotor, and the rotating damping tends to reduce it ✓
   [C] In case of an anisotropic rotor, and the rotating damping tends to amplify it



$\downarrow \omega_{th} < \Omega_{cr} \left(1 + \frac{c_n}{c_{rp}}\right)$

$c_r \downarrow \omega_{th} \uparrow$

3. The phenomenon known as "oil whip" happens
   [A] At a frequency that is equal to the rotor's spin speed
   [B] At a frequency that is half the rotor's spin speed
   [C] At a frequency that is practically constant (with respect to the rotor's spin speed)

4. The Tuplin's and Carter's formula supply
   [A] The value of torsional stiffness equivalent to that of the crank
   [B] The value of a bar's length having a cross section identical to that of the crank shaft with stiffness equivalent to that of the crankpin.
   [C] The value of a bar's length having a cross section identical to that of the crank shaft with stiffness equivalent to that of the crank.

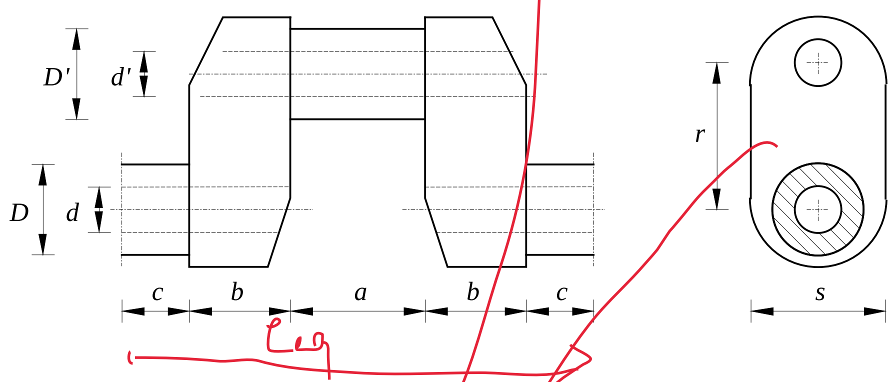
5. The moment J_0, needed to model the web with two concentrated masses, is
   [A] Always positive
   [B] Usually positive
   [C] Usually negative

Solutions: 1) [A], 2) [B], 3) [B], 4) [B], 5) [C].

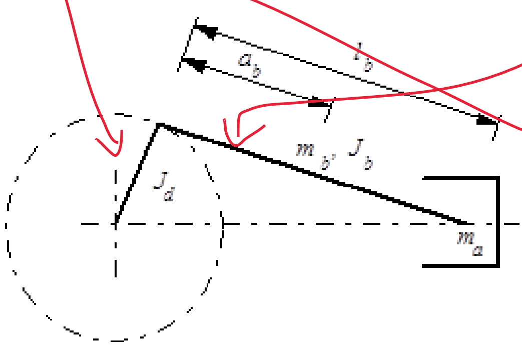
EXERCISES:

1. Using the data reported below that correspond to a small 4 stroke naval engine with two cylinders having a nominal displacement of 1000 cm³ (diameter x stroke 80x98 mm), evaluate
   - the equivalent length of the crank for the computation of the torsional stiffness;
   - the equivalent moment of inertia of the crank J_d
   - and the equivalent moment of inertia J_{eq} of the crank/rod/reciprocating masses.

Data: $r = 49$ mm, $a = 30$ mm, $b = 16$ mm, $c = 20$ mm, $s = 38$ mm,
$D = 30$ mm, $d = 10$ mm, $D' = 28$ mm, $d' = 10$ mm.



Referring to the same motor, calculate the equivalent average moment of inertia of the crank with respect to the axis of rotation.



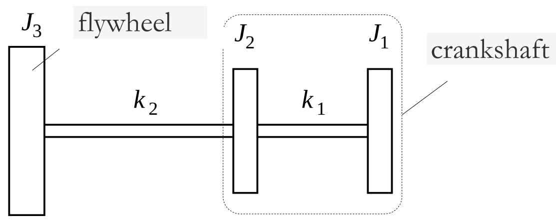
Data:

Length of the rod $l_b = 151$ mm,
Position of the center of gravity of the rod $a_b = 43$ mm,
Mass of the rod $m_b = 1.413$ kg,
Inertia moment of the rod $J_b = 2.686 \cdot 10^{-3}$ kgm²,
Reciprocating masses $m_a = 0.990$ kg.

Solution

$l_{eq} = 149.5$ mm, $\overline{J}_{eq} = 4.647 \cdot 10^{-3}$ kgm².

2. Calculate the torsional natural frequencies and mode shapes for the system shown in the figure. The system is composed by a crankshaft and regularizing flywheel.



Data:

Crank stiffness $l_{eq} = 149.5$ mm, $D = 30$ mm, $d = 10$ mm, $G = 7.7 \cdot 10^{10}$ N/m^2,

Stiffness of the connection between crankshaft and flywheel $k_2 = 5.290 \cdot 10^4$ Nm/rad,

Crank's inertias $J_1 = J_2 = 4.647 \cdot 10^{-3}$ kgm^2

Flywheel inertia $J_3 = 4.980 \cdot 10^{-2}$ kgm^2.

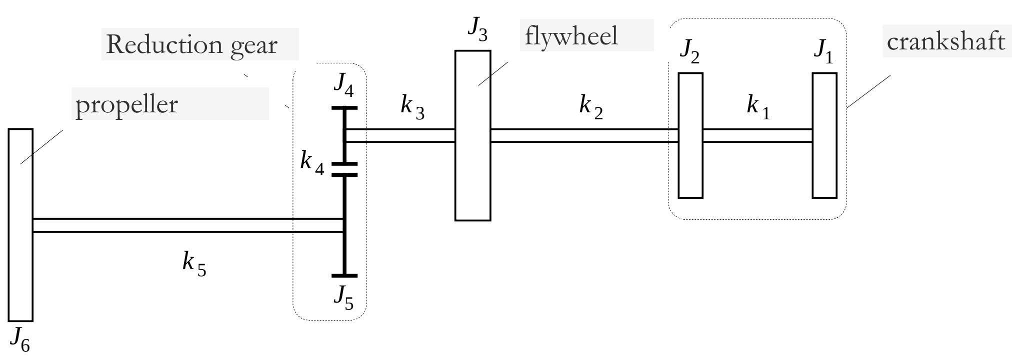
Solution:

$\omega_1 = 2.16 \cdot 10^3$ rad/s, $\omega_2 = 5.02 \cdot 10^3$ rad/s

3. The same motor of the previous exercise is connected to a propeller by means of a gear reduction system (transmission ratio τ) and a transmission shaft. The stiffness k_4 (value already reduced to the primary shaft) takes into account the deformability of the teeth. Calculate the torsional natural frequencies of the system.

Data: $k_3 = 6.541 \cdot 10^4$ Nm/rad, $k_4 = 7.294 \cdot 10^6$ Nm/rad, $k_5 = 3.572 \cdot 10^3$ Nm/rad,

$J_4 = 1.276 \cdot 10^{-4}$ kgm^2, $J_5 = 9.725 \cdot 10^{-4}$ kgm^2, $J_6 = 8.325 \cdot 10^{-2}$ kgm^2, $\tau = 0.304$.



Solution:

$\omega_1 = 2.20 \cdot 10^2$ rad/s, $\omega_2 = 2.16 \cdot 10^3$ rad/s, $\omega_3 = 5.02 \cdot 10^3$ rad/s, $\omega_4 = 1.74 \cdot 10^4$ rad/s, $\omega_5 = 3.72 \cdot 10^5$ rad/s.