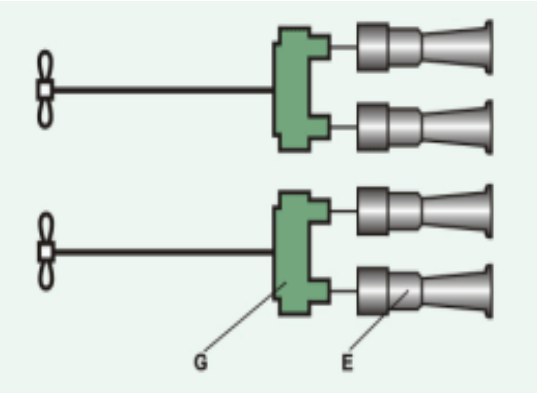
Problem 1 - 10 points

The Kashin was the first naval vessel to be power with gas turbines and was commissioned in 1962. The engine configuration used four gas turbines (single-shaft engines) to propel the ship configured to drive two propellers over two (reversible) gear boxes as illustrated below.



The cruise speed was 37-38 knots and the four gas turbines delivered around 96,000 shp in total (1 shp = 0.746 kW). The turbine material was probably conventionally cast alloy operating uncooled (except for blade root and disc cooling). Carry out a design point calculation for one of the gas turbines. Assume realistic levels on component efficiencies (in particular on the turbine inlet temperature).

Solution:

Assume polytropic efficiencies of 88% on compressor and turbine. Since the turbine operates uncooled a realistic value on a conventionally cast turbine is 1200 K. The low T_{03} indicates that a low pressure ratio was used. Assume a pressure ratio of 8.0 (any pressure ratio between 6-20 will not lead to any deduction of points).

ISA standard => t1 = 288.15, p1 = 101.325 kPa. Compressor exit station:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{\eta_{c,\infty}}\frac{\gamma-1}{\gamma}} \qquad (2.15)$$

t2 = 566.01, p2 = 810.6 kPa

$$P_{03} = P_{02}\left(1 - \frac{\Delta p_b}{p_{02}}\right)$$

$$\frac{\Delta p_b}{p_{02}} \approx 2 - 3\% \text{ (industrial gas turbine)}$$

Assume a pressure loss value of 3%, which gives p3 = 786.3 kPa, t3 = 1200 K. The turbine exit station obtained from:

$$\frac{T_{03}}{T_{04}} = \left(\frac{P_{03}}{P_{04}}\right)^{\eta_{t,\infty}\frac{\gamma-1}{\gamma}} \qquad (2.17)$$

T4 = 764.8 K, P4 = P1= ambient pressure. The power output is

$$w_t - w_{tc} = 217.5\,\text{kW}$$

Power requirement per engine is 17.90 MW which gives a required mass flow per engine of about m = 82.28 kg/s.