AERO0015-1

Mechanical design of turbomachinery

Assignment
Dynamic analysis of a twin-spool turbo-jet engine

Report deadline: November 1, 2024

Consider the model of a twin-spool turbo-jet engine shown in Figure 1.

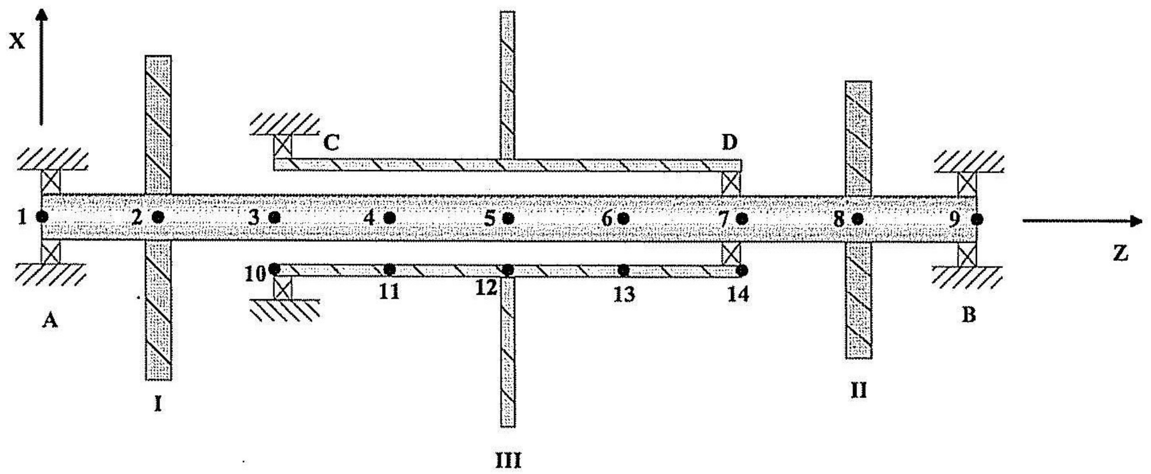

Figure 1

1. Construct the finite element model of the engine using beam finite elements.
2. Plot the Campbell diagram in the range from 0 to 20000 rpm for the seven first modes of vibration. The reference speed of rotation will be the rotation speed Ω_1 of the low pressure rotor.
3. Determine the critical speeds of the whole engine and discuss the stability of the system with respect to a possible nominal rotation speed.
4. Show the mode shapes at $\Omega = 0$.
5. Is the nominal speed of 5000 rpm for the low pressure shaft acceptable? If not, how would you modify the design?

The written report should not exceed 10 pages!

DATA

Material properties: $E = 2.05\ 10^{11}\ N/m^2$, $\rho = 7850\ kg/m^3$

No damping is considered in the system.

Dimensions of the shafts:

- Diameter of the low pressure shaft (Ω_1) = 50 mm.
- Inner diameter of the high pressure shaft (Ω_2) = 70 mm.
- Outer diameter of the high pressure shaft (Ω_2) = 80 mm.
- Relationship between the rotation speeds: $\Omega_2 = 1.5\ \Omega_1$

Geometry:

Node n°	Coordinate (Z) in *cm*
1	0
2	10
3	20
4	30
5	40
6	50
7	60
8	70
9	80
10	20
11	30
12	40
13	50
14	60

Discs:

	Disc n° I	Disc n° II	Disc n° III
Thickness (*mm*)	20	20	15
Diameter (*cm*)	25.7	30	38

Supports:

	A	B	C	D
$k_{xx} = k_{yy}$ (*N/m*)	$3\ 10^7$	$3\ 10^7$	$2.5\ 10^7$	$2.5\ 10^7$
$k_{xy} = k_{yx}$ (*N/m*)	0	0	0	0

The stiffness matrix of a bearing element is

$$\mathbf{K}_P^e = \begin{bmatrix} k_{xx} & -k_{xx} & \frac{k_{xy}+k_{yx}}{2} & -\frac{k_{xy}+k_{yx}}{2} \\ -k_{xx} & k_{xx} & -\frac{k_{xy}+k_{yx}}{2} & \frac{k_{xy}+k_{yx}}{2} \\ \frac{k_{xy}+k_{yx}}{2} & -\frac{k_{xy}+k_{yx}}{2} & k_{yy} & -k_{yy} \\ -\frac{k_{xy}+k_{yx}}{2} & \frac{k_{xy}+k_{yx}}{2} & -k_{yy} & k_{yy} \end{bmatrix}$$