Pump & Fan Blade Pass Frequencies

blade_pass_frequencies_a ver 1.0 by Tom Irvine

Notation

N shaft speed (rpm), Z_r rotor blades or impeller vanes, Z_s stationary vanes (diffuser vanes, volute tongues, cutoffs, stator vanes or struts; 0 = none), $m, n = 0, 1, 2, \ldots$ harmonic integers, k nodal diameter (diametral) order.

Excitation frequencies

1. Shaft speed $\qquad f_1 = \dfrac{N}{60}$ Hz

2. Blade pass frequency (casing, piping) $\qquad \mathrm{BPF} = Z_r\, f_1, \qquad f_m = m\, Z_r\, f_1, \quad m = 1, 2, \ldots$

3. Stator pass frequency (seen by the rotor) $\qquad f_n^{rot} = n\, Z_s\, f_1, \quad n = 1, 2, \ldots$

Rotor-stator interaction (Tyler & Sofrin; Kubota et al.)

4. Diametral order $\qquad k = m\, Z_r - n\, Z_s \qquad \Longleftrightarrow \qquad m\, Z_r \mp |k| = n\, Z_s$

5. Frequency of that pattern $\qquad m\, Z_r\, f_1$ in the casing, $\quad n\, Z_s\, f_1$ on the rotor

6. Pattern speed (stationary frame) $\qquad N_p = \dfrac{m\, Z_r\, N}{k}$ rpm; $\quad k > 0$ turns with the rotor, $k < 0$ against it

7. All vanes in phase ($k = 0$) $\qquad m_0 = \dfrac{Z_s}{\gcd(Z_r, Z_s)}, \qquad n_0 = \dfrac{Z_r}{\gcd(Z_r, Z_s)}$

The app lists every (m, n) with $1 \le m \le$ harmonics, $n \ge 0$ and $|k| \le k_{max}$. $n = 0$ is the rotor pattern alone ($k = mZ_r$). $|k| = 1$ gives a net radial force on the shaft; $k = 0$ gives an in-phase (plane-wave) pressure pulsation.

Duct / pipe plane-wave acoustic modes

8. Open-open (or closed-closed) $\qquad f_j = \dfrac{j\, c}{2L}, \quad j = 1, 2, \ldots$

9. Closed-open $\qquad f_j = \dfrac{(2j - 1)\, c}{4L}, \quad j = 1, 2, \ldots$

End corrections and higher-order (cross) duct modes are neglected. Duct modes are checked by frequency only.

Coincidence check

A natural frequency f_n is flagged when $100\,|f_n - f_e|/f_e <$ margin for an excitation f_e in its own frame (casing / piping: $1X$ and m BPF; rotor: nZ_sf_1) that can drive its nodal diameter ND (blank = any):

m BPF drives ND if $n = (mZ_r \mp \mathrm{ND})/Z_s$ is an integer ≥ 0 ($Z_s = 0$: ND $= mZ_r$); $1X$ drives ND ≤ 1;
nZ_sf_1 drives a rotor mode ND if $m = (nZ_s \pm \mathrm{ND})/Z_r$ is an integer ≥ 0.

A frequency inside the margin whose ND is not driven is reported as "Near, ND differs".

Units

English: L ft, c ft/s. **metric**: L m, c m/s. Both: N rpm, frequencies Hz, cpm = 60× Hz, order = f/f_1.

References

1. J. M. Tyler and T. G. Sofrin, Axial Flow Compressor Noise Studies, SAE Technical Paper 620532, *SAE Trans.* 70, 1962.
2. Y. Kubota, T. Suzuki, H. Tomita, T. Nagafuji, C. Okamura, Vibration of Rotating Bladed Disc Excited by Stationary Distributed Forces, *Bulletin of the JSME* 26 (221), 1952-1957, 1983.
3. C. G. Rodriguez, E. Egusquiza, I. F. Santos, Frequencies in the Vibration Induced by the Rotor Stator Interaction in a Centrifugal Pump Turbine, *J. Fluids Eng.* 129 (11), 1428-1435, 2007.
4. C. E. Brennen, *Hydrodynamics of Pumps*, Concepts ETI / Oxford, 1994, ch. 8 (rotor-stator interaction).
5. L. E. Kinsler et al., *Fundamentals of Acoustics*, Wiley (pipe resonances, open and closed ends).

Note: the sign convention for k follows secondary summaries of refs. 1-3; the original Kubota (1983) text was not checked.