MEC521 Chapter 4: FRF, spectra and diagnosis

Why it matters

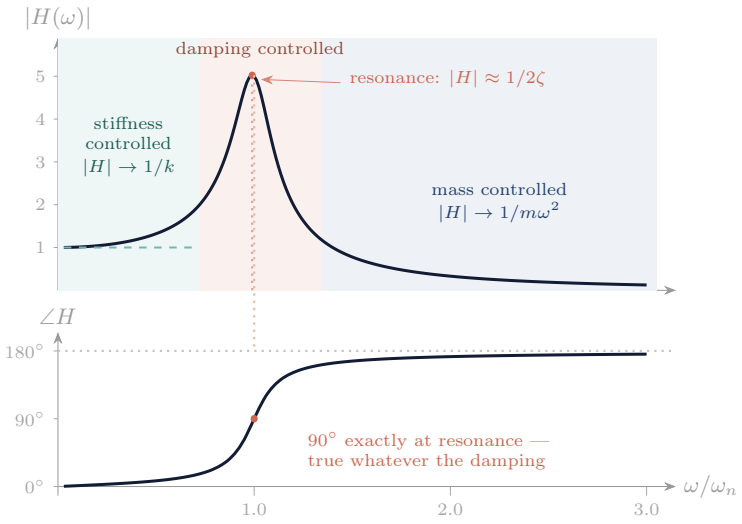
A machine reports its condition in its vibration. This chapter turns a record into a spectrum and a peak into a diagnosis: imbalance, misalignment, a worn gear or a failing bearing.

Start here

Check the measurement before reading any peak. The record length sets the resolution, the sampling rate sets the highest frequency you can trust (F4.2.1, F4.2.2), and a whole number of cycles in the record avoids leakage.

One picture

The FRF is Chapter 2's amplitude and phase as one complex number (F4.1.1): stiffness sets the response below resonance, mass above it, damping only near ω_n. The animation runs a whole modal test.
Animated: `fft-anim/MEC521-ch4-pipe.gif`.

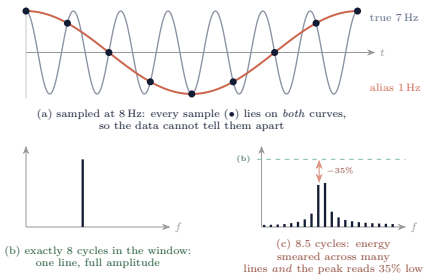


Which formula?

Read the situation first, then pick the formula. The tags are the ones on the examination formula sheet and in Appendix A.

You see...	Use	It holds when
What do these analyser settings give me?	$T = \frac{N}{f_s}, \qquad \Delta f = \frac{f_s}{N} = \frac{1}{T}$ F4.2.1	**Resolution is set by record length alone.** Sampling faster buys bandwidth, not resolution.
	$f_{\text{Nyq}} = \frac{f_s}{2}$ F4.2.2	Nothing above this can be measured. An anti-alias filter must remove it *before* sampling.
A peak with no physical explanation	$f_{\text{alias}} = \lvert f - n f_s \rvert$ F4.2.3	Diagnosing a peak with no physical explanation. The test: change f_s — a real peak stays put, an alias moves.
Gears	$\text{GMF} = N_{\text{teeth}} \times f_{\text{shaft}}$ F4.4.1	Gears. The same number from either shaft — computing it both ways is a free check.
A rolling-element bearing	$\text{BPFO} = \frac{n f_r}{2}\left(1 - \frac{d}{D}\cos\phi\right)$ F4.4.3	Outer-race defect. Characteristically *no* sidebands at f_r, because the defect sits still in the load zone.
	$n\,\text{FTF} = \text{BPFO}, \qquad \text{BPFO} + \text{BPFI} = n f_r$ F4.4.6	**Two free arithmetic checks** that hold for every bearing. If either fails you have mistyped d/D.
Acceleration reading, velocity limit	$v_{\text{rms}} = \frac{a_{\text{rms}}}{2\pi f}$ F4.3.1	Only when the signal is *dominated by a single frequency*. For a broadband signal, integrate in the frequency domain line by line.
Is this level acceptable?	Class II zones: $1.12 / 2.80 / 7.10\,\text{mm s}^{-1}$ F4.5.2	Zone A new, B acceptable for continuous running, C unsatisfactory for continuous running, D damage occurring.

Reading the pictures



The two checks every measurement needs. Aliasing cannot be undone and is stopped before sampling (F4.2.2, F4.2.3); leakage appears whenever the record holds a part cycle, and a window controls it.



Four signatures worth knowing on sight. The diagnosis rests on relative amplitudes and shaft orders; a bearing defect is the one that is not a whole order (F4.4.3).

Ways to lose marks

Faster sampling is not finer resolution. The line spacing is $1/T$, set by the record length alone (F4.2.1). Sampling faster buys bandwidth, not detail.
A peak that should not be there. Change the sampling rate: a real peak stays put, an alias moves (F4.2.3).
Unwindowed amplitudes. A tone that falls between two lines leaks and reads low. Never trust an amplitude read without a window.
Acceleration is not velocity. $v_{\text{rms}} = a_{\text{rms}}/2\pi f$ holds only when one frequency dominates (F4.3.1). The severity zones are in velocity (F4.5.2).
Bearing arithmetic. Two checks hold for every bearing; if either fails, d/D is mistyped (F4.4.6).

Where next. Handbook: § 4.1–§ 4.7 for the worked examples, Appendix A for every tag. **Slides:** the Chapter 4 deck, with every animation.