MAE 298 Aeroacoustics – Homework#4
Turbomachinery Noise

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Problem Statement

You are designing a new aircraft engine and analyzing acoustic propagation generated by a non-uniform flow with angle of attack interacting with rotating fans. You obtained flow fields from CFD for a one-sixth small scale of the engine. The radius for the small scale engine is 13 in and the hub radius is 3 in. CFD provides the velocity gust information as a function of its circumferential modes. The circumferential mode for acoustics can be expressed as $m = nBkV$ where B is the number of blades, V is the number of vanes, n stands for the harmonic of BPF and k is the integer (1, 2, 3...). You consider only positive k at this time (this is related the rotation direction of gust). The number of blades is 18. The number of vanes is considered to be 1 since there is no physical vanes but there is one revolution difference. The Mach number is 0.525 and the fan RPM is 8326.3042, the speed of sound is 13503.937009 in/s and the density is 1.4988E-5 slug/in$\hat{3}$. The dominant noise is generated at the 1st BPF or $n = 1$ in which the angular frequency ω is given as $RPM \times \frac{2\pi}{60} \times B$. We are interested in the propagation through the inlet of !" the engine so that sound propagates to z direction assuming the $+z$ direction is in the flow direction.

I. Eigenvalues

1. [20 points] Determine the first five eigenvalues of acoustics for m=18, 17, 16, 15 or (k=1, 2, 3, 4) or (m,n)=(18,0), (18,1), (18,2), (18,3), (18,4), (17,0), (17,1), (17,2), (17,3), (17,4), (16,0), (16,1), (16,2), (16,3), (16,4), (15,0), (15,1), (15,2), (15,3), (15,4)

	m = 18	**m = 17**	**m = 16**	**m = 15**
n = 0	1.5495	1.4696	1.3895	1.3093
n = 1	1.9612	1.8755	1.7896	1.7032
n = 2	2.2823	2.1932	2.1036	2.0137
n = 3	2.5772	2.4855	2.3932	2.3005
n = 4	2.8585	2.7646	2.6702	2.5753

Table 1: Eigenvalues μ for all modes

I.A. Ground Testing

The most straight-forward of testing methods described by Himelblau is the

II. Eigenfunctions

2. [20 points] Plot the five eigenfunctions (radial modes, n=0, 1, 2, 3, 4) for m=18, 17, 16, 15 or (k=1, 2, 3, 4) and verify n describes the number of zero crossings in the radial direction

III. Wavenumbers

3. [20 points] Determine the wavenumbers in the z direction for (m,n)=(18,0), (18,1), (18,2), (17,0), (17,1), (17,2), (16,0), (16,1), (16,2), (15,0), (15,1), (15,2). Indicate whether the mode is

cut-on (propagating) or cut-off (exponentially decaying). Consider only the propagation in the z direction. Exclude the exponentially growing solution and include only the propagating solutions or exponentially decaying solutions.

m	n	K_z	Cut – on
18	0	(-0.842342752252+0.860467931211j)	No
18	1	(-0.842342752252+1.6539375966j)	No
18	2	(-0.842342752252+2.14865069168j)	No
17	0	(-0.842342752252+0.63804009925j)	No
17	1	(-0.842342752252+1.5105548176j)	No
17	2	(-0.842342752252+2.01642513534j)	No
16	0	(-0.842342752252+0.301624659942j)	No
16	1	(-0.842342752252+1.35896420335j)	No
16	2	(-0.842342752252+1.8801224576j)	No
15	0	(-0.386366560427+0j)	Yes
15	1	(-0.842342752252+1.19608312922j)	No
15	2	(-0.842342752252+1.73881279925j)	No

Table 2: Axial wavenumbers K_z for certian modes and associated cut-on condition

IV. Modal Power Levels

4. [30 points] The pressure distribution file at z=0 plane for m=18 or 1 BPF is provided. The first column is the dimensional radius [in], the second column the real part of the pressure [psi], and the third column is the imaginary part of the pressure [psi]. Using this boundary condition, compute the sound power level for (m,n)=(18,0), (18,1), (18,2). This noise is considered for blade self noise that is not associated with the gust response since k=0. Note that the z=0 plane is not the same as the engine inlet. Use the conversion for the unit for the sound power as follows: $PWL(dB) = 10 * \log_{10}(W_{mn}) - 10 * \log_{10}(7.3756E-13)$

n	PWL(dB)
0	-10.4015
1	-13.3776
2	-22.3880

Table 3: Sound Power Levels in dB of modal power of $m = 18$ circumfrential mode