

# **MAE 298 Aeroacoustics – Homework#4**

## **Turbomachinery Noise**

Logan D. Halstrom

*Graduate Student*

*Department of Mechanical and Aerospace Engineering*

*University of California, Davis, CA 95616*

## 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<sup>3</sup>. The dominant noise is generated at the 1st BPF or  $n = 1$  in which the angular frequency  $\omega$  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  $(m,n)=(18,0), (18,1), (18,2), (18,3), (18,4), (17,0), (17,1), (17,2), (17,3), (17,4), (16,0), (16,1), (16,2), (16,3), (16,4), (15,0), (15,1), (15,2), (15,3), (15,4)$

	<b>m = 18</b>	<b>m = 17</b>	<b>m = 16</b>	<b>m = 15</b>
<b>n = 0</b>	1.549545	1.469574	1.389482	1.309256
<b>n = 1</b>	1.961197	1.875532	1.789559	1.703250
<b>n = 2</b>	2.282319	2.193182	2.103645	2.013674
<b>n = 3</b>	2.577225	2.485453	2.393227	2.300507
<b>n = 4</b>	2.858492	2.764587	2.670191	2.575265

Table 1: test

### I.A. Ground Testing

The most straight-forward of testing methods described by Himmelblau 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	Kz	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

### 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:  $PWL (dB) = 10 \cdot \log_{10}(W_{mn}) - 10 \cdot \log_{10}(7.3756E-13)$