TURBOMACHINERY AERODYNAMICS

Lect - 18

Prof. Bhaskar Roy, Prof. A M Pradeep
Department of Aerospace Engineering,
IIT Bombay

Noise problem in Axial Compressors and Fans

Prof Bhaskar Roy, Prof A M Pradeep, Department of Aerospace, IIT Bombay

- Compressor or Fan noise coming out of the front of the engine is a different kind of noise than the jet noise from the rear of the engine.
- It is mainly due to rotating blades cutting through the air at high speed
- Noise escalates air speed relative to the rotating blades increases. This may due either to higher rotating speed or to higher incoming axial velocity
- Modern transonic / supersonic compressors, thus, make more noise than the old subsonic compressors and fans

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Fundamentals of acoustics:

1) All sound is due to fluctuation of pressure levels and travel of this fluctuation
2) Sound is measured in decibels– A,B & F scales
3) Sound pressure level (SPL) is defined as :

$$\mathbf{SPL = 20 \log_{10}(p/p_{ref}) \quad dB}$$

where p is the RMS pressure fluctuation and p_{ref} is the reference RMS of pressure fluctuation , is taken equal to $\mathbf{2 \times 10^5}$ N/m^2

4) Acoustic power is defined as Power Watt Level

$$\mathbf{PWL = 20 \log_{10}(W/W_{ref}) \quad dB}$$

where $\mathbf{W}$ is the acoustic power in watt, and $\mathbf{W_{ref}}$ is the reference acoustic power = $\mathbf{10^{-12}}$ watt .

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Fundamentals of acoustics:

- The pressure changes or fluctuations travel in waves with certain frequency and amplitude.
- Normally higher the frequency, lower is the amplitude – these are the high pitched noise – of low power
- Conversely, high amplitude noise often has lower frequencies – these are bass sound – and carry high power
- A particular source may carry a whole spectrum of noise frequencies – these are broadband noise

Measure of Sound

1) The overall noise is often measured as overall sound pressure level (OSPL) – which is RMS pressure level of the entire noise signal.
2) However, for more detailed understanding the overall noise signal is broken down into its spectral components mathematically – through Fourier Transform.
3) FT produces spectral density, for which the bandwidth is 1 Hz.
4) Noise is measured from 10 Hz to 20kHz

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Measure of Sound

- Noise is measure in many scales : A, B,C, D and F scales.
- Human perception of sound is restricted between 10 Hz and 12 kHz – beyond which it is often called ultra-sonic sound
- The above scales have been artificially created for various purposes – to meet industrial noise regulatory requirements
- ‘**A**’ scale has been created to correspond to human hearing – very low and very high frequency noise are reduced artificially and noise from 400 Hz to 10 kHz are shown dominantly.

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Measure of Sound

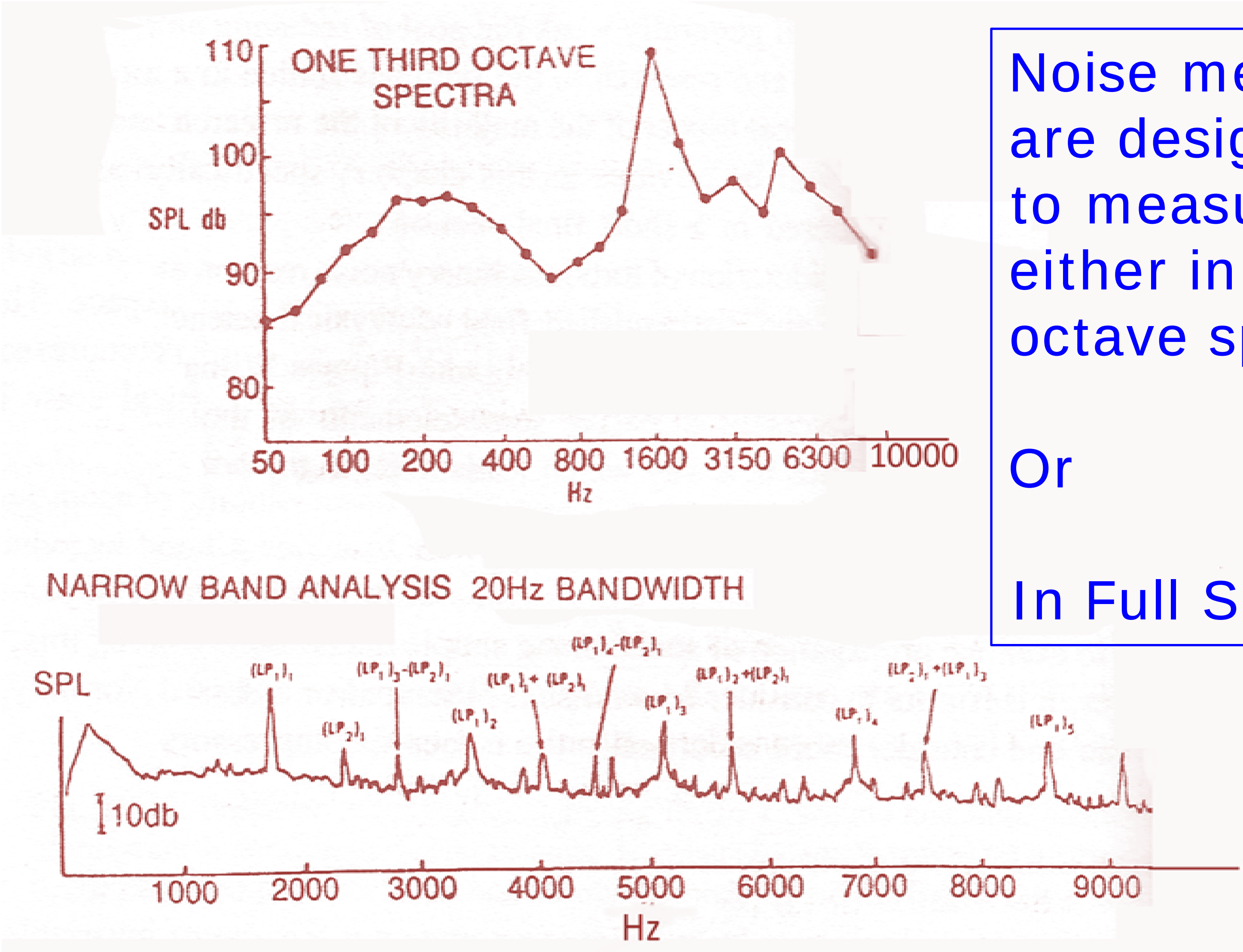
- A more evolved noise rating is the Perceived Noise Level (PNL)
- It is measured as perceived noise decibel (PNDB)
- A further evolved version is used to judge the annoyance created to any person at any time – which normally carried at least one strong tone. The spectrum analysis shows the presence of the dominant tone. A correction is added to account for the presence of a tone.
- This is measured as effective perceived noise decibel (EPNDB)

Pressure fluctuations are expressed as : (derived)

$$p = \frac{\cos\alpha}{4.\pi.r}.\frac{f}{a}.A$$

Where, A is the amplitude of the oscillating force, *f* is the frequency of oscillations, at a distance *r* from the point of observation, and *a* is the speed of sound.

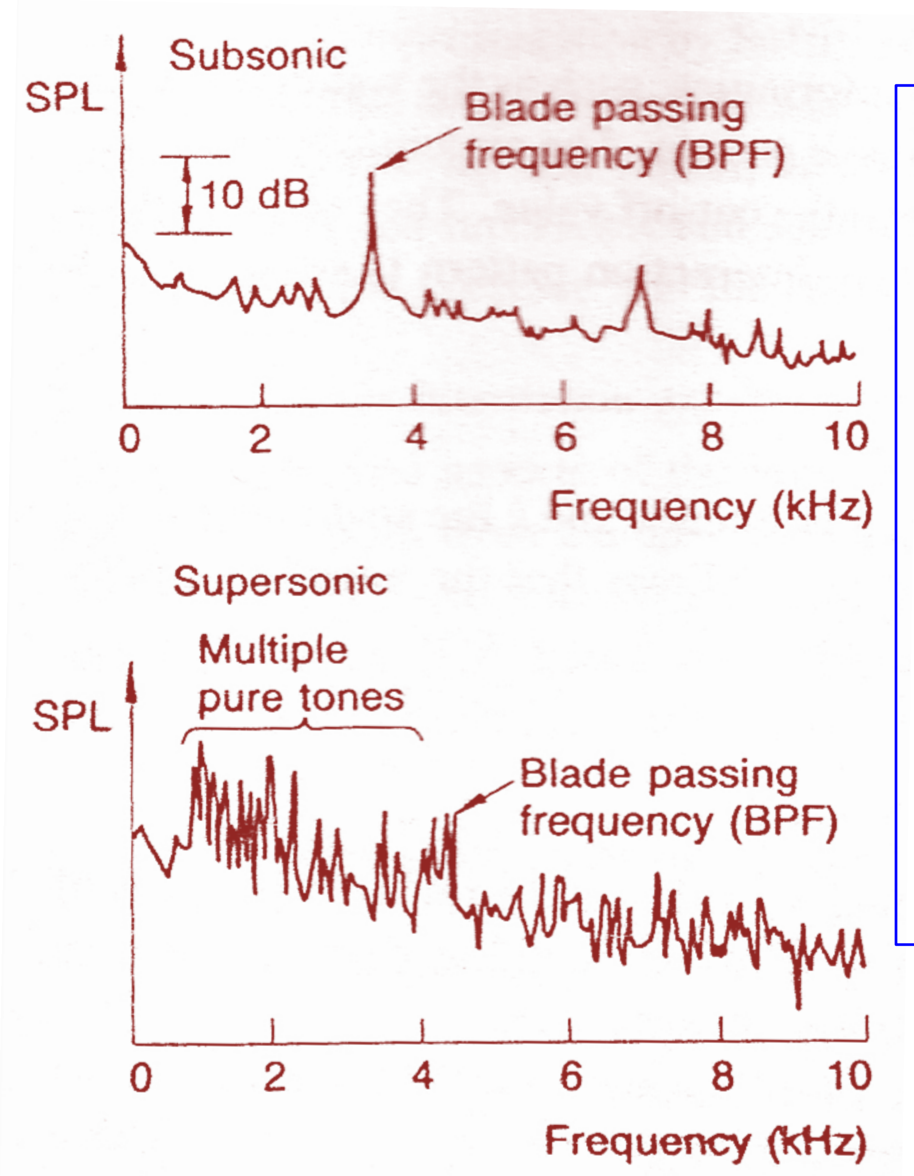
This allows an approximate estimate of the pressure fluctuations and may provide an approximate estimate of the power associated with it. Power is proportional to sixth power of The blade speed.



Noise meters are designed to measure either in 1/3 octave spectra

Or

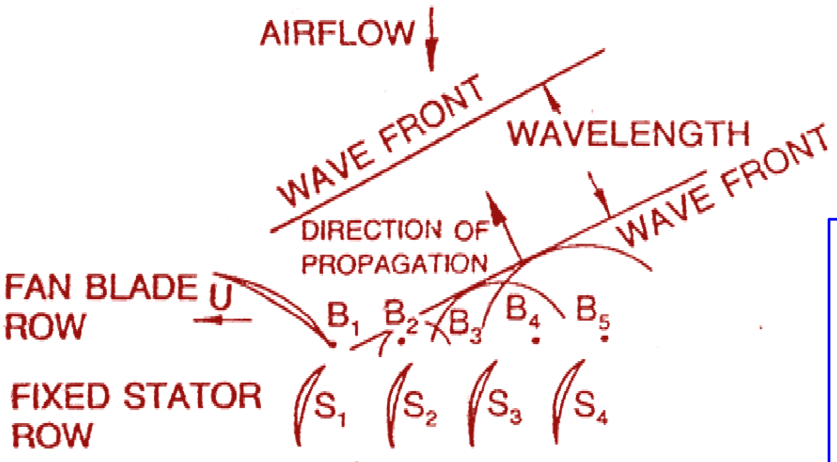
In Full Spectra



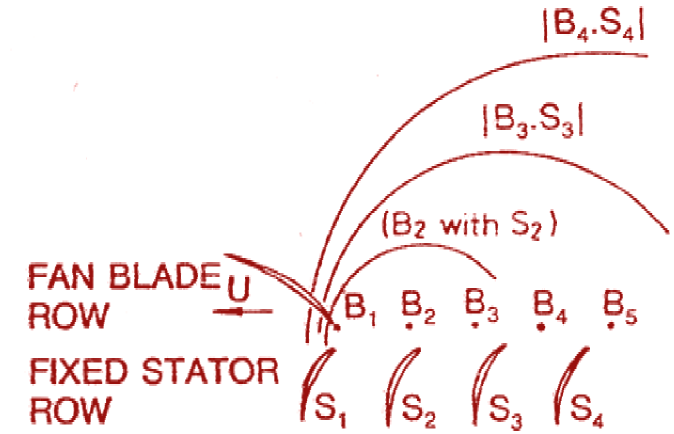
- As long as the compressors and fans were subsonic the compressor & fan noise was mainly from the *blade passing frequency* , which was clearly the most intense noise source, approx. 10 dB above the rest of the noises.

- As the compressors went transonic/supersonic shock generated noise got mixed up with BPF noise peaks

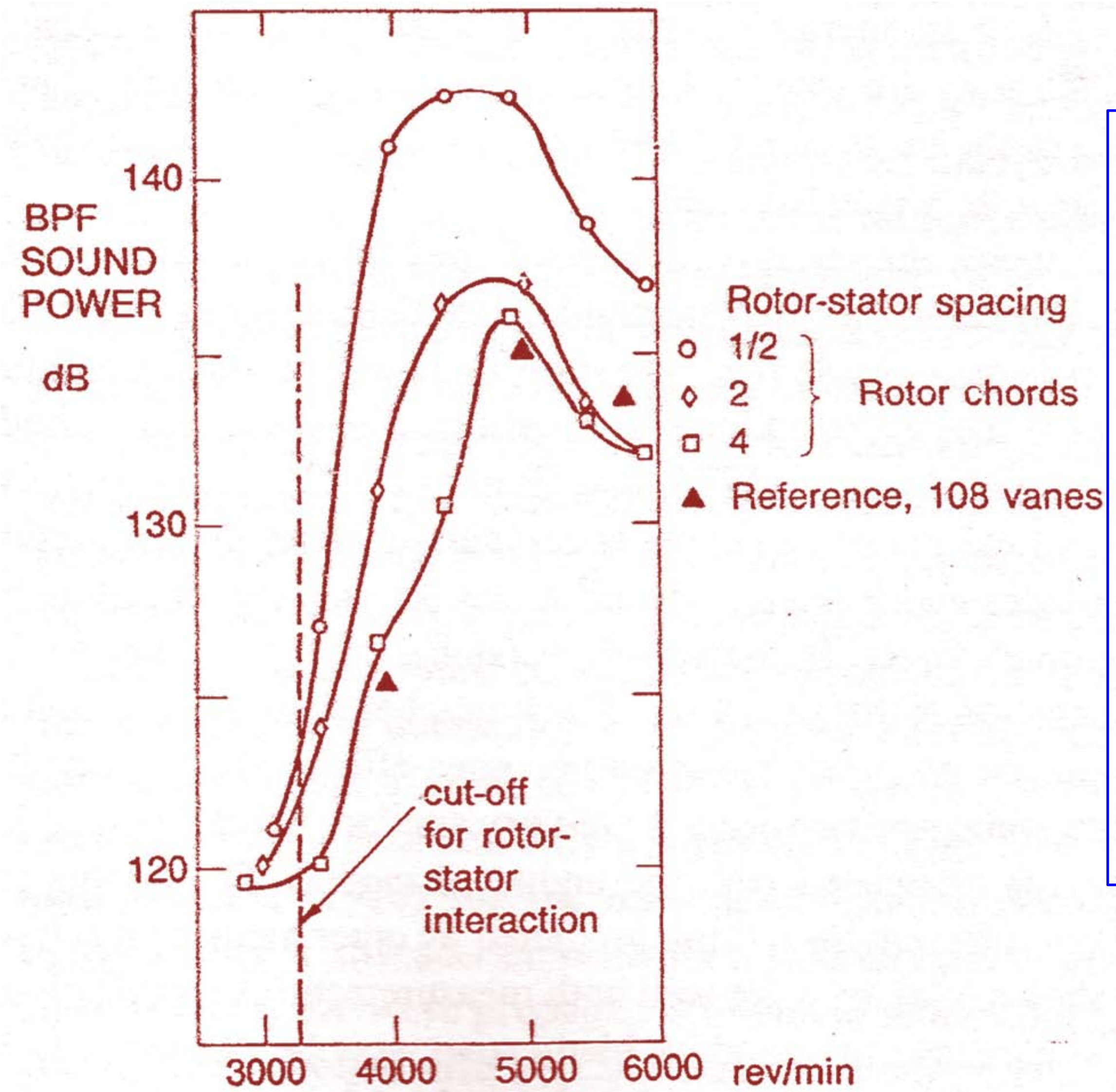
PROPAGATING INTERACTION FIELD



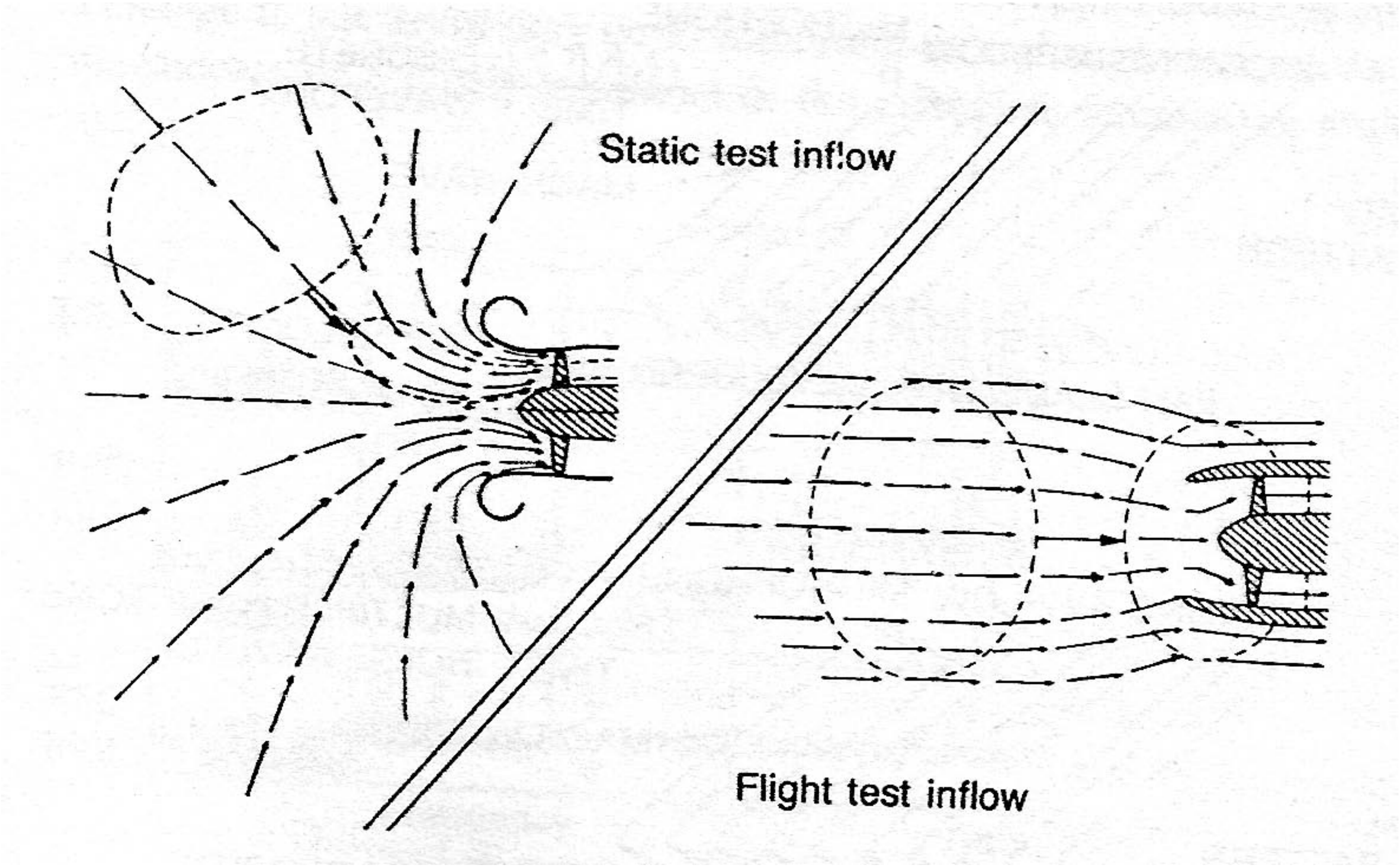
DECAYING INTERACTION FIELD



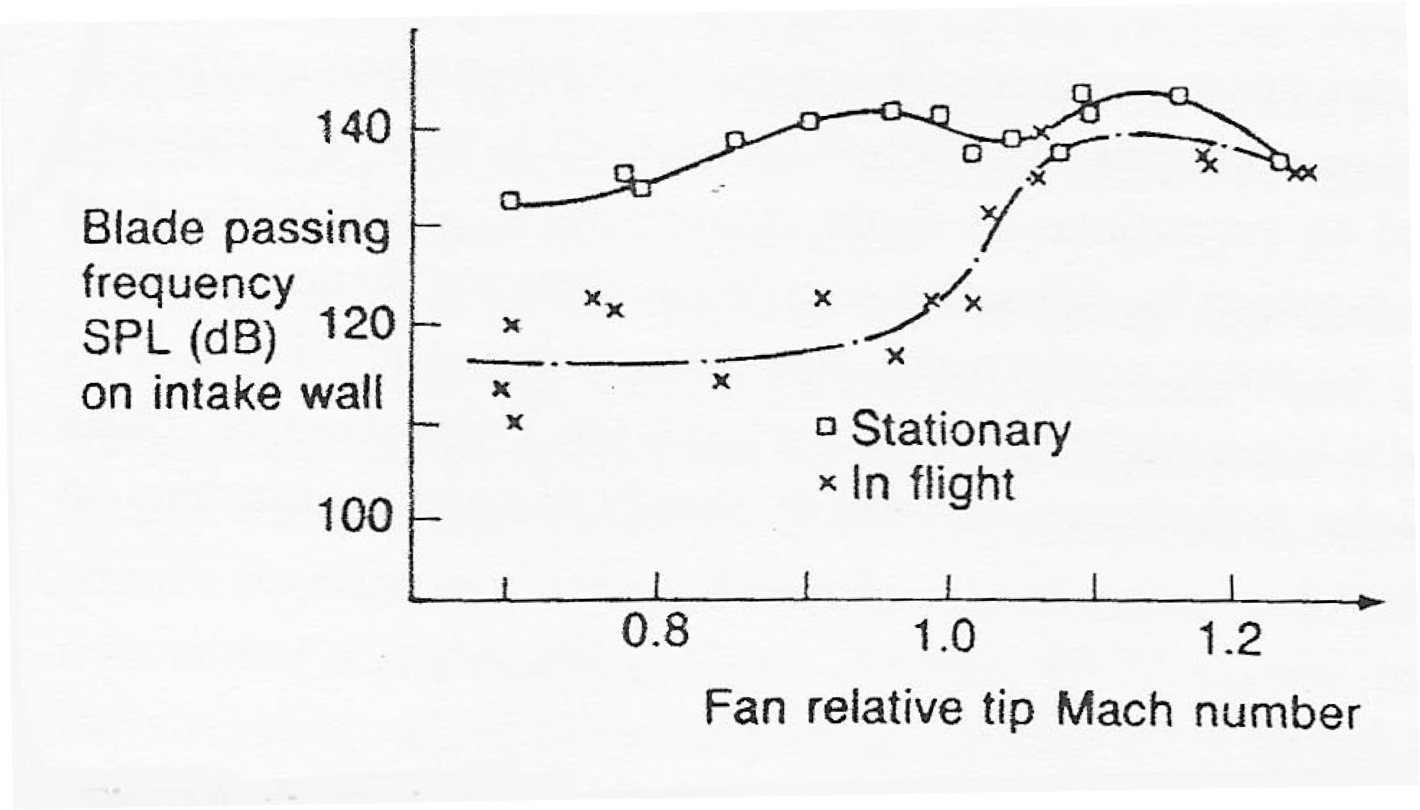
Noise due to interaction between the rotor and the stator may propagate or decay



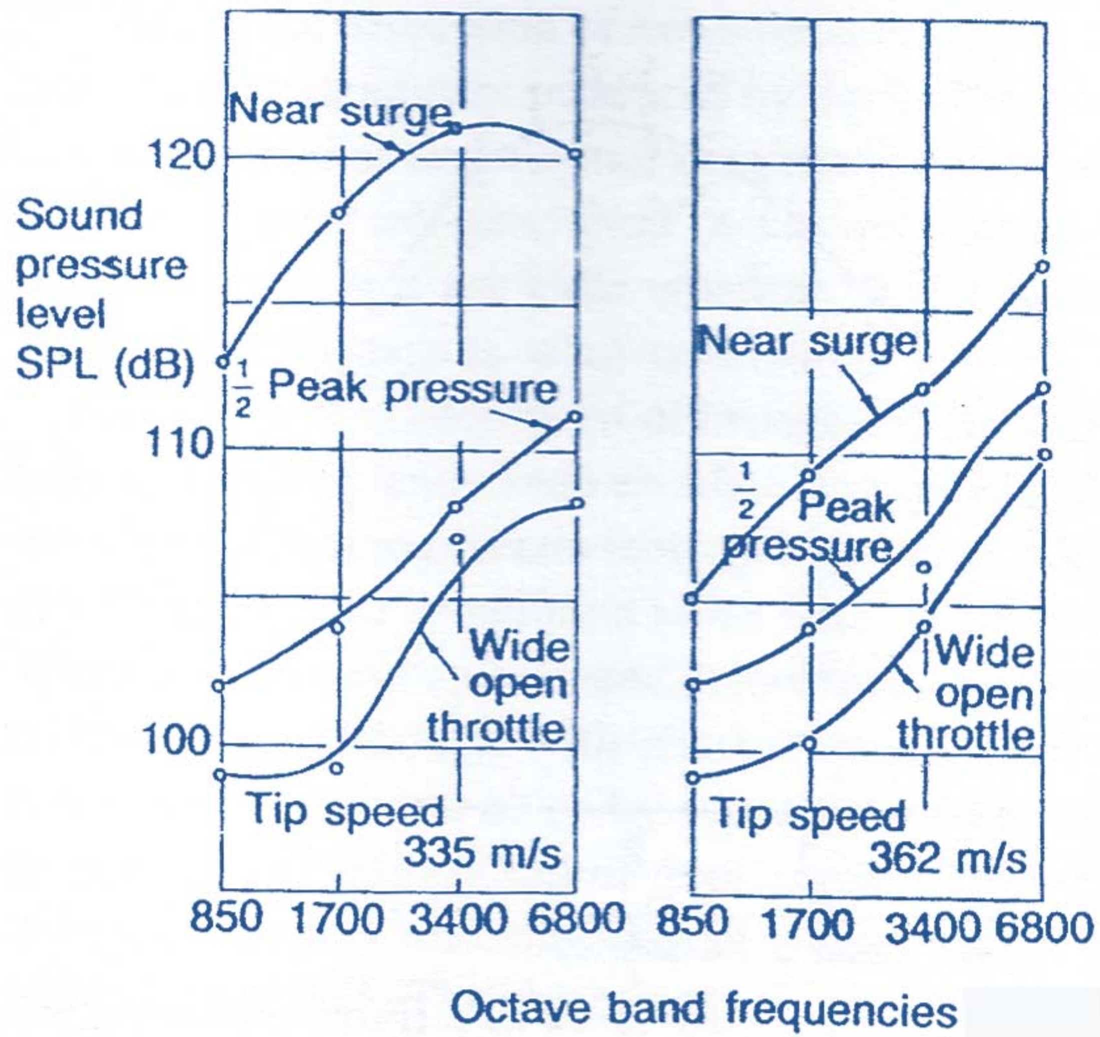
Rotor stator spacing plays an important role in noise generation. Higher spacing produces less noise but also reduces compressor stage efficiency and increases engine size and weight



Flow Ingestion into Inlet of Aero Engine



Stationary Blade noise is higher than In-flight blade noise



Noise created during different operations are different in nature

Noise Levels of various jet engine components :

Jet noise 90 to 140 dB - sub/ supersonic jet

Fan/Compr 90 to 100 dB – subsonic fans/ compressors
100 to 140 dB – trans/supersonic fans/compr

Noise permitted by regulations : 80 to 95 dB

This calls for noise suppressing methods

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Acoustic Treatment – attenuation of noise

- A perforated metal sheet casing surrounded by a honeycomb annular outer structure provides very large attenuation
- Depth of honeycomb structure determines the frequency most attenuated
- Porosity of the sheet metal determines the frequencies over which the attenuation takes place
- The treatment works best for high frequency noise
- High amplitude noise is most difficult to attenuate

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Next Class

Axial Turbine Introduction

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