Michael Raba Portfolio Fall 25

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Insertion Loss for Multichamber vs Competing Mufflers

- Goal: maximize Insertion Loss
    - Insertion loss is the reduction in signal power (e.g., sound or RF) caused by inserting a device into a system, whereas transmission loss measures the total reduction in signal as it passes through a medium or barrier, independent of any added device.
    - IL isolates the muffler's effect, letting evaluate designs without being affected by other parts of the exhaust/environment

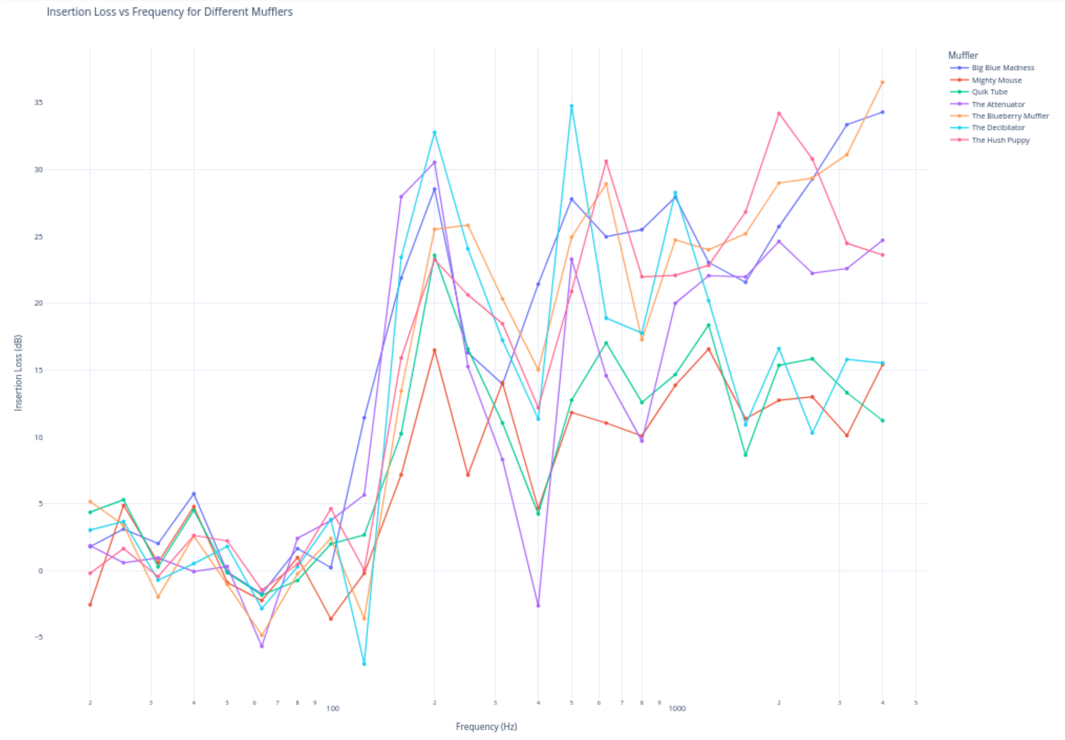


Figure 1: Insertion Loss for Muffler Competition

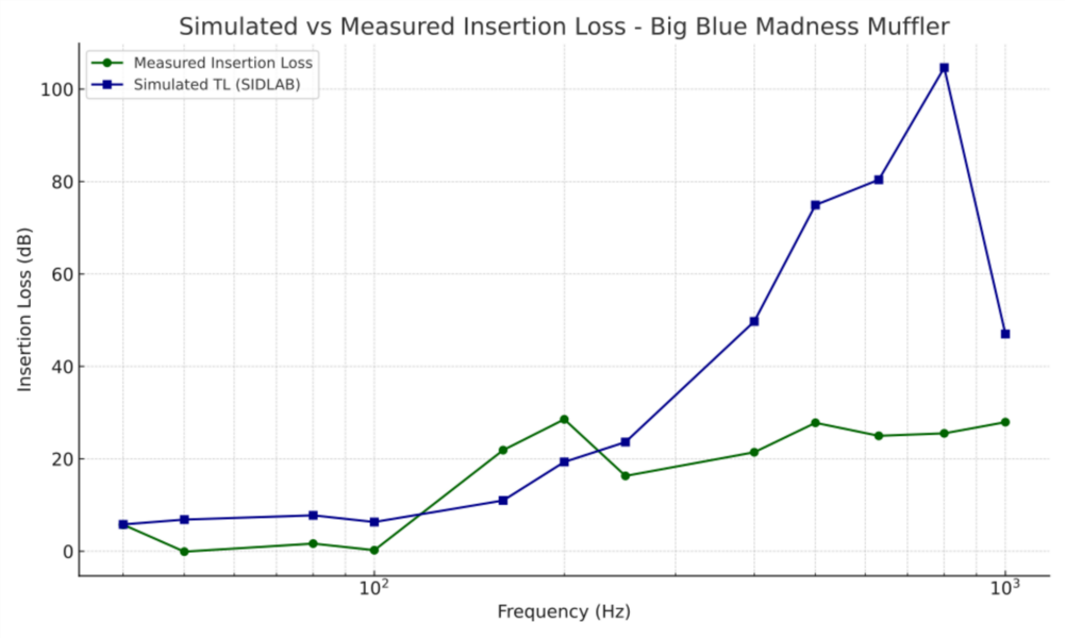


Figure 2: Sidlab 1d Insertion Loss Approximation (Transfer Matrix system)

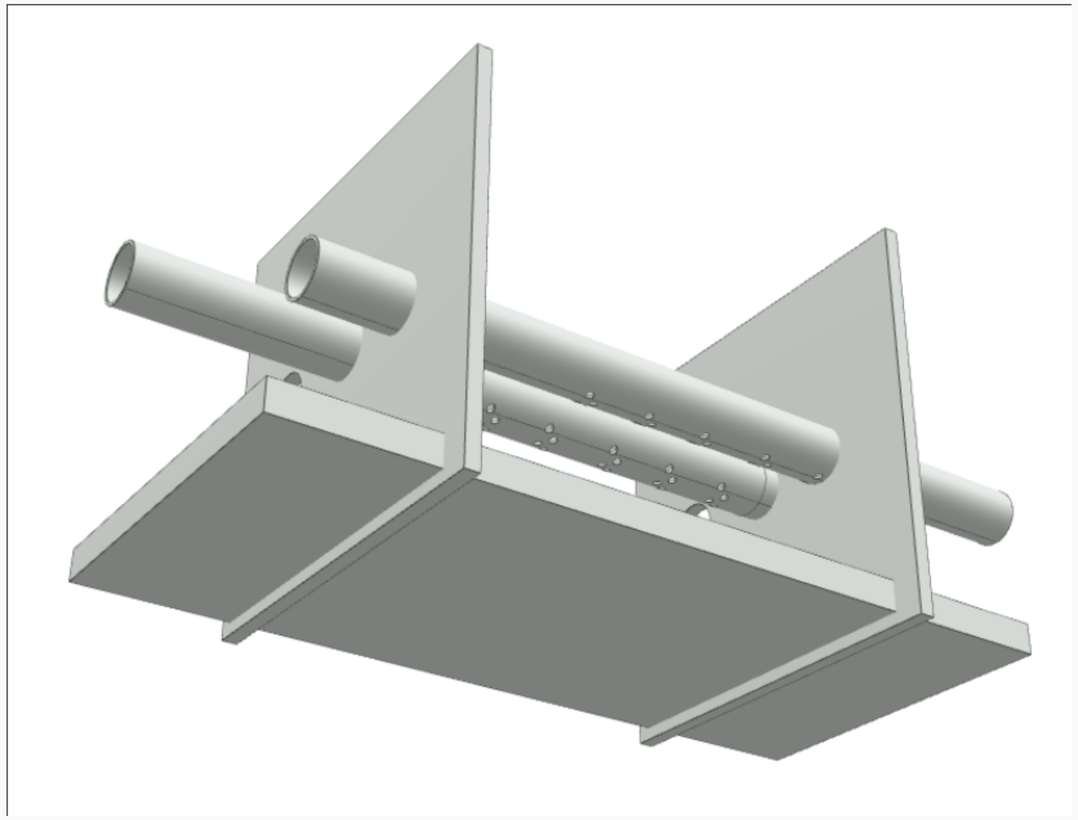


Figure 3: Multicomponent Muffler Internal Geometry (Ansys Workbench/Acoustics Module)

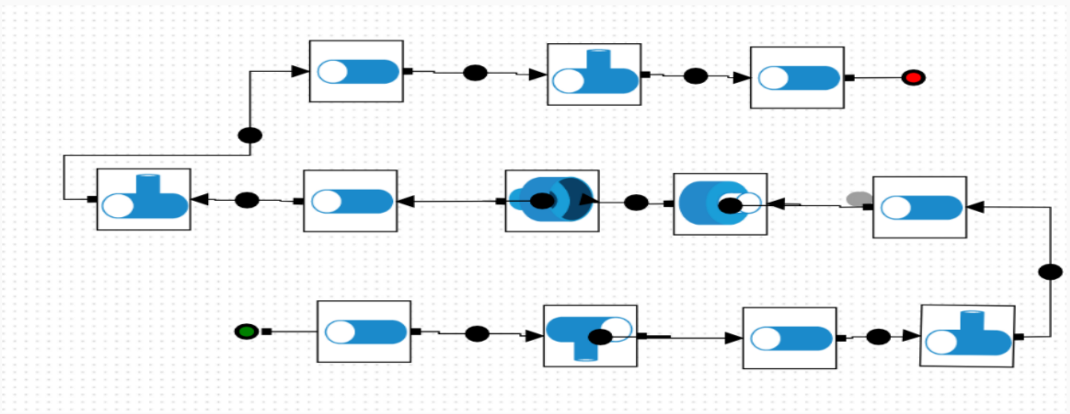


Figure 4: Sidlab 1d approximation (Transfer Matrix system)

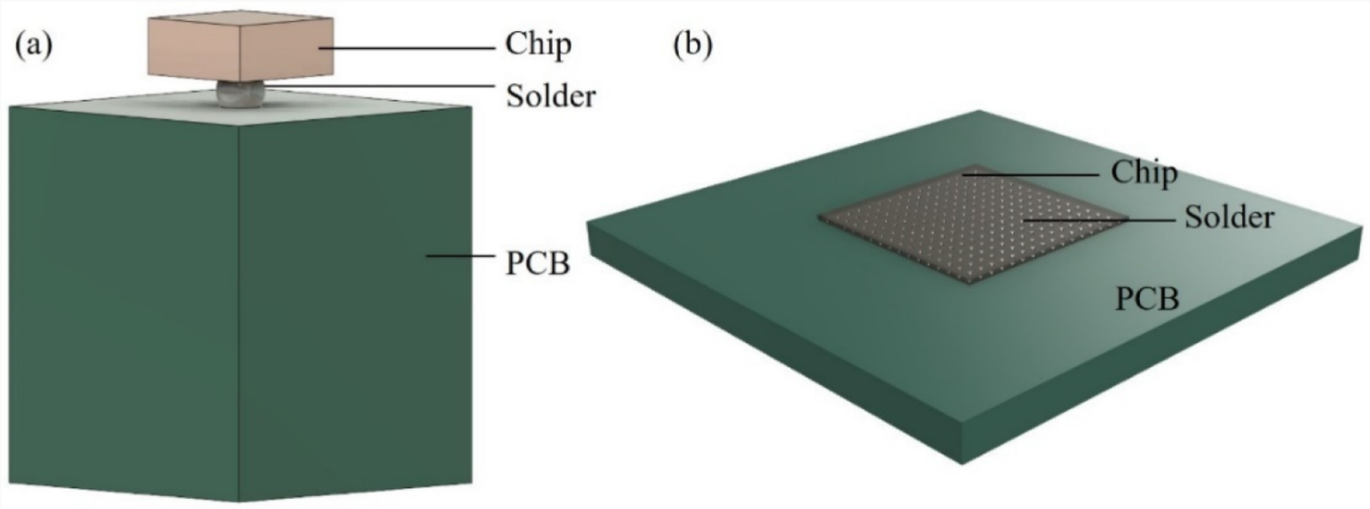


Figure 5: Anand Viscoplasticity model applied to electronics packaging (pcb).

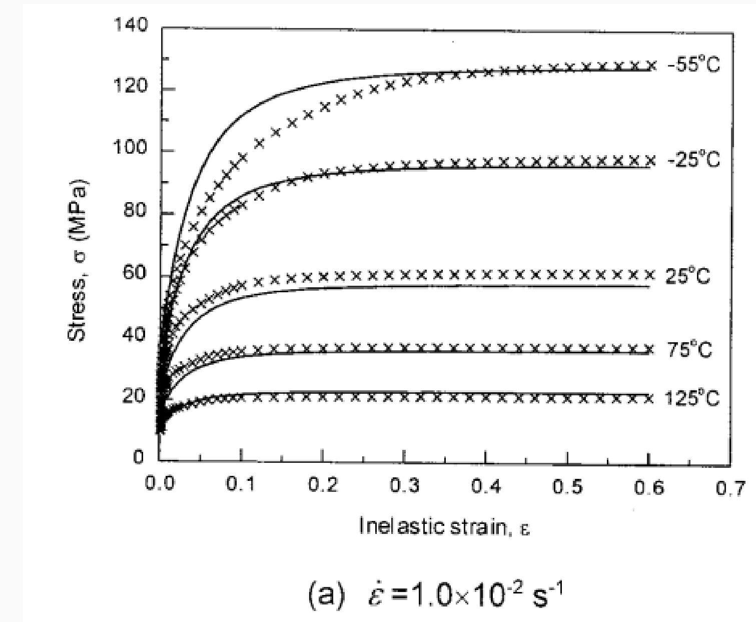


Figure 6: strain-rate and temperature dependence of solder materials (Source: Wang 2001 Paper)

Models Viscoplastic (Metals under Temperature/thermal cycling)

- **Broad Application:** Model metals under thermal cycling! Temperature and Strain dependance!
- Applies Anand's unified viscoplastic framework to model solder behavior
- Anand's model can be reduced and fitted from experiments
- transition the theory into engineering-scale implementation
- Targets solder joints in microelectronic packages (chip on PCB, soldered connections)

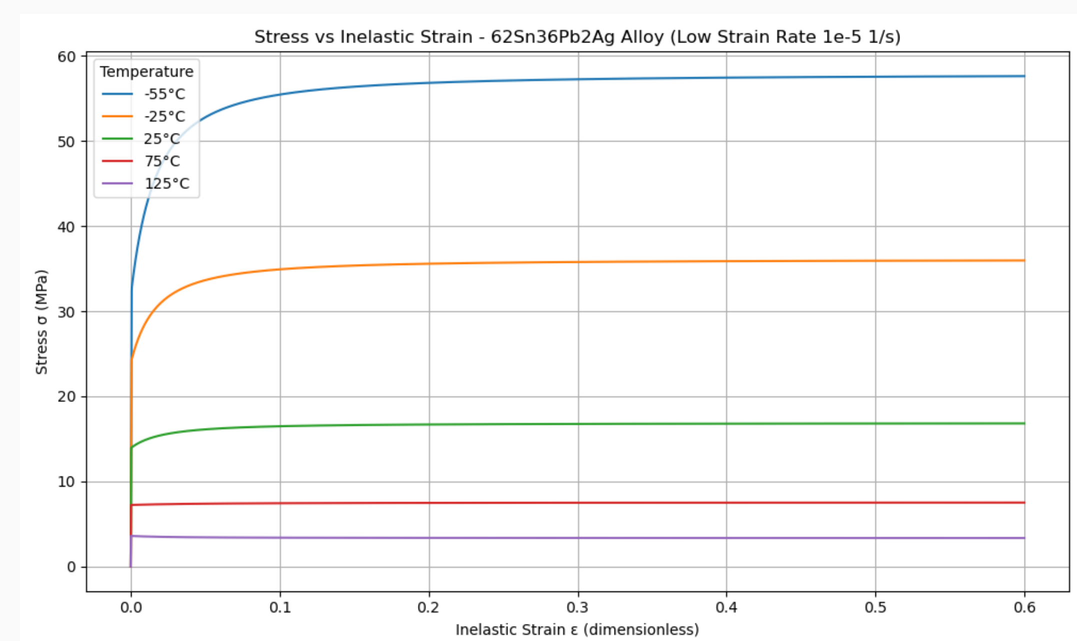


Figure 7: Running model using Forward Euler code

Viscoplastic System of Equations (Anand)

Flow Rule (Plastic Strain Rate): $\dot{\varepsilon}^p = A \exp\left(-\frac{Q}{RT}\right)\left[\sinh\left(\frac{j\sigma}{s}\right)\right]^{1/m},$ (2)

Plastic strain rate increases with stress and temperature,
No explicit yield surface; flow occurs at all nonzero stresses.

Deformation Resistance Saturation s^* : $s^* = \hat{s}\left(\frac{\dot{\varepsilon}^p}{A}\exp\left(\frac{Q}{RT}\right)\right)^n,$ (3)

Defines the steady-state value that s evolves toward,
Depends on strain rate and temperature.

Evolution of Deformation Resistance s : $\dot{s} = h_0\left|1-\frac{s}{s^*}\right|^a \operatorname{sign}\left(1-\frac{s}{s^*}\right)\dot{\varepsilon}^p,$ (4)

Describes dynamic hardening and softening of the material,
s evolves depending on proximity to s^* and flow activity.

{Note: Constants $A, Q, m, j, h_0, \hat{s}, n, a$ are material-specific and fitted to experimental creep/strain rate data.}

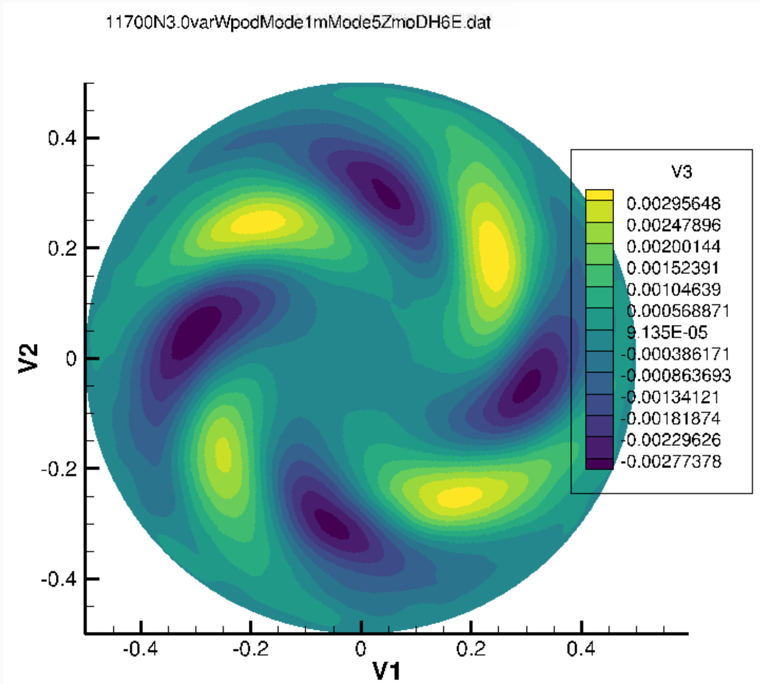
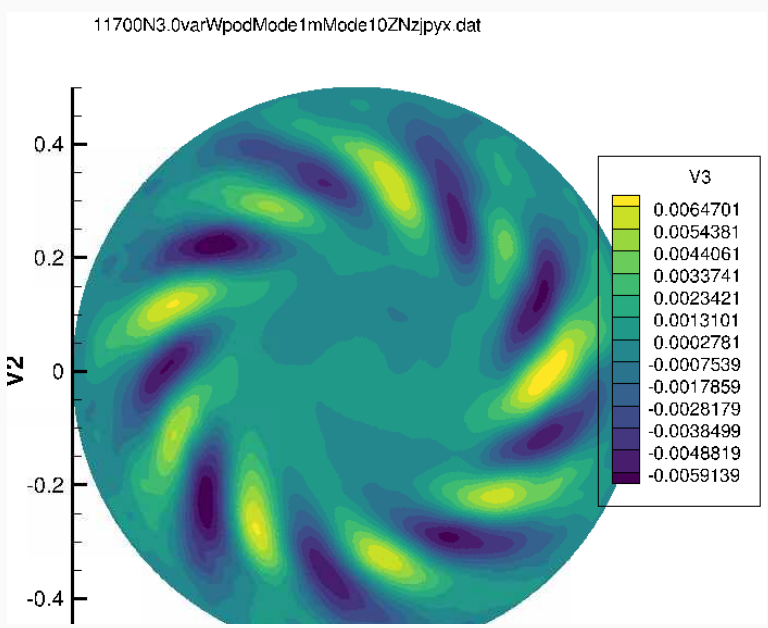


Figure 8: Decompose turbulent pipe flow (Reynolds number $Re = 5300$ and $Re = 11,700$) to Modal FFT/POD decomposition



- Idea: Reduce turbulent flow to FFt-POD so it can be easily studied. The lowest POD modes have the most energy ∴ most important
- Relaminarization occurs by suppression of near-wall vortices and streak breakdown.
- Applications: rotating heat exchangers, turbomachinery, compact fluid systems.

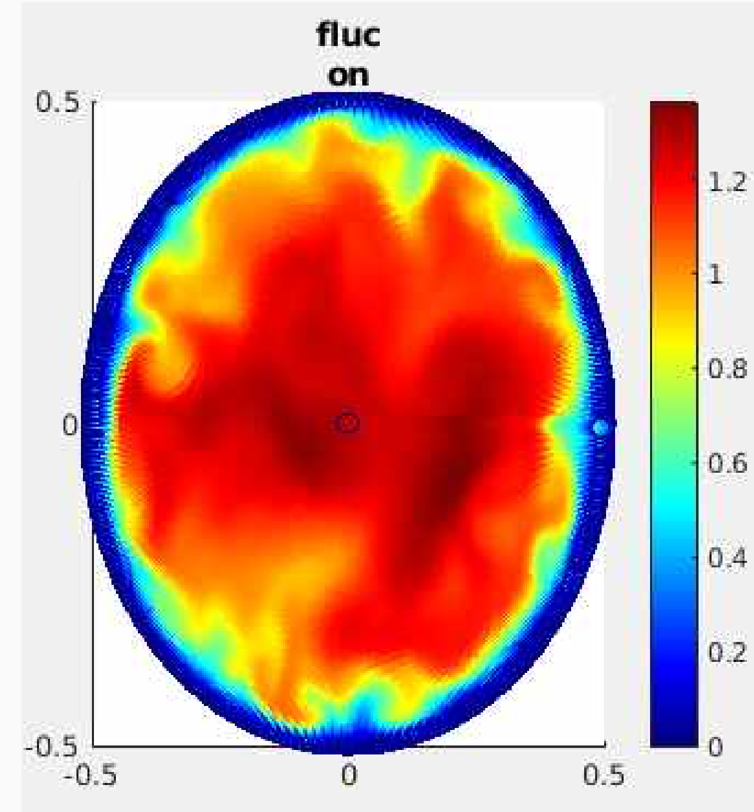


Figure 9: Fluid field in streamwise direction u_w

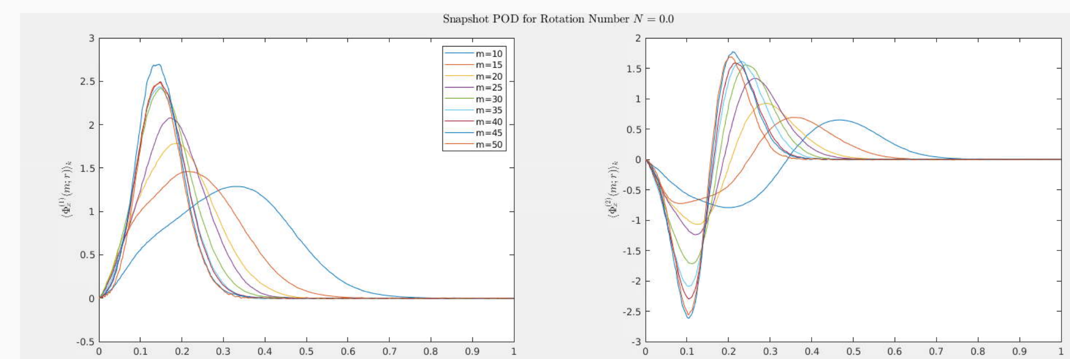


Figure 10: Turbulent Flow

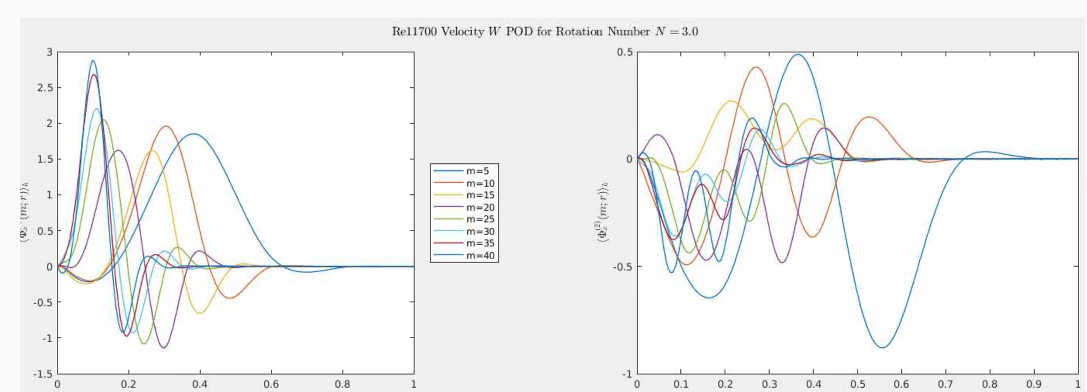


Figure 11: Relaminarized flow (Broadband Energy Distribution)