Innovating New Products using Multiphysics Modeling

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Content

- What is innovation and why it is needed?
- What are different ways to innovate new product/designs
- Design space constraints: time, effort, cost, complexity, feasibility
- Approaches in vogue
- Multi-disciplinary Products
- Modeling/Simulation types and tools
- COMSOL Multiphysics – using more efficiently
- Case Studies:

Challenge to New Product Designer

- Modern products need to meet very demanding requirements
  - Lowest cost
  - Best features
  - Smallest size
  - Longest life
  - Simpler to manufacture
  - Faster to manufacture
  - Require minimum new parts (Re-use)
  - First time right etc.
- So has to resort to methods that help in innovation

What is innovation?

- Is the sweeping change in the product feature(s), cost, life, size etc.
- So It is not incremental improvements. In organizations, the products and processes are gradually refined. So improvements are continuous and do not lead to step change characteristic of innovation.
- Innovation is a result of out-of-box thinking. And break-through thoughts are difficult to come by and are thus rare.
- In industrial R&D, 10% efforts only result in innovative products and the 90% failures contribute to the proportion.

Nature of innovation

- Incremental Change (improvement)
  - Simplification of processes
  - Increase range of values of some features in a product
  - Remove bugs in products
  - Lasting for short term
- Radical Change (breakthrough improvement)
  - More long term and strategic in focus
  - Change capabilities of the firm
  - Supports to jump start
  - Distinguishes from competition

Why innovation is needed?

- Innovative products in terms of cost, performance and feature set are essential to maintain presence in market or thus remain in business (profits? Not always).
- Launch of new products to avoid obsolescence or to increase customer base permits the company to diversify and ensure long time presence in markets with its share of profits.

Different ways to innovate

- Develop product from the idea:
  - costly affair if it does not lead to the conceived performance
  - Risks are too high as the assumptions may not stand valid
  - Management may not support such approach
- Build prototypes:
  - difficult to make a replica so use scaled down model
  - Proto may not exhibit all the product behaviour
  - May not afford costs involved for small numbers
  - Technology may not be available for the concept to realize in short time
  - Costs involved may not be feasible
- So use simulation models:

Why modeling/ simulation?

- Time to market
- First time right
- Lower cost of iterations
- Faster turn-around times
- Larger design space exploration
- Faster analysis of results (automated)
- more assumptions can be relaxed
- Advances in computing allow model of real-life (complex) products

Time to Market

- Higher rate of obsolescence
- Fast pace of technological advancements
- Knowledge is public on the internet
- First time right designs – reduce validation
- Requirements capture
- Design and implementation

First Time Right Approach

- **Requirements Capture**
  - Abstractions of requirements
  - Executable Specifications
  - Rapid Prototypes
- **Design and Implementation**
  - Feature Set
  - Design space exploration
  - Automated synthesis (Hardware/Firmware)
- **Validation**
  - Testing
  - Coverage

Design Space Exploration

- Constraints
  - time,
  - effort,
  - cost,
  - complexity,
  - working environment- exact or approximate (some prototypes not feasible or possible)
- Methods
  - Theoretical Analysis (Exact Formulation and solution)
  - Prototyping (actual or scaled)- Design of Experiments
  - modeling/simulation- limited representation still

Products are Multi-disciplinary

- Products normally involve multiple physical domains
- So experimenting or understanding behavior in single physical domain is incomplete
- Multiple physical domains have to be modeled simultaneously allowing interaction across interfaces
- The coupled models are thus essential which allow integrated behavioral model

Modeling/Simulation

- Single physical domain
- Multidomain (multiphysics) modeling tools (ANSYS, COMSOL, COSMOS, Altair etc)
  - *iterative is time consuming: propose new approach for linear domain*
  - *Non linear design space: Neural Learning, Genetic Algorithms*
- Hybrid Approaches are more efficient – COMSOL is leader in it: LiveLinks with Matlab, SolidWorks, ProEngineer,
- Comparison of modeling approaches

Using COMSOL Multiphysics

Solving complex models is limited by machine capacity

- Machine capacity –
  - Number of CPUs (cores) and clock speeds
  - memory: amount of memory

Likely Alternatives:

- coarse/fine model
- Select suitable solver
- Partition the problem (advanced capability?)
  - Spatial partition and join (grid computing also can be thought)
  - Temporal partition – log intermediate results
  - Hybrid (Spatio-temporal)

Practices followed

- For complex problems not amenable to Multiphysics modeling due to various limitations
  - Analytical results of part of the model
  - Simulation results on part of the model
  - Experimental results
  - Extend/project analytical and experimental results to compare with experimental results
- Desirable capabilities
  - Design parameter sweep
  - Optimization of objective function

Case Studies

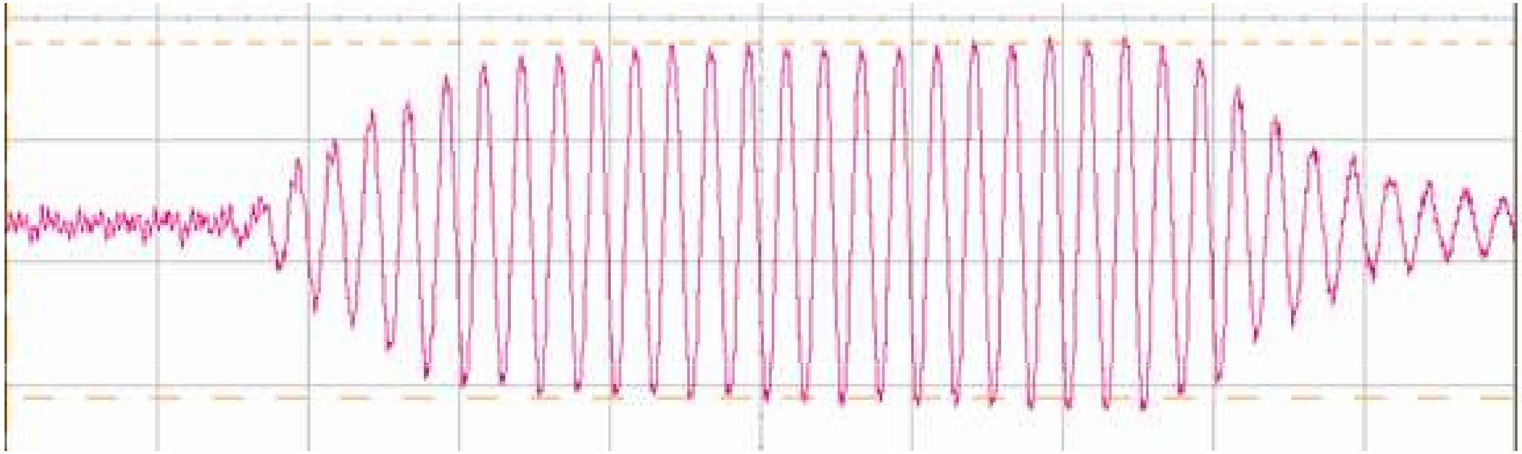
- Acoustics: signal generation, coupling to the structure, acoustic impedance, propagation in media, modal investigations
- Flow: profiling studies obstructions, flanges, fillets, flow domains: laminar, transient or turbulent
- Transducers: modeling, coupling to waveguides, transmission and reception characteristics, fan beam angle

Acoustics

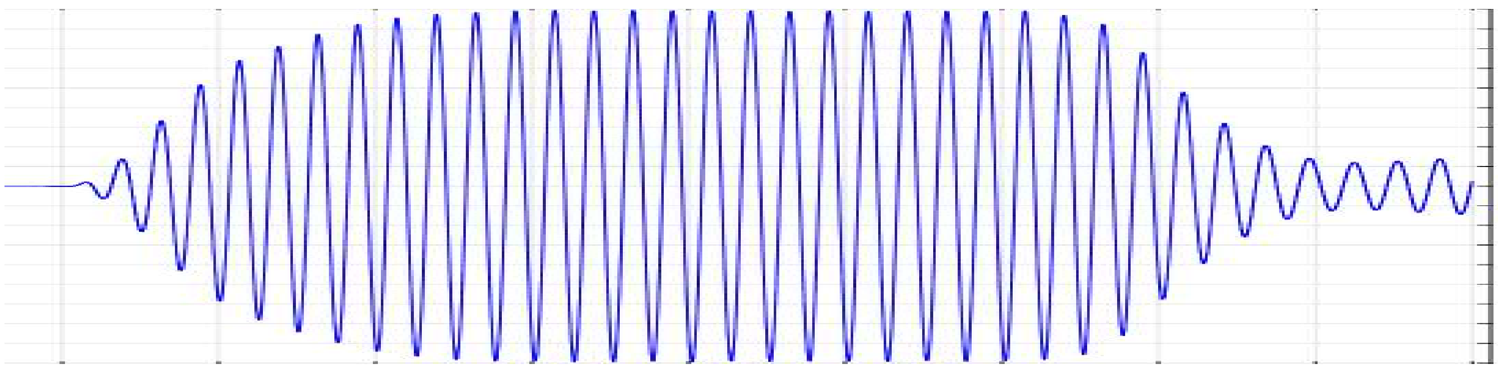
- Validation of model in air
- Propagation different media
- Propagation in different structures

Acoustic Signal Propagation in air

Experimental Signal Plot



Simulation Signal Plot



Acoustic Signal Propagation in Air and Methane)

Signal Shape Study

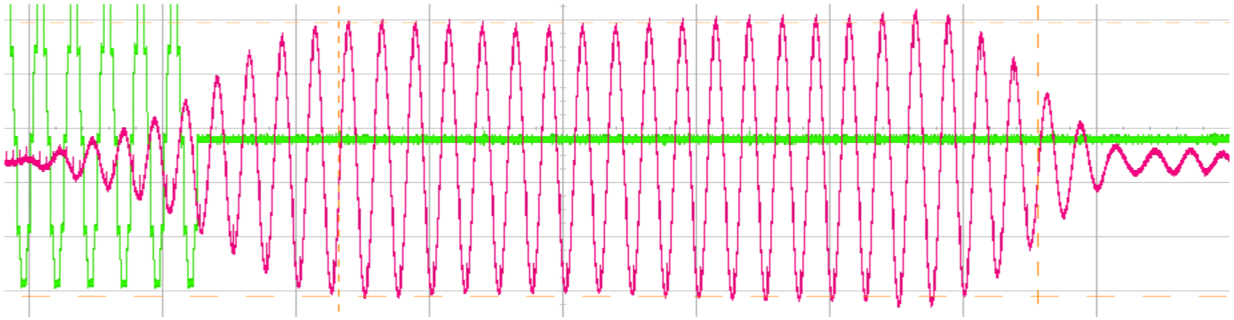
Particulars	Comparison parameter	
	Rise time (#Cycles)	Fall time (#Cycles)
Simulation	9-10	7-8
Experimental	9-10	7-8

Signal Attenuation in Methane

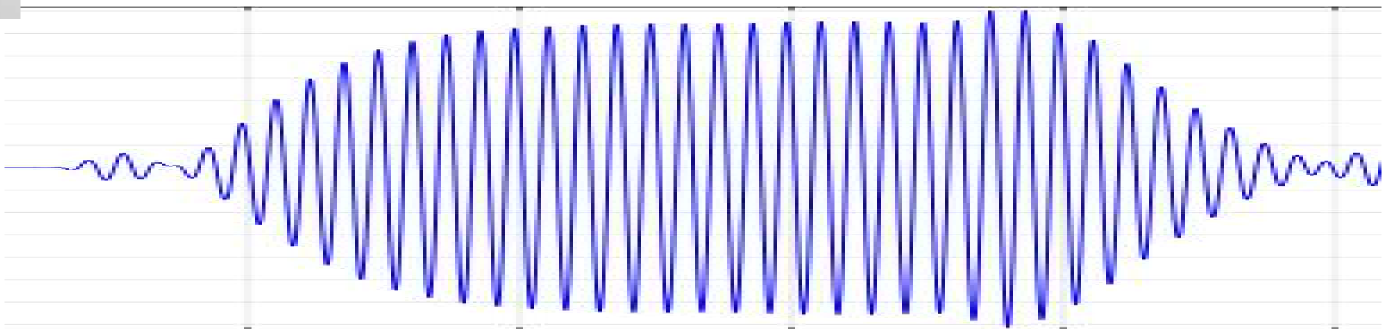
S. No.	Medium	Simulation (Relative Attenuation in dB)	Experimental (Relative Attenuation in dB)
1	Air	900	2.8
2	Methane	500 (-5.1 dB)	1.5 (-5.42 dB)

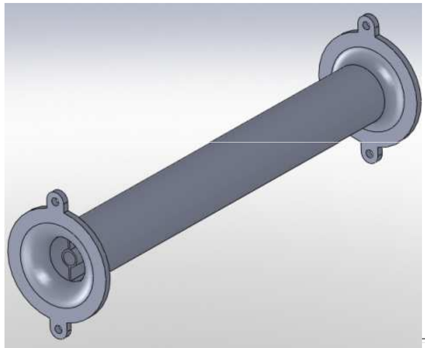
Acoustic Signal through tube geometry

Experimental Signal



Simulation Signal





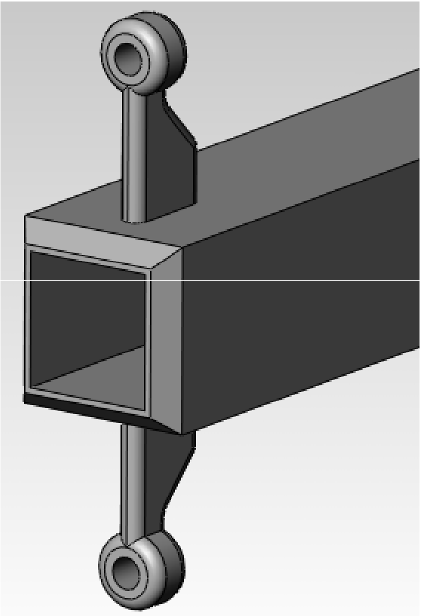
Plastic Tube

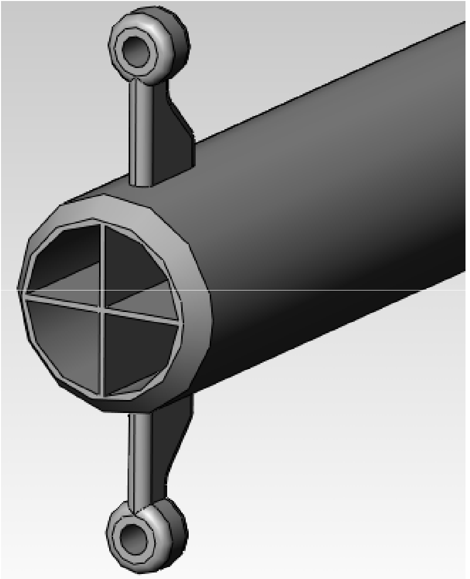
Flow Modeling

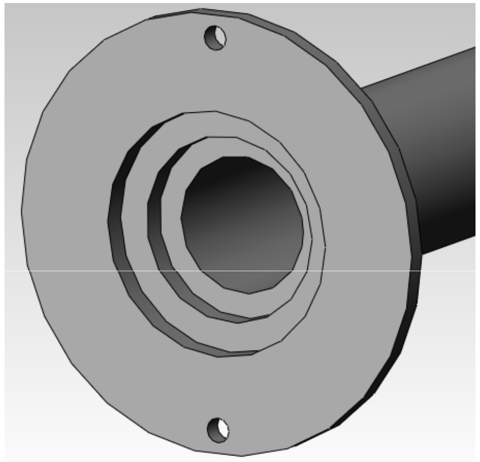
- Profiling around obstructions
  - Dead zones

- Pressure drop
- Nature of flow along critical paths:
  - fully developed (laminar)
  - Transient
  - turbulent

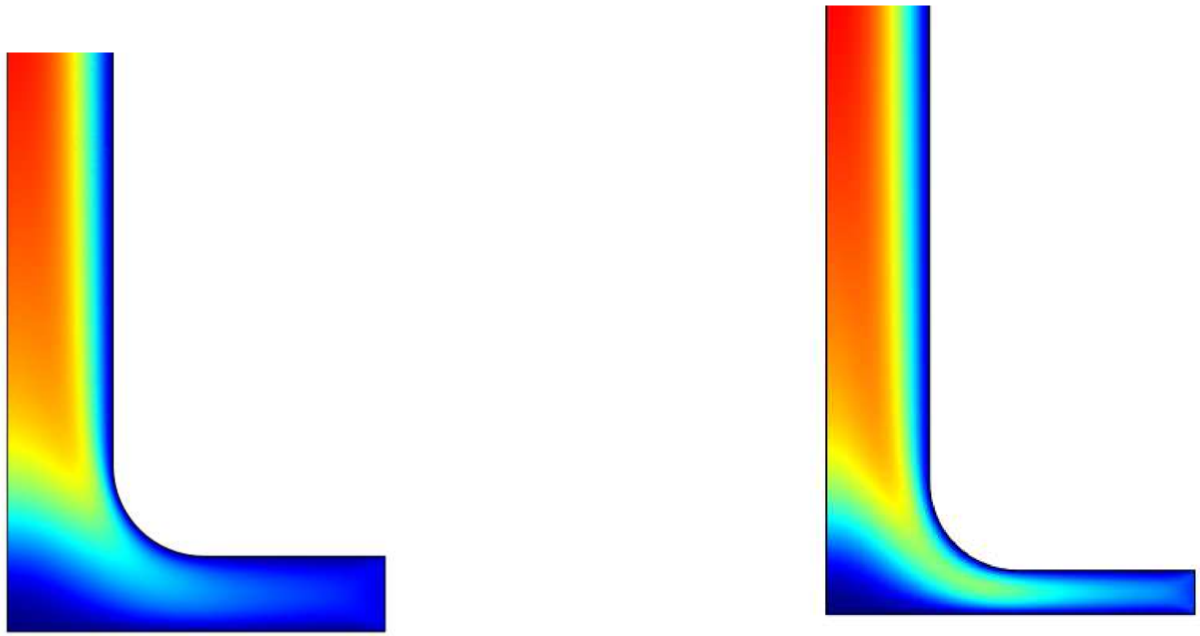
Entry/Exit profile





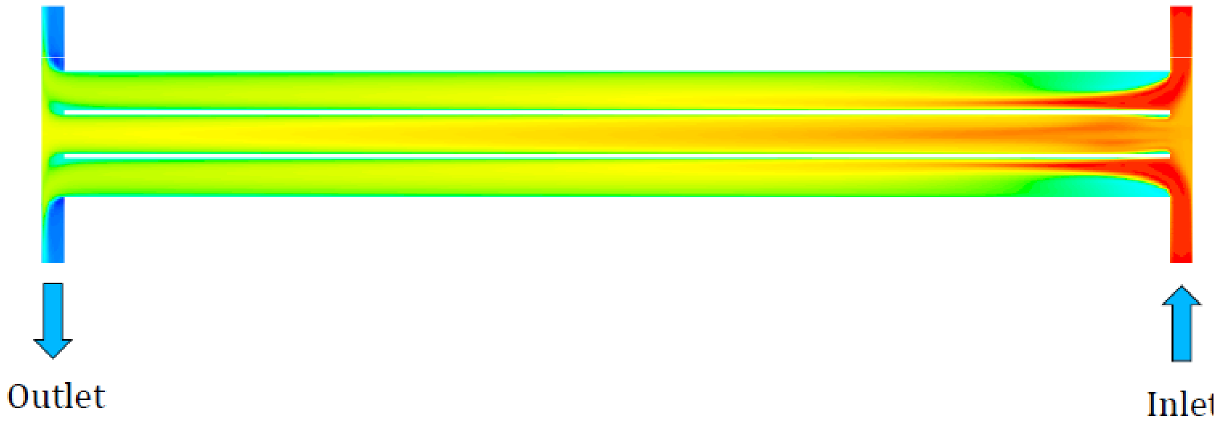


Different fillets



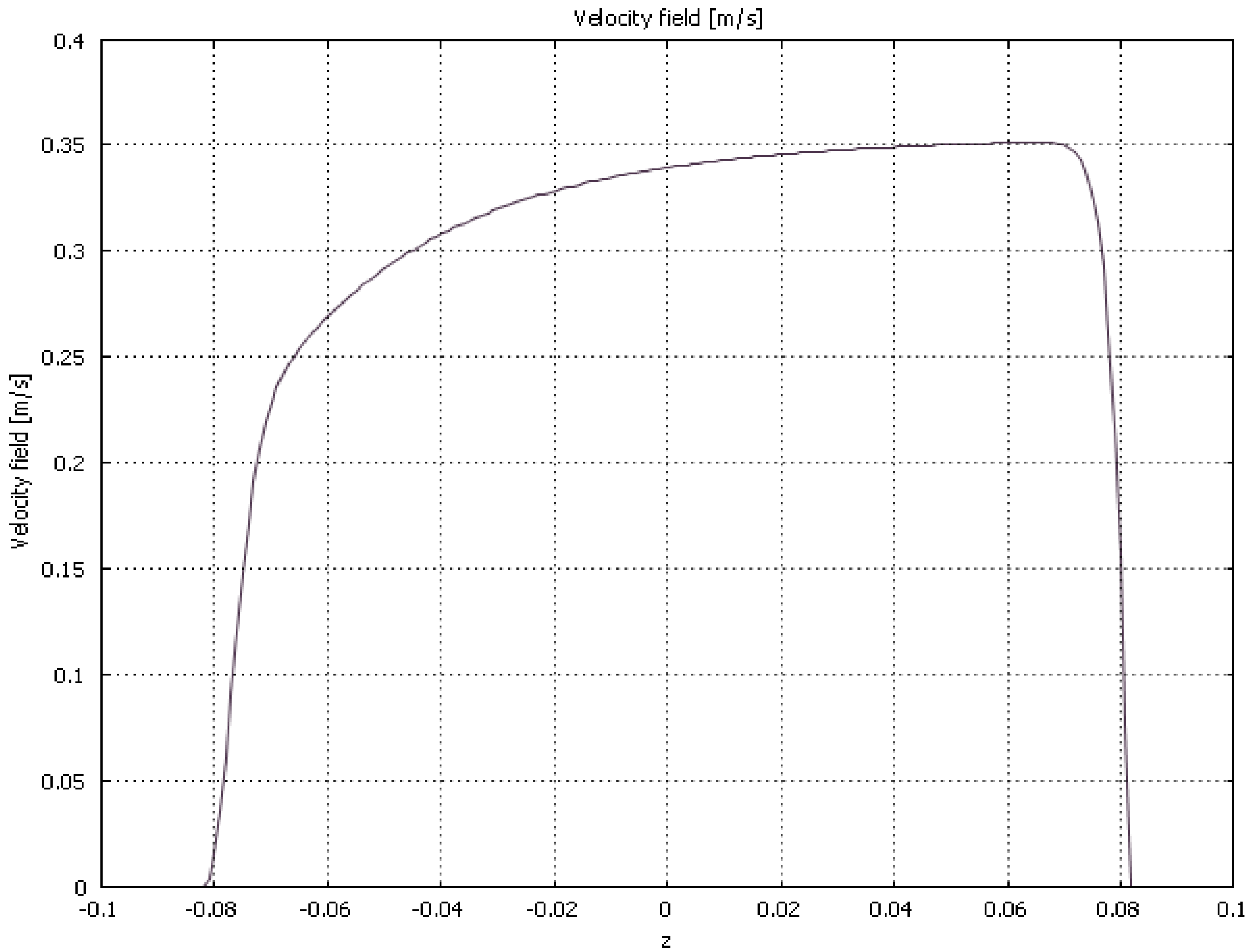
Velocity Profile Comparison at the inlet

Pressure drop

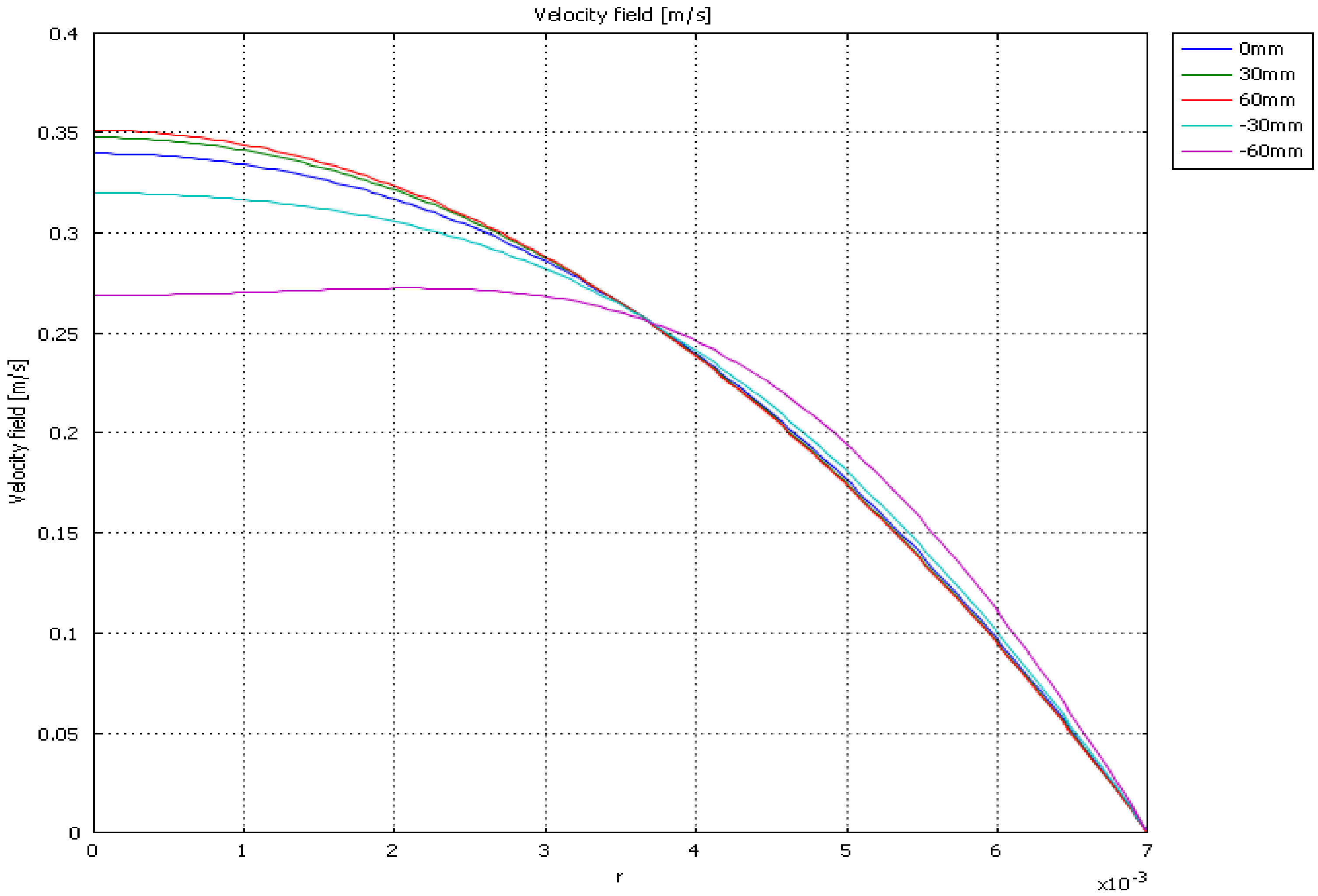


Total Pressure (pascal)

Nature of Flow-1



Nature of Flow-2



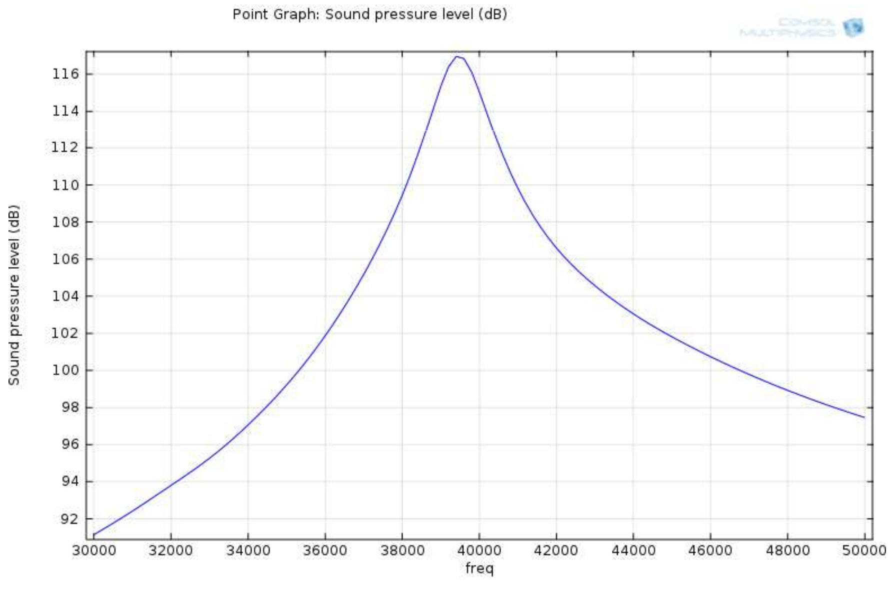
Transducers

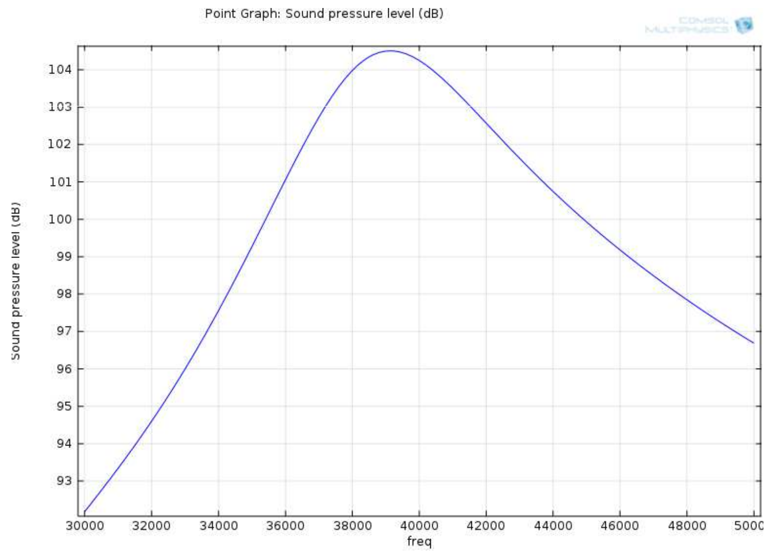
- Design Requirements
  - Signal coupling
  - Beam optimization
  - impedance matching (medium)
  - Bandwidth (pulse or frequency method)

- Types explored
  - Piezo Polymeric: Flexural modes
  - Piezo Discs with interface layer
  - Piezo discs closed form

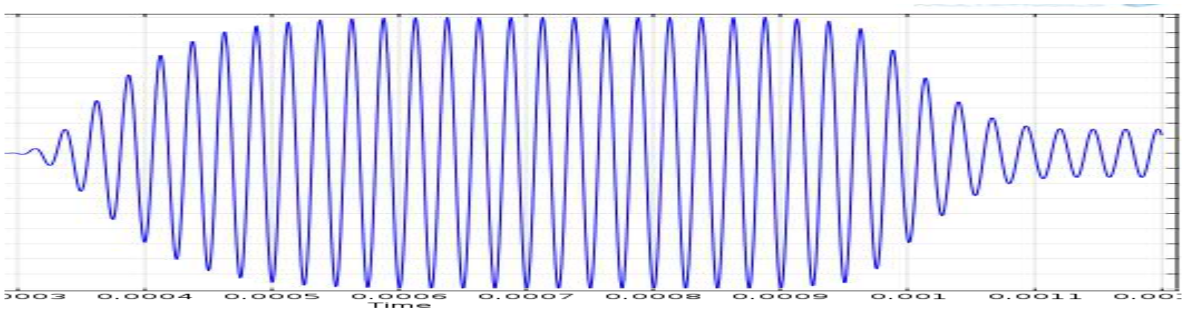
Transducer models

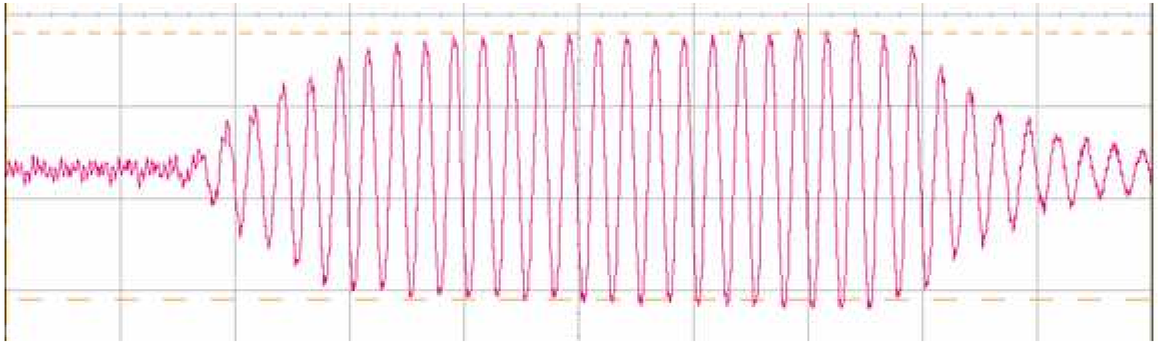
S. No.	Material Description	Relative Damping Factor ξ	Corresponding Stiffness Damping Parameter (β_{dk})
1	Aluminum Casing	0.0004	3.18309 e-9
2	Foam Backing	0.1	7.95775 e-7
3	Silicon Filling	0.05	3.97887 e-7





Transient Behavior





Thanks

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