SmartAnswer - Domain decomposition for modeling of acoustic liners

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Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

Siemens PLM Software

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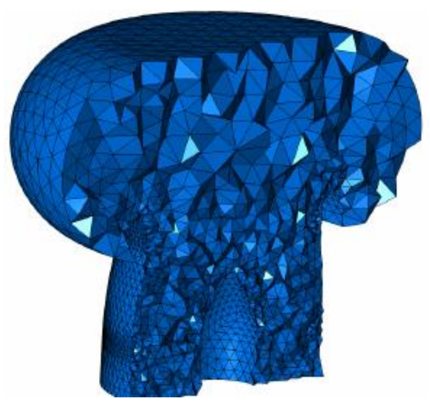
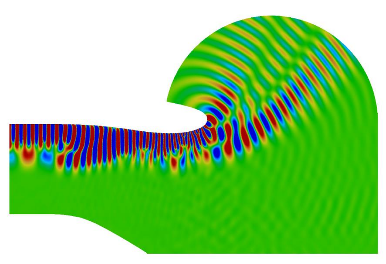
Motivation

In modern aircrafts, engine noise is a major source of noise. There is a growing demand for numerical prediction techniques to help finding better designs and improve acoustic performance.

Current numerical models are computationally very intensive.





Mode (48,1) at 2BPF

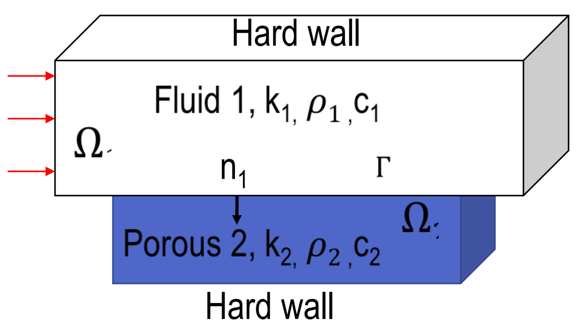
For example, at 2BPF, 3D noise radiation of a given tone in sideline configuration required 5h 30 min [1]. Hundreds of simulations are required to obtain optimal design settings and in particular, **acoustic liner parameters**. The demand for robust, efficient, scalable numerical acoustic methodologies is increasing.

Main Objective

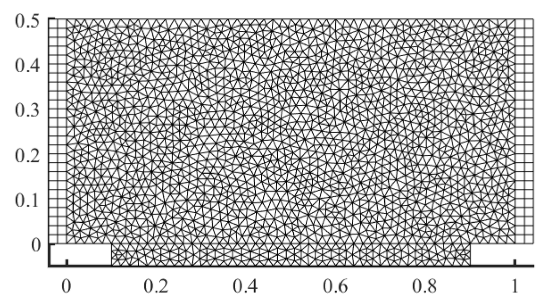
- Domain decomposition methods (DDM) are highly parallel and reduce the computational costs drastically.
- Extension of the non-overlapping domain decomposition methods to liner optimization for fast & robust noise predictions of aircraft engines.

Existing Background

- Porous material is modeled as a fluid with freq. dependent properties.
- Fluid 1 and 2 are governed by Helmholtz equation.



One parameter – **Miki model** used to estimate the fluid properties in the porous material [2].

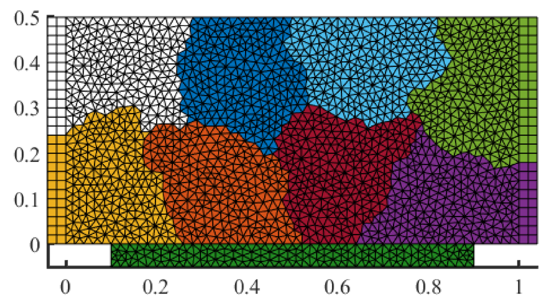


The discretization of the initial problem leads to an algebraic system of equation:

$$\mathbf{K\,u = b} \text{ where}, \mathbf{K} = \widetilde{K} - \omega^2 M$$

- For large problems, quite challenging to solve the system of equations.
- **FETI-2LM** (Finite Element Tearing and Interconnect) and **FETI-H** are used for modeling heterogeneous Helmholtz equation.

Methodology



This system is transformed into smaller subdomain problems using FETI.

$\mathbf{K^n u^n = b^n} + \boldsymbol{\lambda}$,

where n is the no. of subdomains

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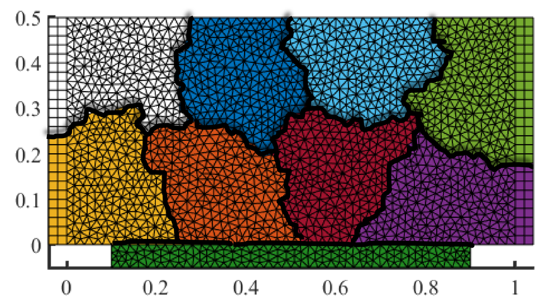
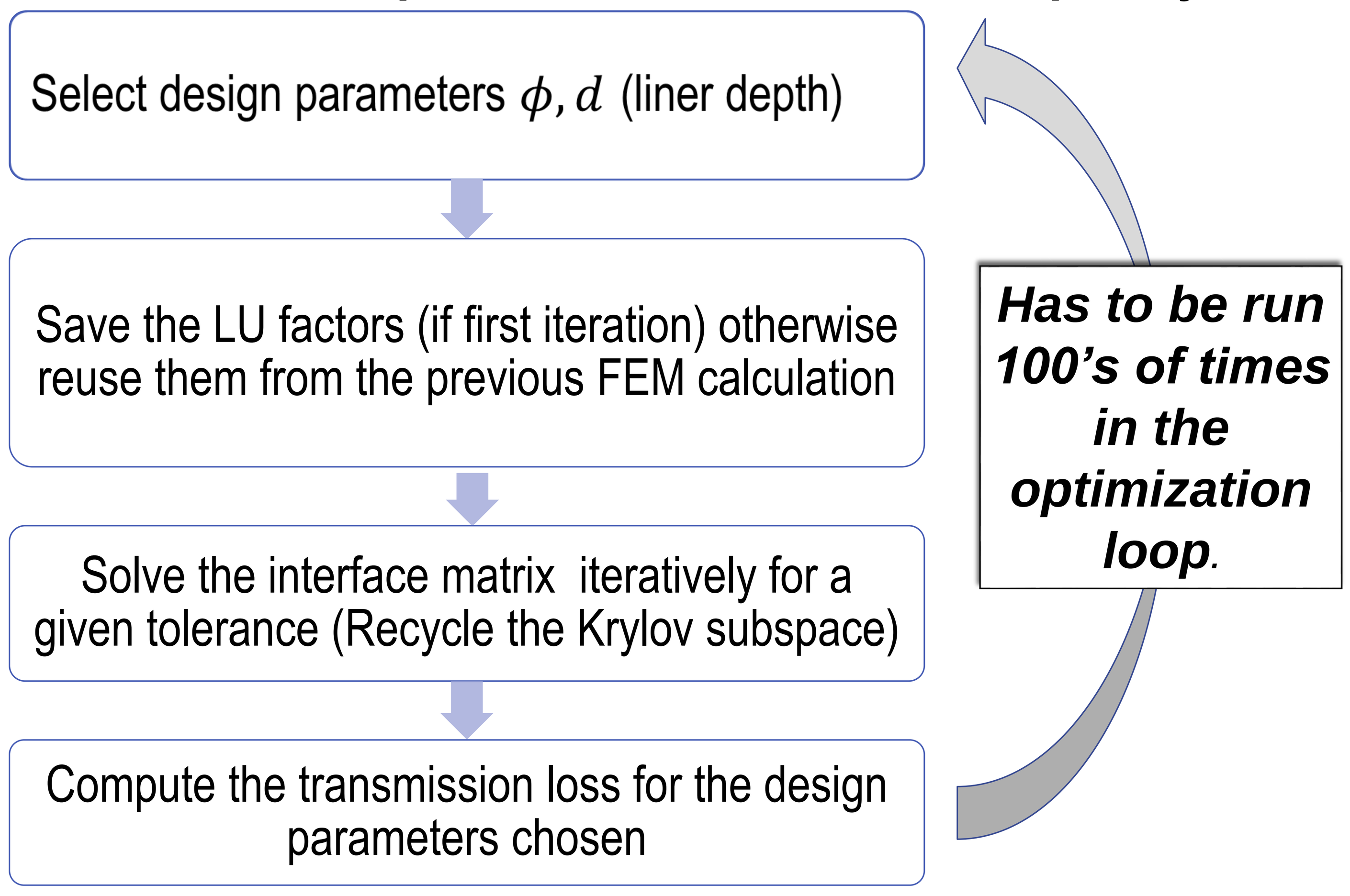


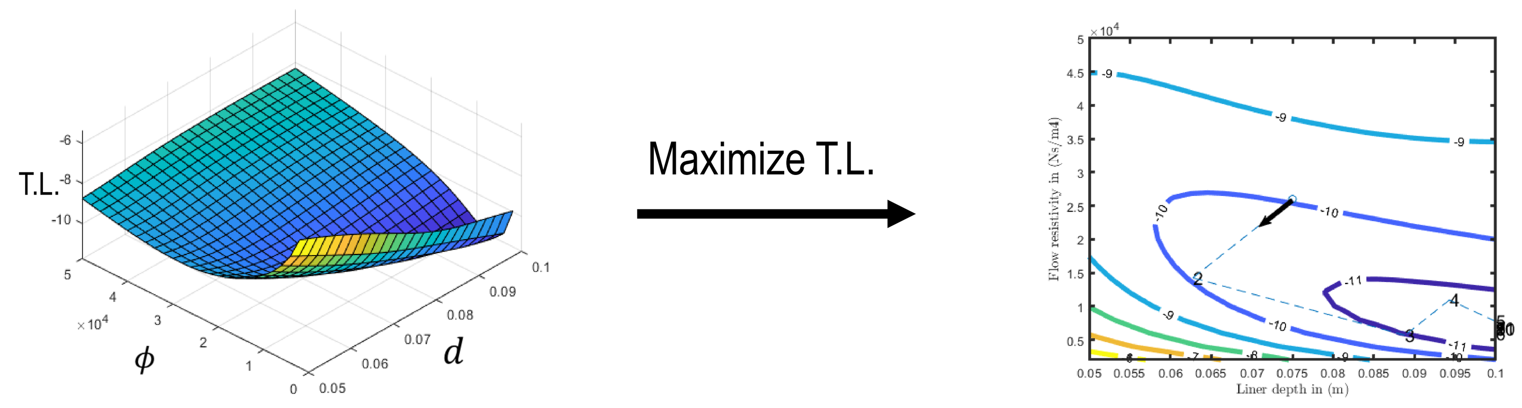
$\mathbf{F_I}\,\boldsymbol{\lambda} = \mathbf{d}$, where λ is a vector of dofs on the partitioned interfaces. This interface problem is solved iteratively using **GMRES** or **ORTHODIR** [3].

Proposed workflow at each frequency



Preliminary Results

- The proposed workflow has been implemented and verified.
- Optimization Results for 1kHz , mode order =1.
- Range of design variables : $\phi = 2e^3 - 5e^4 \frac{Ns}{m^4}$, $d = 5 - 10\ cm.$



Cost function

Optimization using Matlab

- The initial factorization reduce the CPU costs drastically.
- The Krylov subspace recycling reduces iteration count by ~50% in each optimization cycle. (except for the first cycle.)

Expected Outcome

- **An efficient, scalable, robust, easy to use,** implementation of the proposed workflow for liner optimization.
- **Generic tool** which can be easily extended for liner optimization in automotive, commercial and domestic sectors.

References

[1] G. Gabard et al. "*Adaptive, High-Order Finite-Element Method for Convected Acoustics*". AIAA Journal, Vol. 56, No. 8 (2018), pp. 3179-3191.
[2] Jean Allard and Noureddine Atalla. "*Propagation of sound in porous media: modelling sound absorbing materials 2e*". John Wiley & Sons, 2009, pp. 73-74.
[3] Armel de La Bourdonnaye et al.*" A Non-Overlapping Domain Decomposition Method for the Exterior Helmhokz Problem*". In: Contemporary Mathematics 218 (1998), pp. 42-66.

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MARIE CURIE ACTIONS