Preface

Significant pressures can be induced for instance in piping systems due to thermo-acoustic and/or aero-acoustic instabilities. Vibro-acoustic coupling with the structure may result in large vibrations of the enclosing mechanical system, which eventually threaten its structural integrity and lifetime.
One of the aims of the AETHER Marie Curie Research Training Network on aero-acoustical and thermo-acoustical coupling in energy processes is to incorporate the complex multi-physical coupling phenomena in a modelling scheme, which allows to assess numerically the eventual lifetime and possible mechanical failure risk, while preserving an optimal engineering balance between modelling accuracy and computational efficiency. In view of finding the latter engineering balance, two important aspects need to be addressed:

- identification of the possible dominant coupling interactions between the thermal, hydrodynamic, acoustic and structural dynamic phenomena.
- availability of efficient model reduction techniques

The present course notes describe how finite element and boundary element simulation techniques can be used to simulate coupled vibro-acoustic coupling effects. Whether also mutual coupling interactions with the thermal and hydrodynamic phenomena should be taken into account for a proper assessment of the structural integrity of energy process systems, which are subjected to thermo-acoustic or aero-acoustic instabilities, is topic of on-going research within the aforementioned AETHER network and will be reported by the author in due time.

1. Introduction

This text describes the main numerical simulation methods that can be used for solving time-harmonic coupled vibro-acoustic problems.
Section 2 defines the mathematical models that have to be solved in coupled vibro-acoustic problems. The finite element method is the most commonly used prediction technique for the modelling of the structural part of a coupled vibro-acoustic problem. For the acoustic part, both a finite element model or a boundary element model can be used. In this way, a structural finite element model can be coupled with an acoustic finite element model (section 3) or with an acoustic boundary element model (section 4). The last section discusses the main practical limitations, involved with the use of the finite element and boundary element methods for coupled vibro-acoustic analysis.

2. Coupled vibro-acoustic problem definition

As for uncoupled acoustic problems, a fundamental distinction should be made between interior and exterior coupled vibro-acoustic systems, depending on whether the acoustic domain is bounded or unbounded.
In an interior coupled vibro-acoustic system, the fluid is comprised in a bounded acoustic domain V, of which the boundary surface Ω_a contains an elastic structural surface Ω_s $(\Omega_a = \Omega_s \cup \Omega_p \cup \Omega_v \cup \Omega_Z)$, as shown in figure 1.

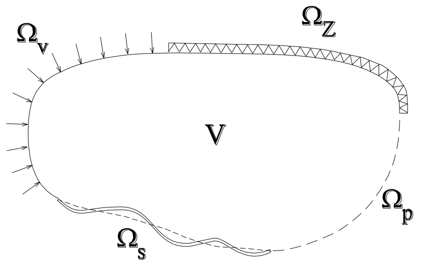

Figure 1 : interior coupled vibro-acoustic system

In an exterior coupled vibro-acoustic system, the fluid is comprised in an unbounded acoustic domain V, which is the space between a boundary surface Ω_a, containing an elastic structural surface Ω_s, and a boundary surface Ω_∞, located at infinity, as shown in figure 2.

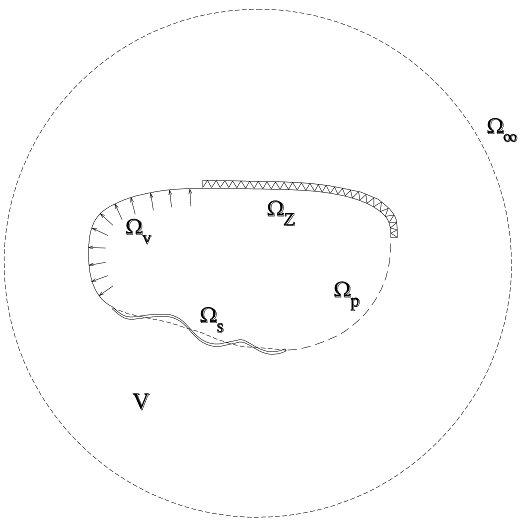

Figure 2 : exterior coupled vibro-acoustic system