DETAILED PROGRAMME

- 6th MCRTN Smart Structures Workshop -

15 - 16 December 2009 - Cnam Paris, France

Tuesday December 15, 2009 / Chaire de Mécanique

- **12h00 - 13h30 :** ***Arrival, lunch and free discussion / Welcome***
- **13h30 - 13h50 :** ***Characterisation of anisotropic porous materials***
  – Christophe VAN DER KELEN, ESR fellow, KTH –
- **13h50 - 14h10 :** ***A substructuring FE model for reduction of stuctural acoustic problems with dissipative interfaces***
  – Romain RUMPLER, Cnam, Future ESR fellow at KTH –
- **14h10 - 14h30 :** ***Influence of design parameters´ changing on the performance of a Smart Structure. Numerical assessment and case discussion***
  – Daniele GHIGLIONE, ESR fellow, KUL –
- **14h30 - 14h50 :** ***Progress in parametric model reduction***
  – Jan MOHRING, Scientist-in-charge, ITWM –
- **14h50 - 15h10 :** ***Generating Parametric Models from Tabulated Frequency Domain Data***
  – Sanda LEFTERIU, ESR fellow, ITWM –

— 15h10 - 15h30 : Coffee break —

- **15h30 - 18h00 :** ***Management meeting / Visit of the "Arts et Métiers Museum"***

Wednesday December 16, 2009 / Amphi Fabry Pérot

- **09h00 - 09h20 :** ***Arrival, coffee and free discussion / Welcome***
- **09h20 - 09h40 :** ***Active Noise Control : Study of the Algorithm***
  – Marco GALLO, ESR fellow, LMS –
- **09h40 - 10h00 :** ***ANC System Development and Algorithm Implementation in a Passenger Car***
  – Guangrong ZOU, ESR fellow, VTT –
- **10h00 - 10h20 :** ***Self-tuning control systems of decentralised velocity feedback***
  – Michele ZILLETTI, ESR fellow, ISVR –
- **10h20 - 10h40 :** ***Modelling inertial actuators and cochlear micromechanics***
  – Stephen J. ELLIOTT, Scientist-in-charge, ISVR –

— 10h40 - 11h00 : Coffee break —

- **11h00 - 11h20 :** ***Magnetic Mass Actuator (MMA)***
  – Kiran SAHU, ESR fellow, VTT –
- **11h20 - 11h40 :** ***Dynamics of an Adaptive Vibration Absorber***
  – Neven ALUJEVIC, ER, LBF –
- **11h40 - 12h40 :** ***Meeting of the scientists-in-charge together with the fellows***

— 12h40 : Closing lunch —

First day : Tuesday December 15, 2009

- **12h00 - 13h20 :** ***Arrival, lunch and free discussion***
- **13h20 - 13h30 :** ***Welcome***
- **13h30 - 13h50 :** ***Characterisation of anisotropic porous materials***

  – Christophe VAN DER KELEN, ESR fellow, KTH –

  A challenge which the automotive industry faces, is the design of future lightweight, cost effective vehicle generationswith a high level of noise and vibration comfort at a low environmental impact. Smart Structures Technology could potentially offer tremendous opportunities for improving the performance, quality and environmental impact of products in this and in many other industrial sectors. One of the main challenges is to optimally integrate the layers in a design where their respective properties are fully utilised.

  To derive adequate simulations models that lead to the design of such an optimised layer construction, it is necessary to determine the properties of the materials to be integrated as layers. These properties have to be known with a relevant precision. The work going on concentrates on porous materials, which are non-isotropic in elasticity/ viscoelasticity/ viscoacoustic properties. New measurement methods to determine these properties in porous materials were developed at MWL. Together with an inverse estimation procedure, the measurement results are used to describe the anisotropic material properties. In a next step these properties will be integrated in an anisotropic Biot model, to optimise an integrated layer design with porous materials.

  During the presentation, it will be concluded that the porous material tested are orthotropic, and that the measurement method is at least repeatable, a first step towards concluding reliability.

- **13h50 - 14h10 :** ***A substructuring FE model for reduction of stuctural acoustic problems with dissipative interfaces***

  – Romain RUMPLER, Cnam, Future ESR fellow at KTH –

  In this work, a fixed-interface component mode synthesis is applied to the acoustic part of a vibroacoustic problem including porous material at interface. The aim is to downsize the problem to the dimension of the interfaces. It leads to a reduced overall number of dofs, by a transformation combining selected normal modes of the components restrained at interface, with the so-called "static modes" obtained by introducing a mobility at the interface dofs. A displacement-pressure (for the structure and the acoustic fluid respectively) formulation is used to describe the vibroacoustic problem, involving a large and non-symmetric coupled problem. For the porous medium at interface, a poroelastic model based on the Biot-Allard theory is used, where fluid and solid phase displacements are retained as primary variables. Acoustic and poroelastic hexahedric elements, structural elastic quad shell element, as well as the proposed reduction method are implemented in the Fortran-based finite element program FEAP.

  The method is tested on academic examples, and on the concrete car model. A comparison in terms of computational time and accuracy of the results is then conducted, validating the proposed CMS method. Further reduction methods applied to the poroelastic medium itself are under investigation.

- **14h10 - 14h30 :** ***Influence of design parameters´ changing on the performance of a Smart Structure. Numerical assessment and case discussion***

  – Daniele GHIGLIONE, ESR fellow, KUL –

  Smart structures´ design must take into account characteristic variables of both the structure and the electronic devices at the same stage to achieve an optimal configuration. This presentation shows, through simple cases implemented on a dedicated numerical calculation tool, how the performance of a piezoelectric ASAC on the Concrete car responds to variation of parameters such as sensor - actuator positioning, controller´s gain and firewall thickness.

- **14h30 - 14h50 :** ***Progress in parametric model reduction***

  – Jan MOHRING, Scientist-in-charge, ITWM –

  In my presentation I will recall the need for parametric model reduction in designing active systems and illustrate our new approach for the LMS concrete car benchmark. The focus will be on numerical and theoretical improvements concerning parallel computing, weighting of i/o-channels due to their parameter dependence, stability preservation etc. Moreover, I will present a new benchmark - the LMS acoustic aquarium - for which FE-model and measurements are available now.

- **14h50 - 15h10 :** ***Generating Parametric Models from Tabulated Frequency Domain Data***

  – Sanda LEFTERIU, ESR fellow, ITWM –

  Creating parametric models which incorporate the dependence on parameters is of great importance during the design phase of a product, when certain variables (eg. sound pressure level inside a car at the location of the passenger's ears) needs to be optimized. Design parameters could relate to the geometry of the product (length, width of the piezoelectric patch) or deal with material properties (Young's modulus, Poisson's ratio). Models for many configurations of the design parameters are needed inside an optimization loop, so making measurements to extract the necessary model for each of these parameter configuration is not feasible since it will take a long time. Thus, having parametric models available ensures a faster design workflow.
  After describing our approach, we will investigate the preservation of properties of the original system (mainly stability). Moreover, we will show how doing some steps differently gives better or worse results on some numerical test cases which we analyzed.

— 15h10 - 15h30 : Coffee break —

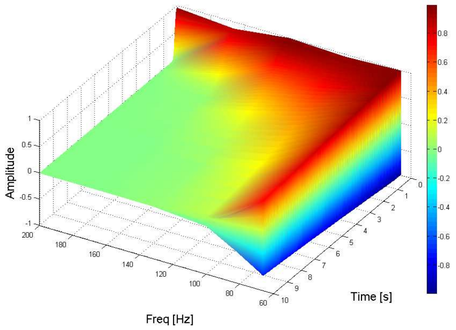
- **15h30 - 18h00 :** ***Management meeting / Visit of the "Arts et Métiers Museum"***
- **18h00 :** End of the day - Free programme with suggestions for the evening

Second day : Wednesday December 16, 2009

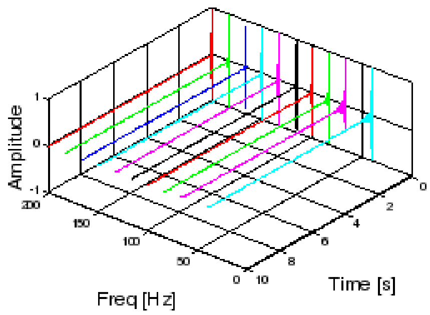
- **09h00 - 09h20 :** ***Arrival, coffee and free discussion / Welcome***

- **09h20 - 09h40 :** ***Active Noise Control : Study of the Algorithm***
  – Marco GALLO, ESR fellow, LMS –

  Active control has been proposed as a possible solution for noise reduction. The job done was focused on evaluate an adaptive feed-forward controller on engine sound quality ; the control strategy is based on the feed-forward filtered LMS algorithm (Fx-LMS), with some modifications in order to improve the convergence rate.



(a) Evolution of error in time for different disturbance frequencies for the Fx-LMS



(b) Evolution of error in time for different frequencies for the NEX-LMS

  First of all the convergence speed of Fx-LMS and NEX-LMS is studied. As it can be seen in Fig.(a) and Fig.(b), the NEX-LMS algorithm (Normalized Equalized x- LMS) extends the fast convergence to the whole frequency range.
  Then, simulation with real car data and latency time study were carried out, in order to choose hardware components of the system, like the board and the processor.
  Right now the job is focused on programming, debugging and optimizing board and processor.

- **09h40 - 10h00 :** ***ANC System Development and Algorithm Implementation in a Passenger Car***
  – Guangrong ZOU, ESR fellow, VTT –

  With the widespread use of the passenger cars in people´s daily life, the requirement to the noise environment inside the car is becoming stricter and stricter. For most cars, the engine-related periodic noise is the dominant part of the internal noise. A multiple-channel narrowband feedforward active noise control system using a modified Filtered-x Least Mean Squares (FXLMS) algorithm has been developed and installed in a passenger car to reduce the low-frequency noise components.
  After a brief introduction to the set-up of the ANC system, the algorithm development and implementation will be presented in detail. In practice, the performance of the ANC system will be affected mainly by the accuracy of the plant estimate, the convergence speed, and also the robustness of the ANC algorithm. During the first experiments, the practical ANC system has already been proven to some extent to be effective to attenuate the periodic noise, specifically the 2nd order engine harmonic. However, because of the complexity of acoustic environment inside the car and the frequency dependent convergence behavior of the algorithm, more work need to be focused on the optimization of plant estimate and the ANC algorithm to improve the performance of the ANC system in the future study.

• **10h00 - 10h20 :** ***Self-tuning control systems of decentralised velocity feedback***
– Michele ZILLETTI, ESR fellow, ISVR –

The active control of vibration on large structures requires multiple actuators and sensors. The complexity of such a control system scales linearly with the number of actuators and sensors if these are arranged in collocated pairs and controlled using only local, decentralised, feedback. Although the use of such a modular approach to active control has several attractions, to provide good performance they must be able to self-tune their feedback gain to adapt to the environment they find themselves in.
The presentation is focused on the realisation of an active vibration control system using multiple local velocity feedback control loops. A simple approach is proposed to automatically tune the feedback gains in such a way that the frequency-averaged response to broadband random excitation is reduced. The self-tuning of each control feedback loop is based on the maximisation of their power absorbed estimated from the velocity measured signal. The maximisation of power absorbed, which requires only local measurements, provides a good approximation to the minimisation of the overall kinetic energy of a structure, corresponding to its global response. In the last part, the experimental set-up of the control system implemented on a panel using reactive actuators will be discussed.

• **10h20 - 10h40 :** ***Modelling inertial actuators and cochlear micromechanics***
– Stephen J. ELLIOTT, Scientist-in-charge, ISVR –

Some current research trends in active vibration control are discussed, focusing on the use of many locally-acting modular controllers to reduce the global vibration in large structures. Such modules would contain a single actuator, sensor and controller, together with a self-tuning element to adapt the controller to the environment it finds itself in. If the actuator and sensor are collocated and dual, the global performance of an array of locally acting controllers can be almost as good as a fully centralised controller, but without the design and communication problems. The use of inertial shakers as practical actuators in such systems is considered, together with the stability problems associated with using these devices in local feedback loops.
The action of the cochlear amplifier within the inner ear is then discussed in terms of the control of the global vibration behaviour through the action of a large array of locally acting feedback systems, with actuation provided by the outer hair cells in this case. The cochlear amplifier enhances the vibration within the inner ear, by 40-50 dB, greatly improving the sensitivity and selectivity of our hearing. The changes in the basilar membrane dynamics required to amplify a wave propagating along the cochlear are described, and the way in which these changes are achieved is discussed for various micromechanical models of the organ of Corti. It is seen that the kind of lumped parameter model used to understand the action of a feedback loop in the case of an inertial actuator, used to attenuate the vibration in engineering structures, can be used to describe the dynamics of the basilar membrane under feedback control, which amplifies the vibration in the inner ear.

— 10h40 - 11h00 : Coffee break —

- **11h00 - 11h20 :** ***Magnetic Mass Actuator (MMA)***
  – Kiran SAHU, ESR fellow, VTT –

  In VTT from quite a sometime now, research has been carried out to develop an elastic mass actuator (EMA) to reduce the sound radiation by suppressing the first radiation mode, which is the most efficient sound radiating mode in low frequency region. Unlike the active damping device (ADD), which works only on resonance ; EMA is working quite well in a frequency band. In EMA, a mass plate is driven in between two electromechanical film (EMFi) layers. Electric interaction forces, which have been generated by supplying electric current to the EMFi layers, are controlled in such a way that the mass element tends to absorb vibrational energy, and thus, decrease the sound radiation of the panel on which it is attached. However, the amplitude of movement of the mass plate is quite low. Therefore, we were searching for a new solution which would improve the amplitude of vibration of the middle mass. In this study, a magnetic mass actuator (MMA) has been proposed in which a permanent magnet would be driven in between two electromagnets by changing the polarity of the supply current. By taking a feedforward/feedback signal from the plate vibration, the movement amplitude of the permanent magnet will be adjusted by adjusting the supplied current. In principle, both the electric and magnetic fields develop the Maxwell stress tensor to develop the interaction forces. Therefore, we expect the MMA would work exactly like the EMA but with improve performance.

- **11h20 - 11h40 :** ***Dynamics of an Adaptive Vibration Absorber***
  – Neven ALUJEVIC, ER, LBF –

  The study presents the design and a theoretical analysis of a lightly damped adaptive vibration absorber. Vibration absorbers can efficiently absorb vibrations at their characteristic frequency. Therefore, they can be used to suppress vibrations generated by, for example, reciprocating machinery such as internal combustion engines or piston type compressors. This is because such machines generate vibrations at discrete frequencies : multiples of the machine RPM. However, as the RPM will typically vary during the operation, the absorber characteristic frequency should be tuneable so as to respond to the variation of the machine RPM.
  In this study a low cost, beam-type vibration absorber is considered. The absorber consists of two masses symmetrically mounted at two ends of a flexible beam. In the middle, the beam is attached to the vibrating machine. The free length of the beam is used to accommodate piezoelectric strain actuators and the two masses at the end are equipped with inertial accelerometers. This arrangement can be used to generate a direct acceleration feedback. Such feedback control generates an active mass effect, which in turn shifts the absorbing frequency of the device. Three different sensor-actuator configurations were analysed theoretically, using a mobility-impedance approach in order to model the passive and active characteristics of the adaptive absorber. In particular, the stability of the feedback loops used is studied using the Nyquist criterion in order to estimate the limits on the tuneable range of frequencies. The analysis included estimation of the influence of small misplacement of the piezo actuators and also the effects due to the dynamical response of the sensors.
  The study indicates that the sensors-actuator arrangements should be carefully considered in order to extend the range of tuneable absorbing frequencies. For example, it is shown that although unconditional stability is theoretically possible for ideal placement of the actuators and sensors, in practice the metrics of the feedback loop stability and thus the adaptability of the device decrease due to even small imperfections in the physical arrangement.

- **11h40 - 12h40 :** ***Meeting of the scientists-in-charge together with the fellows***
  Discussion on the upcoming network course (Feb 3-5, 2010) and on the fellows´ training programmes.

— 12h40 : Closing lunch —