MODA

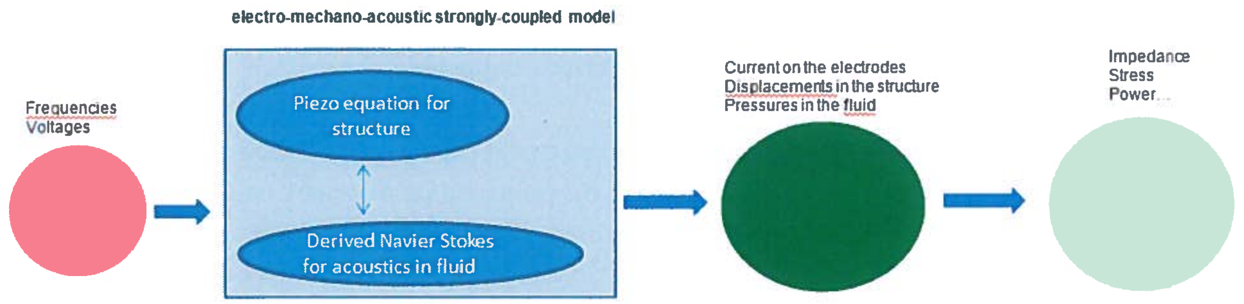
Modelling data documenting one simulation

Name <PROTECT, Piezo transducers, electro-mechano-acoustic modelling >

Metadata for these elements are to be elaborated over time

Purpose of this document:
Definition of a data organisation that is applicable to ALL materials modelling simulations. The fiche should contain all elements that are needed to describe a simulation. This information spans from the end-user (manufacturer) information to the computational modelling details.

OVERVIEW of the simulation			
1	USER CASE	Piezo electric transducer emitting ultrasounds in liquid	
2	CHAIN OF MODELS	MODEL 1	Tightly coupled set of solid mechanics, fluid mechanics and electrical continuum equations, describing the behaviour of excitation voltage, electric potential in the piezo ceramics, strain in the whole transducers, vibration amplitude and pressures in fluid
		MODEL 2	
		...	...
3	PUBLICATION ON THIS ONE SIMULATION		
4	ACCESS CONDITIONS	The FEM model is implemented in the commercially available ATILA FEM software, developed by IEMN (France) and available http://www.mmech.com/atila-fem	
5	WORKFLOW AND ITS RATIONALE	ATILA FEM is dedicated to 2D /3D electro-mechano-acoustic modelling of piezo transducers generating acoustic energy in fluid. It has been initially developed by IEMN for French and US Navy for sonars.	



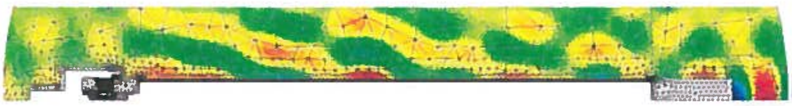
Workflow

Each model used in this simulation can be documented in four chapters:

1. Aspect of the User Case or System simulated with this model

2. Model
3. Computational aspects
4. Post processing

MODEL

1	**ASPECT OF THE USER CASE/SYSTEM TO BE SIMULATED**	
1.1	**ASPECT OF THE USER CASE TO BE SIMULATED**	The piezo transducers for acoustic generation to be developed in the project can be described as : - a transducer composed of one or several stacks of polarised piezoelectric ceramics rings and copper electrodes on which a sinus electric high voltage is applied - a pre-stress bolt made of steel - mechanical parts - a tube linking all the previous parts; the external side of the tube vibrating in the fluid to generate acoustic waves - this transducer is preferably excited at resonance and is working at ultrasonic frequencies
1.2	**MATERIAL**	Steel Piezo ceramics (PZT)
1.3	**GEOMETRY**	typically a tube type structure : See an example below of axial-symmetry FEM of transducers generating acoustic pressure waves in fluid 
1.4	**TIME LAPSE**	A vibration occurs at 20kHz, which means a period of 50*µs.
1.5	**MANUFACTURING PROCESS OR IN-SERVICE CONDITIONS**	excitation frequency and voltage on the electrodes
1.6	**PUBLICATION ON THIS ONE SIMULATION**	

2	**GENERIC PHYSICS OF THE MODEL EQUATION**		
2.0	**MODEL TYPE AND NAME**	Continuum solid mechanics approximated for piezo effects in transducers and CFD (NS) approximated to describe acoustics in the fluid	
2.1	**MODEL ENTITY**	Finite element	
2.2	**MODEL PHYSICS/ CHEMISTRY**	**Equation**	Solid mechanics and electrical equations for the piezo transducer in fluid in contained in the following variationals L and Lf : -For the piezo structure

	EQUATION **PE**		$L = \frac{1}{2} \iiint_{\Omega_s} S_{ij}\, C^E_{ijk\ell}\, S_{k\ell}\, d\Omega_s - \frac{1}{2} \rho_s\, \omega^2 \iiint_{\Omega_s} u_i^2\, d\Omega_s$ $- \iint_{\Gamma_T} f_i\, u_i\, d\Gamma_T - \iint_{\Gamma_u} (u_i - u_i')\, n_j\, (C^E_{ijk\ell}\, S_{k\ell} - e_{kij}\, E_k)\, d\Gamma_u$ $- \iiint_{\Omega_s} \frac{1}{2} (2S_{k\ell}\, e_{ik\ell}\, E_i + E_i\, \varepsilon^s_{ij}\, E_j)\, d\Omega_s$ $- \sum_{p=0}^{M} \iint_{\Gamma_p} (\Phi - \Phi_p)\, n_i\, (e_{ik\ell}\, S_{k\ell} + \varepsilon^s_{ij}\, E_j)\, d\Gamma_p + \sum_{P=0}^{M} \Phi_p\, Q_p$ And for the interaction betweenf the transducer and the fluid a derived form of the Navier Stokes equation is used: $L_f = \iiint_{\Omega_s} \frac{1}{2} (S_{ij}\, C_{ijk\ell}\, S_{k\ell} - \rho_s\, \omega^2\, u_i^2)\, d\Omega_s$ $+ \iint_{\Gamma_u} (u_i - u_i')\, n_j\, C_{ijk\ell}\, S_{k\ell}\, d\Gamma_u - \iint_{\Gamma_T} f_i\, u_i\, d\Gamma_T$ $+ \iiint_{\Omega_f} \frac{1}{2\, \rho_f \omega^2} \left[\left(\frac{\partial P}{\partial x_i}\right)^2 - k^2\, P^2 \right] d\Omega_f$ $- \iint_{\Gamma_P} \frac{1}{\rho_f \omega^2} (P - P')\, n_i\, \frac{\partial P}{\partial x_i}\, d\Gamma_P$ $- \iint_{\Gamma_n} \frac{1}{\rho_f\, \omega^2} P\, \psi\, d\Gamma_n - \iint_{\Gamma_{in}} P\, u_i n_i\, d\Gamma_{in}$ The coupling between both variatonal occurs on fluid structure interface
		Physical quantities	U=displacements ; Phi=electric potential ; P=fluid pressure F=Force ; q=electric charge ; Psi= acoustic velocity
2.3	**MATERIALS RELATIONS**	**Relation**	Piezo materials, elastic materials $T_{ij} = C^E_{ijk\ell}\, S_{k\ell} - e_{kij}\, E_k$ $D_i = e_{ik\ell}\, S_{k\ell} + \varepsilon^s_{ij}\, E_j$ Helmoltz equation for fluid
		Physical quantities/ descriptors for each MR	T = Stress ; S = Strain ; E = Electric Field ; D = Dielectric field P = Acoustic Pressure ; Psi= acoustic velocity
2.4	**SIMULATED INPUT**		

3	SOLVER AND COMPUTATIONAL TRANSLATION OF THE SPECIFICATIONS		
3.1	NUMERICAL SOLVER	The software is based on the Finite Element Method in harmonic analysis involving Cholesky algorithm for the linear solver	
3.2	SOFTWARE TOOL	ATILA	
3.3	TIME STEP	*If applicable*	
3.4	COMPUTATIONAL REPRESENTATION	PHYSICS EQUATION, MATERIAL RELATIONS, MATERIAL	FEM with nodal values coupled by the following matrix **Piezoelectric structure in water :** $\begin{bmatrix} [K_{uu}]-\omega^2[M] & [K_{u\Phi}] & -[L] \\ [K_{u\Phi}]^T & [K_{\Phi\Phi}] & [0] \\ -\rho^2c^2\omega^2[L]^T & [0]^T & [H]-\omega^2[M_1] \end{bmatrix} \begin{bmatrix} \underline{U} \\ \underline{\Phi} \\ \underline{P} \end{bmatrix} = \begin{bmatrix} \underline{F} \\ -\underline{q} \\ \rho c^2 \underline{\psi} \end{bmatrix}$ U=displacements ; Phi=electric potential ; P=fluid pressure F=Force ; q=electric charge ; Psi= acoustic velocity
3.5	COMPUTATIONAL BOUNDARY CONDITIONS	Voltage is prescribed on the electrodes. Displacement of the structure surface is free (ie force = 0), excepted at the fluid interface ; Velocity at Fluid external surface is 0.	
3.6	ADDITIONAL SOLVER PARAMETERS	Mesh density is chosen in way each element to contain no more than a quater wave lentgh .	

Post processing

The "raw output" calculated by the model is per definition the physics variable in the PE(s).
*This is already specified in the entry 2.2 and **will appear in your dark green circle in the workflow picture**.*

This output is often processed by a post processor in order to calculate values for physics variables for different entities that can be input to the next model. Or the output is homogenised for larger volumes in the form of a MR or Descriptor Rule that are the final output of the total simulation.
This will appear in your light green circle in the workflow picture and also in 2.4 of the next model.

The methodology (often including new physics) used to do this calculation is to be documented.

4	POST PROCESSING	
4.1	THE PROCESSED OUTPUT	Main out put are: Required current I Displacements & Stresses in the transducer Pressure in the fluid
4.2	METHODOLOGIES	Electric current : I = ωq Electric Impedance : Z = V/I
4.3	MARGIN OF ERROR	in the range of 10%.

Herewith I confirm you can go public with this file,

Frank Claeyssen, Managing Director, CEDRAT TECHNOLOGIES

CEDRAT TECHNOLOGIES
59 Chemin du Vieux Chêne Inovallée
38246 MEYLAN Cedex
Tél. : 04 56 58 04 00
Fax : 04 56 58 04 01
R.C. 7112B - Siret 310 416 334 00046