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Fluidtronic activity, Ampère Lab, INSA Lyon, France*

Eric BIDEAUX**, Xavier BRUN**

1. INTRODUCTUON

These few pages are briefly introducing the Fluid Power activity at the Ampère Lab. It gives an overview of our main research aims and few application examples.

For us, it is real pleasure to be associated to the 40th anniversary of the JFPS, as one the main world conference in Fluid Power, especially in pneumatics and its applications.

2. THE AMPERE LABORATORY

Ampère Lab and the Fluidtronic research team

The Fluid Power research activity started in Lyon about 30 years ago initiated by the Professor Serge Scavarda. Until 2007, this research group was part of the Laboratoire d'Automatique Industrielle (LAI) of the Lyon National Institute of Applied Sciences (INSA). In 2007, it merged with the Centre de Génie Electrique LYonnais (CEGELY) and a microbiology group to form a joint laboratory among the French National Center for Scientific Research (CNRS), INSA Lyon, Ecole Centrale de Lyon and University Lyon I.

The Ampère Lab is made up of 6 research teams (Actuators & Systems, Control, Power Electronics, Materials, Modeling, and Microsystems & Microbiology) collaborating on 8 transversal research themes, one of them being Fluid Power. The research activities are funded by government, institutional funding and industry (around 3,5 M€ / year). About 50 academics, 10 full time researchers, 19 support staff, 11 post-docs, and 80 PhD students are working at the lab.

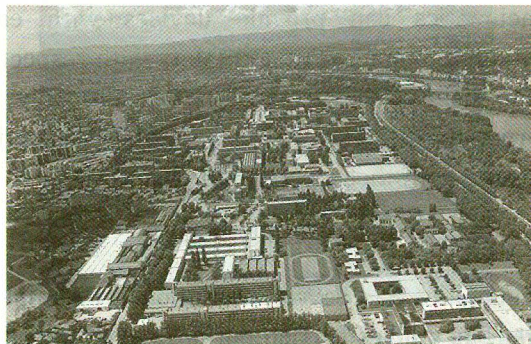


Fig. 1 Lyon National Institute of Applied Sciences

The Institut National des Sciences Appliquées of Lyon

Celebrating last year its 50th anniversary, INSA Lyon (Fig. 1) is one of the top French Engineering schools for offering one of the best preparation for the professional world. Its strength: quality of education and pedagogy, an emphasis placed on educational staff and applied research, and international outlook. There are over 6,000 students taking first and higher degrees.

The fluidtronic research team is mainly linked to the Mechanical Engineering Design Department and the Electrical Engineering Department. Strong international relationships have been established: dual diplomas, international academic exchange, industrial internship abroad, Erasmus Mundus Master in Mechanical Engineering.

The scientific objectives of the Ampère Lab

The Ampère Lab has a general scientific objective, namely the *efficient management and the rational utilization of energy in systems in relation with their environment*, with respect to a wide range of fields:

- Domains: System and Control, Electrical and Electromechanical Engineering, Microbiology,
- System range: from power transmission components to energy systems,
- Frequencies of the phenomena: from static to microwave (GHz),
- Application range: from transport systems to

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energy, environment and bioengineering,

- A general approach in engineering: understand the physical phenomena in order to design complex systems.

Scope of activities and key words are:

- dielectric and magnetic materials, power electronics, high voltage, electromagnetic compatibility, electromagnetic modelling,
- power transmission and control, mechatronics, Fluid Power, robotics, diagnostics and operational security,
- ecological engineering and gene transfer.

3. RESEARCH TRENDS

The study of the transmission of power using a fluid (oil, water or gas) constitutes, with electrical power transmission, complementary aspects to one of the major research problem at the present time, that is to say the design of energy efficient systems.

From this point of view, the Ampère Lab is unique in France since it has a recognized expertise of all these technologies for power transmission. This expertise is essential when considering the previous economic and scientific issues. The research in Power Transmission and Control is divided in 3 main scientific areas:

- multi-domain and multi-scale modelling,
- methods and tools for system design,
- system control.

The specificity of our research is to deal with multi-disciplinary aspects on the theoretical viewpoint as well as on the experimental side.

Multi-domain and multi-scale modelling

This research activity tackles theoretically as well as experimentally the modeling of multi-energy power transmission systems, and particularly when fluid energy is used. Since 1998 research works have also been done coupling electrical drives and conventional power transmission (hybrid vehicles), and recently very original research projects have been initiated (pneumatic-electric battery). It leads to the implementation of several libraries in AMESim (LMS-IMAGINE).

Structured modeling and multi-scale systems

On the theoretical side, a unified and structured approach of the modeling for multi-physic and multi-scale systems (Bond Graph) is developed,

aiming at preserving the real nature of the mathematical models before any step of space and time discretization (Fig. 2). It allows an easier interconnection of sub-models, multi-domain modeling, mixing conservative and irreversible processes, and structure analysis (controllability, observability, inverse methods, and passivity).

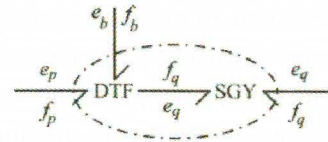


Fig. 2 Decomposition of a Stokes-Dirac structure.

System optimization with parameterization in CFD

Concerning the simulation aspects, the problem of coupling numerical codes for fluid mechanics and for system dynamics is also considered, this in order to globally optimize a component or a circuit, considering the mutual influence of control and local flow phenomena. We apply a novel approach based on the parameterization of the CFD computed solution (Fig. 3). This method can give all the results corresponding to a continuous variation of the design parameters from one single design step, which means one single flow computation on one single mesh.

New experimental procedures in pneumatics

Finally, on the experimental side with a strong link with industry, the expertise acquired on the pneumatic technology is still reinforced. For example, new experimental procedures have been developed for the characterization of pneumatic components, which relies on the discharge or the charge of a tank using heat transfer models. Good results have been obtained and it allows a wide range of applications to be explored now.

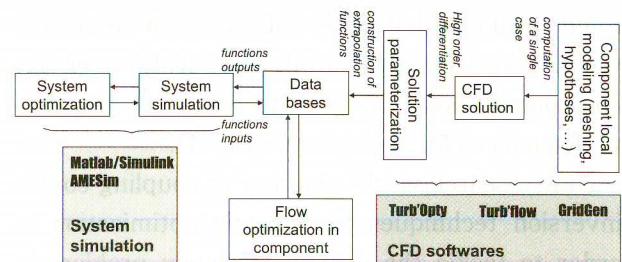


Fig. 3 Parameterization in CFD for system simulation and optimization.

Methods and tools for system design

The main objective of this research work is the theoretical and methodological development of tools for studying the generic and intrinsic properties of systems. Our approach, based on an inverse methodology, is a break with the conventional simulation methods applied in engineering since it tries to avoid the conventional try/error/correction iterative procedure (Fig. 4). Because inverse approaches are the natural way to define design problem (generally, output are specified variables while inputs are unknown), it leads to more efficient and relevant methods (a single calculation is required).

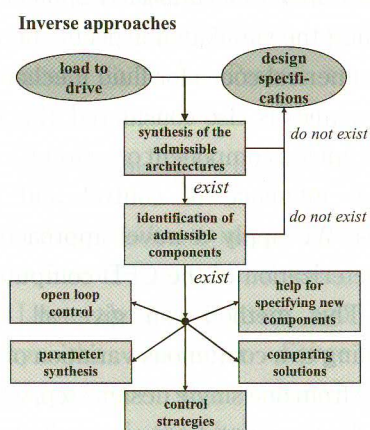


Fig. 4 Inverse approach for system design.

The final goal is here to give simple rules and methods that can easily be used in industry for design purposes. These works are based on Bond Graph energy conservation principles, causality concepts, model inversion techniques, algebraic approach, and operational analysis in infinite dimension. With our approach based on causal and bicausal concepts, this information can be obtained at the early stages of the design project (on the Bond Graph model). This indicates how to change the architecture, the output specifications or the component choice in order to reach the required performances for the system (Fig. 4).

New research works aim now at coupling couple inversion techniques to dynamic optimization in order to tackle the energy efficiency problem in system design. The expected results should solve a wide range of problems in engineering, such as system design, choice of component technology and system architecture, robustness, control law

structural analysis. Software developments within MS1 (Lorenz Simulation) and Modelica (Modelica Association) are now available.

System control

Started 20 years ago, this activity focuses at the adaptation, synthesis, implementation and comparison (performance, cost, ... criteria) of modern control laws, issued from the new development in control theory of the international automatic community. The Lab has wide theoretical and experimental experience on gains scheduling, nonlinear I/O linearization, adaptive, first order and higher sliding mode, flatness, backstepping control, with aims to adapt these different strategies in prototypes or experimental test rigs.

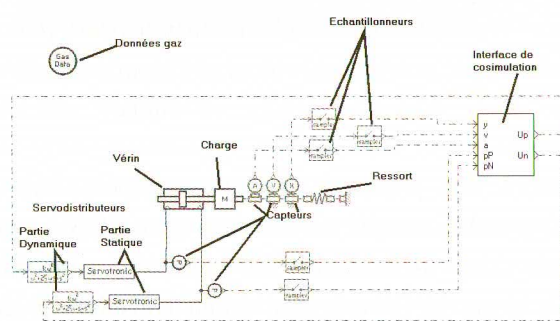


Fig. 5 Virtual bench test: cosimulation AMESim - Matlab/Simulink (rudder control)

Our methodology is based on several steps: 1) simulation models are developed, 2) control strategies are developed using co-simulation tools (Fig. 5), 3) rapid control prototyping tools (dSPACE) are used for testing the control algorithm on experimental rigs, 4) the control algorithms are finally implemented on specific electronic devices.

High order sliding mode Control and virtual sensors

We proved the interest of high order sliding mode algorithm for a missile rudder pneumatic positioning compared to gains scheduling approach and electrical technology. This work leads also to the development of specific observers (extended or not) using a single mechanical sensor (Fig. 6).

Strictly positive real system and stick-slip phenomenon

From 2007, some works have permit to propose a new method to study the stability of the equilibrium set of nonlinear models. It has been applied to path planning of electro-pneumatic actuator. Moreover using an appropriate switching

strategy between different control laws (path planning or pressure regulation), the undesirable stick slip occurrences have been reduced to zero.

Control of hybrid Fluid Power systems

An actuator controlled by on/off valves is structurally considered as a hybrid dynamic system. This class of system presents simultaneously continuous dynamic (actuator) and discrete behavior (on/off valves). Due to the recent development of fast on/off valves, it is now possible to replace classical servovalves by low cost valves using the appropriate control algorithm. A first application of this technique in the Lab is the development of a specific electro-pneumatic haptic system in the medico-chirurgical context.

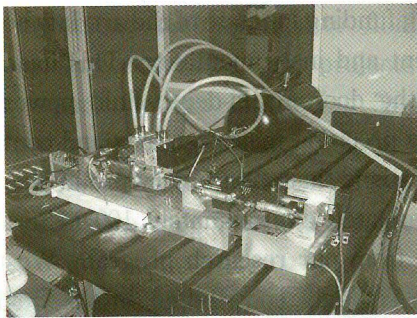


Fig. 6 Experimental test bench for rudder control

4. OUR FUTURE VIEW ON FLUID POWER

The main originality of these researches is the strong link between theory and application. Today, researches focus on energy efficiency and robustness, developing new modeling, design and control methods. To our point of view, one challenge in Fluid Power is the development of more user-friendly and globally optimized components that integrates control, health monitoring, energy management, ... Coupling the high power density

and reliability of Fluid Power components to smart electrical devices and electronics is certainly one aspect to consider.

5. CONCLUSIONS

Our biggest expectation for the next JFPS Symposium on Fluid Power in Okinawa 2011, is that it remains the high level conference it has been for many years now: friendly, high quality papers, fantastic exhibition, and of course the place good scientific discussions.

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[Introduction of Author]

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He obtained a Mechanical Eng. degree in 1991, and the Ph.D. in Automation & Control in 1995. He joined INSA Lyon as assistant professor in 1995. Since 2006, he has a professor position at the Ampère Lab in Lyon and is in charge of the Actuator & Systems research group. His research fields are in mechatronics and Fluid Power with a specific focus on Bond Graph formalism for modeling, simulation and design of energy efficient systems.

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