UNIVERSITY of Liège

AUTOMOTIVE Engineering

AUTOMOTIVE ENGINEERING
UNIVERSITY OF LIEGE

Pierre DUYSINX
University of Liège
Automotive Engineering

UNIVERSITY of Liège

AUTOMOTIVE Engineering

OUTLINE

- INTRODUCTION
  - University of Liège
  - Aerospace & Mechanics Department
- SIMULATION & OPTIMIZATION
  - Simulation of mechatronic systems, flexible mechanisms, myltiphysic problems
  - Shape & topology optimization
- CLEAN TECHNOLOGIES
  - Hybrid vehicles
  - Fuel cell propulsion system
- CONCLUSIONS

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INTRODUCTION

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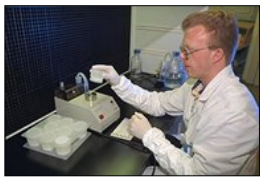
AUTOMOTIVE Engineering

UNIVERSITY OF LIEGE

- One of the 3 'complete' universities in the French speaking part of Belgium
- 10 faculties:
  - Philology,
  - Law and Criminology,
  - Medicine,
  - Veterinary Medicine,
  - Economics, Management and Social Sciences
  - Psychology and Educational Sciences
  - Sciences,
  - Engineering.
- People:
  - Professors: 450
  - Researchers & Ph D students: 1500
  - Students: 17.000



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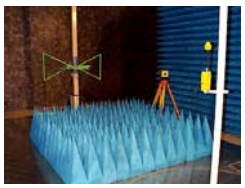
ENGINEERING FACULTY

- One of the earliest school of the University (1850)
- Most of engineering disciplines are represented:
  - Electricity, Electronic & Computer Science,
  - Aerospace & Mechanics,
  - Chemical Engineering
  - Civil Engineering
  - Architecture,
  - Geology & Mines.
- People:
  - 65 professors
  - 200 researchers
  - 1.500 students (mostly from Belgium and EU)



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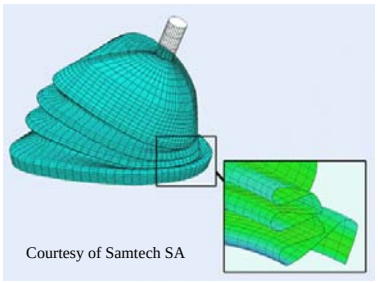
AEROSPACE AND MECHANICS DEPARTMENT

- Aerospace & Mechanics Department is one of the biggest department of the Engineering Faculty:
  - 23 professors
  - >100 researchers
  - >120 students get an engineering diploma every year
- Covers several domains:
  - Aerospace (only one in Belgium)
  - Mechanical & Automotive (only one in Belgium) engineering
  - Energy
  - Material Sciences



Courtesy of Samtech SA

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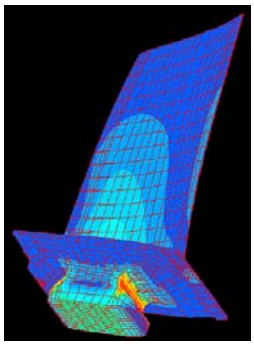
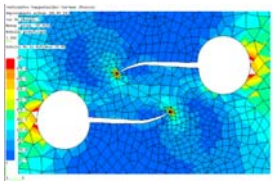
LTAS – Laboratoire de Techniques AéroSpatiales

- Since 1961 pioneer in Finite Element Methods with Prof. Freijs de Veubeke
- 1970: research in Finite Elements leads to the SAMCEF code. The F.E. code is disseminated in Belgium and French Aerospace Industry (SNECMA, Airbus, SONACA…)
- 1985: SAMTECH company is founded to commercialize the SAMCEF code.
- Research in F.E. simulation has now been applied to many problems and application fields: composite materials, vibrations, flexible mechanisms, multiphysics problems (MEMS), fracture mechanics, metal forming, impact problems, optimization…





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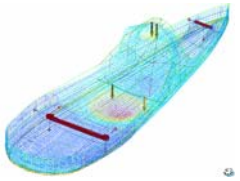
AUTOMOTIVE ENGINEERING GROUP

- Founded to promote automotive applications in Aerospace & Mechanics Department and LTAS
- Activities
  - Until 2001, mostly Internal Combustion Engines and Hybrid vehicle activities (Prof. Jamoule)
  - Since 2003, development of a simulation and optimization expertise as well (Prof. Duysinx).
- Man Power: researchers (5) + staff (2)
- Research programs for ~500.000 € every year



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SIMULATION AND OPTIMIZATION

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- Researches realized in the tradition of LTAS
  - Tradition of scientific quality
  - Tradition of collaborating with industry partners
- Development in SAMCEF environment
  - SAMCEF MECANO for flexible multibody systems
  - OOFELIE: Object Oriented Finite Element Led by Interactive Execution: simulation of strongly coupled multiphysic problems
  - Boss Quattro: open environment for optimization of structural, multidisciplinary and multiphysic problems
- Many results are transferred to the SAMCEF codes

INTRODUCTION | SIMULATION & OPTIMIZATION | CLEAN PROPULSION TECHNO | CONCLUSION

SIMULATION AND OPTIMIZATION

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- Major topics are:
  - Simulation of vehicle dynamics / engine dynamics
    - Engine dynamics in extreme and rapid motions (motor sport for instance)
    - Vehicle as a mechatronics system: semi-active suspensions, vehicle dynamics control…
  - Optimization of structures
    - Shape
    - Topology
    - Generalized shape (Extended Finite Element Methods)
  - Multiphysic simulation and optimization of MEMS (micro electromechanical systems)

ENGINE SIMULATION

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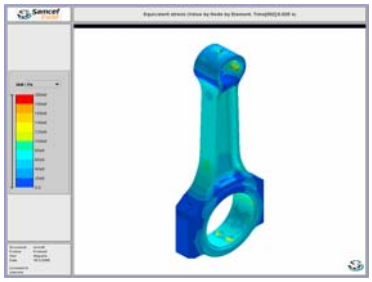
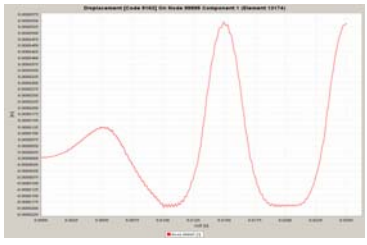
- Flexible multibody simulation of engines in extreme conditions (e.g. motorsport)
- Verification of engine elements
  - Flexibility, buckling, fatigue of connecting rods
  - Vibrations and fatigue of cranckshafts
- Collaboration with SAMTECH, GDTech and Excilis





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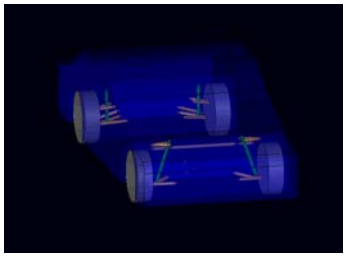
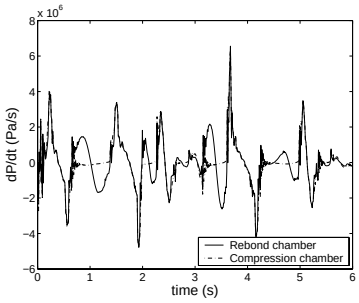
VEHICULE MECHATRONICS

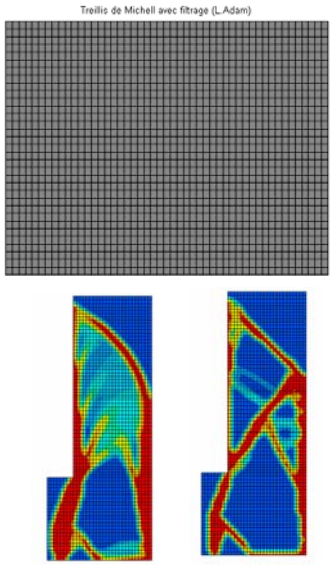
- Integrated simulation of flexible multibody systems and their control systems
- Unified formulation of controlled multibody dynamics using F.E. and block diagram formalism
- Reduced-order strategy of multibody systems for control strategy synthesis
- Example: simulation of the dynamics of a semi-active shock absorber
- Technology transferred to OOFELIE package





TOPOLOGY OPTIMIZATION

- Topology optimization is formulated as an optimal material distribution (Bendsoe & Kikuchi, 1988)
- Numerous contributions to the problem:
  - Stress constraints
  - Optimization algorithms able to solve very large scale problems
  - Perimeter constraints
  - Discrete 0/1 variables
  - ...
- Applications to industrial problems e.g. Airbus Industries



TOPOLOGY OPTIMIZATION

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- Topology optimization of the number/position of welding spots

Topology optimisation with 0/1 variables
(Beckers & Fleury, 1998)

Minimise number of welding spots
s.t. displacements constraints


Partie étudiée


Points de soudure


Maillage de la partie étudiée

GENERALIZED SHAPE OPTIMIZATION WITH XFEM

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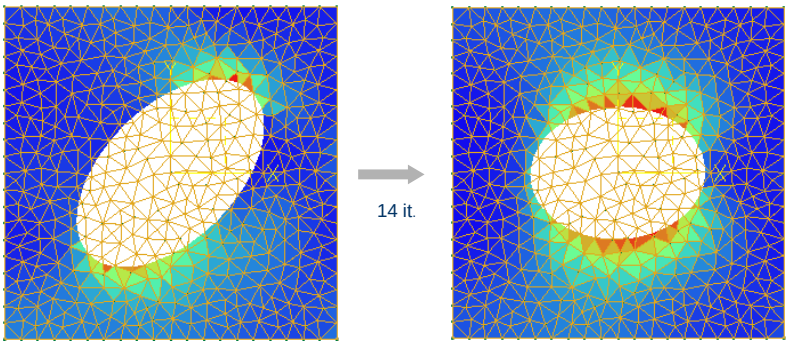
- Novel Finite Element method to capture variable boundary problems like fracture propagations, solidification or shape optimization
- Application to shape optimization is very promising
  - Fixed mesh
  - Modification of topology possible



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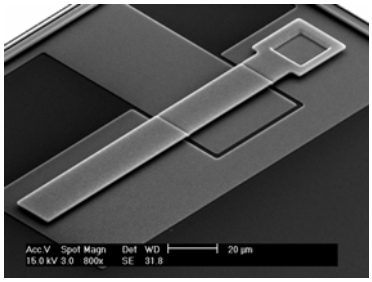
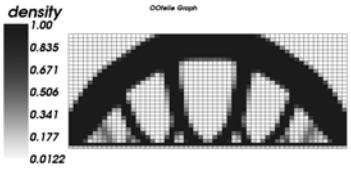
SIMULATION / OPTIMIZATION OF MEMS

- Simulation of multiphysics problems: application to MEMS
- Monolithic simulation of strongly coupled problems: mechanical deformations and vibrations, electric and magnetic fields, fluid flows…
- Optimization of shape and topology using material distribution method or XFEM
- Technology transferred to OOFELIE (Open Engineering S.A.)





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CLEAN PROPULSION TECHNOLOGIES

INTRODUCTION SIMULATION & OPTIMIZATION CLEAN PROPULSION TECHNO CONCLUSION

HYBRID ELECTRIC VEHICLES

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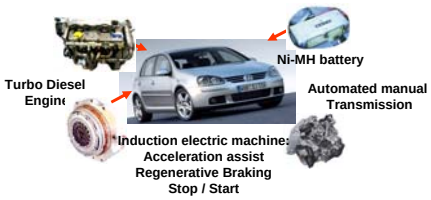
- Ten year ago, research activities of the automotive group moved from engines to electric and hybrid vehicles
- Simulation and optimization of hybrid electric (/hydraulic) vehicles
- Experimental validation
- Several test facilities: chassis dynamometer, test beds for IC engine, batteries and electric propulsion systems…
- Transfer of technology to Green Propulsion SA, spin off of ULg



HYBRID ELECTRIC VEHICLES

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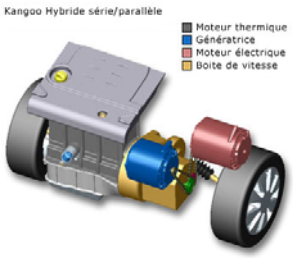
- Green Propulsion SA is a spin-off of the Automotive Engineering group founded to promote industrial applications in HEV
- Green Propulsion is specialized in designing and prototyping hybrid vehicles
- Modeling and testing of components: batteries, motors…
- Several projects have been successfully conducted in the last past years
- Information available on www.greenpropulsion.be



Renault Kangoo Hybrid Green Propulsion

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FUEL CELL POWERED VEHICLES

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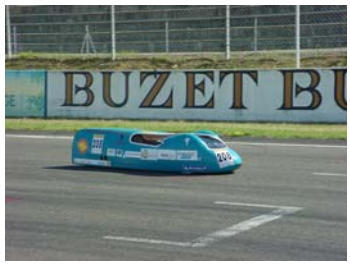
- Research in Fuel Cell powered vehicles
  - Simulation & Optimization
  - Testing of components
  - Developments of prototypes
- Proof of concept with Shell Eco Marathon competition
  - Top 10 team of the competition en 2005 (2136 km/ equiv liter of gazoline)
  - Eco design price in 2004 and 2005



FUEL CELL POWERED VEHICLES

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- Collaboration between several research groups of University of Liège:
  - Chemical Engineering (Prof. A Germain): PEM membranes, fuel cell validations
  - Energy transport (Prof. Lilien): batteries and super capacitors
  - Conversion of electromagnetic energy (Prof. Legros & Genon): motor and power electronics
  - Thermal energy management (Prof. Lebrun & Ngendakumana)
  - Vehicle engineering (Prof. Duysinx)

ECO EFFICIENCY INDEX

- Objective comparison of solutions have to be made on the basis of the life cycle assessments (LCA)
- Satisfaction of users' and customers' needs must also be taken into account!
- Development of an ECO EFFICIENCY INDEX =

$$\frac{\text{Satisfaction of needs}}{\text{Eco score}}$$

- New methodology to assess the satisfaction criteria
- Results are sometimes surprising and against well-established ideas!

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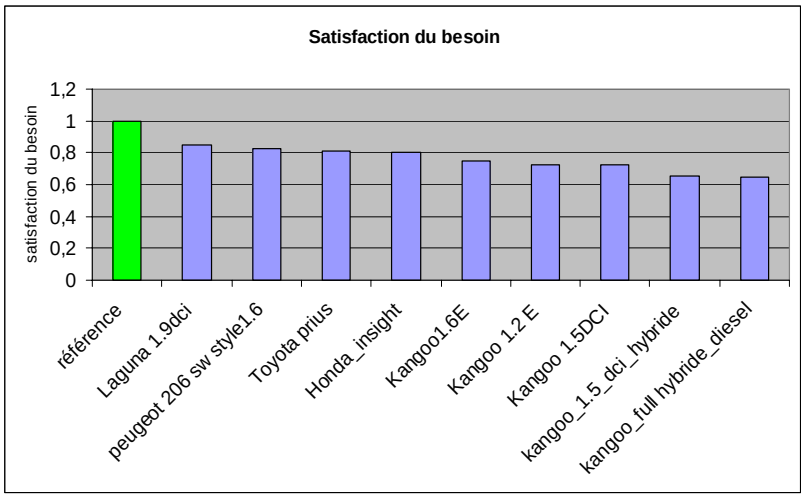
ECO EFFICIENCY INDEX - EXAMPLE

USER SATISFACTION



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ECO EFFICIENCY INDEX - EXAMPLE

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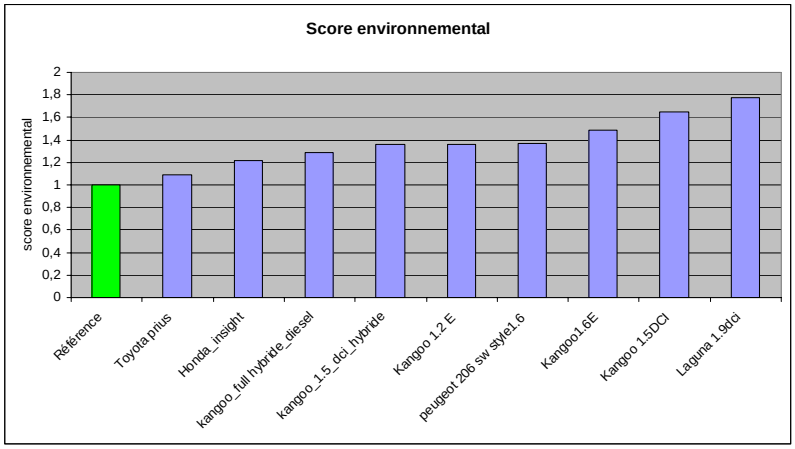
ECO SCORE



ECO EFFICIENCY INDEX - EXAMPLE

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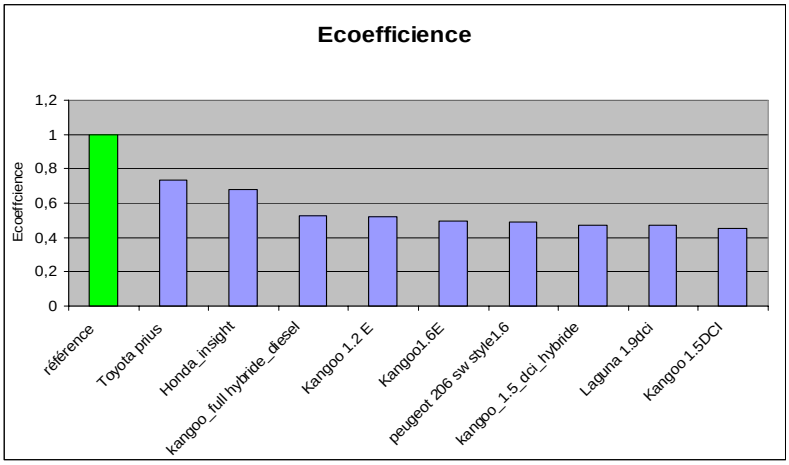
ECO EFFICIENCY INDEX



'THE GREEN FAMILY' CONFERENCE

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- Conference theme
  - The Conference is dedicated to any means available to reduce that CO2 amount by a significant part, obviously in a LCA approach (Life Cycle Assessment).
  - How to reduce residential environmental impact ?
    - Energy demand and management in house including case studies
    - Energy in transportation (private and public car), plug-in hybrid car, etc… with practical data (only realistic car/buses)
    - Energy in house, new design, material, etc.. including case studies
- Organized by the Fuel Cell group of ULg in fall 2006
- Information: http://www.conf-aim.skynet.be/green_family/Conference.htm

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CONCLUSIONS

INTRODUCTION | SIMULATION & OPTIMIZATION | CLEAN PROPULSION TECHNO | CONCLUSION

CONCLUSIONS

- Automotive Engineering
  - is at the center of research activities at University of Liège
- Simulation and optimization
  - 40 years tradition at LTAS of Ulg
  - Long tradition of quality and collaboration with industry partners
- Clean propulsion systems
  - Hybrid electric vehicles
  - Fuel cell powered vehicles
  - Eco efficiency indices
- University of Liège is a reliable partner for your R&D activities

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CONTACT

Pierre DUYSINX

Automotive Engineering
Aerospace and Mechanics Department
of University of Liège

Chemin des Chevreuils, 1 building B52
4000 Liège Belgium

Email: P.Duysinx@ulg.ac.be
Tel +32 4 366 9194
Fax +32 4 366 9159
url: www.ingveh.ac.be

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