ECOMEF Project
Eco-design of a mechanized equipment for hardwood harvesting

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Harvesting Machine for crooked trees

5th Forest Engineering Conference, September 23-26, 2014, Gerardmer, France
FUI ECOMEF project: Partners and Funders

Global Budget: 3,8 M€

Project partners:
- ISI (SME, project leader)
- FCBA
- IFMA / Pascal Institute
- IRSTEA (ex CEMAGREF)
- France Bois Régions (Auvergne Promobois, Interbois Périgord)
- Comptoir des Bois de Brive (France)
- Lycée Claude Mercier
- Accredited by Viameca et Xylofutur clusters

Funders:
- FUI French Government
- Auvergne, Limousin and Aquitaine regions
- FEDER Auvergne
- FEDER Limousin
- Clermont Communauté
- General Council of Puy de Dôme
- General Council of Allier
- Brive conurbation
ECOMEF project at IFMA and Pascal Institute

IFMA : French Institute for Advanced Mechanics

- A prestigious **public engineering school** since 1991, part of «Grandes Ecoles» system
- 608 engineer students and 42 engineers by apprenticeship
- 2387 graduated eng. since 1991
- **115 staff**, including 30 academic researchers
- **3 poles**: structures, machines, industrialisation
- 1 Technology Transfer Center
- Favoured relationship with industry

Pascal Institute

- UMR CNRS/UBP/IFMA 6602 created in January 2012
- Sciences of engineering and systems
- 130 researchers / 27 engineers and technicians / **115 PhD students**
- **Axis Mechanics, Materials and Structures** (MMS)
  - Machines, Mechanisms et Industrials Systems (MMSI)
  - Mechanisms and robots synthesis
  - Behaviour modelling of complex systems in real conditions

http://www.ifma.fr

Delimbing

- Objectives
- Partners
- Presentation

Conclusion

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Project FUI ECOMEF (2011-2015)

Presentation

- FUI: a pre-competitive project aimed at developing industrials products

Eco-design of a mechanized equipment for hardwood harvesting

Problem

- Think up innovative concepts and products for mechanized / robotized hardwood harvesting
- Current equipments are not suitable for hardwood
- Lumberjack: a dangerous job with poor job prospects
- French forest is growing being underexploited

A team for research and development

- 2,5 FTE jobs of engineers at IFMA
- 2 PhD thesis (innovative design / modelling and simulation)
- One full-scale demonstrator
- Several mono-functional demonstrators
- A Knowledge Database of hundreds innovating concepts
- Many expected patents

- Energy wood
- Timber
Project objectives

1. Designing machines that fit broadleaved tree structure

- Conifer: linear trunk & fragile branches easy to cut by shock
- Broadleaved trees: crooked, numerous strong branches, hardwood

2. Increasing productivity

- Conifer: Fir
  - Time: 1 min 38 sec
  - 9 short-logs + 2 logs
  - Processed volume: 2.3 m³
  - Quality: good

- Hardwood: Beech
  - Time: 2 min 14 sec
  - 15 short-logs
  - Processed volume: 1.1 m³
  - Quality: poor

Our Goal: design better harvesting machines to increase productivity of mechanized harvesting heads by 40% on hardwood trees
Project Technical Objectives

Theme 1: Harvesting Machines for crooked trees

Existing harvesters are designed for rectilinear trunks: crooked trees have to be managed in several stages.

Our goal: feeding crooked trees without stopping or damaging the head.

Theme 2: Delimbing optimization on hardwood

Today, hardwood big branches require to be managed separately by the driver:
- Letting the trunk down
- Catching the branch
- Sawing the branch as a trunk

Our goal: delimbing without stopping or damaging the head.
Primary modeling of the system

Measuring on a real harvesting head

- In association with a lumberjack
- Sensor integration
- Experimental results
Primary modeling of the system

Computer modeling
- 3D CAD software: CATIA
- Multibody dynamics simulation: Adams; Video_8

Problems related to numerical models
- Difficulty of modeling the contacts
- Lack of informations
- Possible solution: Small scale demonstrators

Harvesting Machine for Crooked trees
- FUI ECOMEF
- Engineering
  - Context
  - Modeling
  - Demonstrator
  - Tests
- Conclusion

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Small scale demonstrator

Why a small scale demonstrator?

- **Faster** design time
- **Reduced cost** of development
- **Simpler** system than full scale demonstrator

Scale effect consideration

- Use of **dimensionless numbers**
  - Eg: Reynolds, Blake, …
- Difficulty to find suitable scaling laws
  - Numerous parameters
  - Actuators technology

Considered scale

- 1/4 geometric scale
Small scale demonstrator

**Purpose**
- Reproduce the **feeding action** on a reduced scale
- Study of the influence of different **configurations**
- Find the set of parameters allowing curved trunks passage

**Used equipments**
- **Actuators**:
  - Electrical linear actuators
  - Motoreductors
- **Command system**:
  - Lego NXT automaton
  - Home-made control boards
- **Simulation trunk in PVC tube**:
  - Straight and curved
  - Covered with rubber

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Tests campaigns

First campaign

- **Debugging** the demonstrator
- **Dimensioning** the actuators
- Find **limits** of the demonstrator

Second campaign

- **Trunk feeding**
  - Main influential parameters
- Effect of **guidance length**
  - Trunk behaviour
  - Conditions for correct passage of curved trunk
- Final correct set of **parameters**
Tests campaigns

First campaign

- Motor power: Video_13.1
  • Changing actuators
Tests campaigns

First campaign

- Rubber cover:
  - Traces on the rubber
  - Difficulty of the feeding; Video_13.2
Tests campaigns

First campaign

- Results of the tests:
  - Adjust actuators:
    - Change the motors type
    - Doubling linear actuators
  - Modify the architecture of the demonstrator
    - Placement of motors and linear actuators
  - Perceive the limits of demonstrator:
    - Speed and power of actuators
    - Similarities with the reality
  - Select relevant real conditions:
    - Remove the rubber covering
Tests campaigns

Second campaign

- Complete small scale demonstrator
  - CAD
  - Real
Tests campaigns

Second campaign

- Complete small scale demonstrator
  - CAD
  - Real

- Design of experiment:

  For an initial configuration of the demonstrator, do
  For a specified experimental trunk, do
    For a specified openings of rollers and/or knives, do
      For a guidance length of the demonstrator, do
        Feed the trunk;
        End For;
      End For;
    End For;
  End For;
End For;
End For;
Tests campaigns

Second campaign

Tests on the effect of the guidance length:

- Guidance length = 50 mm
  - Time of passage: 7.3 s
  - Mean power: 5.96 W

- Guidance length = 116 mm
  - Time of passage: 6 s
  - Mean power: 4.12 W

- Guidance length = 188 mm
  - Time of passage: 7.45 s
  - Mean power: 6.51 W
Tests campaigns

Second campaign

Test on the ability of passing curves:

- Horizontal curves:
  - Example: Video_17.1
    » Fixed head, with support
    » Guidance length = 116 mm
    » Rollers openings = 77 mm
    » Knives openings = 46 mm

- Vertical curves:
  - Examples: Video_17.3, Video_17.2
    » Fixed head, with support
    » Guidance length = 50 mm, 116 mm
    » Rollers openings = 71 mm, 77 mm
    » Knives openings = 43 mm, 46 mm
Tests campaigns

Second campaign

- Results of the tests:
  - Most relevant parameters on feeding
    - Rollers openings
    - Guidance length
  - Passing horizontal curves
    - Possible with different configurations
    - Confirmation of professional observations
  - Guidance length effects
    - Medium length is better for straight trunks
    - Small length tend to help passing curved trunks
  - Passing vertical curves
    - Caused damage to the test materials
    - Impossible with current architectures

Conclusion

- Existing head do not work
- New harvesting heads architectures
Theme 1 : Conclusion

Realised work

- Small scale demonstrator
- Tests campaign allowing better comprehension of real harvesting heads.
- Main parameters:
  - Guidance length
  - Roller opening
  - Curvature orientation

Difficulties

- Scale effect
- Boundary conditions

Results and future work

- Optimal parameters were found
- Existing heads cannot fit vertical curvature
- New head architectures
- Several patents pending
Engineering

- A team of researchers, engineers & students of IFMA-IRSTEA-FCBA-ISI
- In association with wood professionnals
- Eco-design of one full scale demonstrator
- 4 mono-functional demonstrators (test benches)
- A goal: +40% productivity during hardwood exploitation

Research

- Thesis 1: innovation methodology allowing generation and traçability of innovating concepts
- Thesis 2: two experimentaly validated models for feeding and cutting

Results with social impact

- Several pending patents
- Sustainable development of wood ressource
- Decreasing head energy consumption
- R&D to design future harvesting machines for a SME of Auvergne (ISI)
- Developing the wood sector in Auvergne, France and abroad
Thank you for your attention

Feel free to ask your questions