Université Moulay Ismaïl
Ecole Nationale Supérieure d'Arts et Métiers

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Towards a knowledge base for a wind electric pumping system design

Abdelaziz ARBAOUI[1,2(*)]
[1] M2I, Ecole National supérieure d'Arts et Métiers
BP 4024, Meknès Ismaïlia, Morocco.
abdelaziz_arbaoui@yahoo.fr

Mohamed Allae BENNINI[2] and **Mohamed ASBIK**[2]
[2] LP2MS, URAC 08, Faculté des Sciences
BP 11201, Zitoune, Meknès, Maroc
asbik_m@yahoo.fr, bennini.allae@gmail.com

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INTRODUCTION

The NATO SfP-982620 project

Sahara Trade Winds to Hydrogen: Applied Research for Sustainable Energy Systems

Building two applied research platforms within Morocco and Mauritania's main research centers in partnership with large local end user groups to initiate a far ranging, comprehensive program aimed at integrating wind energies in the Saharan/Sahel region.

Sahara Trade Winds

Academic Networks

NATO OTAN *This project is supported by:* The NATO Science for Peace and Security Programme

INTRODUCTION

The small wind turbine integration problem

- **The small wind turbine market has good potential.**

  The applications range from remote sites to distributed generation to reduce electricity bill.

- **Despite this potential, the SWT project is still in demonstration phase at the regional level .**

The causes are multiple:

- **High cost**
- **Not yet mature technology**
- **Complex market and local manufacturing absence**
- **Absence of regional wind map**
- **Absence of national Legal rules**

INTRODUCTION

Proposed actions to support the SWT Integration

Research focus 1

Local design and manufacturing process of small wind turbine

The solutions:

- **Optimal design in order to maximize SWT performance**
- **Local manufacturing of SWT in large quantities**
- **Good SWT choice, sitting and an adequate tower height.**

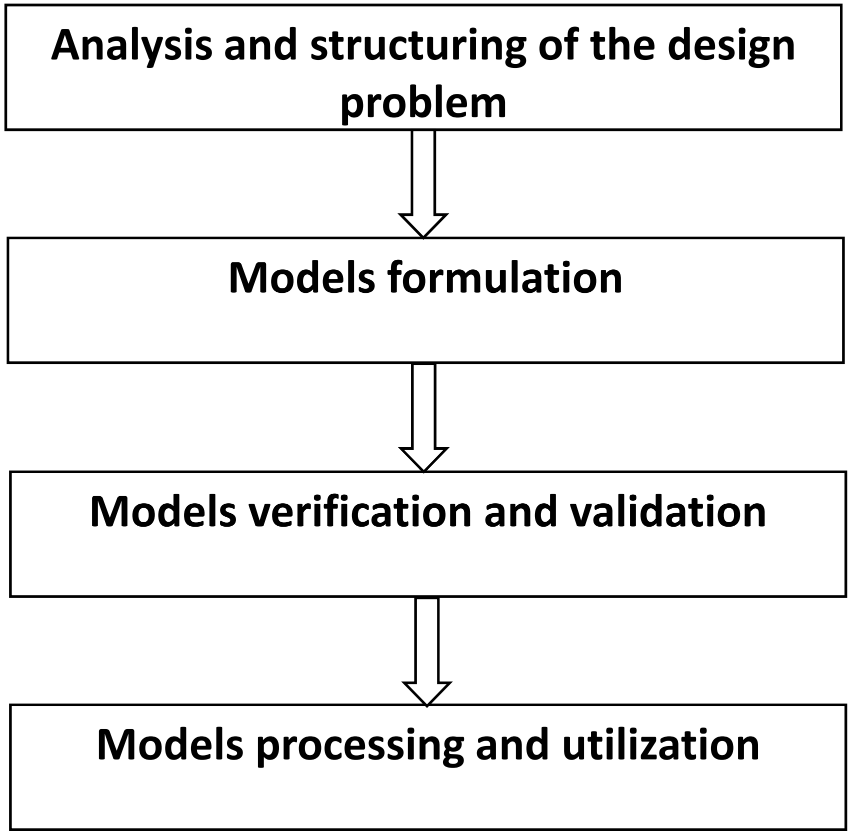
Research focus 2

Decision support to the end user in the development of their SWT projects

LIST OF CONTENTS

Design Approach

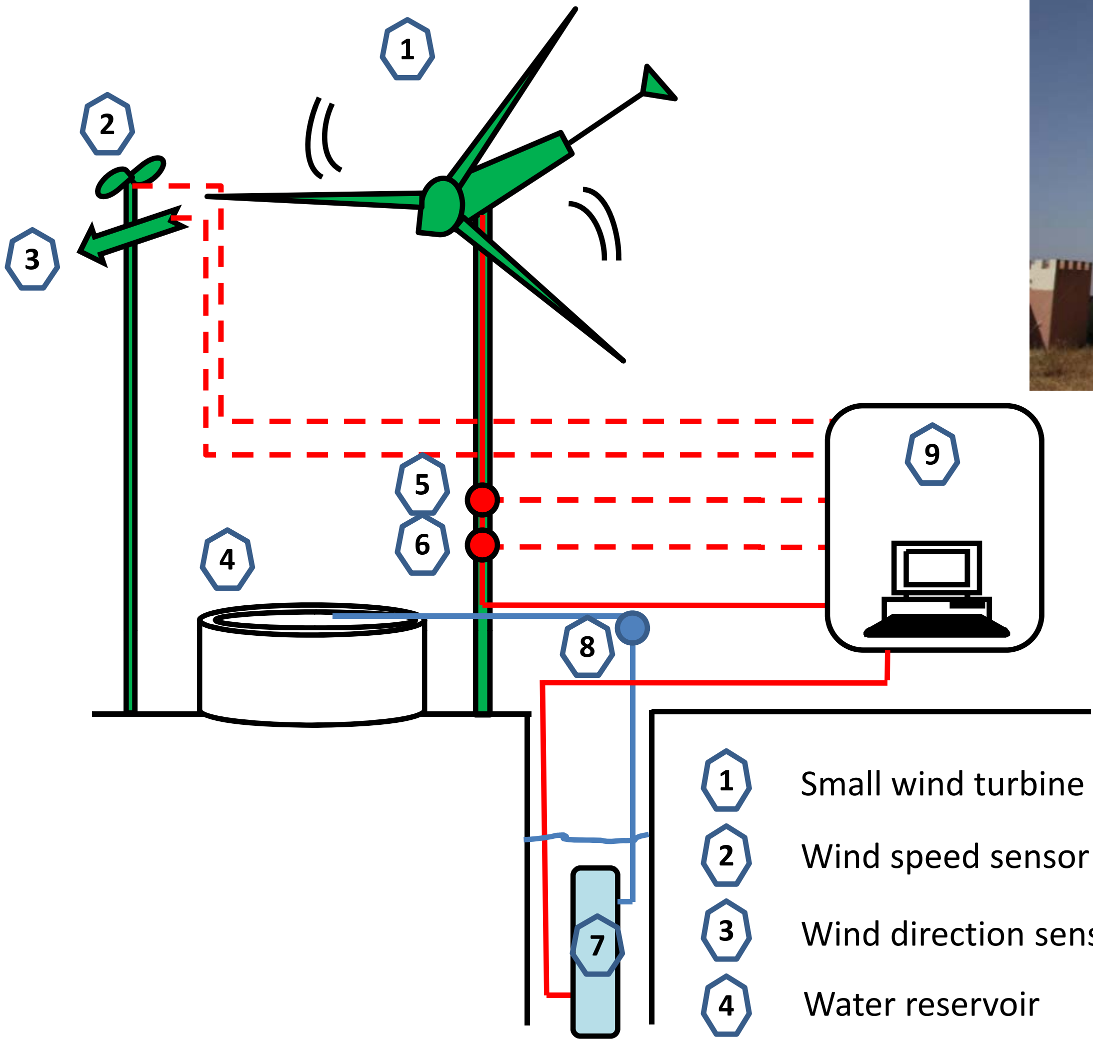
The development of the knowledge base system has been performed through four main steps:



In this presentation the used approach is illustrated through the rotor component

DESIGN APPROACH

The ENSAM test bench

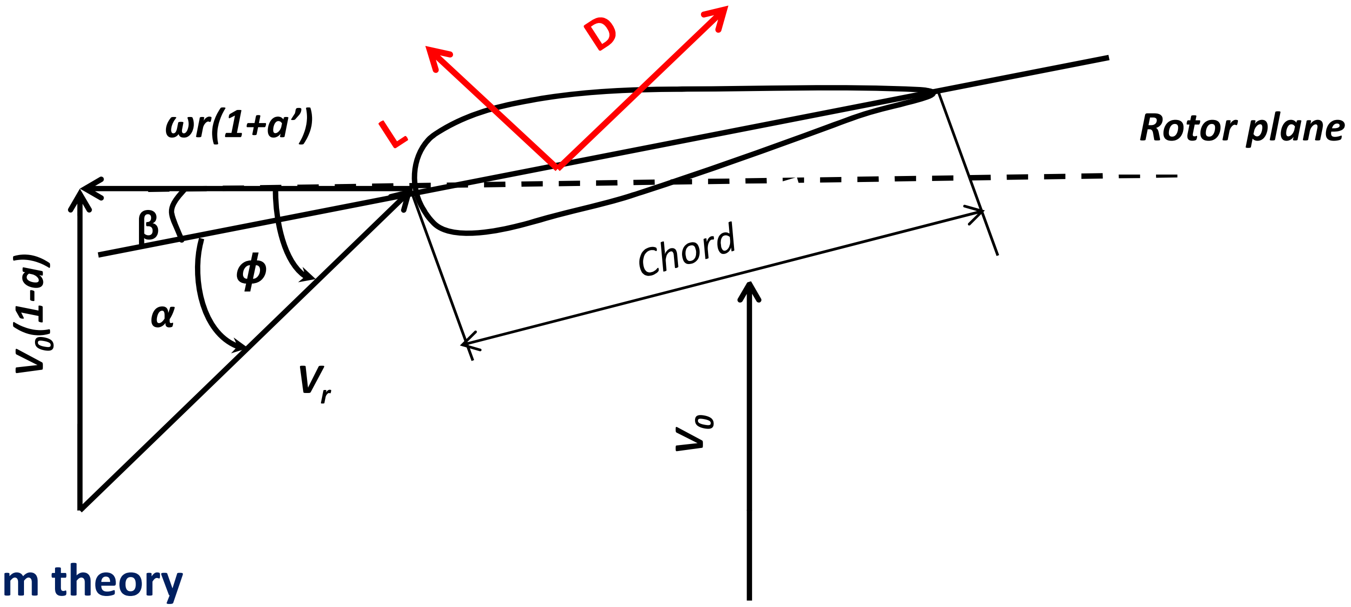


1 Small wind turbine
2 Wind speed sensor
3 Wind direction sensor
4 Water reservoir
5 Electrical power sensor
6 Electrical frequency sensor
7 Pump
8 Water flow sensor
9 Control and data acquisition system

ROTOR MODEL FORMULATION

Blade geometry for flow analysis

The performance of the rotor is predicted using the axial momentum theory combined with the blade element theory



Axial momentum theory

Based on a global description of the flow by using the conservation of the linear and angular momentum. It assumes the wind to be incompressible nonviscous flow

Blade element theory

uses the definition of the lift and drag to obtain the thrust and the torque; it employs the airfoil geometry and aerodynamic characteristic.

ROTOR MODEL FORMULATION

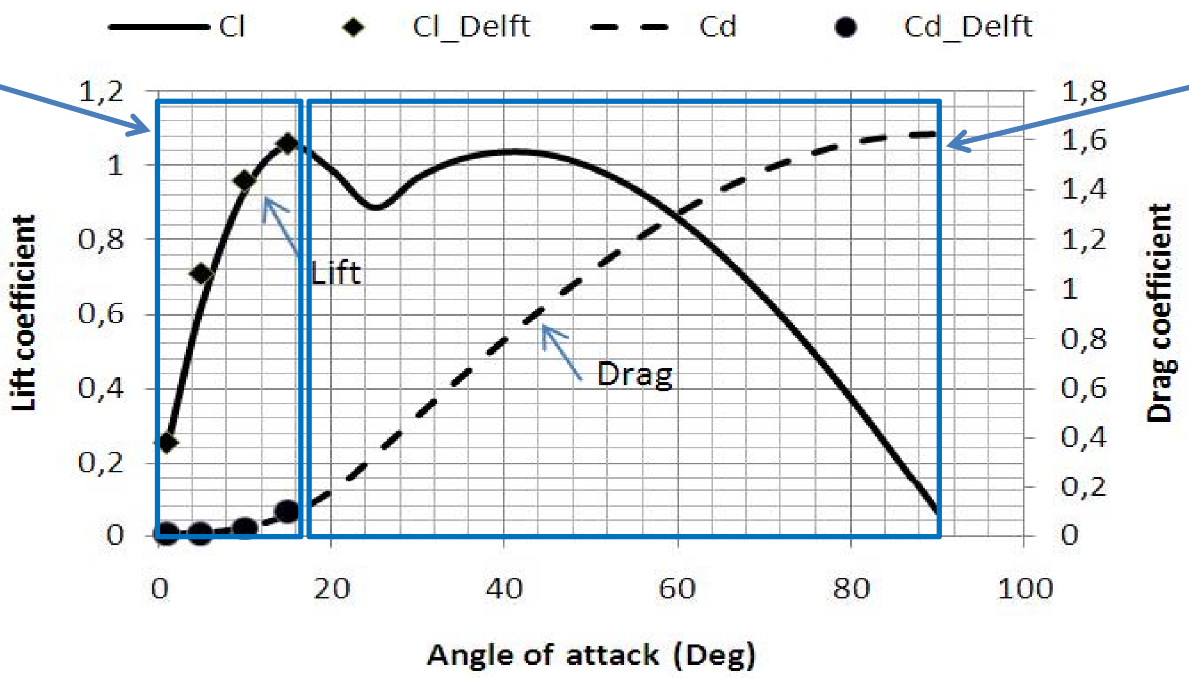
The lift and drag coefficients

Experimental data obtained using a wind tunnel or those obtained by CFD simulation

AERODAS (Analytical model)

Pre-stall data

Post-stall data



Simulated lift and drag coefficients for the S809 airfoil using AERODAS model compared with experimental data of Delft University

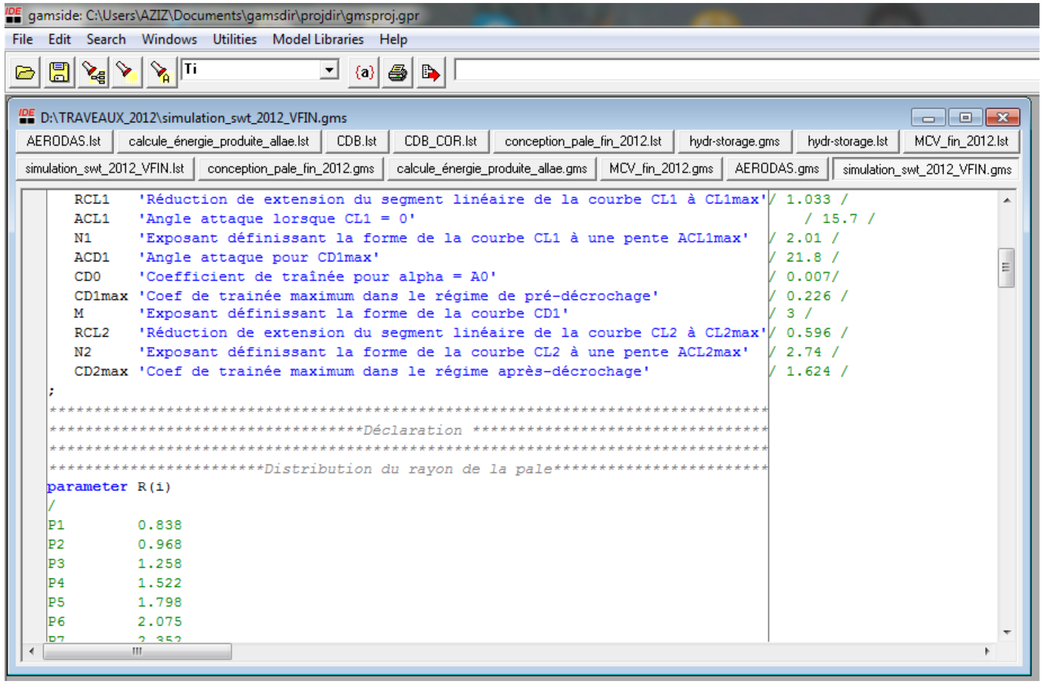
MODEL VERIFICATION AND VALIDATION

Problem solving

In order to verify and validate the formulated model, we refer to the experimental data of NREL (National Renewable Energy Laboratory) obtained using the NASA Ames wind tunnel.

These data relate to a wind turbine with a diameter of 10m. The blade is twisted with the chord variable along it and with an S809 airfoil

PATH SOLVER
For a simulation problem



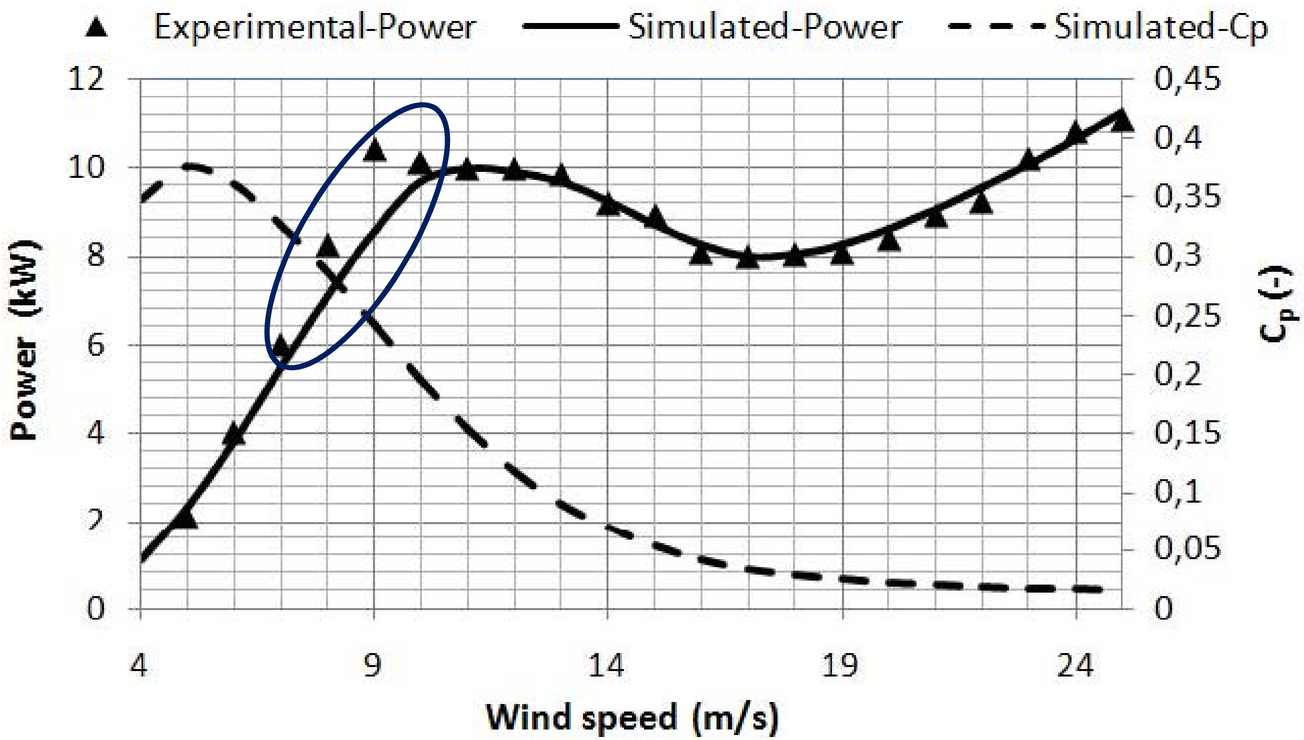
CONOPT SOLVER
For an Optimization problem

GAMS SOFTWARE
Generalized Algebraic Modeling System

MODEL VERIFICATION AND VALIDATION

The input variables of the global model are:

- o Blade tip and root radius
- o Number of blade
- o Chord along the blade
- o Pitch angle along the blade
- o Airfoil aerodynamic characteristics (AERODAS°)
- o Rotational speed



For a predicted power, in the worst case, the observed deficiency is about 17,5% for the range of wind speed between 8m/s and 10m/s

MODEL PROCESSING AND UTILIZATION

Model reuse

The model is used to design a blade for a small wind turbine which we attempt to manufacture locally

The goal is to find, the pitch angle distribution along the blade that maximizes the power coefficient

The optimum blade chord distribution is introduced by :

$$\frac{\lambda C_l N l}{2\pi r} = \frac{8/9}{\sqrt{(\lambda r/r)^2\left[1+\frac{2}{9(\lambda r/R)^2}\right]^2+\frac{4}{9}}}$$

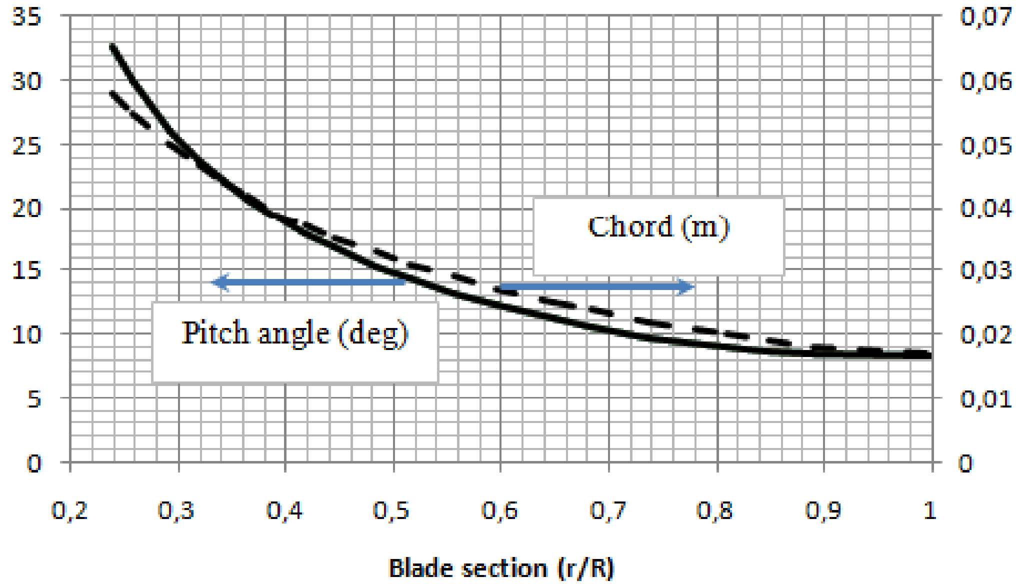
To perform optimization of the power coefficient, some input variables need to be chosen:

- The design wind speed =7m/s
- The rotor diameter = 0.45m
- The number of blade =3
- The tip speed ratio = 6
- The angle of attack = 3°
- The blade airfoil (NACA 4412)

MODEL PROCESSING AND UTILIZATION

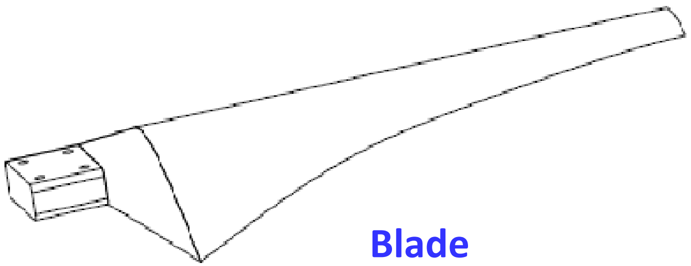
Model reuse

The power coefficient, which is the optimization criteria, reaches 0.39

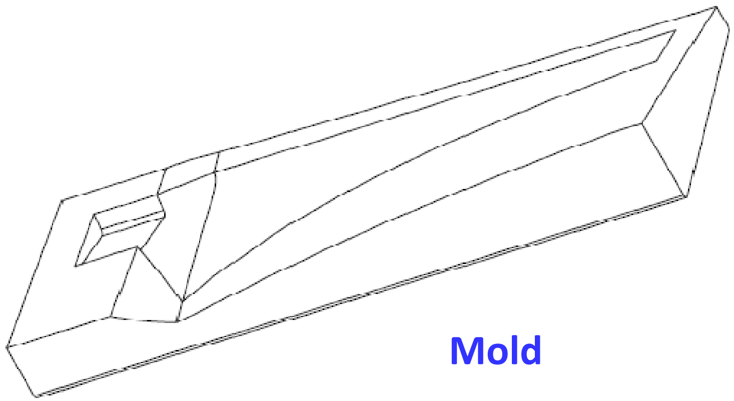


Optimal pitch angle and chord variation along the blade of a new designed rotor

CAD Model with CATIA Software



Blade



Mold

CONCLUSIONS AND PERSPECTIVES

A new approach to design a wind electric pumping system is presented and illustrated through the rotor component

In the used model, the power of the rotor is predicted using the axial momentum theory combined with the blade element theory

The global model is implemented and solved using the GAMS software

The obtained result shows that there is a good agreement between the simulated power curve and the experimental data.

Finally, the global model is used to design a blade for a small wind turbine which we attempt to manufacture locally

Currently, we develop models of the other component (generator, pump, tower …)

The global model will be validated using the experimental data obtained with our test bench before being used to support decisions in the design process of such systems.

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