Ecole nationale des ponts et chaussées

Laboratoire d’Analyse des Matériaux et Identification

Jean-François Caron

ECOLE NATIONALE DES PONTS ET CHAUSSEES

ENPC composites expertise

The Four main themes are :

- **Civil Engineering** : construction, reinforcement and repair

- **Simulation** : design of composite structures

- **Testing facilities** : damage characterization (delamination, transverse cracking...)

- **Sports and leisure** : tennis rackets, skis and snowboards, archery bows manufacturing…

People activity

Dr Rui Pedro Carreira

Sports and leisure, simulation

Pr. Dr Jean-François Caron

Composite group manager, damage characterization, multilayered models

Dr Olivier Baverel

Design of innovative composite structures

Dr Gilles Foret

Construction reinforcement and repair

Sports and leisure applications

<u>Enseignement des composites par l'objet sportif.</u>

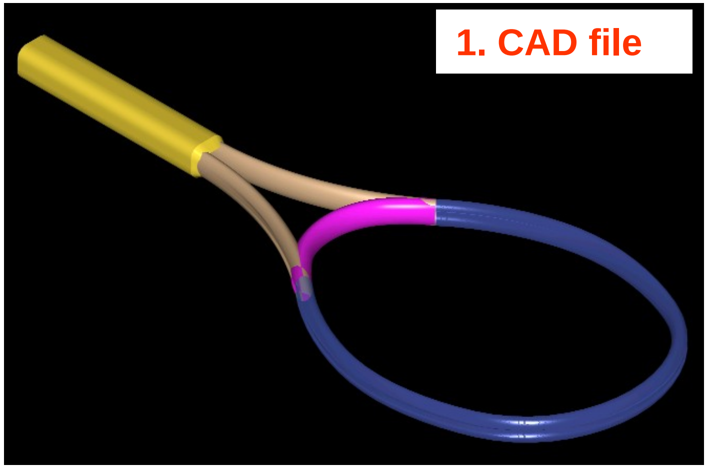
-ENPC, département Génie-Mécanique-Matériau

-Paris-Tech, (ENPC,ENSMP,ENSTA,ESPCI,…): Sem.Eurpéenne

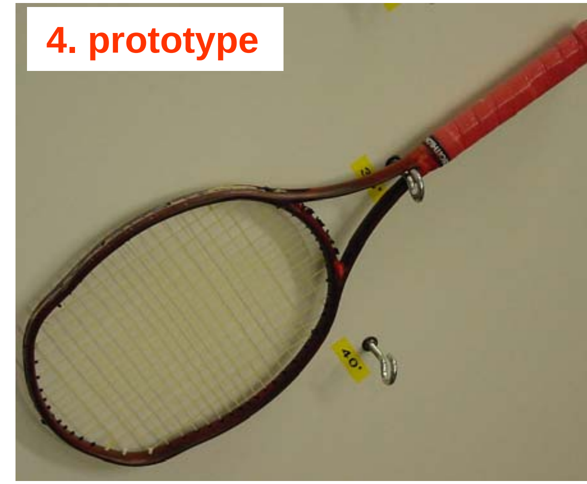
-Ecole Polytechnique, Modex

- ESTIA, Bidard, Master sport de glisse,

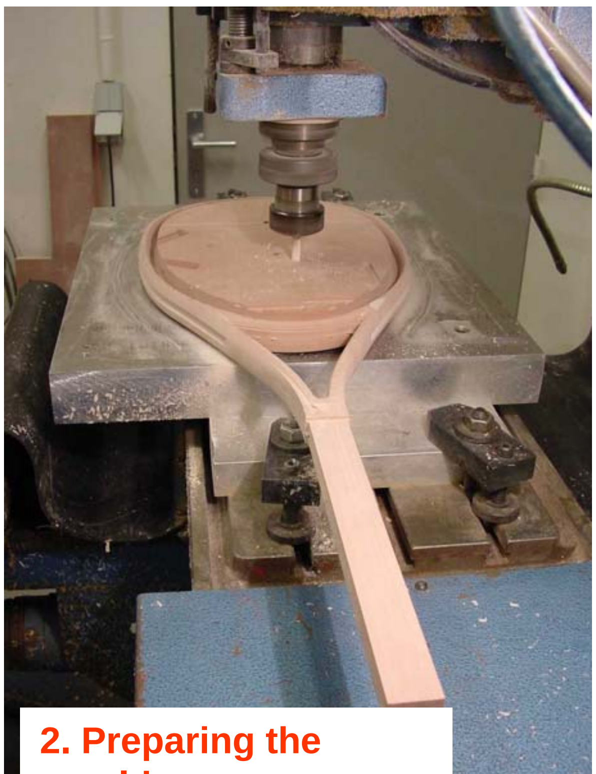
Tennis racket elaboration



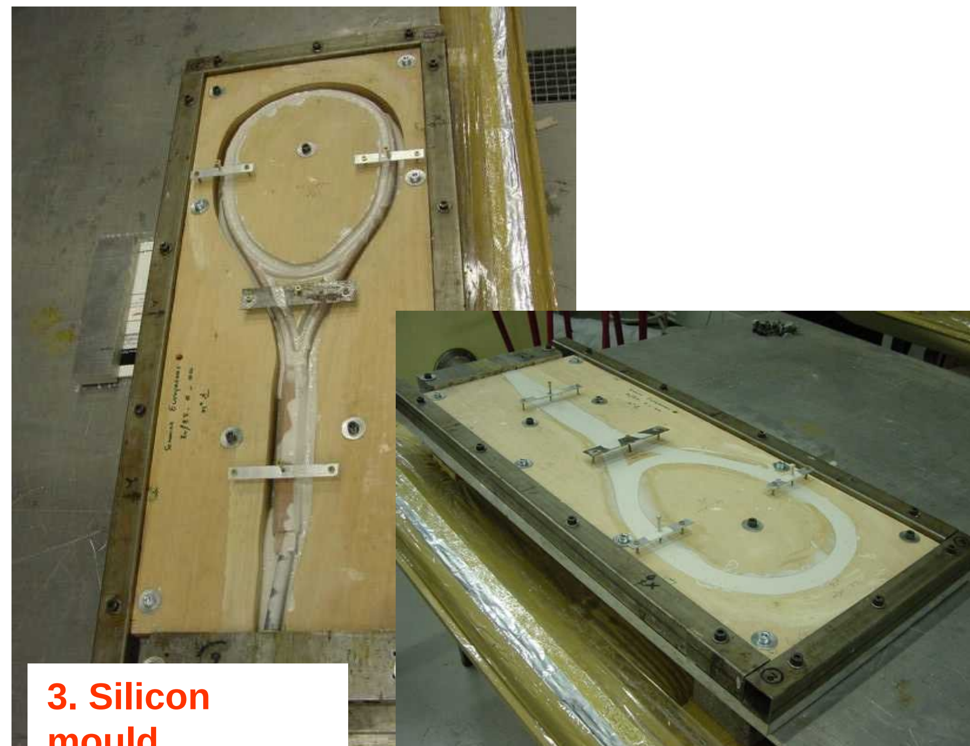
1. CAD file



4. prototype



2. Preparing the mould



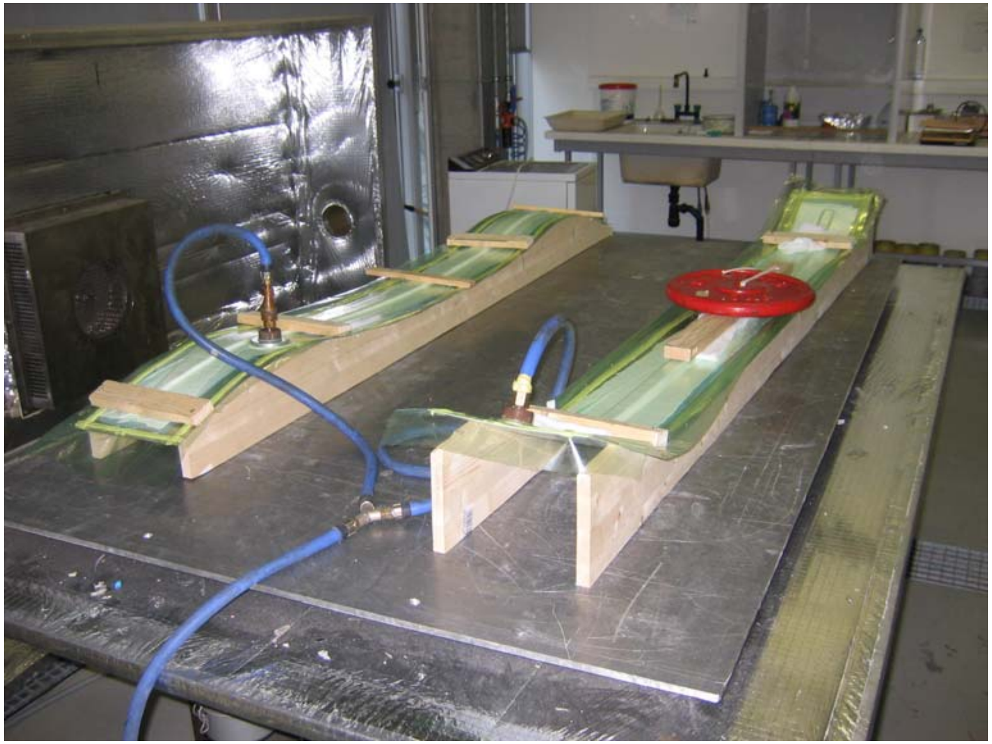
3. Silicon mould

Skis manufacturing

Long bow manufacturing

2. Force draw curve characterization

1. Bows lay-ups



EXPOSE INTRODUCTIF

MECANIQUE

- Fabrication de plaques
- élasticité anisotrope
- Modèle de plaques multicouches
- Critères de rupture
- tests de plaques

DESSIN

- AUTOCAD
- Dessin du Profil
- Dessins des Sections

FABRICATION DES MOULES

- Traitement des Fichiers AUTOCAD
- Usinage des Formes
- Finitions des Formes
- Moulage
- Séchage

FABRICATION DES RAQUETTES

- Découpage des Bandes
- Enroulement
- mise en place
- Polymérisation

DIMENSIONNEMENT DES RAQUETTES

- CRITERES
- CASTEM 2000, ANSYS
- Géométrie / Maillage
- Conditions Limites
- MacLam
- Inerties
- Echantillonnage
- Analyse des Résultats

TESTS

- Statiques
- Dynamiques

FINITIONS DES RAQUETTES

- Perçage
- Peinture
- Manche
- Cordage

Géométrie

Sorties Graphiques

Fiches Techniques

Moules

Raquettes

Résultats et Comparaisons

Static Characteristics

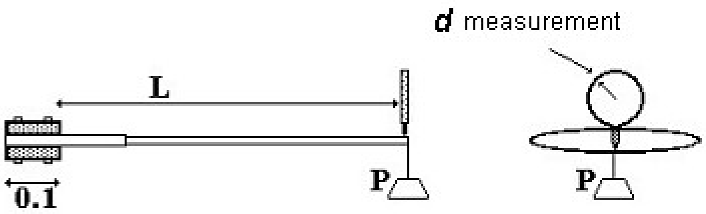
- Weight

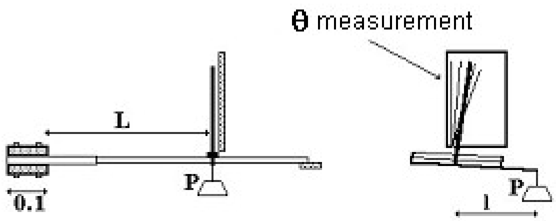
- Centre of gravity (balance)

- Swing weight (weight distribution)

$$I = T^2 \frac{P(X_G - 0{,}1)}{4\pi 2}(kg.m^2)$$

- Bending stiffness
- Torsional stiffness



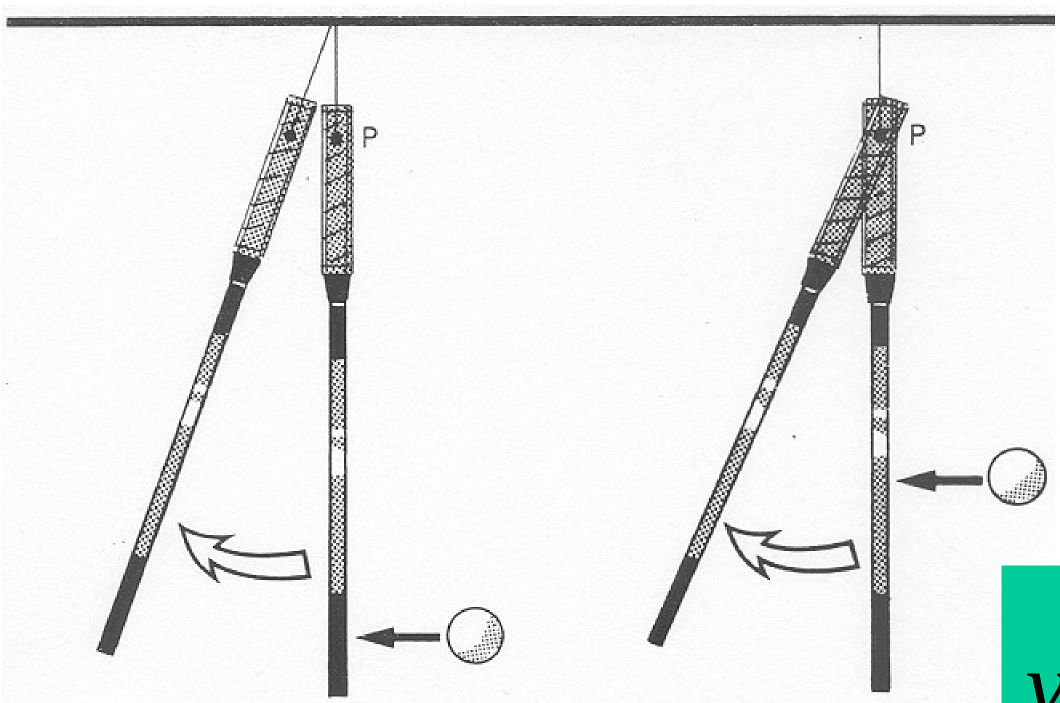


$$K_{bending} = \frac{PL^3}{3d}$$

$$K_{torsion} = \frac{P.l.L}{\Theta}$$

Dynamic Characteristics

1. centre of percussion

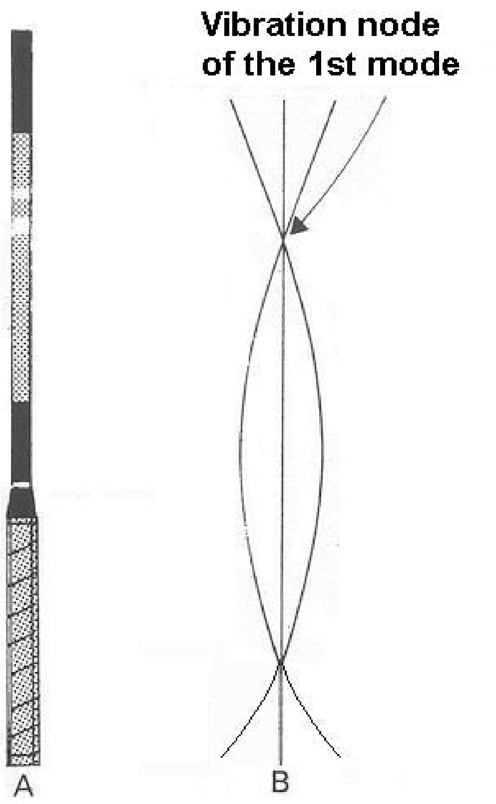


$$y_{C_P} = \frac{J_{xx/P}}{m\left(y_G - y_P\right)} + y_P$$

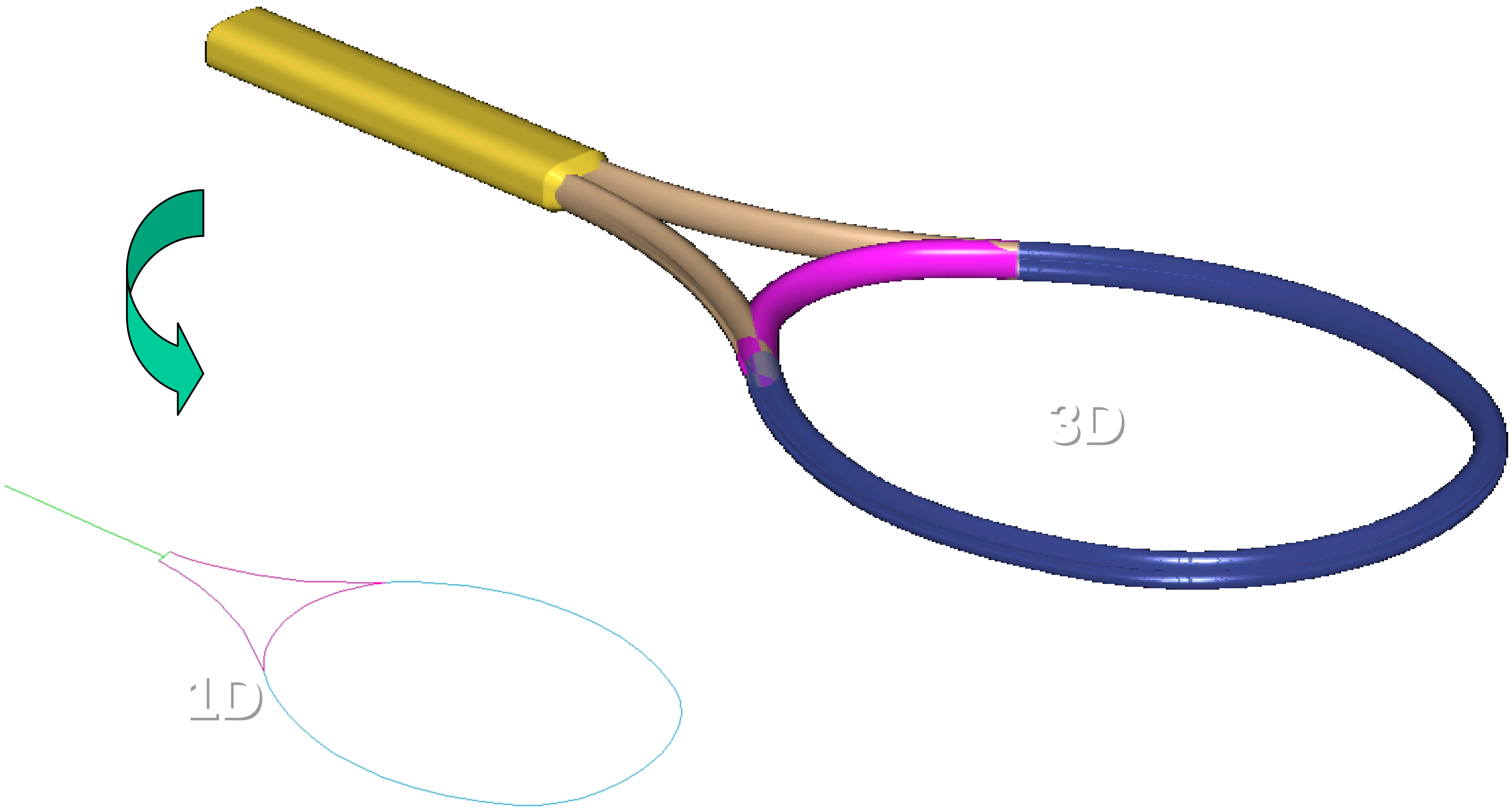
Vibratory analysis of the racquet as it is submitted at impact

2. What is the vibration node?

- 1^{st} mode running to 150 Hz
- When the ball hits the racquet on the vibration node, the corresponding mode is not excited
- If the shot is offset, the player may suffer some “tennis elbow”
- Importance to make coincide node of vibration and geometrical center



I. Creation or importation of a geometrical model



Description of a mechanical problem as a 1D FE model

I. Creation or importation of a geometrical model
   - CAD model

II. Choice and definition of the associated elements
   - beam, shell or volume

III. Definition of the material properties
   - moduli, density

IV. Meshing the model

V. Loadings and displacements are applied

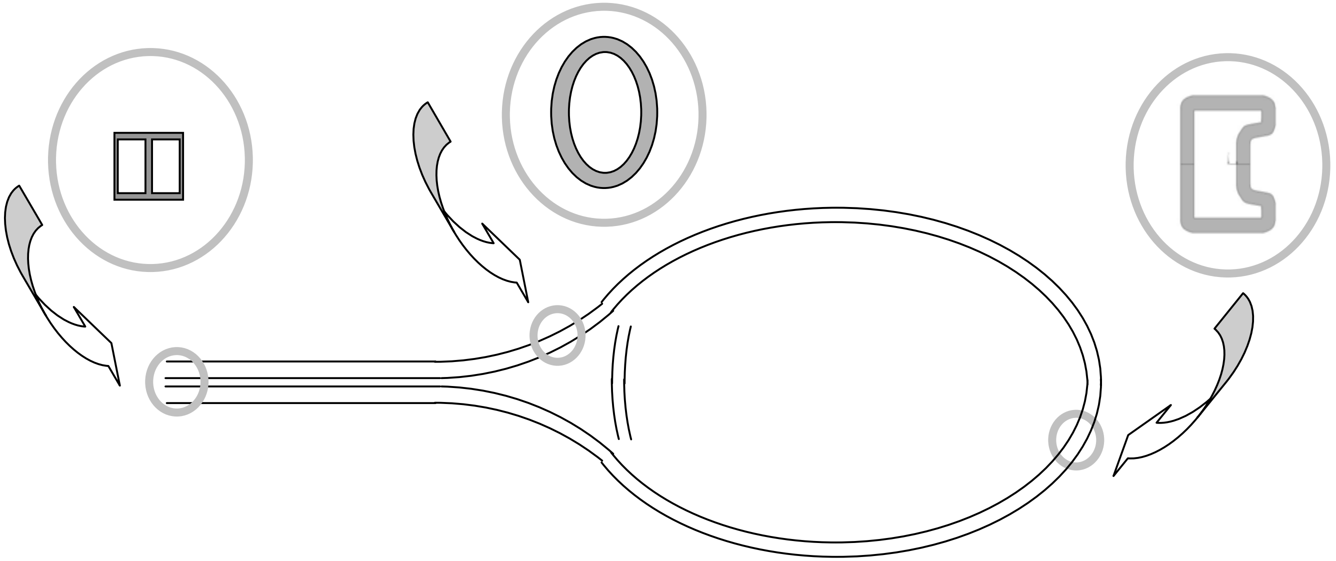
VI. Performing the calculation
   - static linear, modal

VII. Post processing the results
   - Deformed results, stresses

II. Choice and definition of the associated elements

III. Definition of the material properties

The FE model of the racquet is described by means of beams which characteristics (geometry and material properties) acting on stiffness are different according to whether it is the head, the throat or the handle.



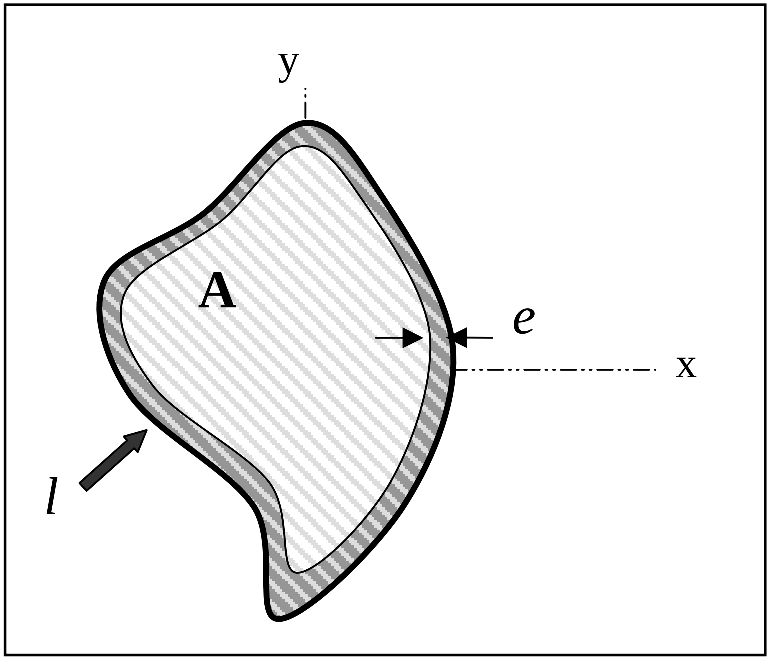
Calculation of moments of inertias for thin tube sections of unspecified form

It is thus necessary to calculate the moments of inertia for the various sections of the racquet (moments of inertia with respect each axis and the polar moment of inertia) depending on the outside geometry and the number of plies (thickness)

$$I_x = \int y^2 d\mu$$

$$I_y = \int x^2 d\mu$$

$$I_z = \frac{4A^2 e}{l}$$

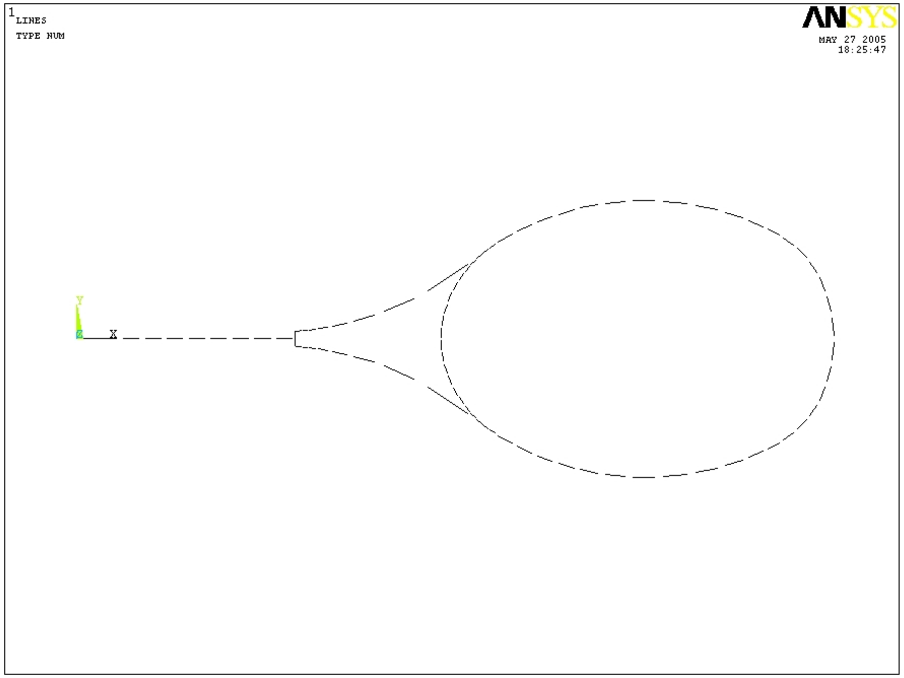


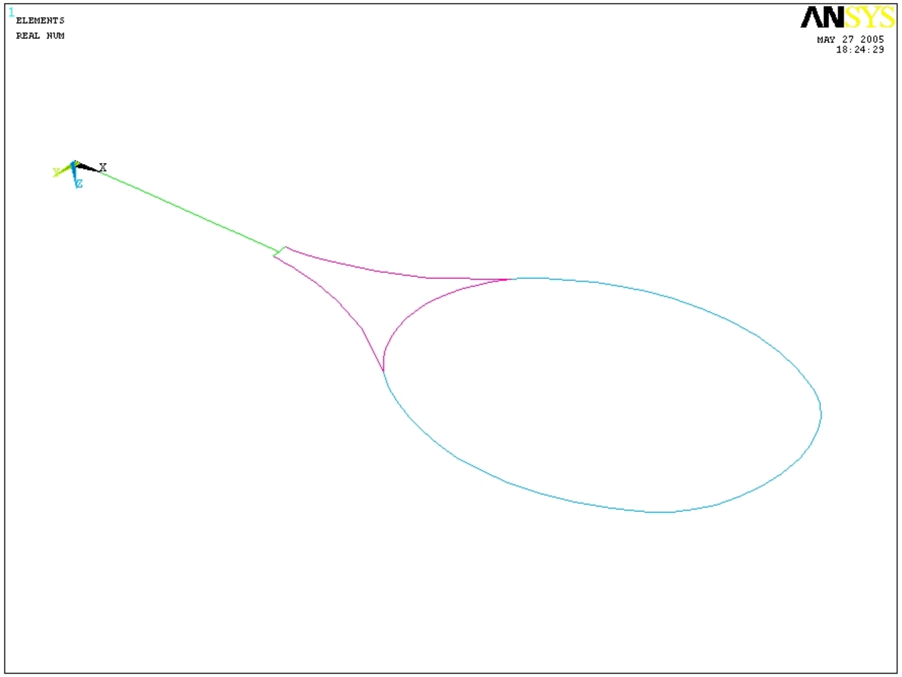
Calculation of the equivalent characteristics using Classical Lamination Theory

- Defining the composite ply (CFRP, GFRP):
  - Young's and shear moduli, Poisson's coefficient
  - ply thickness
  - density
- Creating the stacking sequence :
  - by combining different plies, their thicknesses and orientations
- Calculation of the equivalent properties (as needed to define the beam material property) :
  - E_{eq} (Young's modulus)
  - G_{eq} (shear modulus)

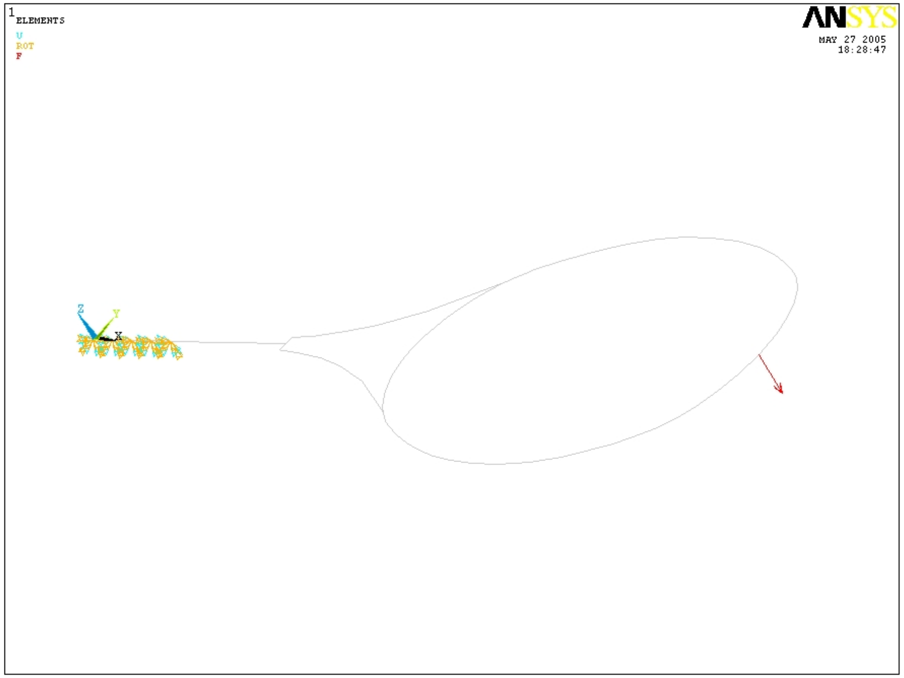
MAC LAM.lnk

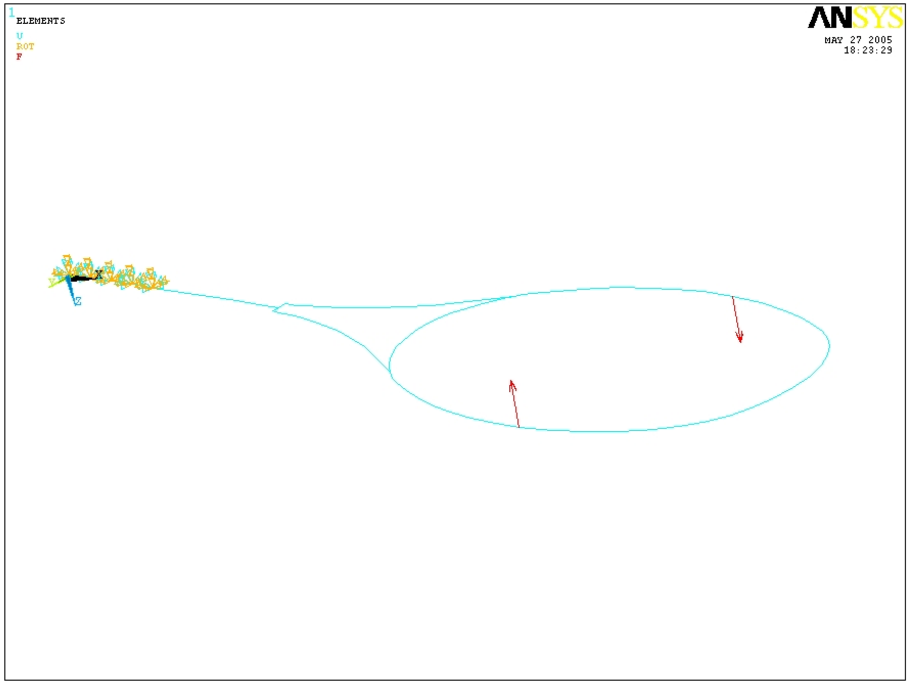
IV. Meshing the model





V. Loadings and displacements are applied



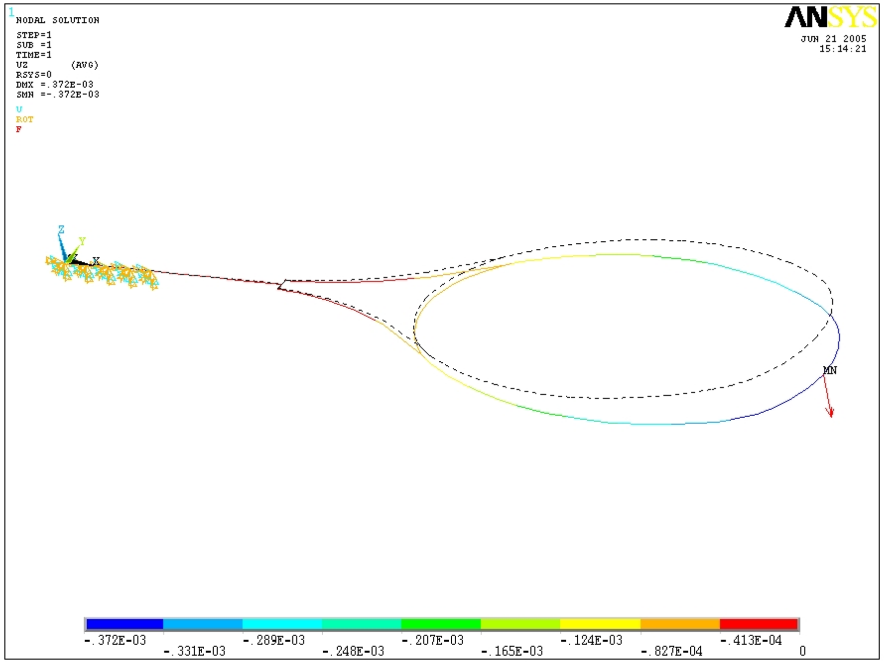


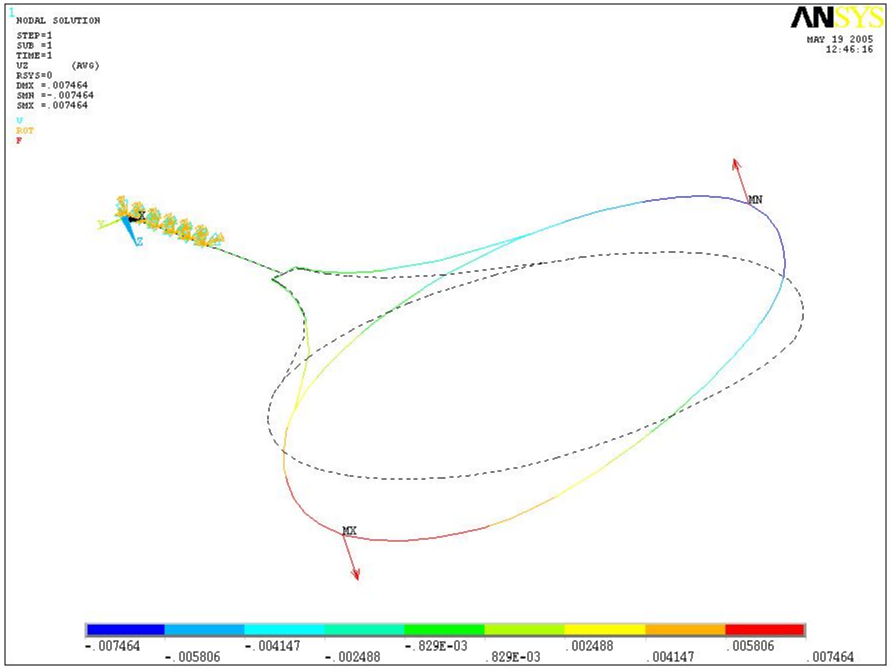
- Bending
- Torsion

VI. Performing the calculation

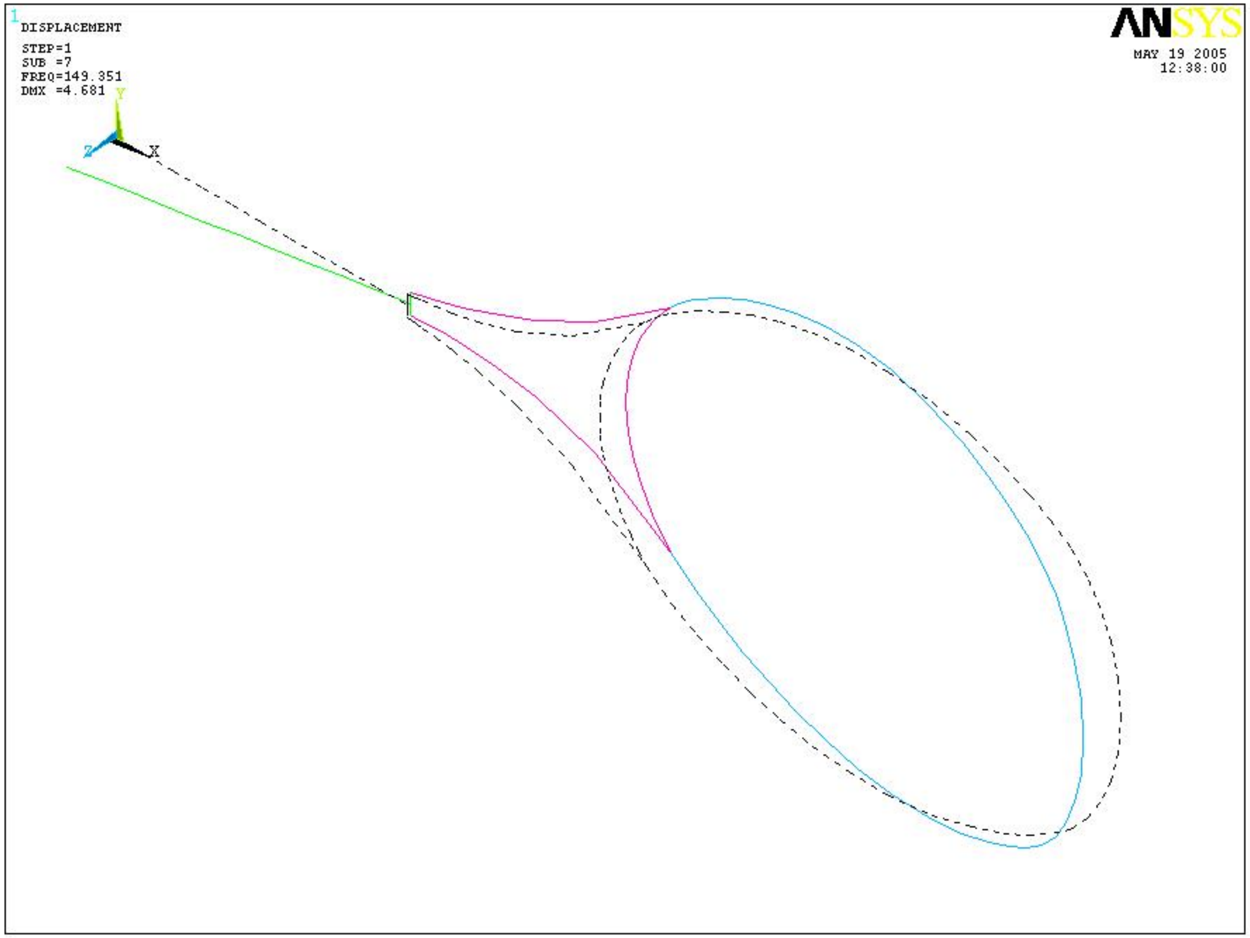
VII. Post processing the results

- ➢ displacement, angle, natural frequency



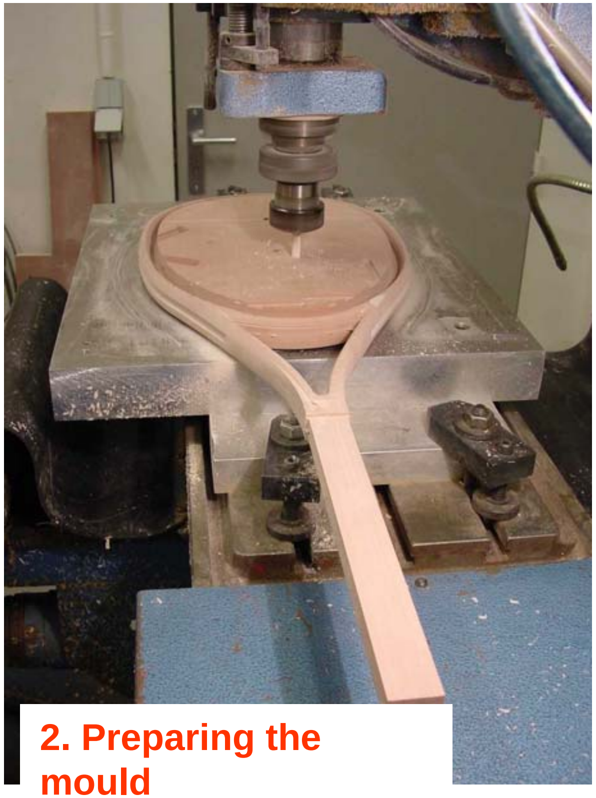


- Bending
- Torsion

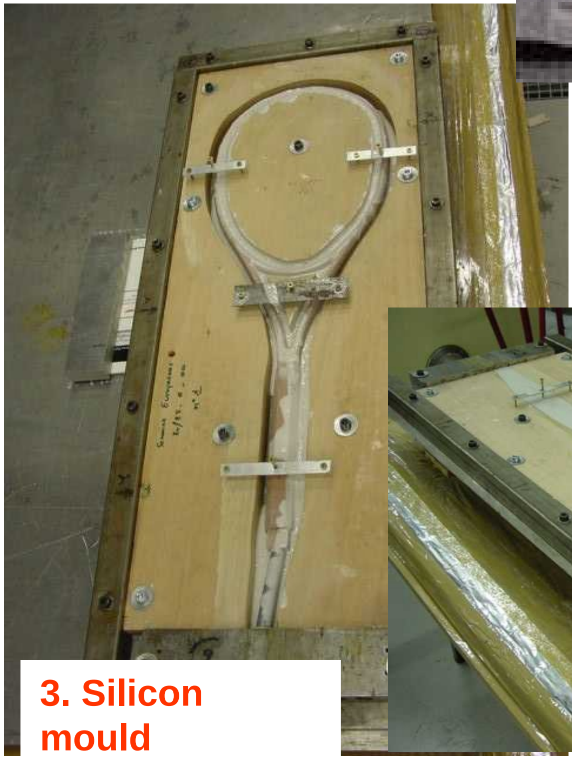


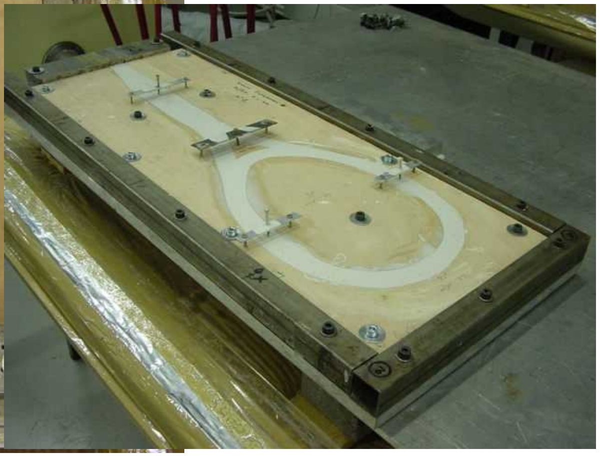
- Modal analysis

Tennis racket elaboration



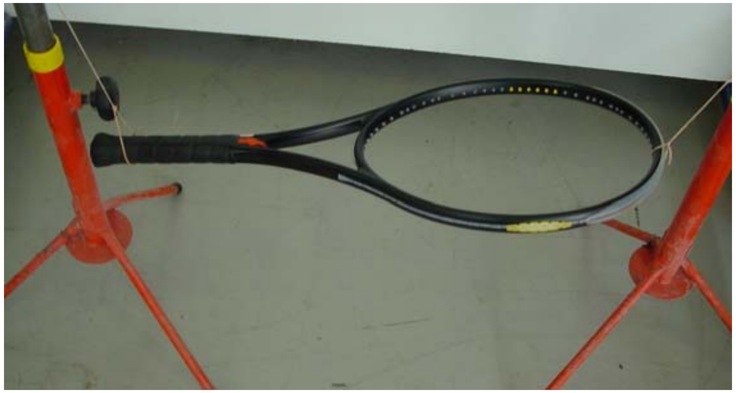
2. Preparing the mould

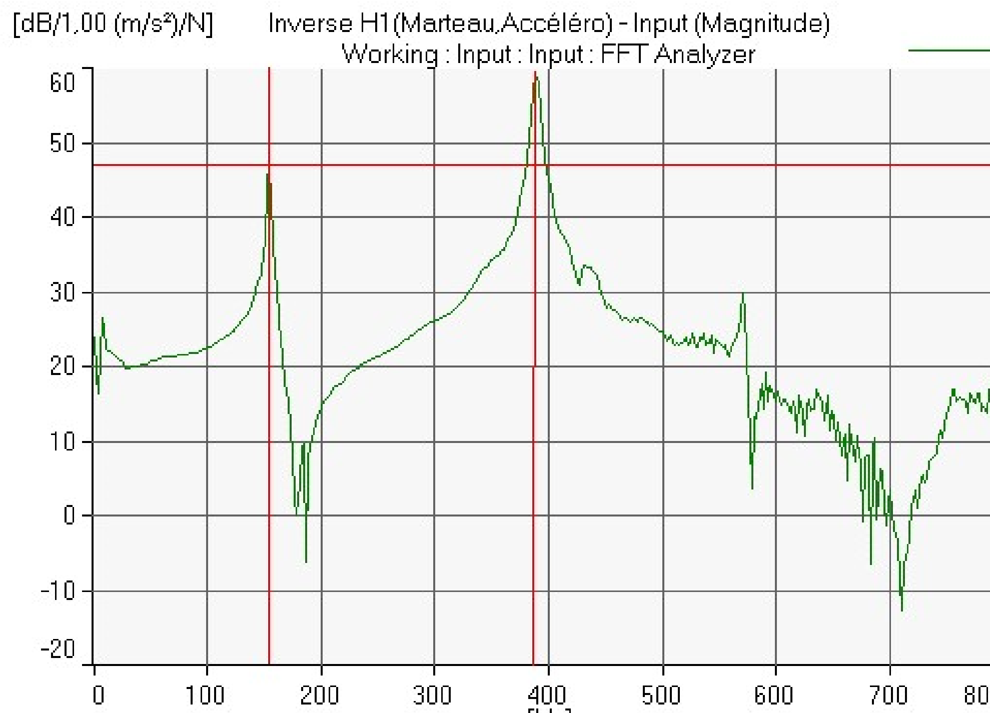




3. Silicon mould

Free boundary conditions measurements



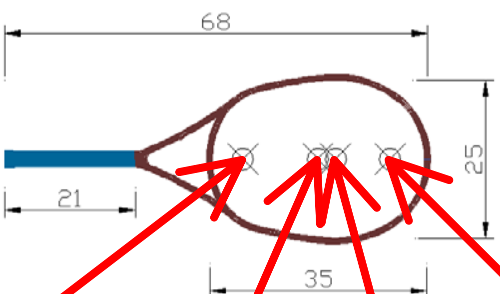


CONCEPTION D'UNE RAQUETTE DE TENNIS

CONCEPTION D'UNE RAQUETTE DE TENNIS

Molitorisz Peter
Vanderschelden Hugues
Dubié Loïc

Caractéristiques géométriques



Centre de masse

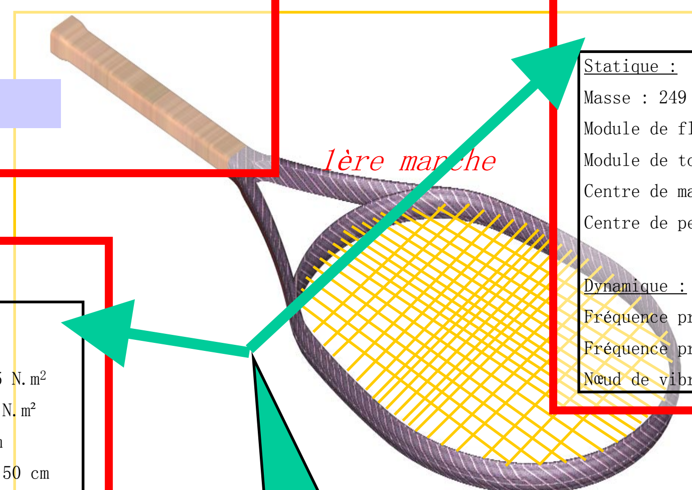
Centre de percussion

Centre du tamis

Nœud de vibration

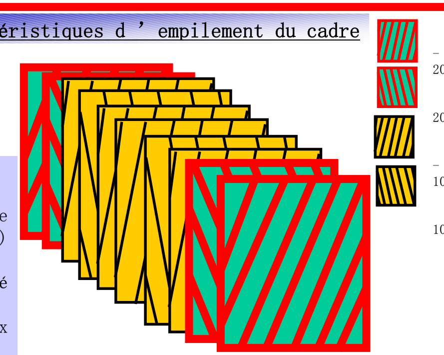
Profil de la section du cadre

1ère manche



Caractéristiques d ' empilement du cadre

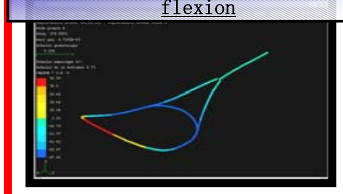
Le cadre est empilé sur 10 couches (comme sur le dessin) et le manche est lui empilé sur 8 couches (sans les deux du milieu)



3ème manche

Caractéristiques calculées avec Samcef

Visualisation de la déformée en flexion



Statique :

Masse : 202 gr

Module de flexion : 135 $N.m^2$

Module de torsion : 96 $N.m^2$

Centre de masse : 38 cm

Centre de percussion : 50 cm

Dynamique :

Fréquence propre 1 : 34 Hz

Fréquence propre 2 : 178 Hz

Nœud de vibration : 62 cm

2ème manche

Tests

Statique :

Masse : 249 gr

Module de flexion : 146 $N.m^2$

Module de torsion : 83 $N.m^2$

Centre de masse : 38 cm

Centre de percussion : 50 cm

Dynamique :

Fréquence propre 1 : 36 Hz

Fréquence propre 2 : 178 Hz

Nœud de vibration : 61 cm

Visualisation des modes propres

4ème man

La corrélation entre l ' expérimentation et la théorie est très correcte aussi bien pour les résultats statiques que dynamiques.

La raquette finale

- Grand tamis (686 cm^2) donc une bonne puissance.
- Equilibre de tête donc une bonne puissance et une bonne précision
- Le poids est correct et permet une bonne maniabilité

5ème manche

Pascal CHRISTOL
Hala CHAAR

Conception d'une raquette de tennis

I – Dessin de la structure sous AutoCAD

Caractéristiques géométriques :
L'origine est prise au bout du manche

Longueur :	69,8 cm
Largeur :	26,4 cm
Surface tamis :	667 cm²
Masse de carbone :	211 g
Centre de gravité :	36,5 cm
Centre géométrique :	51,7 cm
Centre de percussion :	50,8 cm
Point pivot :	10 cm

II – Dimensionnement avec Castem

- **Maillage**

- **Caractéristiques statiques**
  Module de flexion : 234 GPa
  Module de torsion : 122 GPa

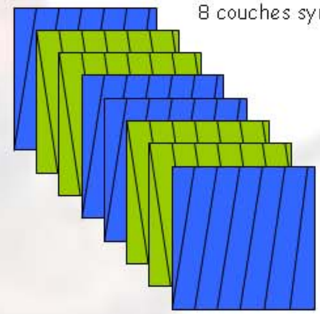
- **Caractéristiques dynamiques**
  Modes propres de flexion :
  - 1^er mode : 45 Hz < 50 Hz
  - 2^ème mode : 228 Hz > 200 Hz

  Nœud du 2^ème mode : 59,1 cm

C'est une raquette très rigide en flexion et très souple en torsion pour joueur puissant et de bon niveau

III – Fabrication de la raquette

- Toute la raquette est réalisée avec un empilement de 8 couches symétrique équilibré : [15°, -15°, -15°, 15°]



Caractéristiques de l'empilement :

Épaisseur :	1,36 mm
Masse volumique :	1500 kg/m³
E_{xx} :	80 GPa
G_{xy} :	8 GPa

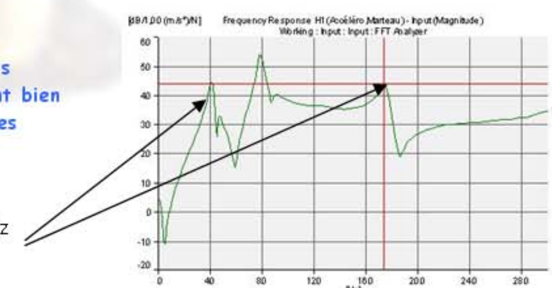
- Création de la chaussette (empilement, découpage)
- Cuisson
- Démoulage et finition

IV – Tests

	Mesures	Erreur
Masse	238 g	12,7%
Module de flexion	219.5 GPa	5.3%
Module de torsion	105 GPa	13%
Centre de percussion	51.3 cm	1%

Les données mesurées correspondent relativement bien aux données théoriques

Flexion : 41Hz et 175 Hz



Ski and snowboard design

ECOLE NATIONALE DES PONTS ET CHAUSSEES

- 1. Introduction
- 2. Laboratory tests
- 3. FE model of a snowboard

- 1. Introduction
- 2. Laboratory tests
- 3. FE model of a snowboard

« Skier » characteristics influent in ski or snowboard choice

- morphology (skier weight)
- skill level (beginner to expert)
- on-snow style (freeride / freestyle / freecarve)

…the speed increases from a "freestyle" approach towards a mode of "freeride" and especially one of "freecarve"…

The objective of the design : to achieve the adequacy between board / skier

Some ski and snowboard criteria

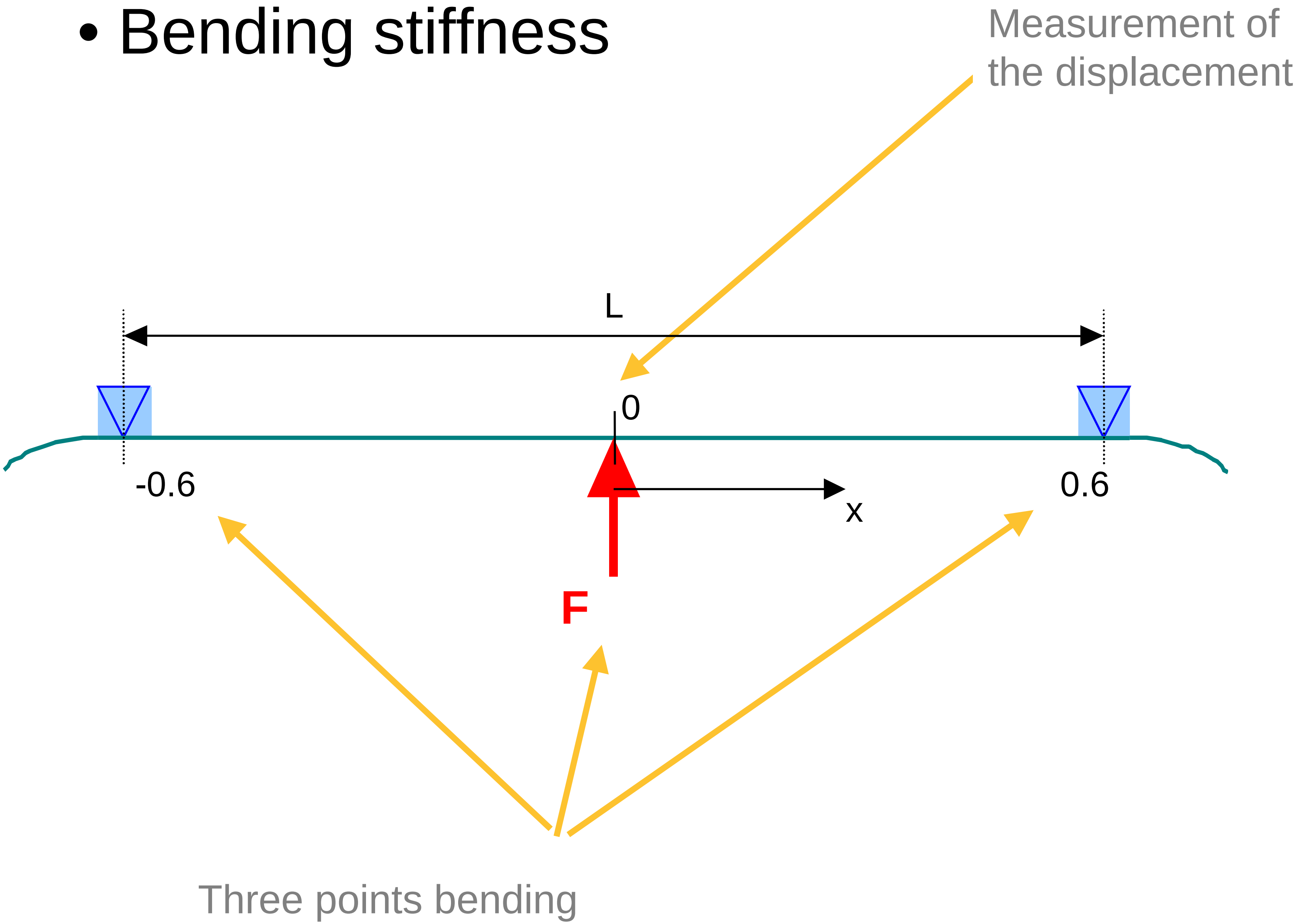
- Control
  - Accuracy of the trajectory
  - Forgiveness
- Manoeuvrability
  - Facility to change the direction, particularly sensible for freestyle
- Comfort
  - Absence of vibrations

Design steps

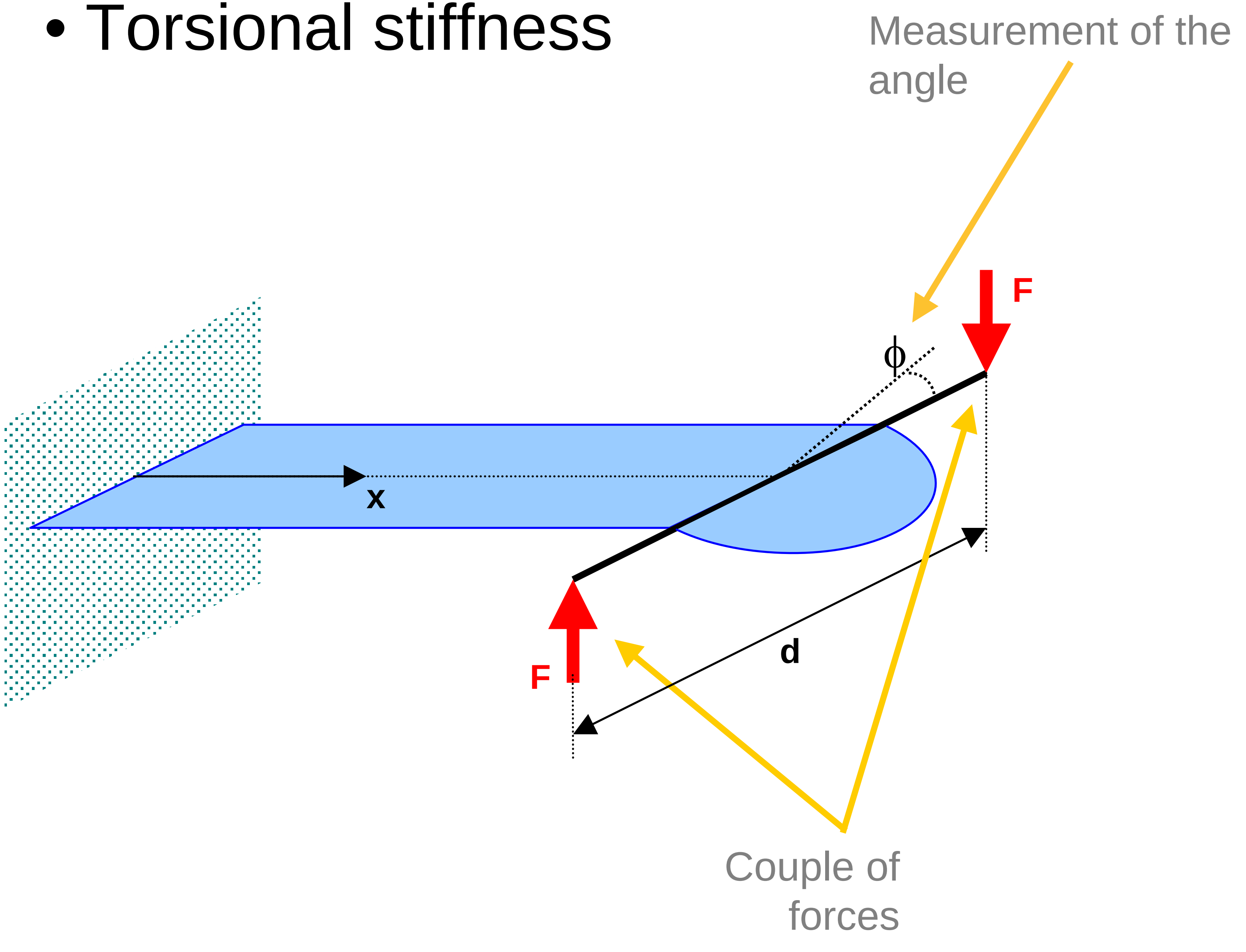
- Determine what criteria for a given use (according to style, technical and physical levels…)
- Taking process constraints into account
- By means of FEA using shell model:
  - height distribution
  - material choice
  - number of the plies
  - ply orientation

- 1. Introduction
- 2. Laboratory tests
- 3. FE model of a snowboard

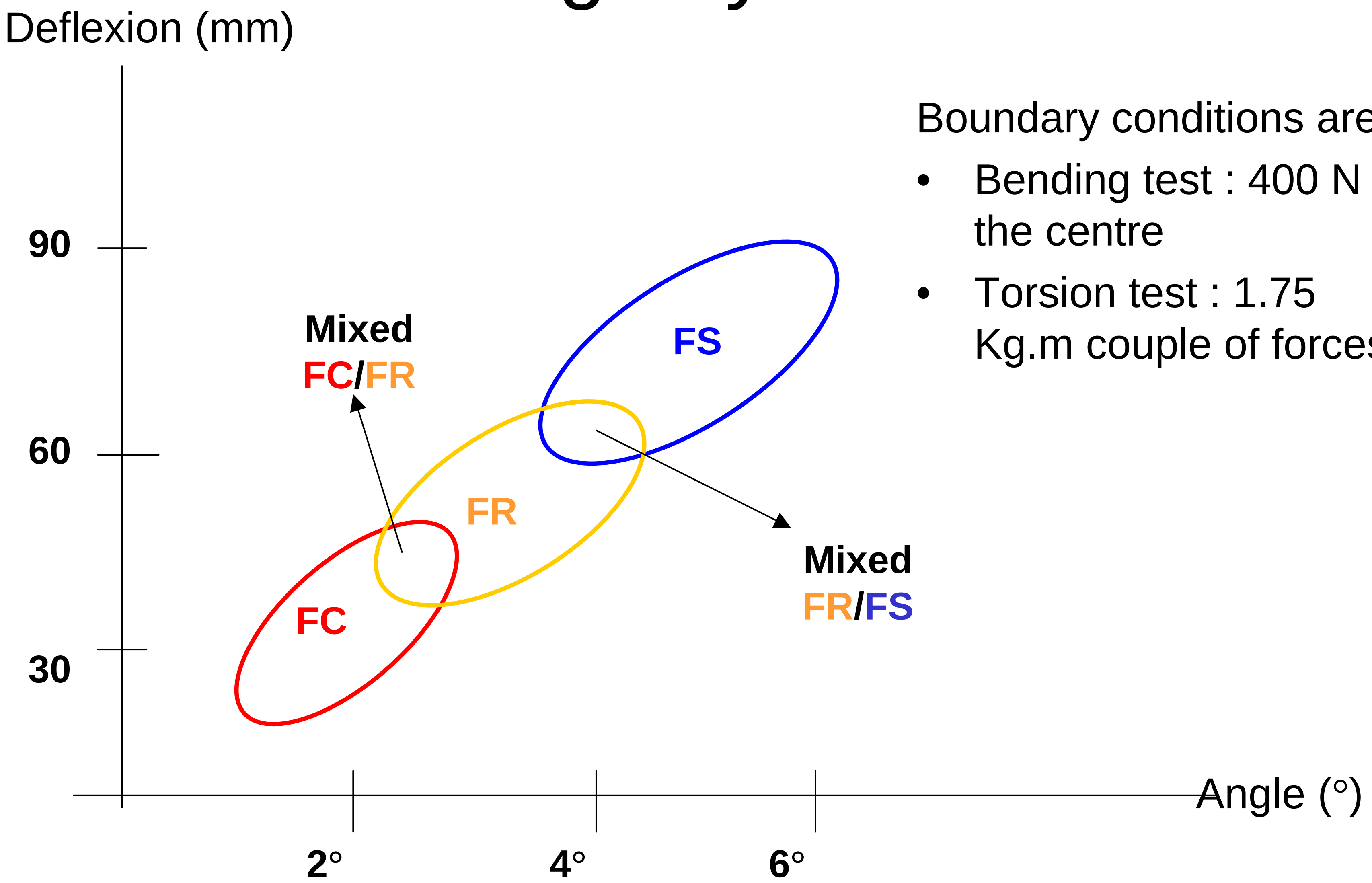
- Bending stiffness



- Torsional stiffness



What characteristics will you choose according to your need?



Boundary conditions are :

- Bending test : 400 N at the centre
- Torsion test : 1.75 Kg.m couple of forces

- 1. Introduction
- 2. Laboratory tests
- 3. FE model of a snowboard

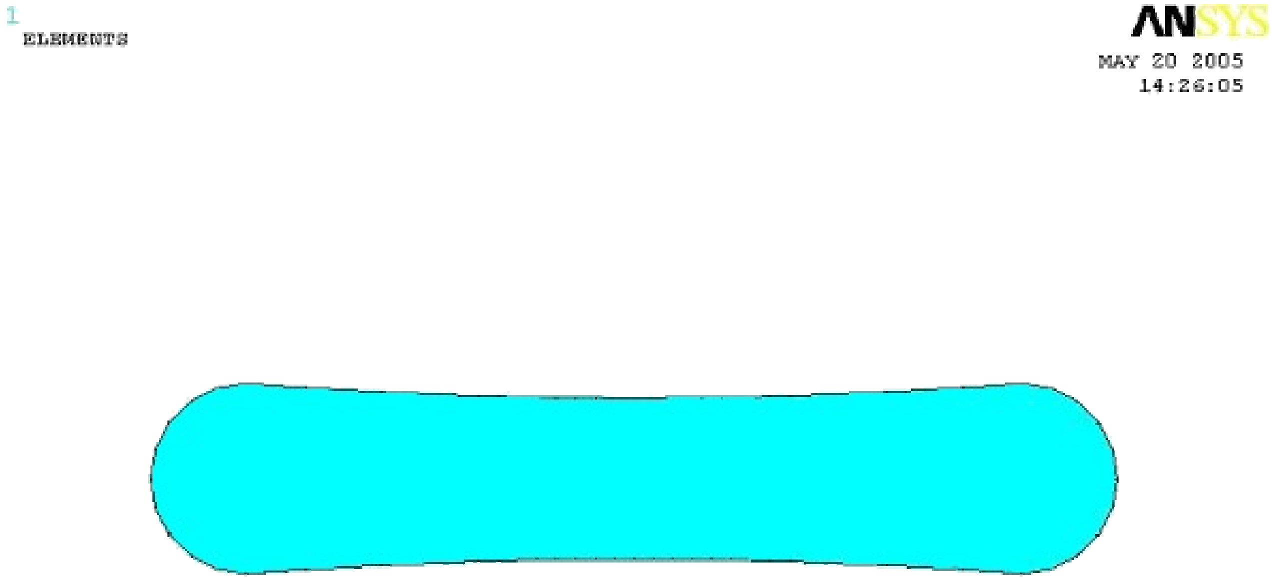
Description of a mechanical problem as a FE model

I. Creation or importation of a geometrical model
   CAD model
II. Choice and definition of the associated elements
   beam, shell or volume
III. Definition of the material properties
   moduli, density
IV. Meshing the model

V. Loadings and displacements are applied

VI. Performing the calculation
   static linear, modal
VII. Post processing the results
   Deformed results, stresses

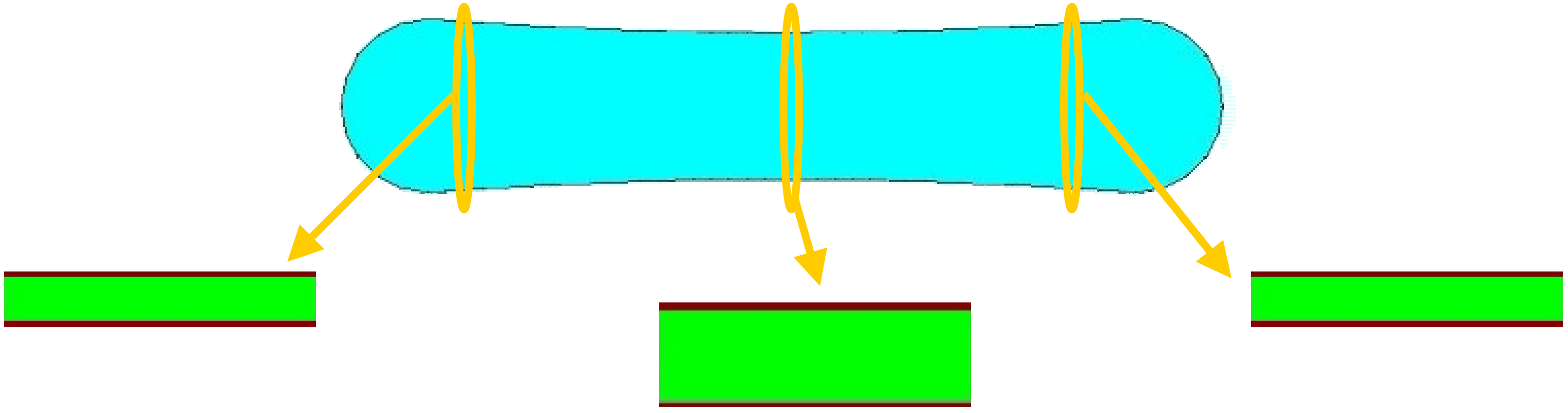
I. Creation or importation of a geometrical model



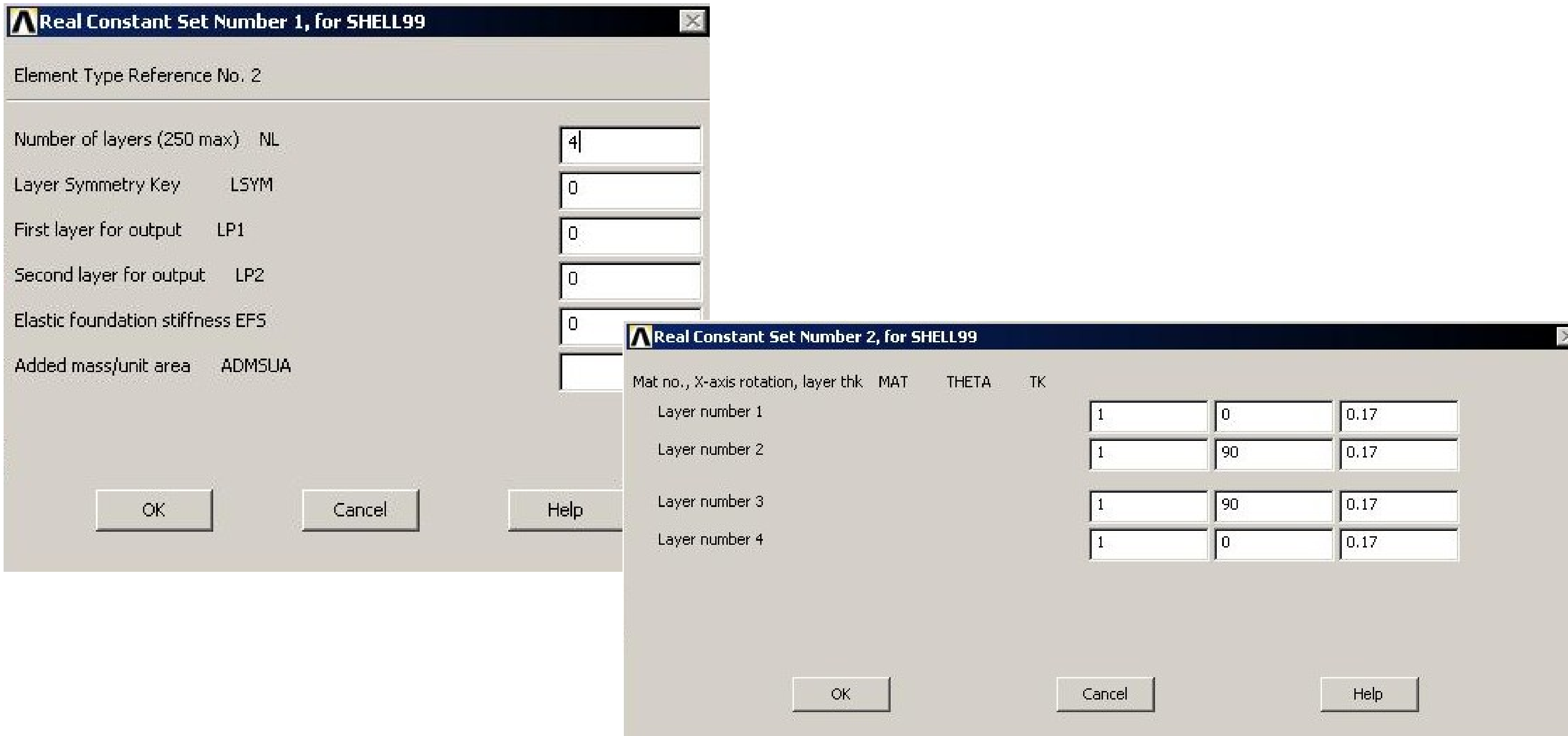
II. Choice and definition of the associated elements

III. Definition of the material properties

The FE model of the snowboard is described by means of shells which characteristics (number of plies, associated thicknesses, ply orientations and material properties) are different according to the location on the ski or snow length.



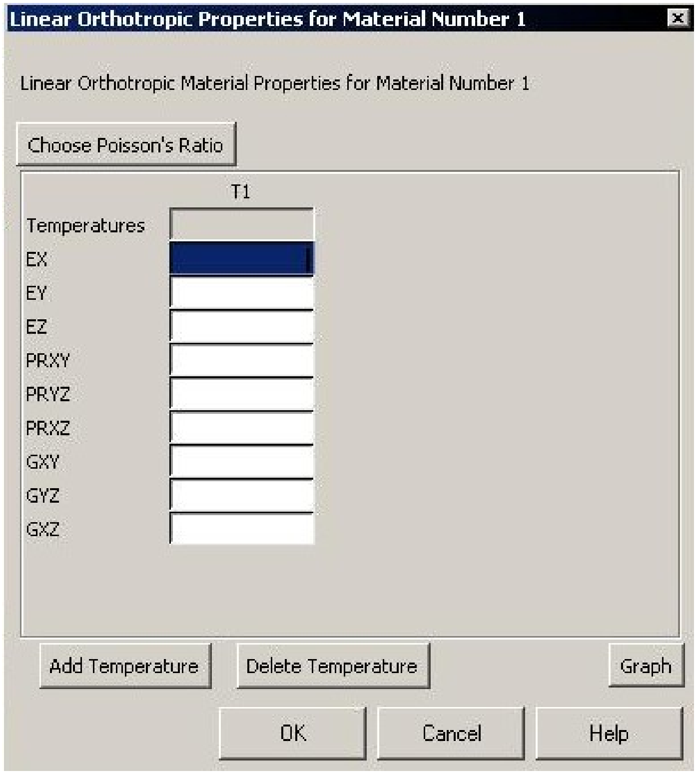
Definition of a composite shell and creation of the stacking sequence by combining different plies and their thicknesses and orientations in ANSYS



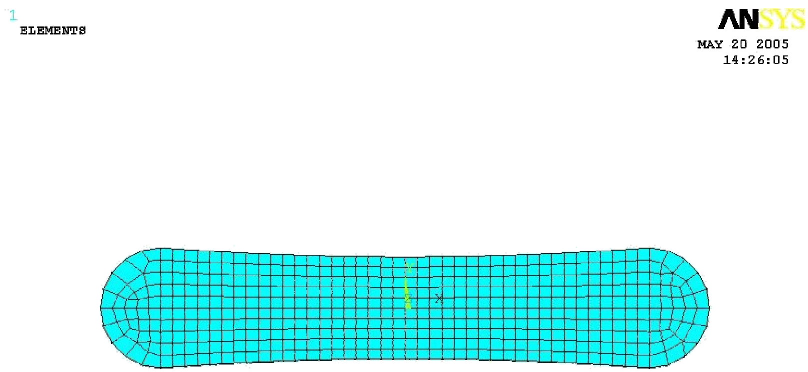
Definition of the material properties of an orthotropic material in ANSYS

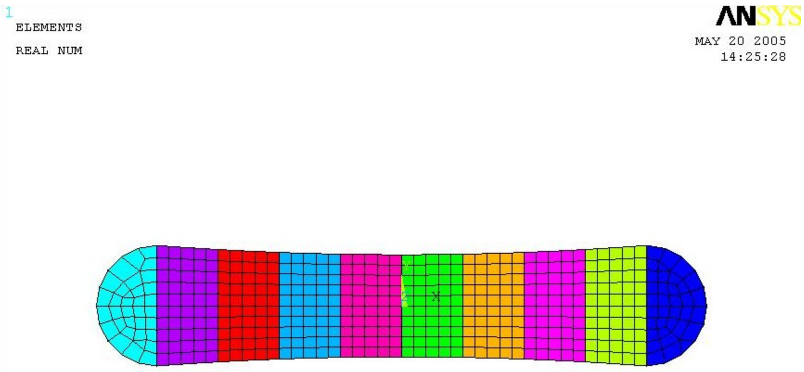
Defining the composite ply :

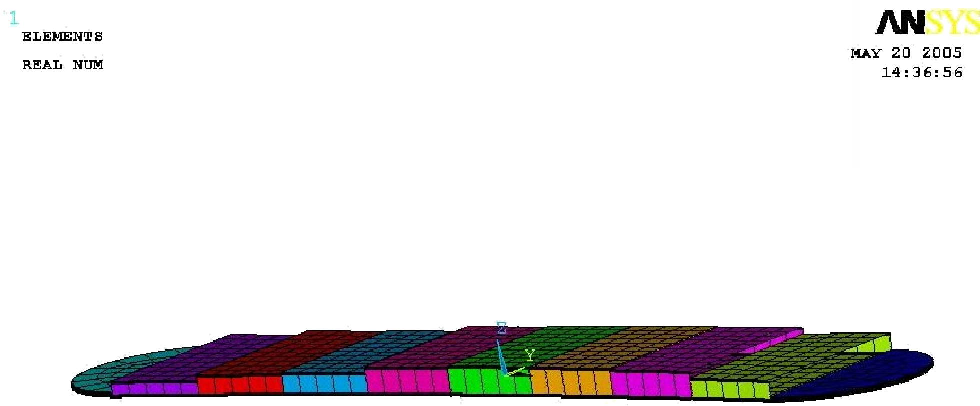
- Young’s and shear moduli, Poisson’s coefficient
- density



IV. Meshing the model







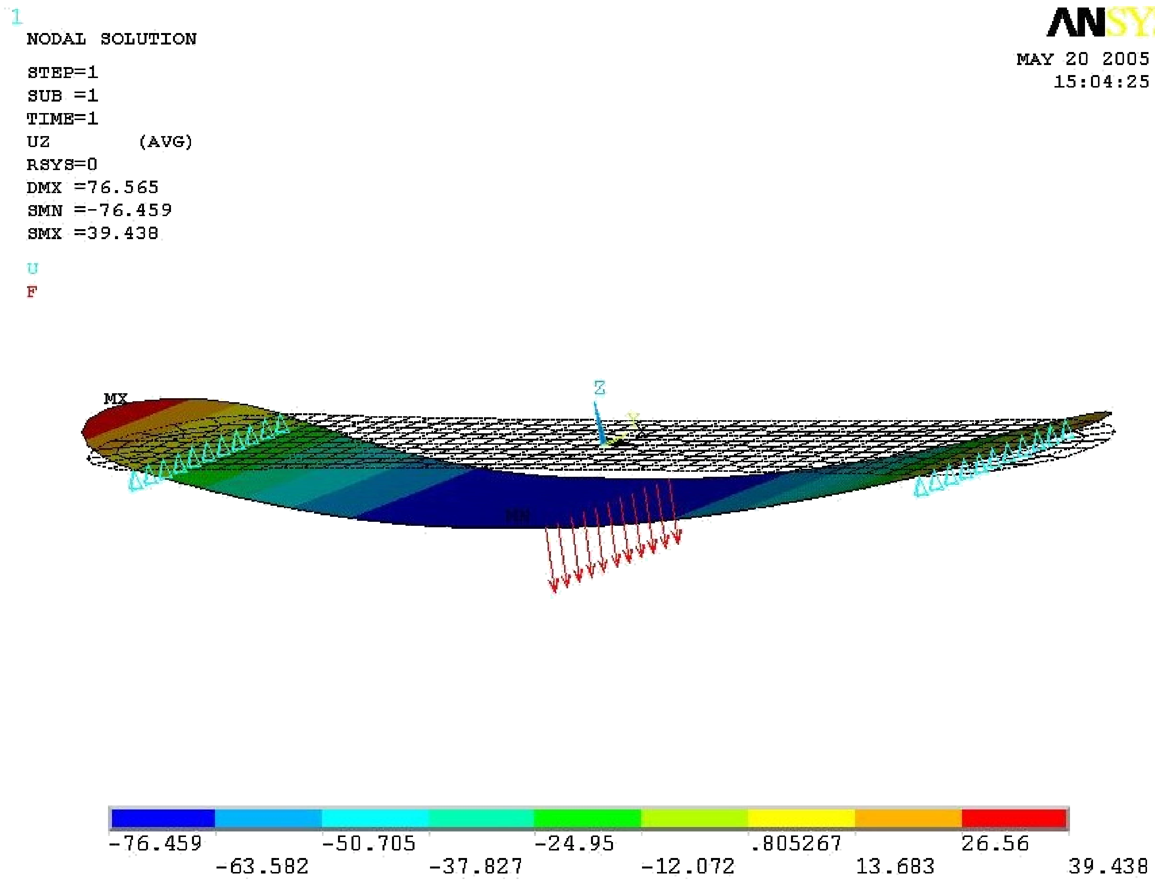
Different stacking sequences groups

V. Loadings and displacements are applied

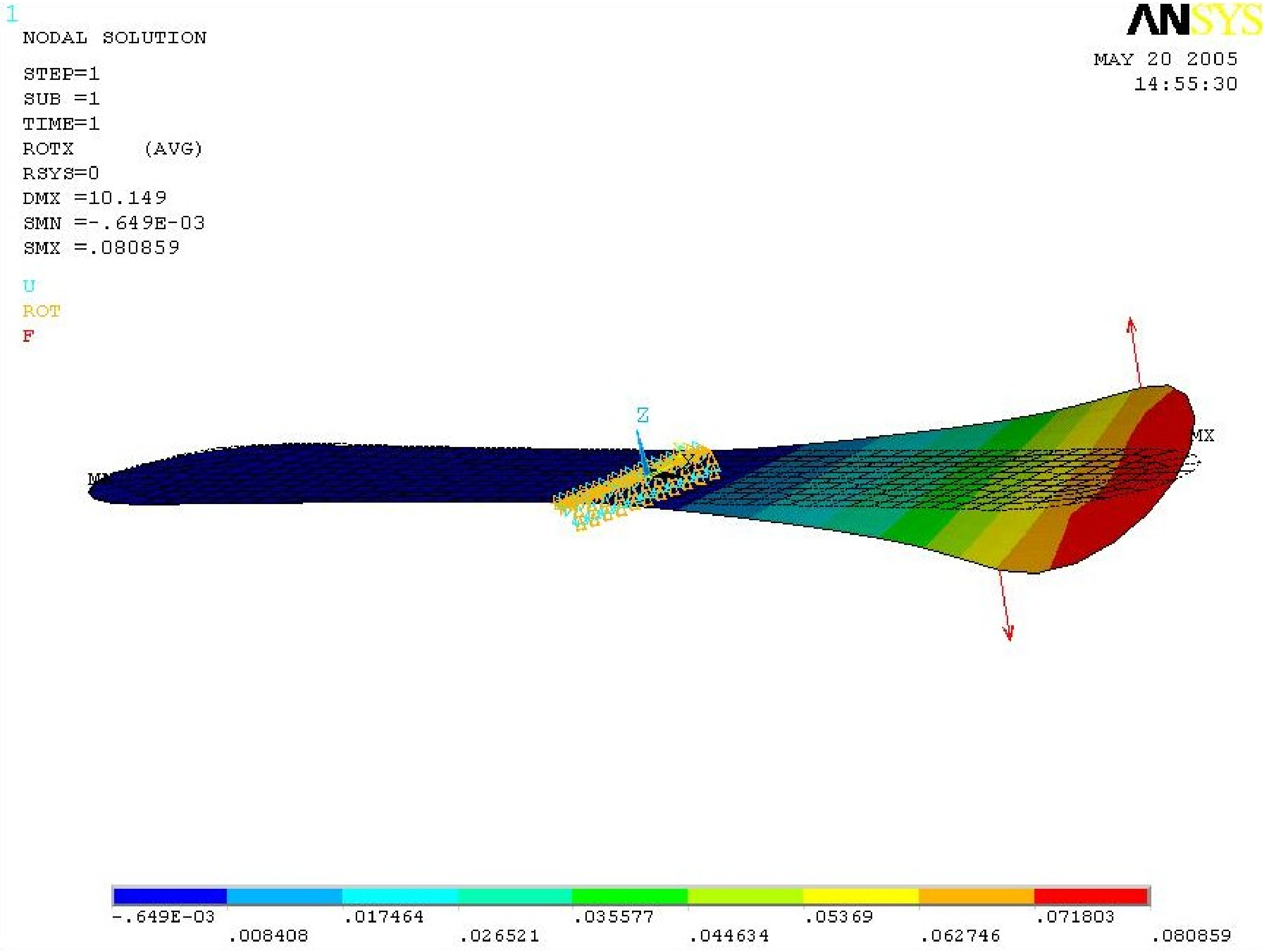
VI. Performing the calculation

VII. Post processing the results

- Bending

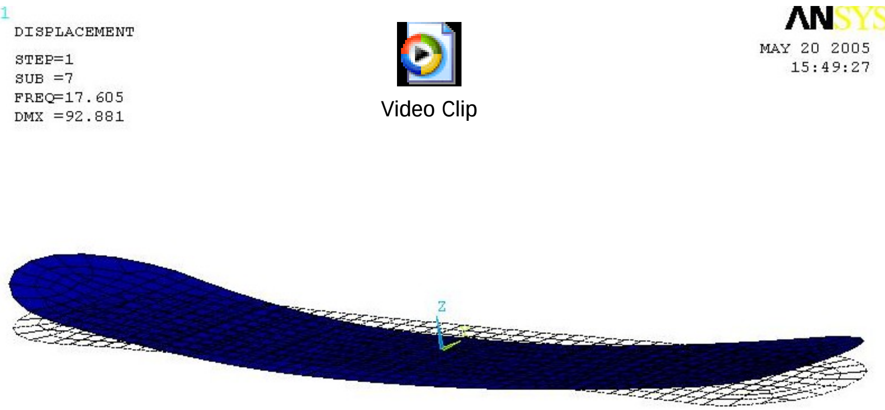


- Torsion

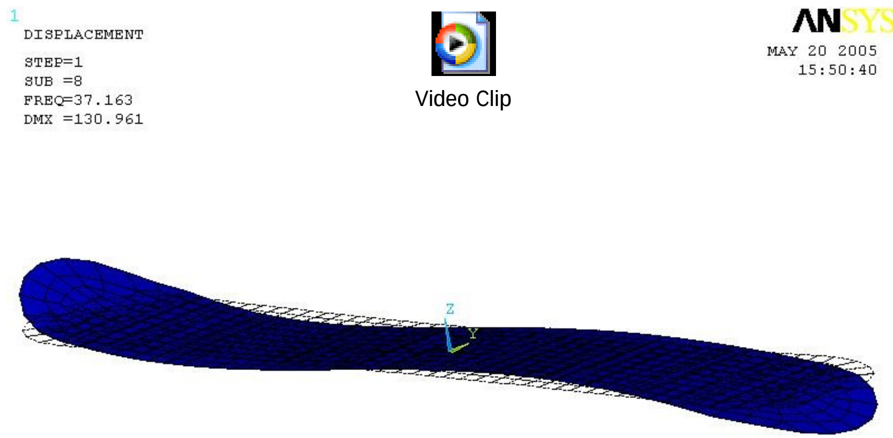


1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
ROTX (AVG)
RSYS=0
DMX =10.149
SMN =-.649E-03
SMX =.080859
U
ROT
F
ANSYS
MAY 20 2005
14:55:30
Z
MX
-.649E-03
.008408
.017464
.026521
.035577
.044634
.05369
.062746
.071803
.080859

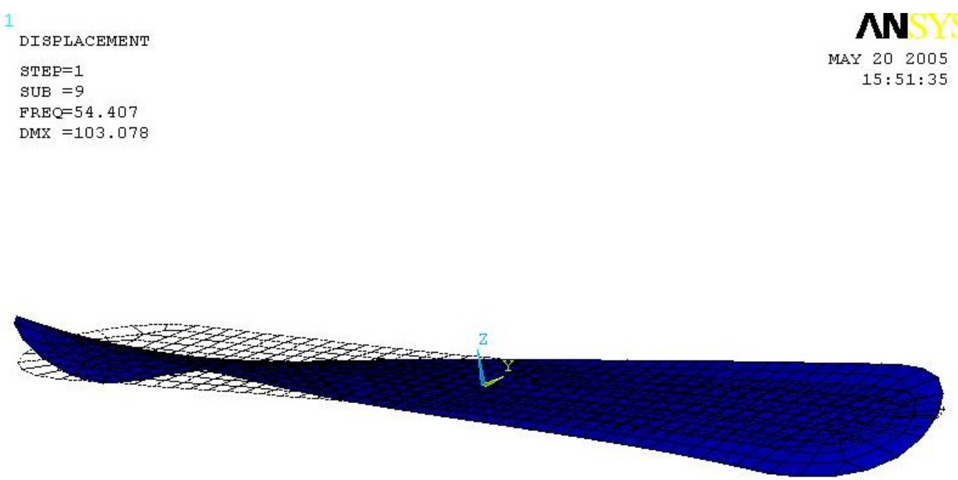
- Natural frequencies



Video Clip



Video Clip



Video Clip

Thank you very much