


CISM Udine 2012

autor: MN





$V=0$




- enrichment ←
- numerical integration ←
- treatment of interface conditions ←
- ↳ DoF management

Size of
mesh M, N
→



Level set





$$\sum N_i (T_i, a_i)$$

Chordal graph

$$G_i = |P_i - 1|$$





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3-D Structural Optimization

Different Approaches

© Nowak, 1997-2010

Handwritten notes on a chalkboard:

- Stabilization
- Lagrange
- Mitsche
- Integration
- Method

Handwritten notes on a chalkboard:

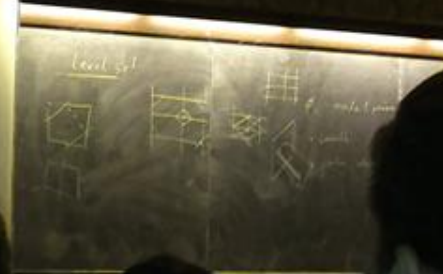
- Level set



Outline

- INTRODUCTION
- OPTIMAL DESIGN (2D & 3D)
- TRIANGULAR BONE REMODELING PHENOMENON
- ELEMENTS OF THE FINITE ELEMENT METHOD
- COMPOSITE - STRUCTURAL OPTIMIZATION TOOL
- CONCLUSIONS

$$\vec{T}_i(\omega) = \sum N_i(\vec{r}_i) \cdot \vec{G}(\vec{a})$$



Strain energy minimization - the stiffest design

The engineer's goal is to find the form of the designed structure (not to determine the forces in the structure).
Z. Wasylutycki

For the stiffest design the energy density along the shape to be designed must be constant.

Research Center Design, Structures and Materials
Poland, 2014, 2015, 2016, 2017, 2018, 2019, 2020

Comparison of stress optimization with other
stress optimization: structural strength optimization
https://www.researchgate.net/publication/338124846

Stress, 2014, 2015, 2016, 2017, 2018, 2019, 2020
https://www.researchgate.net/publication/338124846

Research Center Design, Structures and Materials
Poland, 2014, 2015, 2016, 2017, 2018, 2019, 2020

$$\min(U_\epsilon) \quad V = \text{const.}$$

$$u_i = \text{const.}$$

$$\min(U_\epsilon) \quad \text{where} \quad V = \text{const.}$$

$$u_i = \text{const.}$$

$$\min(V) \quad \text{where} \quad U_\epsilon = \text{const.}$$

Handwritten notes on the chalkboard include:
- $V = 0$
- "Stabilized Lagrange Multiplier"
- "Wilsche"
- "Integration of..."
- "of..."

Handwritten notes on the chalkboard include:
- "Level"
- A diagram of a square with internal lines and arrows.

$u_i \neq 0$
 Stabilized
 Lagrange M.P.
 Nilische
 Integration
 of
 conditions

Strain energy minimization - the stiffest design

The engineer's goal is to find the form of the designed structure (not to determine the forces in the structure).
Z. Wasyluytski

For the stiffest design the energy density along the shape to be designed must be constant.

$\min U(\epsilon) \quad V = \text{const.}$

$u_i = \text{const.}$

$\min U(\epsilon) \quad \text{where} \quad V = \text{const.}$

$u_i = \text{const.}$

$\min V \quad \text{where} \quad U(\epsilon) = \text{const.}$

Haslinger, P. Optimal Design: Structural and Material. Research in Applied Mechanics, 1998, pp. 101-114.
 Zienkiewicz, J. Shape Optimization with Finite Elements. Structural Strength Optimization. Journal of Structural Optimization and Design, 1995, pp. 1-10.
 Dini, F., Ming, Z. Multiparameter structural shape optimization: The level set method. Int. J. Num. Meth. Eng. 71, pp. 247-270, 2004.
 Haslinger, P. On the optimality of the form according to the minimum potential energy with respect to equal strength. In: Proceedings of the 1st International Conference on Structural Optimization, 1993, pp. 233-238, 1993.



Trabecular bone surface adaptation

- Bone remodeling - bone growth and resorption at the surface
- Mechanical stimulus - bone adaptation



Handwritten notes on the left chalkboard include mathematical expressions such as $\vec{N}(\vec{r}, t)$ and $\vec{v} = \vec{v} - \vec{v}_0$, along with various geometric diagrams and sketches of bone structures.

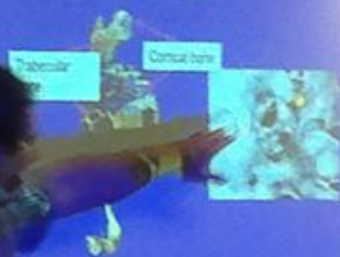
Handwritten notes on the right chalkboard include the text 'level of' and several diagrams showing different cross-sections and arrangements of bone trabeculae.



Trabecular bone surface adaptation

- Bone remodeling - tissue growth and resorption on the surface

- Mechanical stimulation - tissue mechanosensation



10/10



Lat. Level of
response MP
ilische

- enrichment ←
- numerical integration ←
- treatment of
interface conditions ←
- Data management

Level set













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