

***Maxence Bigerelle,
Hauts-de-France Polytechnic University.***

cnrs GDR Groupement
de recherche
Surf Topo - 2077
Topographie des Surfaces



Hauts-de-France Polytechnic University.
Professor, School of Engineering INSA
Laboratory LAMIH UMR 8201 CNRS
Campus Mont Houy, 59313 Valenciennes
Cedex 9

<http://scholar.google.com/citations?user=OjWep5kAAAAJ&hl=en>

Mail : maxence.bigerelle@uphf.fr

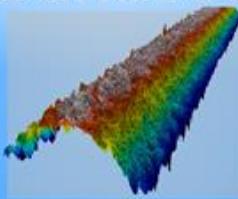
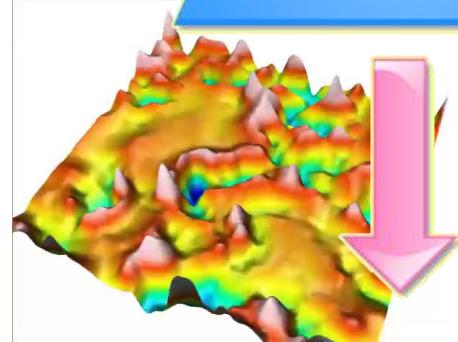
Journée thématique commune GDRs TACT et SurfTopo, 21 novembre 2024 à Jussieu

La Journée thématique 2024 du GDR se tiendra le 21 novembre à Sorbonne Université site de Jussieu en commun avec le GDR SurfTopo.

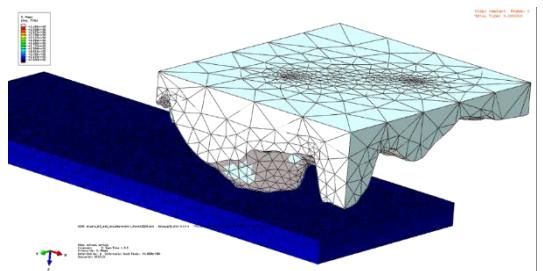
Structuration
Procédés

Surfaces

Fonctionnalités
Physiques

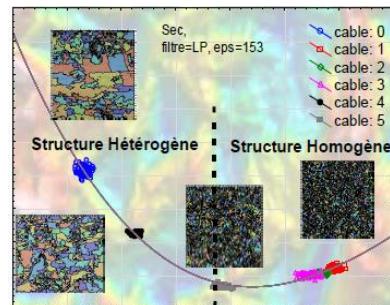


Modéliser

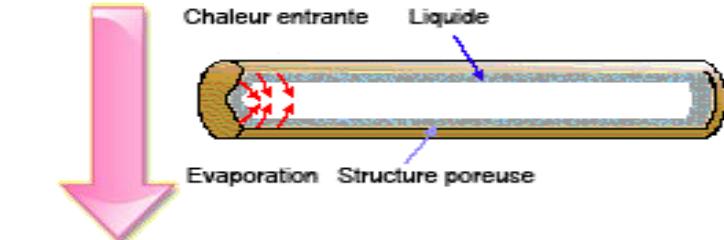


Tribologie, Micro-Fluidique

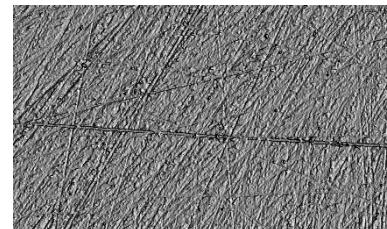
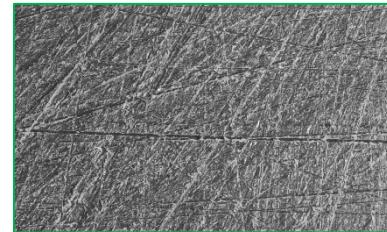
Optimiser



$$\Delta(G_f) = \limsup_{I_x \rightarrow 0} (\log r_c(I_x) / \log I_x)$$



Modéliser





MorphoMeca

La plateforme MorphoMeca a été créée et **inaugurée en 2018** dans le cadre du projet ELSAT2020, cofinancée par l’Union Européenne avec le Fonds européen de développement régional, par l’Etat et la Région Hauts de France ainsi que par des partenariats industriels

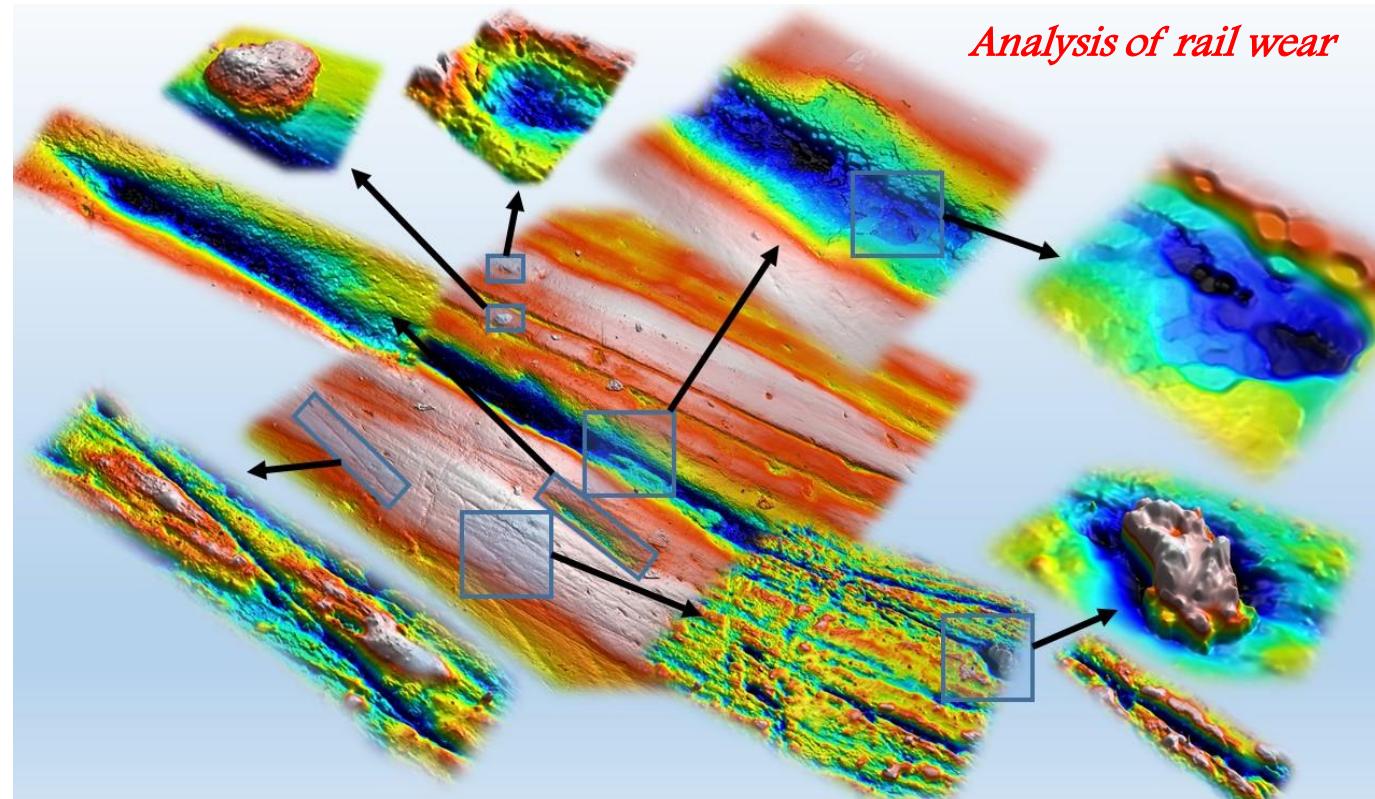
MORPHOMECA PLATEFORM, A REGIONAL PLATFORM FOR SURFACE INSPECTION



Topography: a memory, a signature, a forecasting

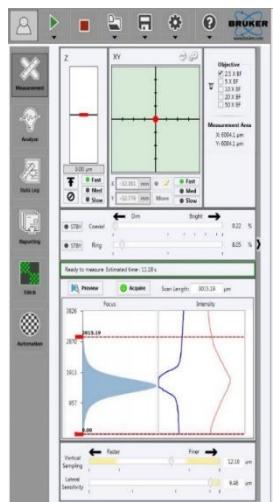
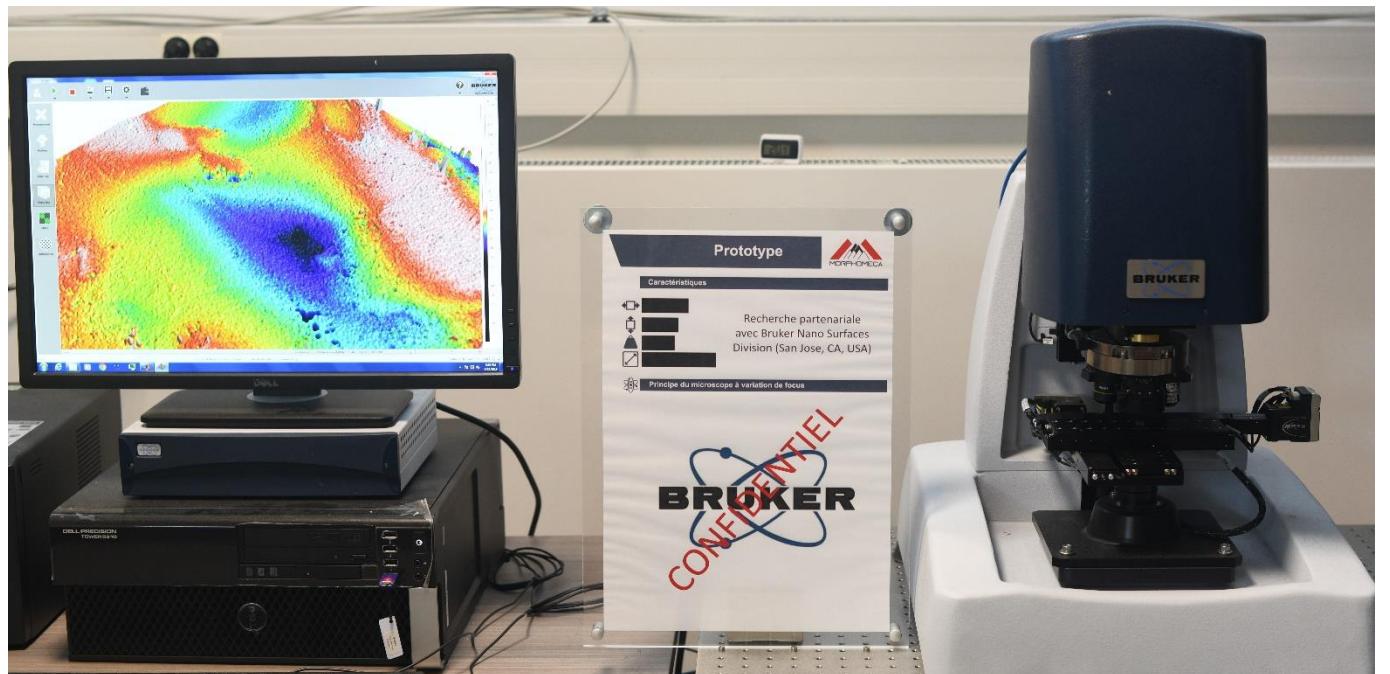
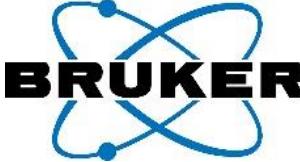
Objective : Quantifying the role of surface roughness on the functionality of the material to analyze, interpret and optimize the surface structuration processes

Originality : Measuring large with nanometric precision to determine the most relevant gauging scales



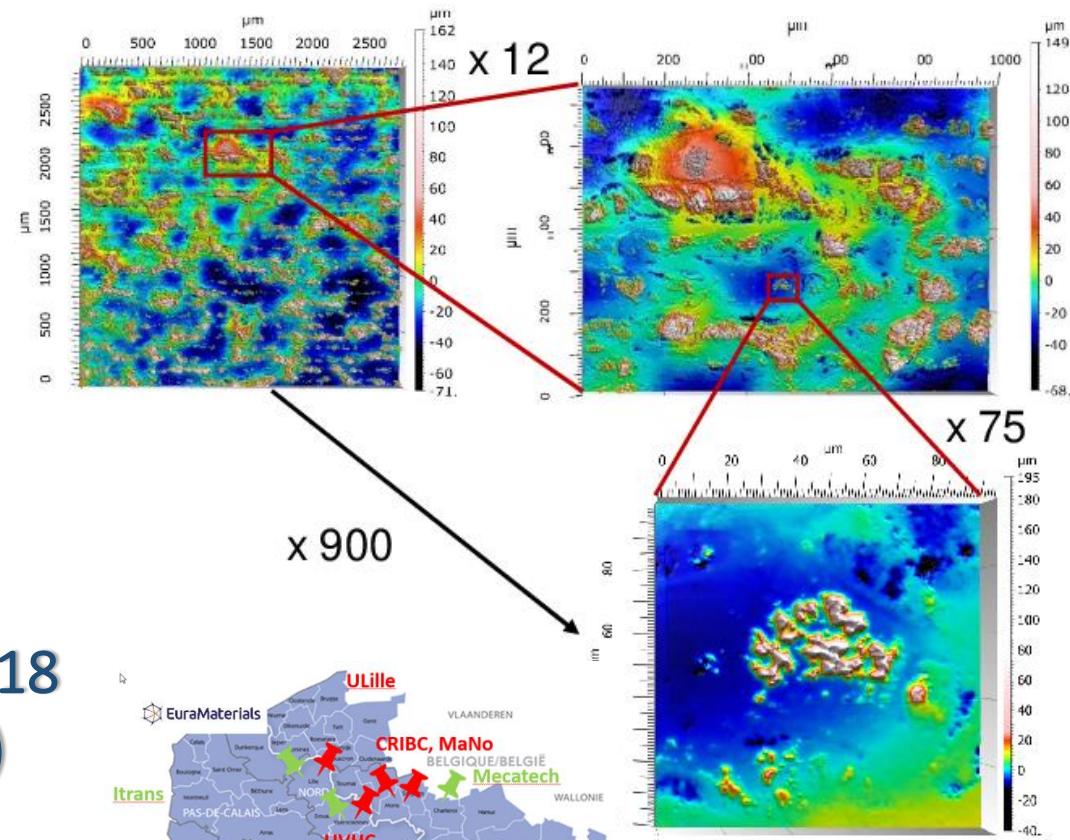
Some Partner industries: Transports (Renault), Aviation (Ariane), Forming processes (Toyota), Textile (Velysam), Optics (Essilor), Self-Cleaning Surfaces (Manitou), Painting (Kremlin Rexson), Plastics (Visteon), Metallurgy (Arcelor), Food (Staub), Electric contact (RTE), Lubricant (Total), Petroleum (Vallourec), Foundry (Manoir), Antibacterial (Sebbin), Sensors (Bruker), Kitchen utensil (Staub), Additive fabrication (Zodiac), Cosmetics (Channel), Skin (Loreal), Prosthesis (Selenium Medical), Watch manufacturing (Rolex) ...

MorphoMeca and Dimensional Metrology: International partnership to develop a new microscope with Bruker

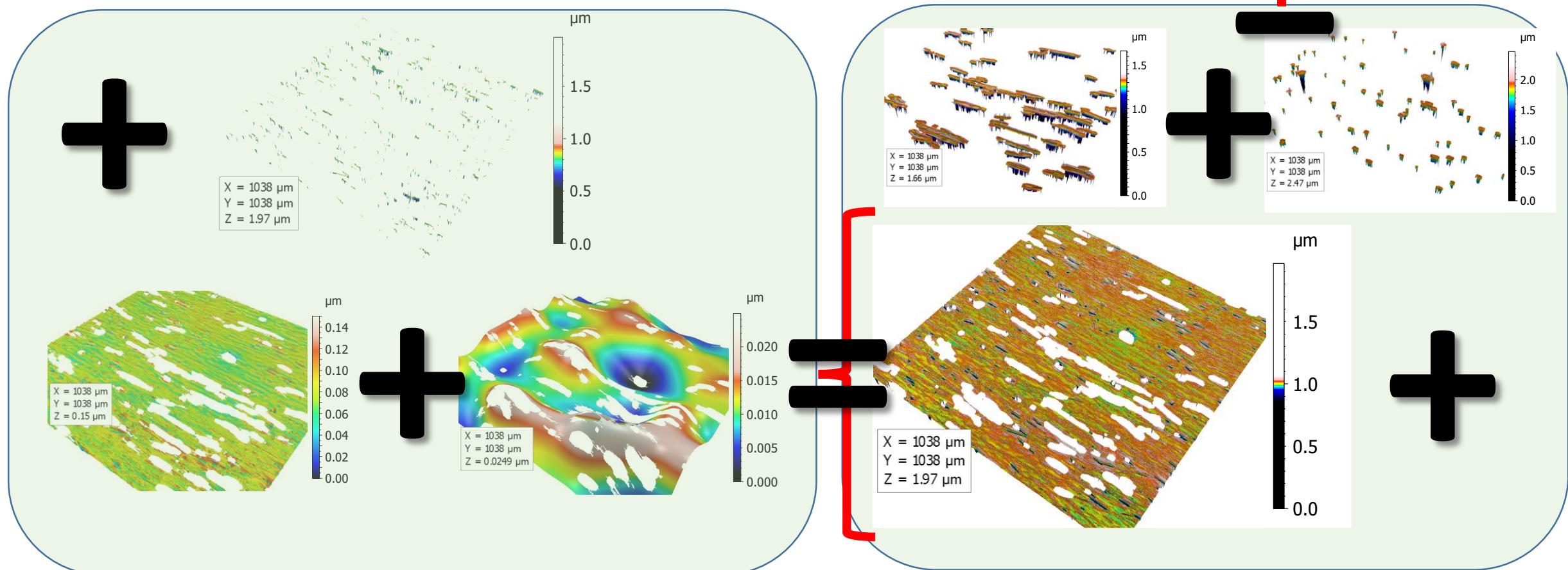
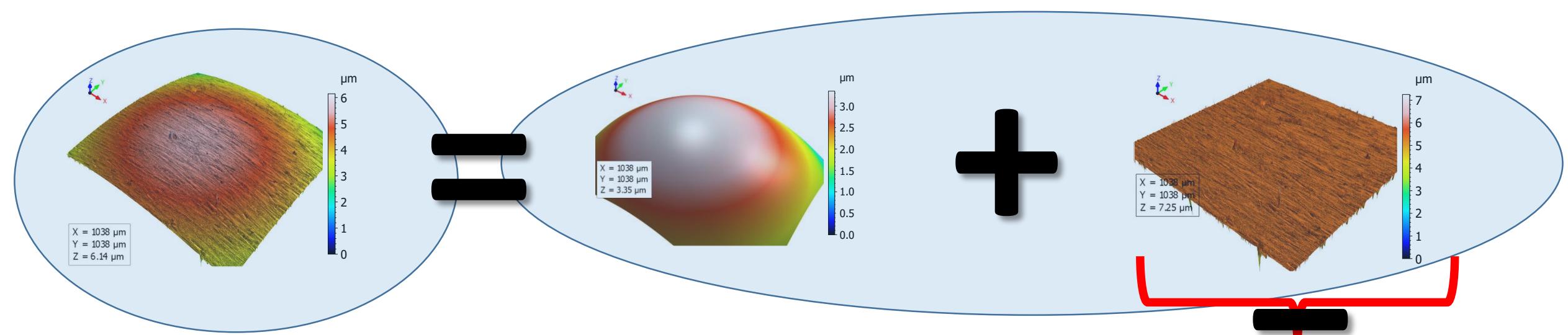


- LAMIH/BRUKER partnership signed in 2018 (Bruker Nano Surface, San Jose, CA, USA)
- Device integrated on the MorphoMeca platform Allows multi-scale HQ measurements
- Interreg ALLIHENTROP: Morphomechanical Characterization

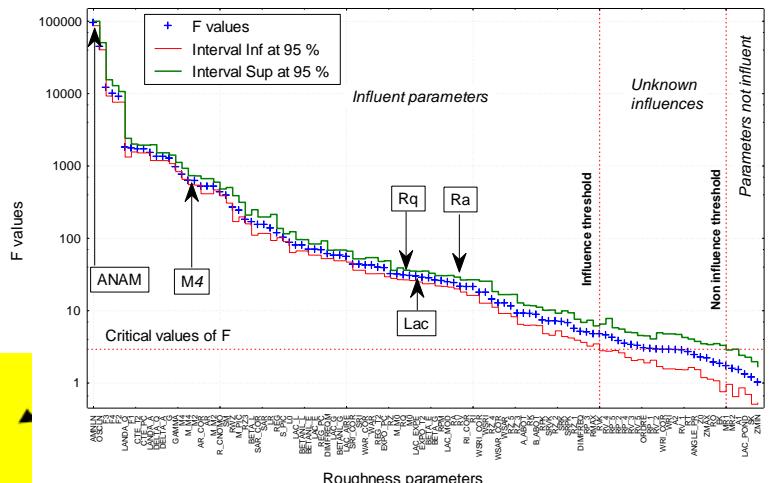
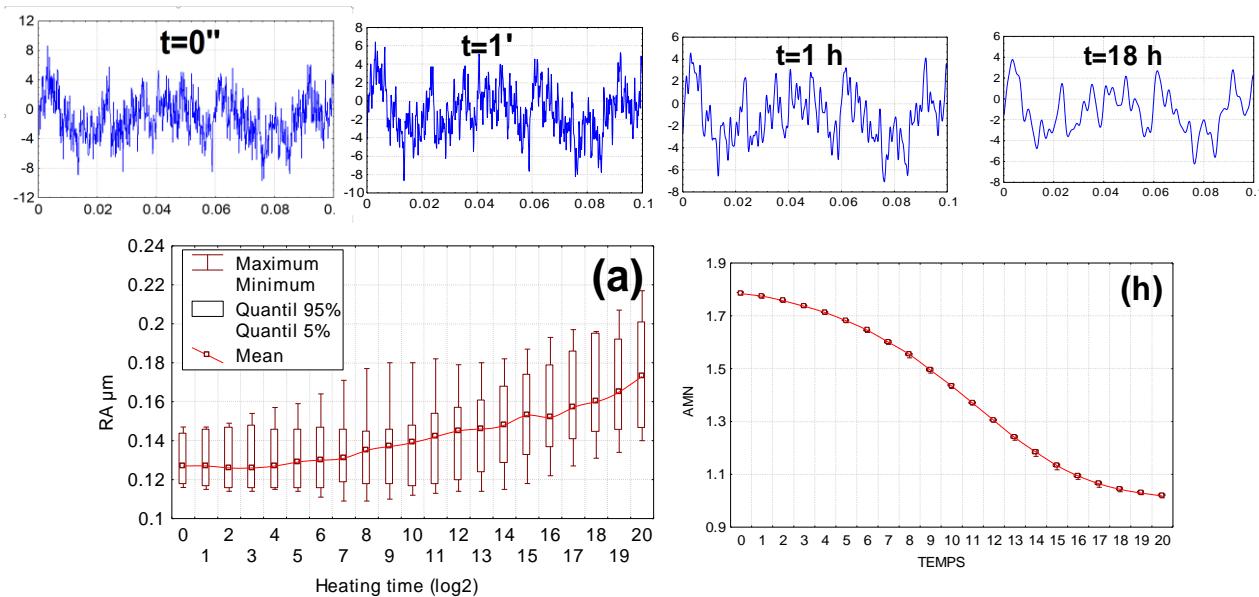
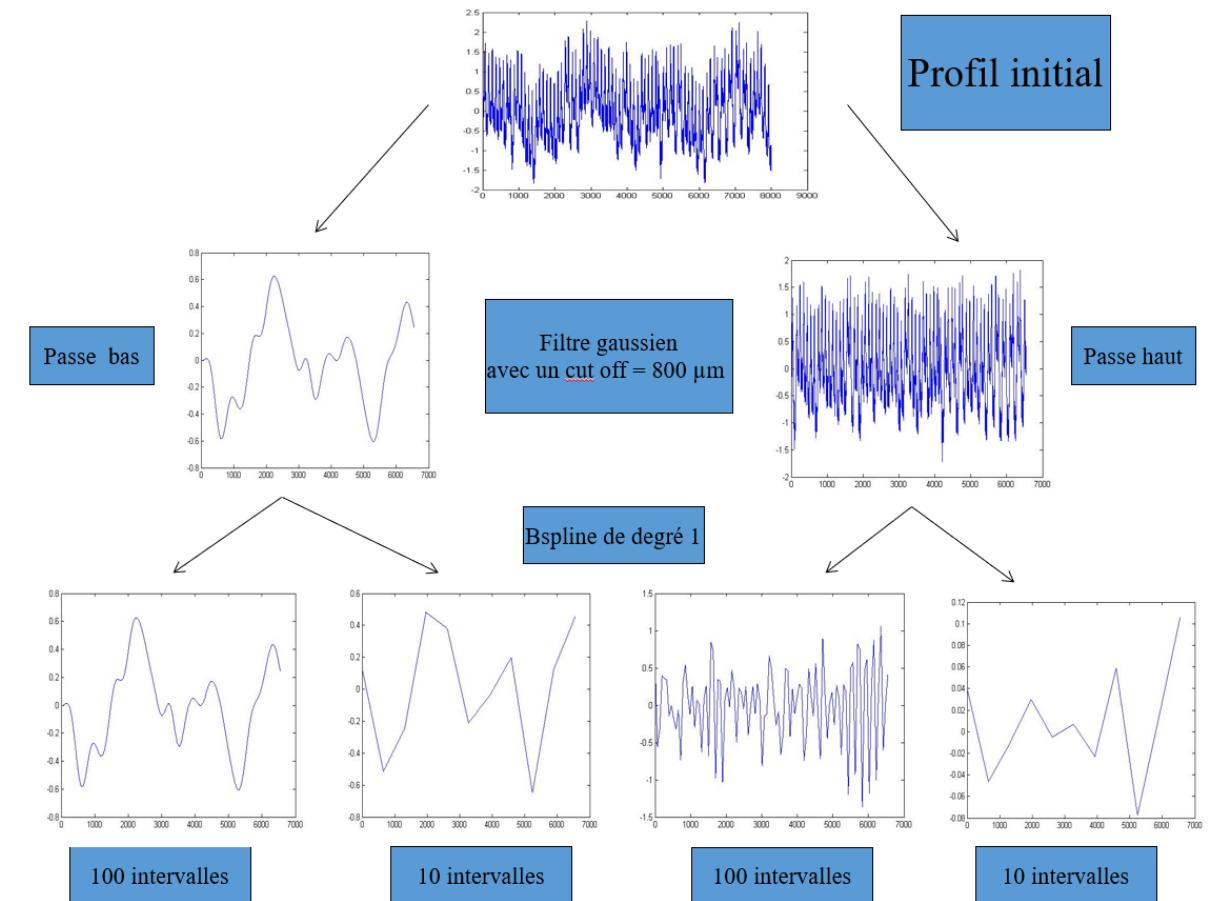
High Entropy Coating, Laser Fusion (SLM)



Interreg
France-Wallonne-Vlaanderen
UNION EUROPÉENNE
EUROPEAN UNION
ALLIHENTROP



Un logiciel Métier d'aide à la décision : Mesrug



$$K_\tau^\alpha(f, a, b) = \frac{1}{b-a} \int_{x=a}^{x=b} \left[\frac{1}{\tau^2} \int_{t_1=0}^{\tau} \int_{t_2=0}^{\tau} |f(x+t_1) - f(x-t_2)|^\alpha dt_1 dt_2 \right]^{\frac{1}{\alpha}} dx$$

$$K_\tau^\alpha(f, a, b) = c \tau^{H(f, a, b)}$$

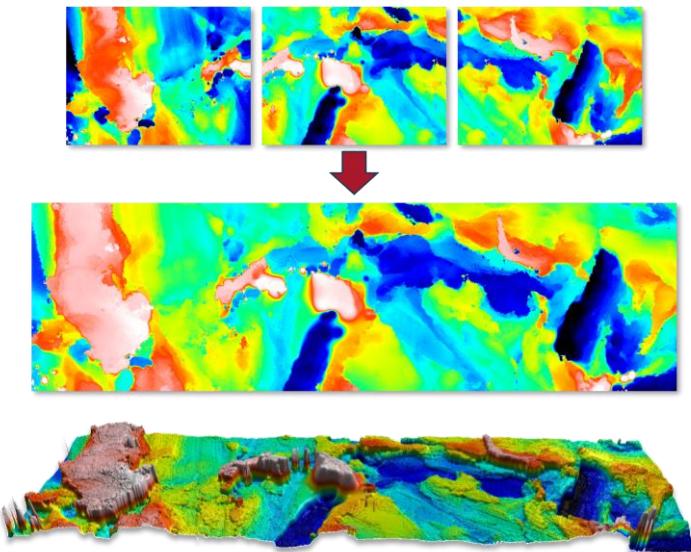
$$\Delta(f, a, b) = \lim_{\tau \rightarrow 0} \sup \left(2 - \frac{\log K_\tau^\alpha(f, a, b)}{\log \tau} \right)$$

Stitching de topographies 3D

Une collaboration entre les départements Mécanique et Informatique

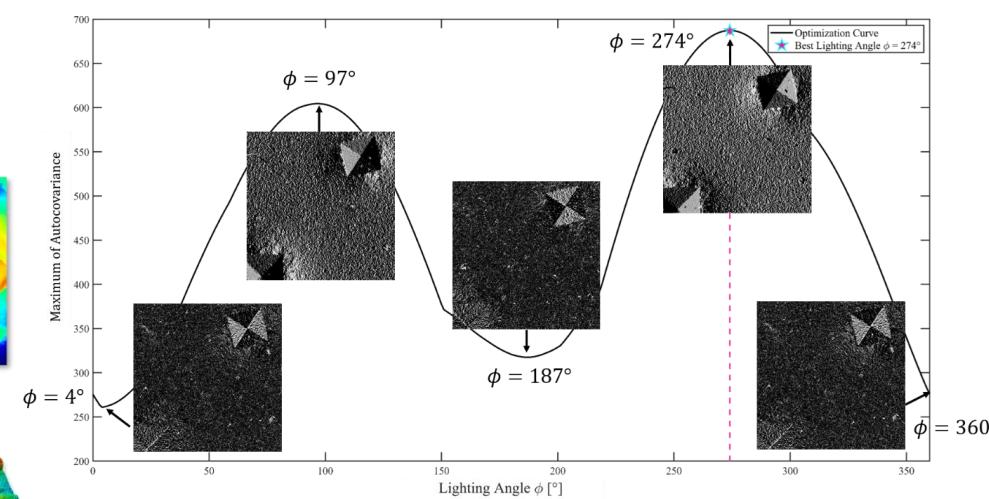
Challenge : Aucun système ne peut faire de très grand stitchings de topographies 3D (max 5 000 surfaces élémentaires)

Développement d'un nouveau logiciel de stitching¹ : Morpho^{Stitch}



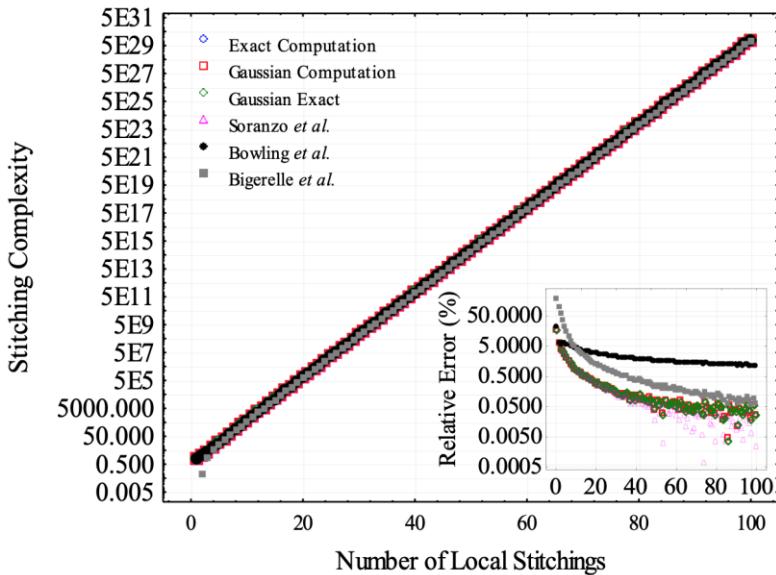
Stitching de 160 000 (400x400) surfaces élémentaires
~ 31,5 Gpixels
(153 696 × 204 928 points)
~ 124 Go

Nouvel algorithme de stitching :
the *rising sun stitching algorithm*²



Optimisation de maps de réflectance + stitching multimap
(topographies 3D + reflectance)

Etude théorique complexité du stitching : un problème NP-complet ?



Complexité exponentielle au minimum

L'art et la topographie de surface

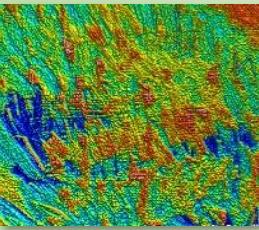
Utilisation de la dimension fractale pour authentifier les œuvres de Van Gogh



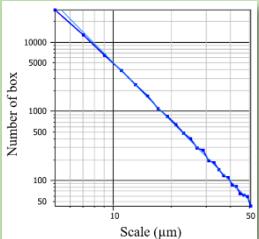
Œuvres authentiques de Van Gogh



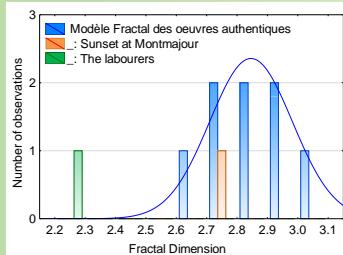
Œuvre reconnue comme attribuée à Van Gogh mais considérée fausse puis authentifiée



Conversion en topographies de surfaces

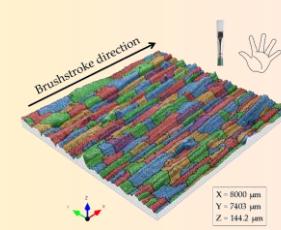


Calcul de la dimension fractale

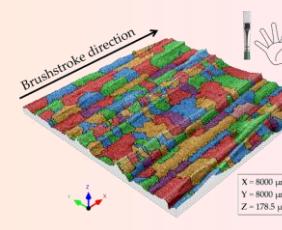


Modélisation pour discrimination des fausses œuvres

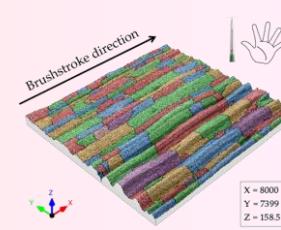
Utilisation de la topographie pour différencier les peintres droitiers et gauchers



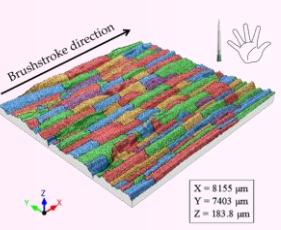
X = 8000 μm
Y = 7403 μm
Z = 144.2 μm



X = 8000 μm
Y = 7399 μm
Z = 158.5 μm

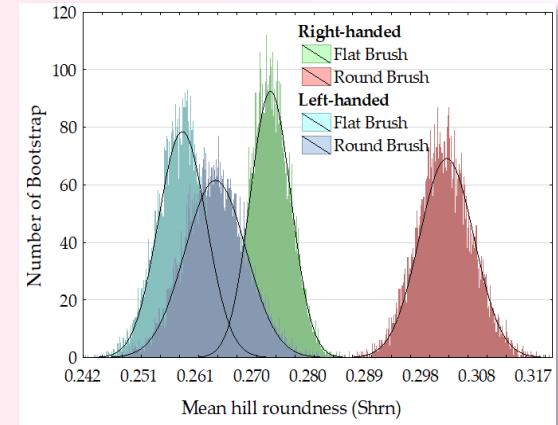


X = 8000 μm
Y = 7403 μm
Z = 183.8 μm



X = 8155 μm
Y = 7403 μm
Z = 183.8 μm

Expérimentation sur 4 groupes différents (types de pinceau et main directrice)



Rondeur des collines

Paramètres de rugosité pertinents pour différencier les droitiers et gauchers

Théorisation d'un langage de description des topographies de surfaces

Problématique :

La morphologie des surfaces est un sujet au cœur des préoccupations dans de nombreux domaines : de la mise en forme à la nano texturation. Les chercheurs n'ont de cesse de varier l'aspect et la fonction des surfaces pour des résultats optimaux. Un problème demeure : dans ce vaste champ de recherche difficile d'avoir accès à aux informations sur les surfaces rapidement.

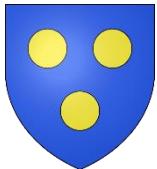
Seule norme existante ISO 8785 pour le vocabulaire des surfaces mais peu pratique



Figure 7

L'héraldique utilise un langage visuel et textuel spécifique comprenant des couleurs, des formes et des objets pour identifier un personnage ou une institution.

Le blason est la partie graphique, le blasonnement est la partie textuelle

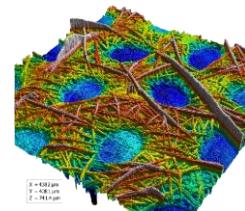


D'azur à 3 besants d'or

« D'azur » mot renseigne sur la couleur du fond

« D'or » Indique la couleur des objets ajoutés

« Besants » : nom des objets superposés

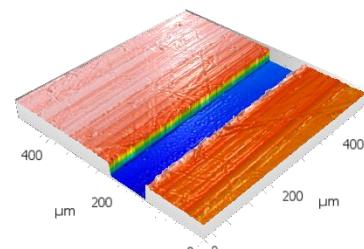


Surface masque chirurgical

Notre objectif : décrire une surface en vocabulaire normé pour donner une image visuelle universelle

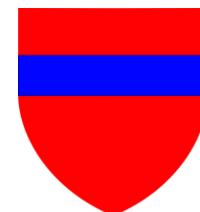
Avantages :

- vocabulaire normalisé entre les domaines
- indexation efficace
- résultats mieux comparables

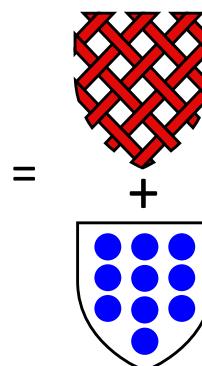


Surface fraisée

=



De gueules à une fasce d'azur



Motif treillissé pour les fibres

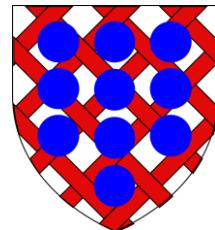
Le rouge indique la couche supérieure de la rugosité en lien avec les fausses couleurs de la topographie

Motif besanté pour les creux

Le bleu indique la couche inférieure de la rugosité.



=

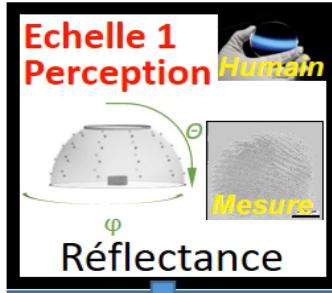


Treillissé de gueules et besanté d'azur

L'héraldique une modernité insoupçonnée

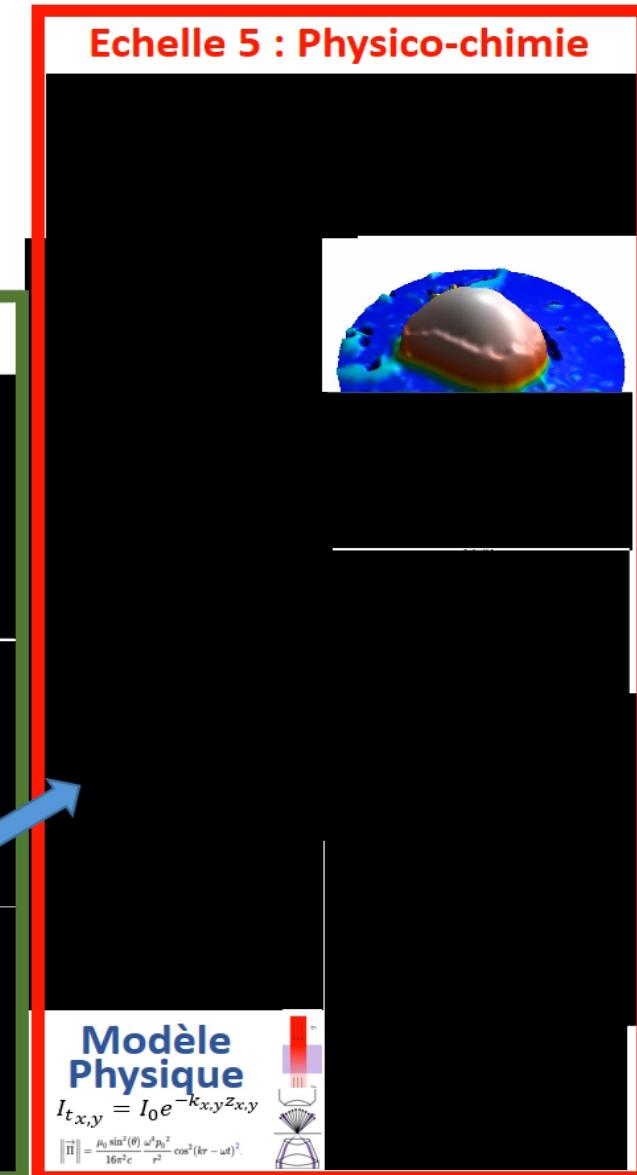
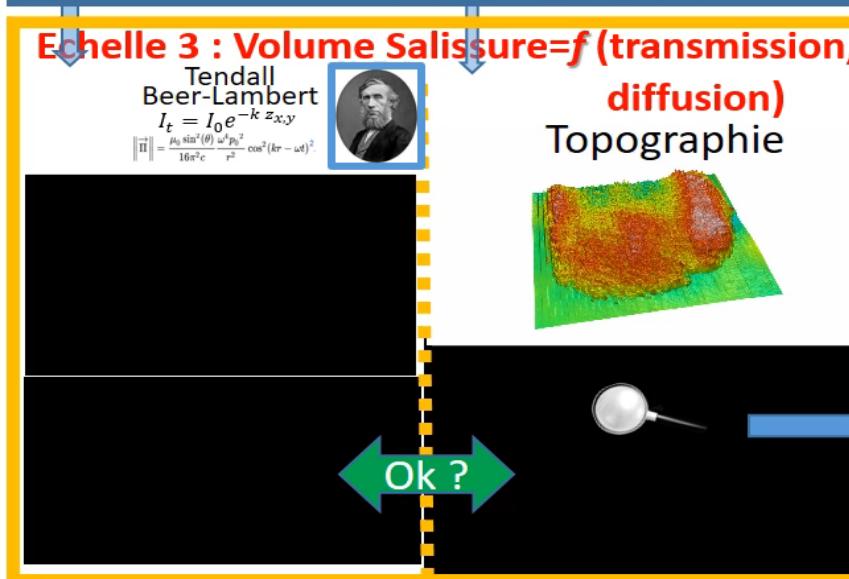
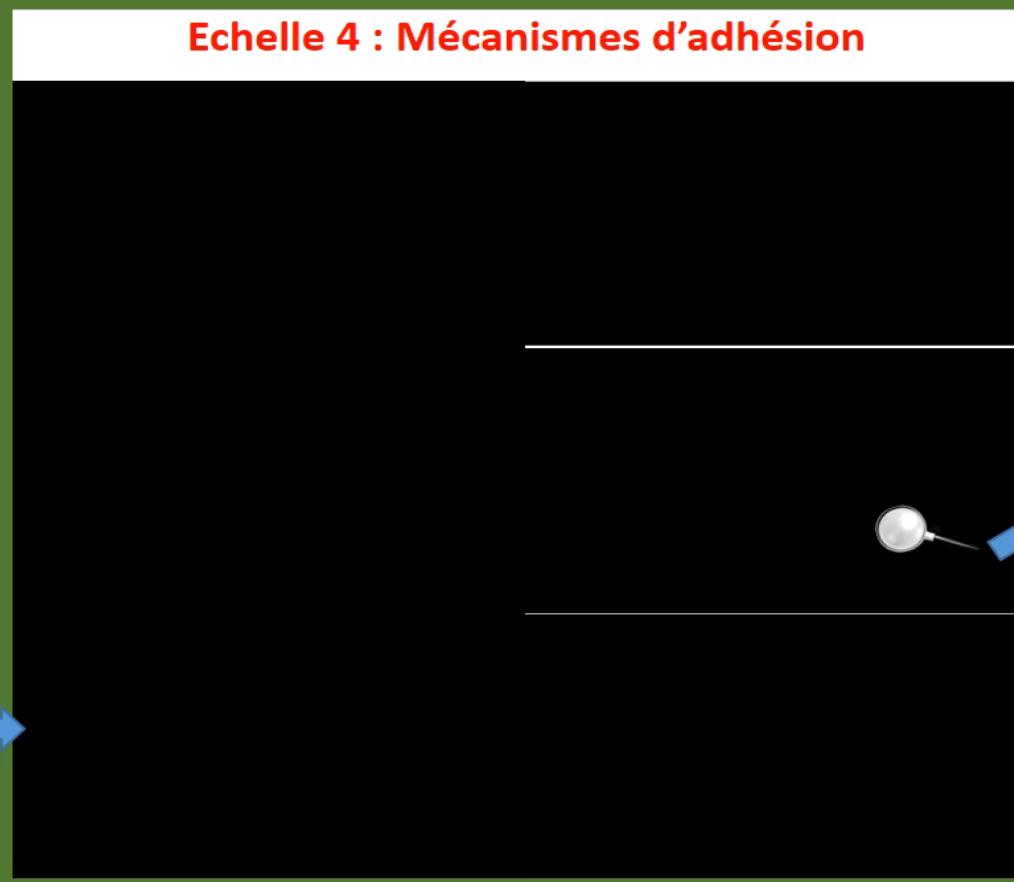
La fasce est un élément rectiligne et unique sur le blason cependant on peut préciser le nombre si il y en a plusieurs et au-delà de 5 nous utiliserons le terme « fascé » pour un motif

Échelles Physiques caractéristiques de la fonctionnalité



Les cinq échelles de la salissure des verres ophthalmiques

- **Echelle 1 :** Perception extérieure de la salissure : Réflexion sur verre
- **Echelle 2 :** Ressenti de la salissure : Perte acuité, gène du porteur
- **Echelle 3 :** Mesure épaisseur du sébum : Transmission lumière, relation Beer-Lambert
- **Echelle 4 :** Mesure hétérogénéité : Mécanisme d'adhésion, nettoyage, antosalissure
- **Echelle 5 :** Mesure des formes d'amas : Compréhension physicochimique de la salissure

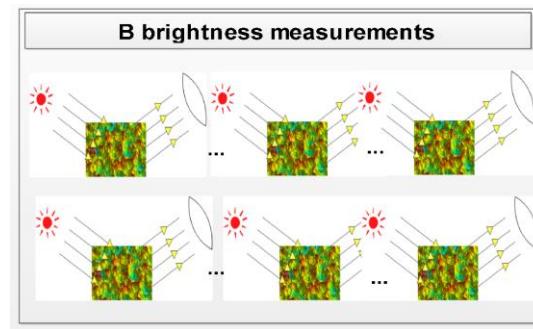
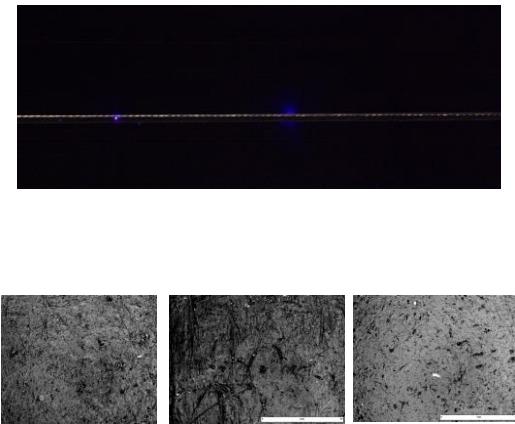


Keywords : Roughness, Surface Topography, Fractals, Signal Processing, Images analysis, Metrology.

Philosophy : Quantify the role of surface roughness on the functionality of the material to optimize the surface structuration processes.

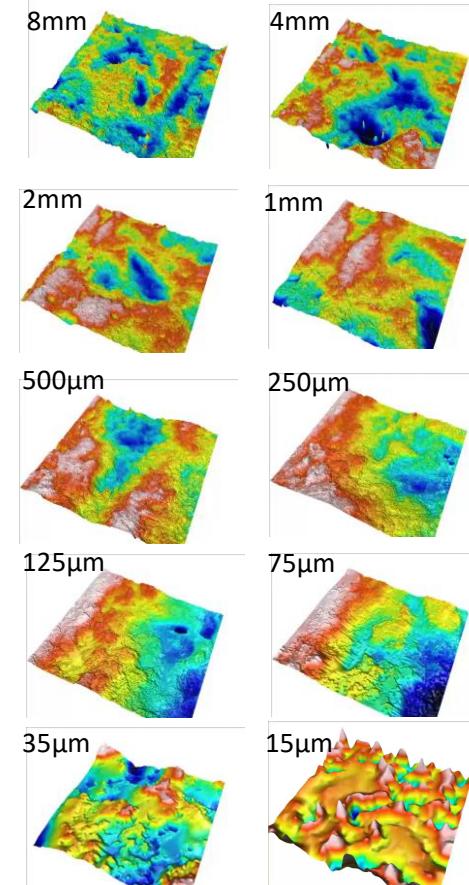
Originality : Construction of an expert system for relevant roughness parameters by multi-scale analysis to optimize the structuring processes.

● FUNCTIONALITY OR INTEGRITY OF SURFACES



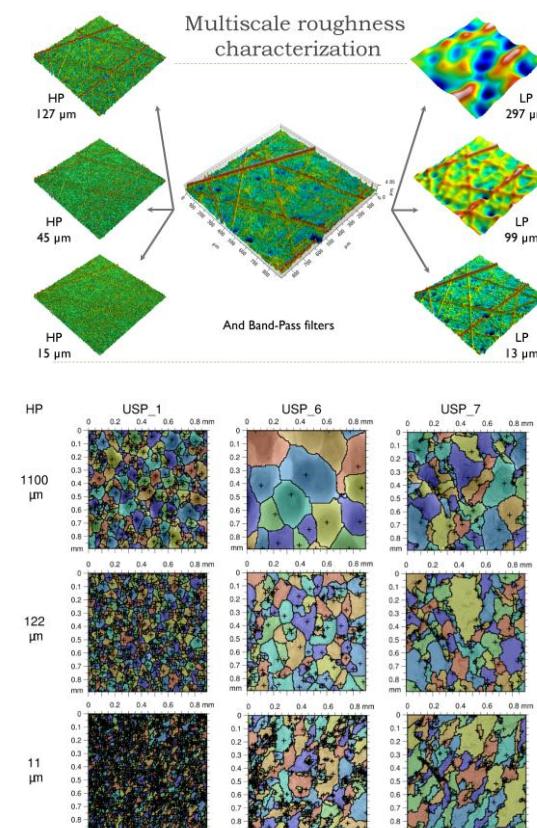
Measures a functionality or an integrity of a set of rough surfaces

● HIGH RESOLUTION MULTISCALE MEASUREMENTS



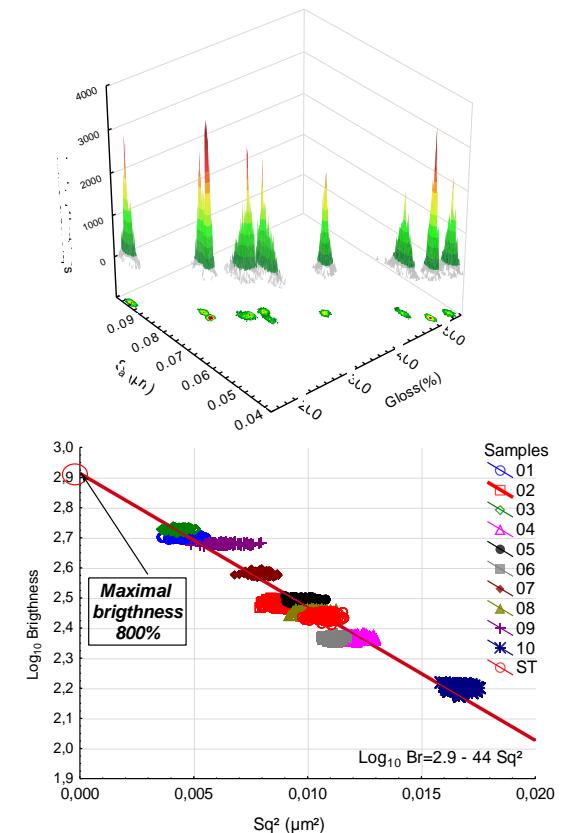
Measure on high resolution with appropriate metrology the surface topography.

● MULTISCALE ANALYSES (FOURIER, WAVELET, MODAL...)



Find relevance scales with appropriate multi-scale decomposition to quantify physical effects.

● CLASSIFICATION OF RELEVANT ROUGHNESS PARAMETERS



Give the model linking the most relevant roughness parameters and the index of functionality or integrity.

The parameter rash — is there a cure?

D.J. Whitehouse,
Wear, Volume 83, Issue 1, 1 December 1982, Pages 75-78

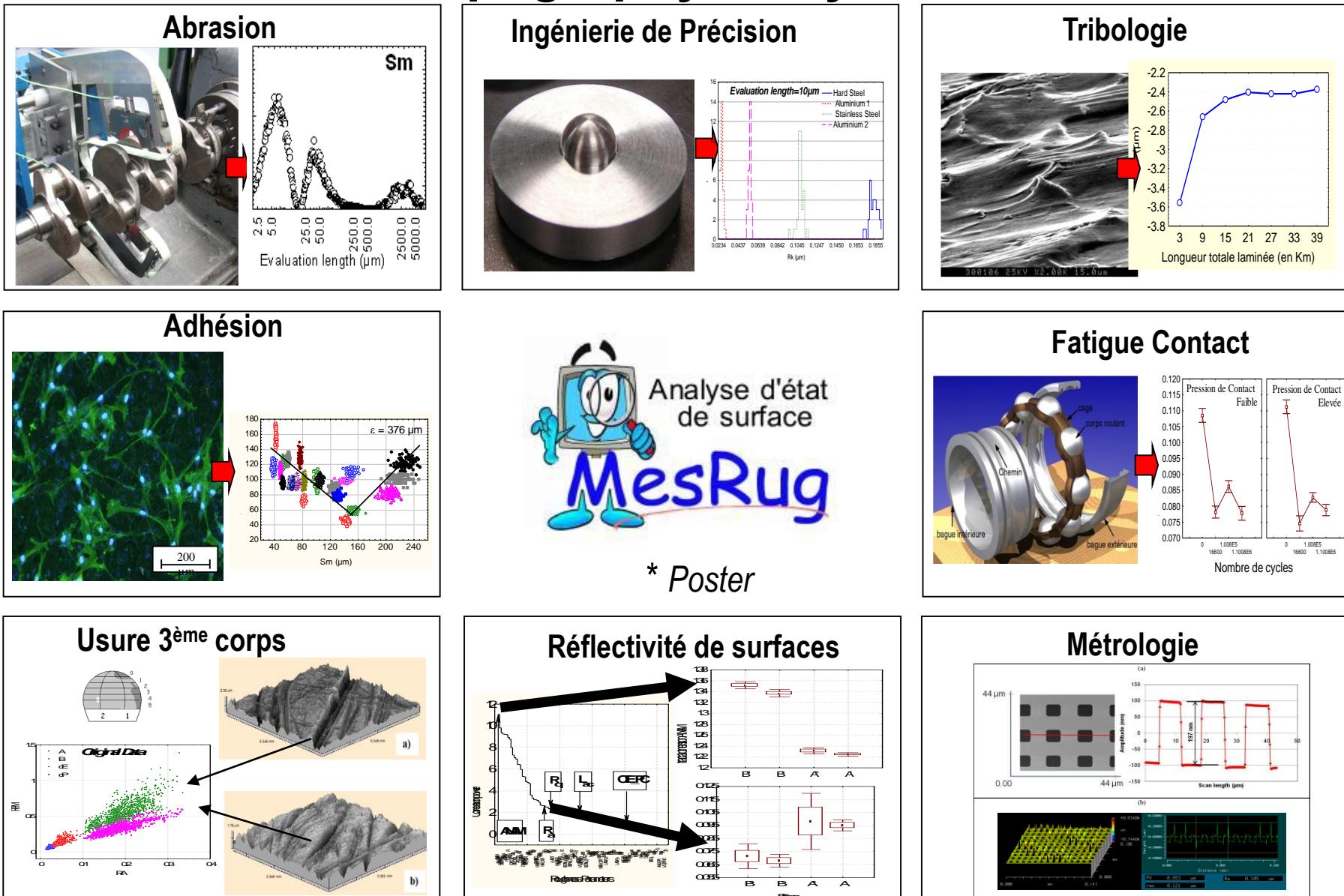
« In recent years there has been a proliferation of parameters with which to specify surface texture. Some of these parameters are useful, but most are not. The result of this rash is confusion and expense. The cause of the growth of such parameters is identified and ways of minimizing it are explored. »

Is that possible to find relevant roughness parameters without pre conceived opinion ?

Create a methodology based on an expert system to analyse the relevance of all roughness parameters

MesRug : An expert System for Surface Topography analyses

14



14

Relevancy Phylosophy

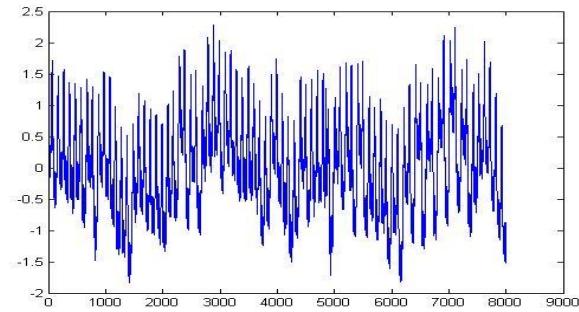
- No pre-conceived opinion about a given roughness parameters.
- Built a robust statistics.
- Test of homogeneity of data
- All roughness parameters are considered as a stochastic variable
- Create a probabilistic parameters independent of the number of roughness parameters.
- Classify roughness parameters according to their relevance.
- Groups of parameters with same relevance.
- Gives visual representation of the relevancy.
- Relevancy analyses is automatically performed

Avoiding too severe statistical assumptions :
Bootstrap theory is applied on all procedures

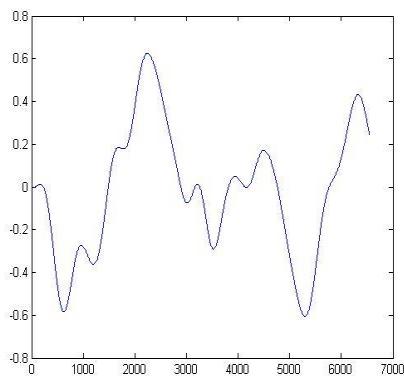
Methods of pre-treatment

- Different least square for removal forms.
- Different filtering method.
- Multi-scale analyses :
 - * Wavelet
 - * B-splines method.
 - * Classical Filtering methods
 - * Modal analyses

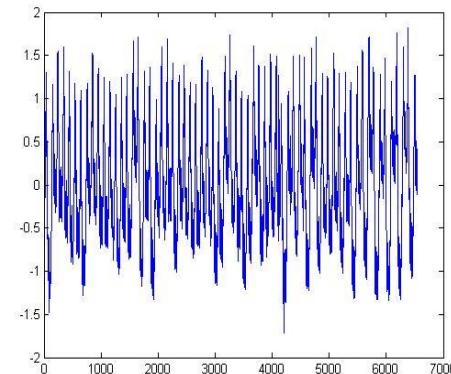
Profil initial



Passe bas

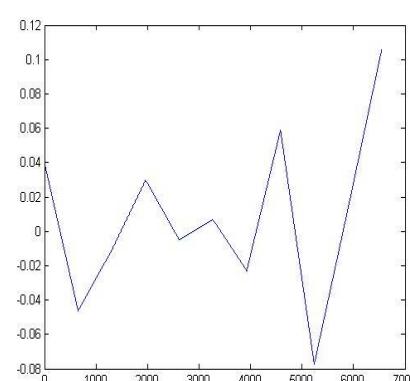
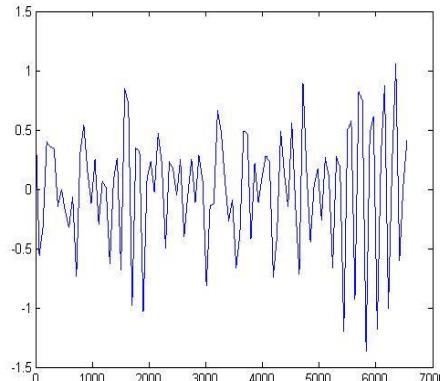
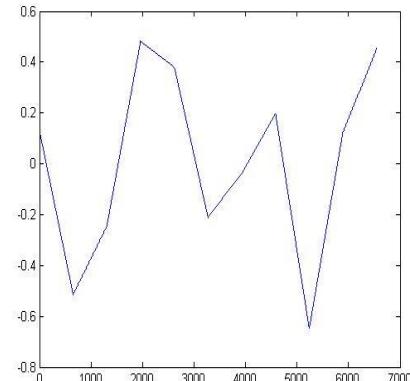
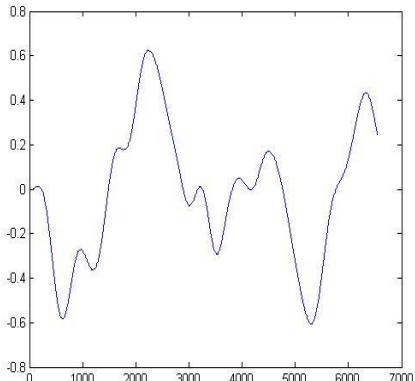


Filtre gaussien
avec un cut off = $800 \mu\text{m}$



Passe haut

Bspline de degré 1



100 intervalles

10 intervalles

100 intervalles

10 intervalles

2 D roughness parameters

→ Amplitude Parameters: Ra, Rq, Z0, Ek, Zmin, Zmax, Rt,

Rz1,...,Rz5, Rp1,...,Rp5, Rv1,...,Rv5, Rmax, Rv, Rpm, Rz, R3z, Angle.

→ hybrid parameters : L0, LR, Δa, Δq, λa, λq, g, γ, R_{wz}, R₀.

→ Computation of the power spectrum spectral density, amplitude spectrum.

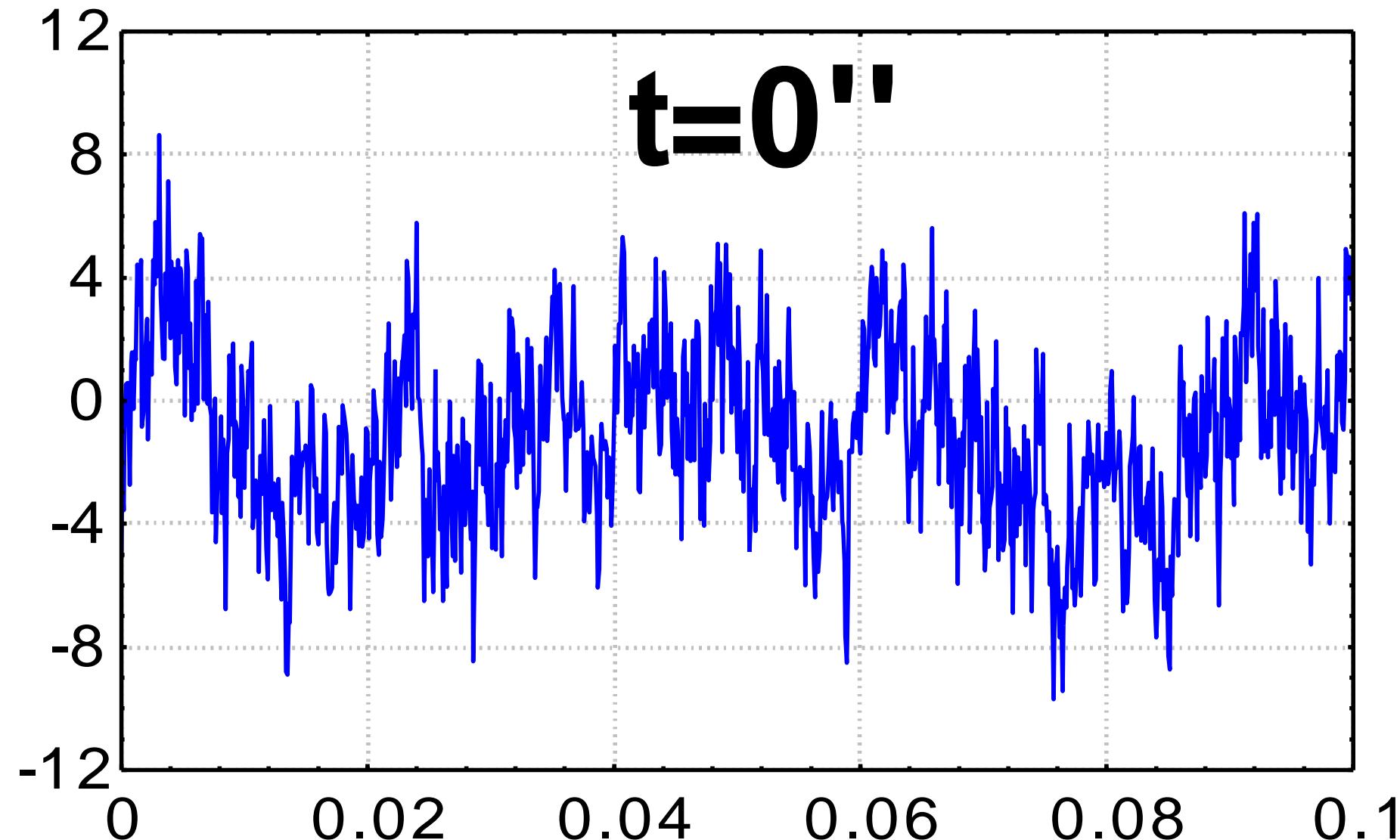
frequency parameters: RSm, F1, F2, F3, F4, DF(fractal dimension)

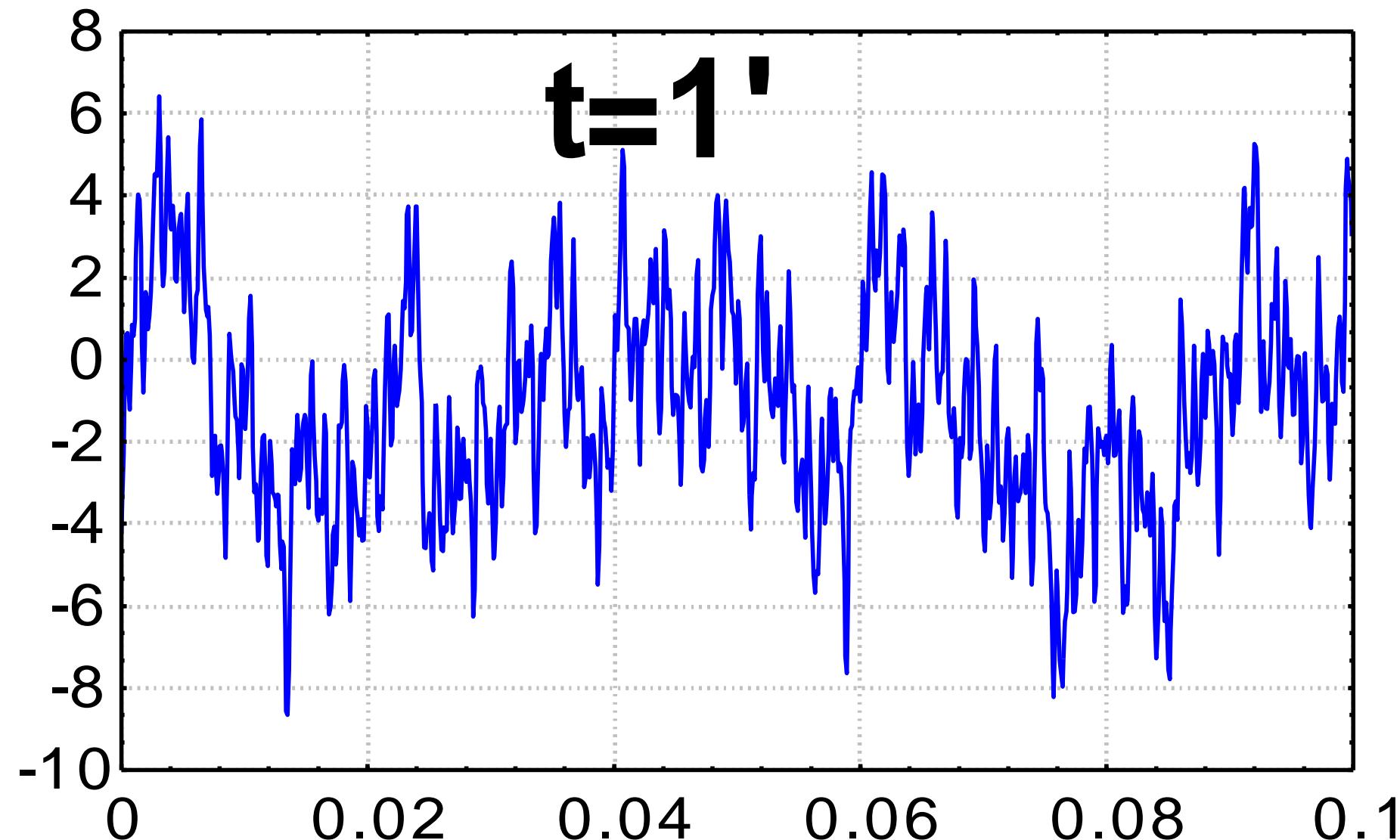
First Mesrug analysis

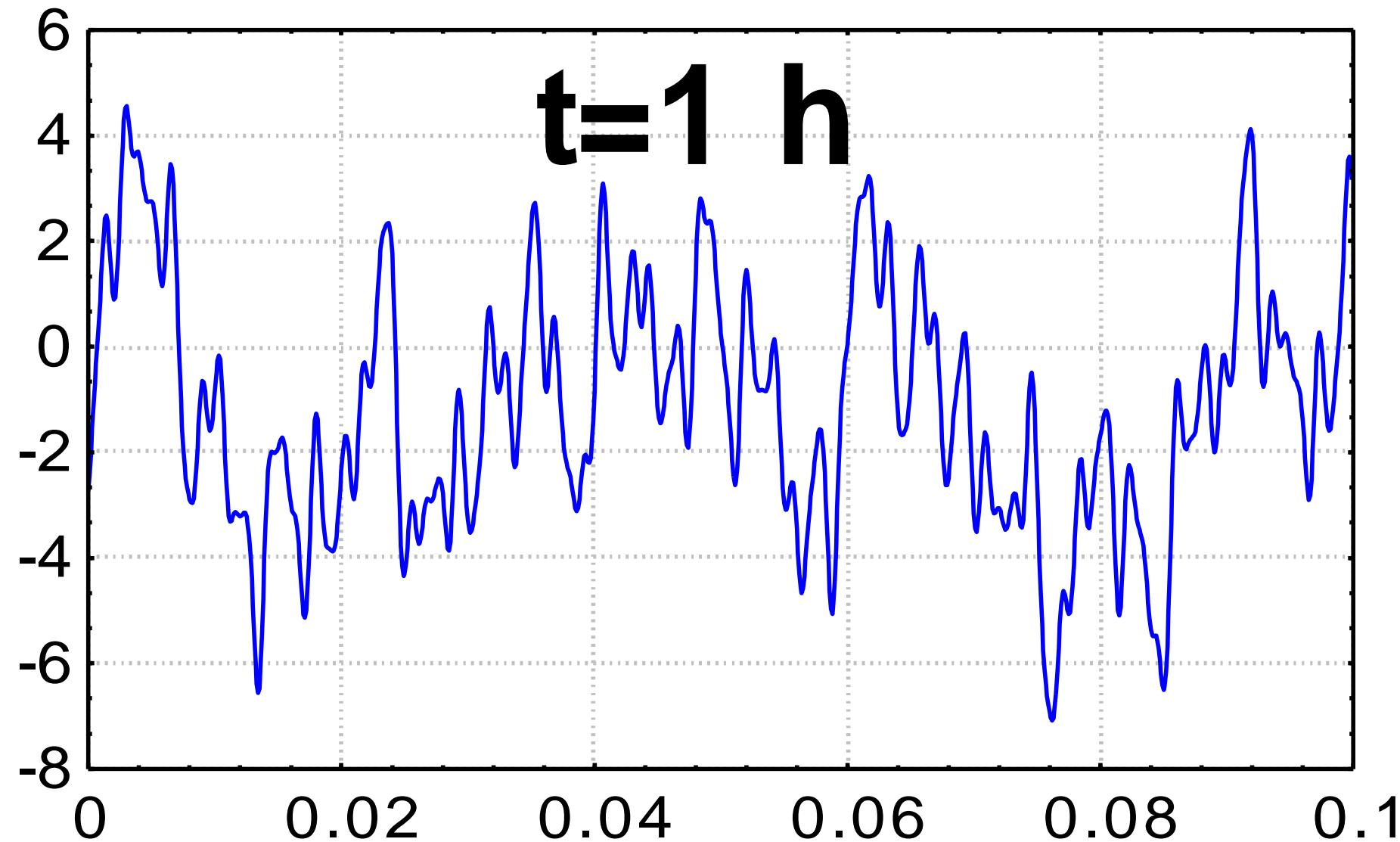
What is the best roughness
Parameter that discriminate
n surfaces

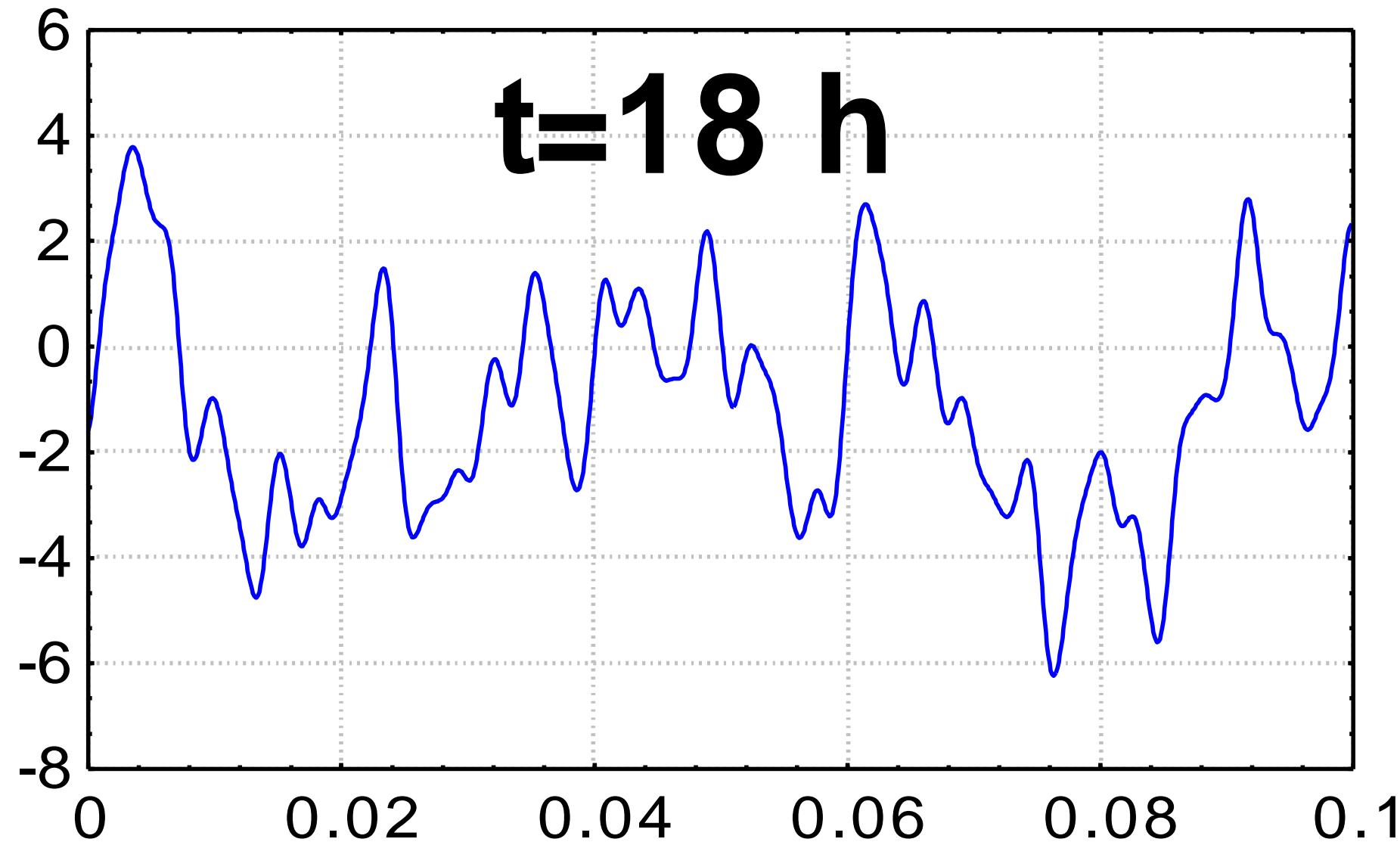
Method : Analyses of variance + bootstrap for
each roughness parameters

An example: Best roughness parameter to
characterize superficial diffusion condensation on
rough surfaces

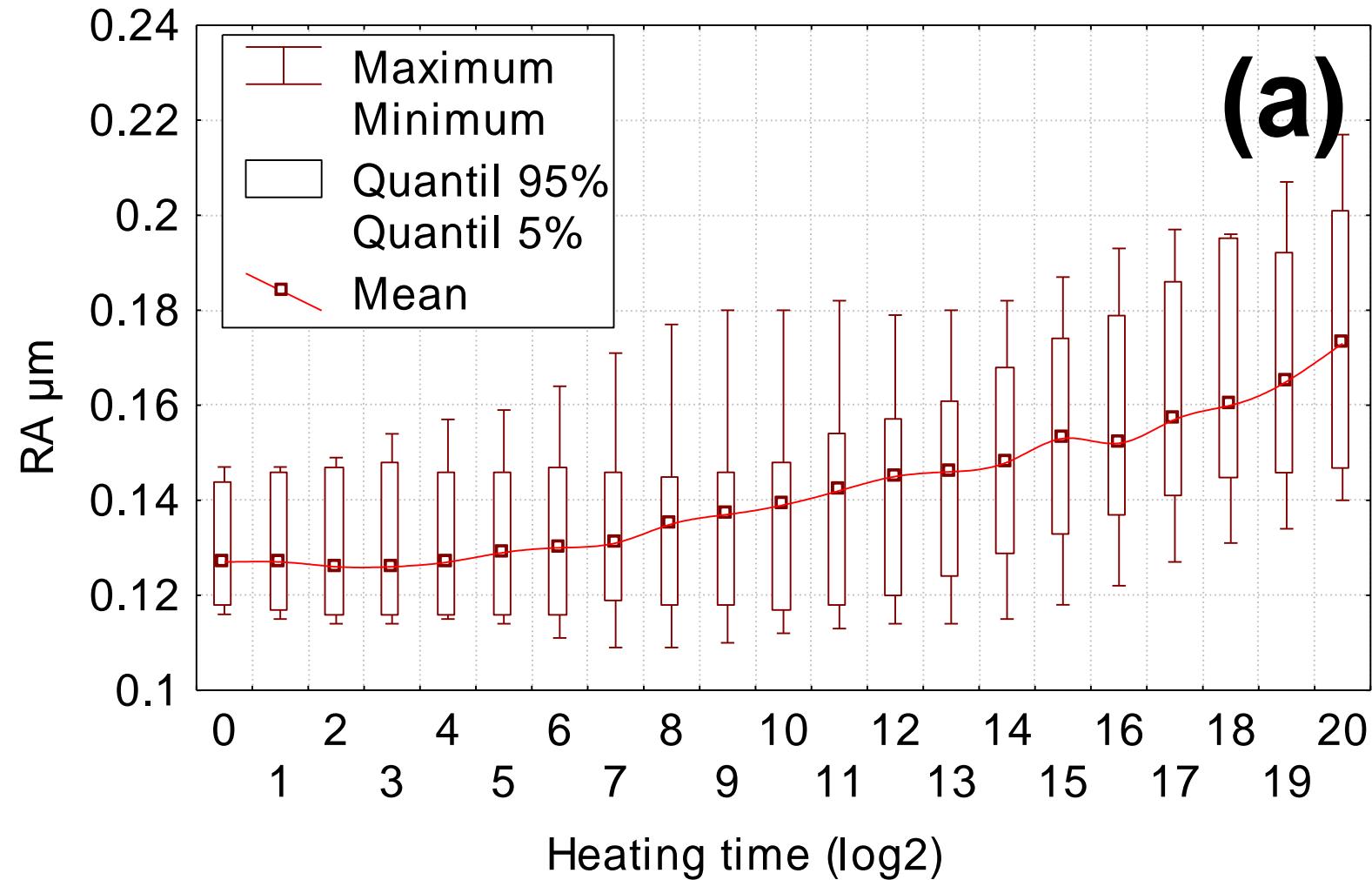




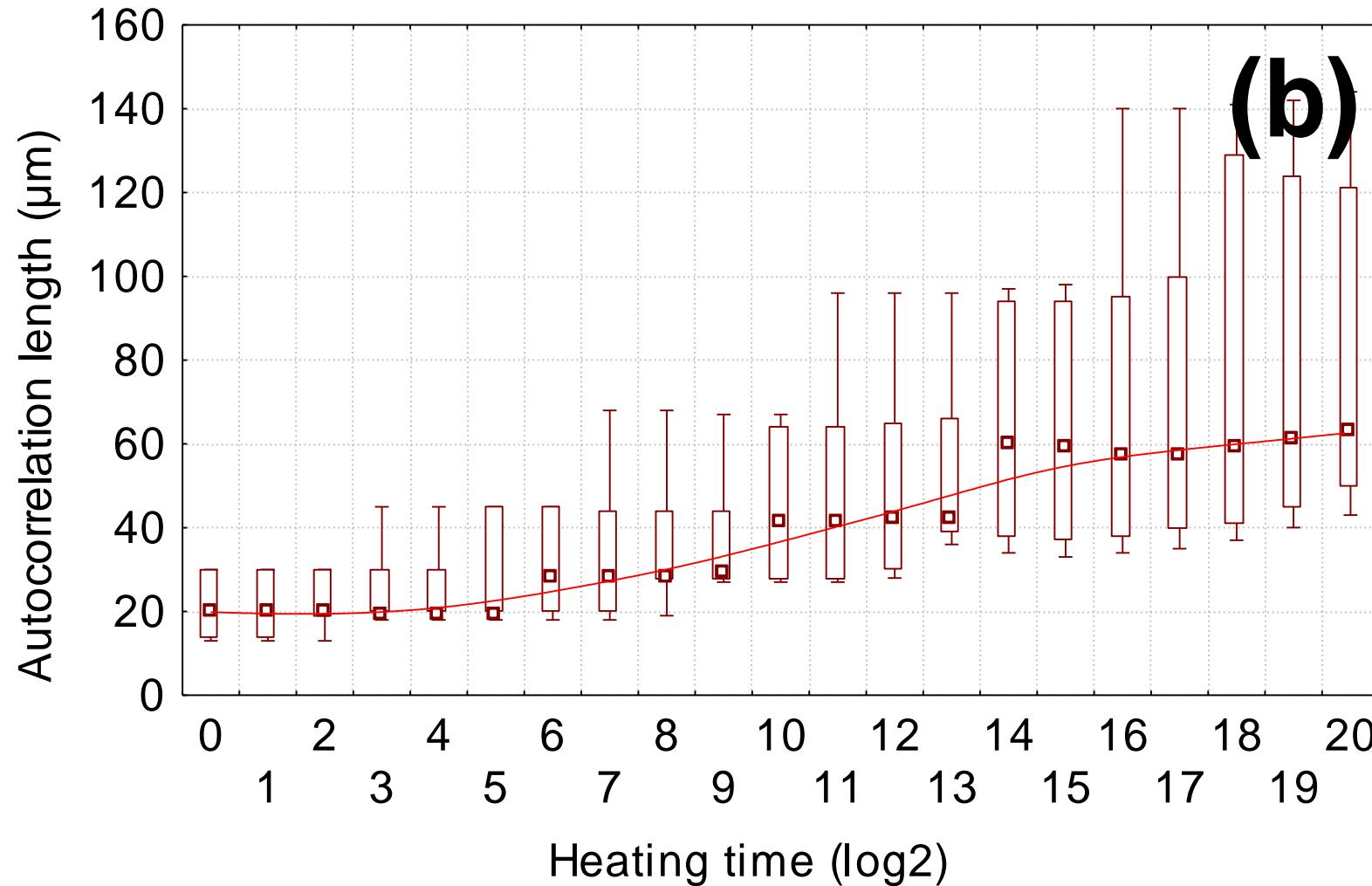




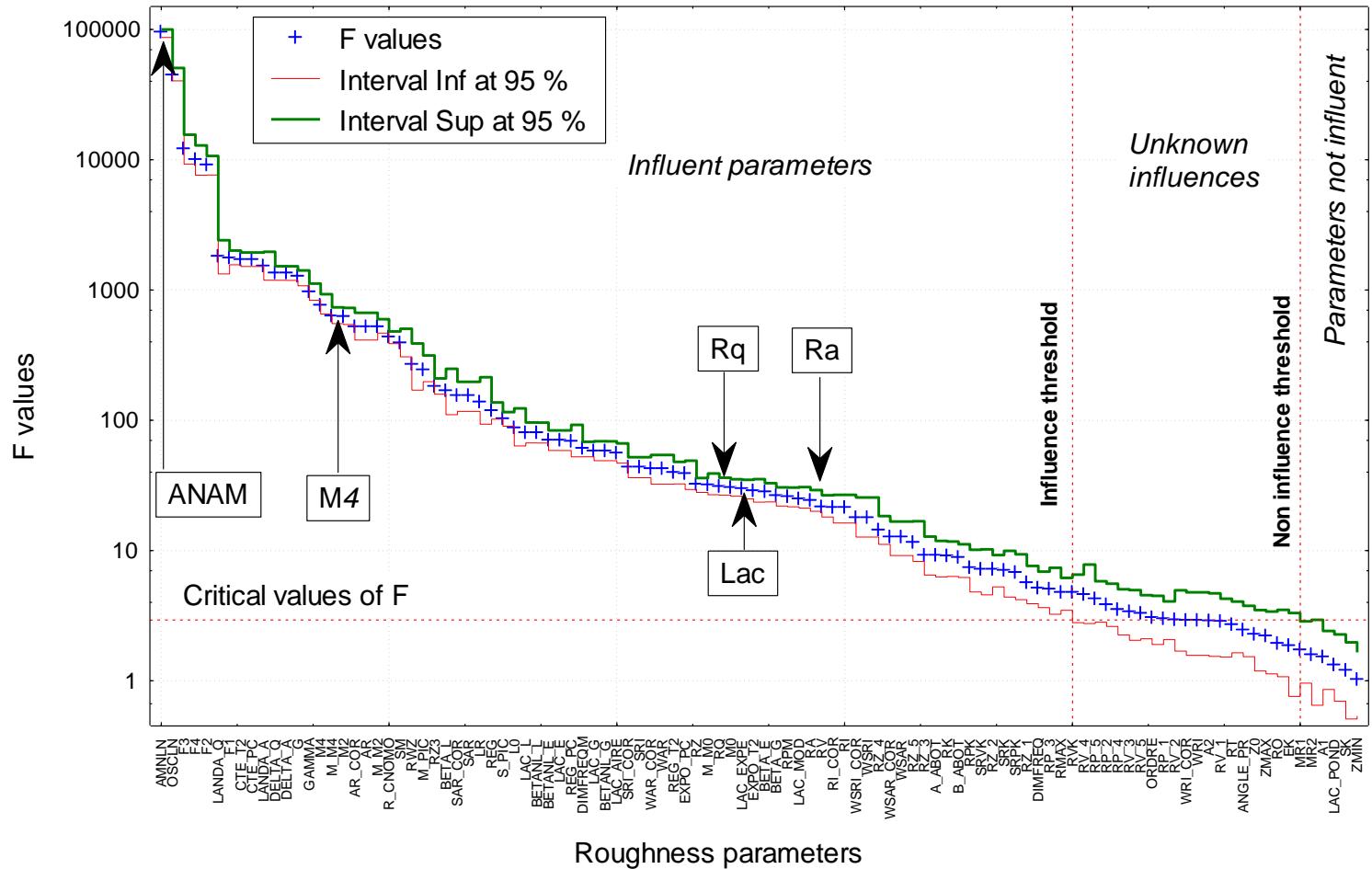
Ra



Autocorrelation length



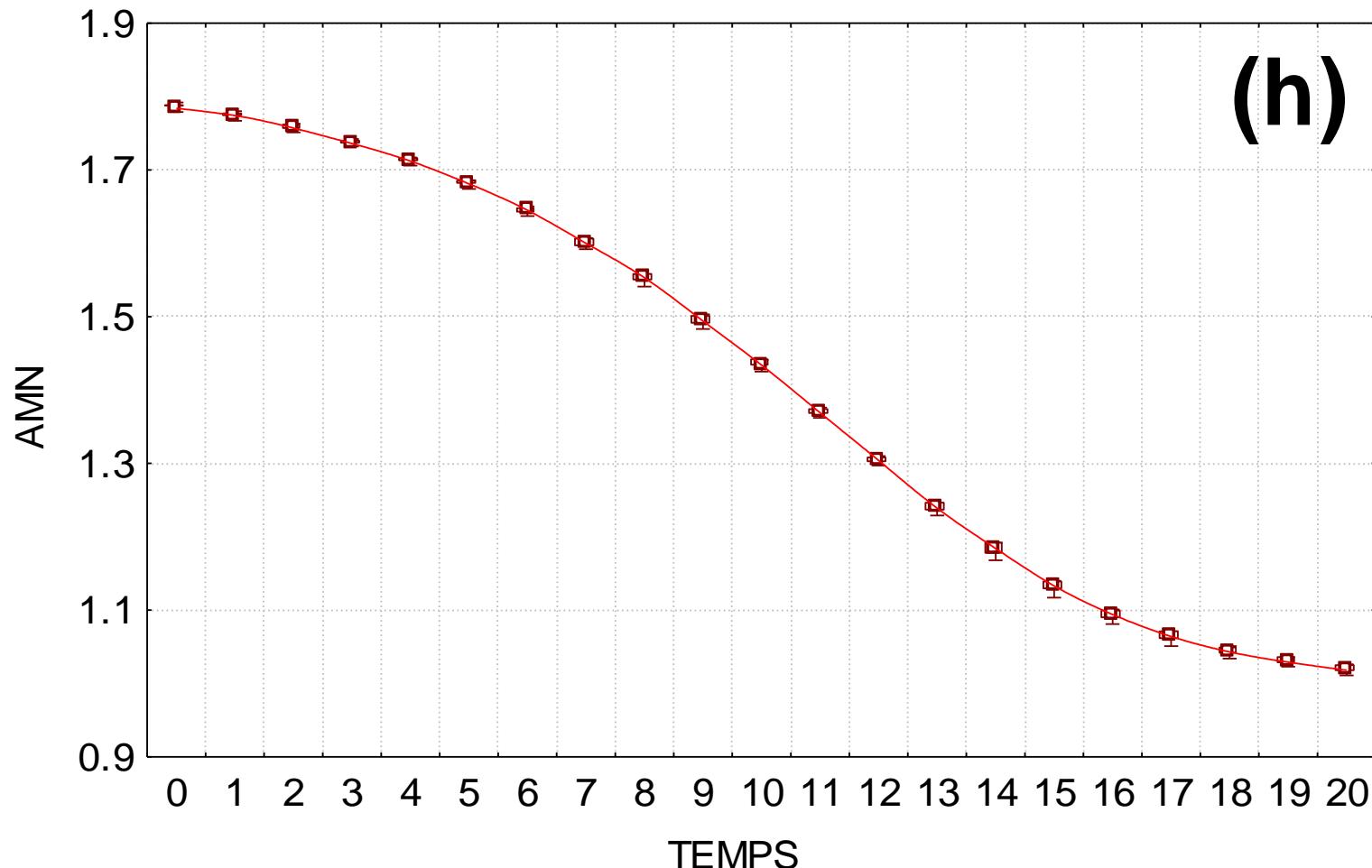
Relevancy graph of roughness (Mesrug)



ANAM fractal dimension is the best roughness parameters that characterize diffusion on rough surfaces

Best Roughness parameters

Fractal Dimension



2nd Mesrug analysis

What is the best roughness Parameter to characterize on relation between a physical surface properties and surface morphology

Method : Regression analyses on bootstrapped data for each roughness parameters

An exemple: Best roughness parameter to that involves a relation between brightness and surfaces

Relation between brightness and surface morphology

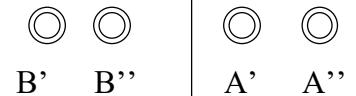
Problème : Relation brightness – Skin passed sheet (cold rolling) 3. Parameters

1. Process

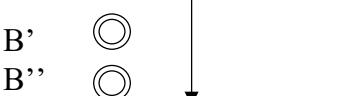
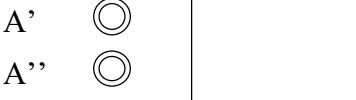
HOT-ROLLING
(SOLLAC DUNKERQUE)



4 STAND TANDEM MILL



BATCH ANNEALING



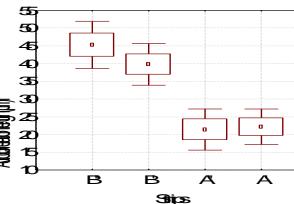
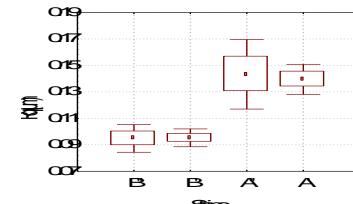
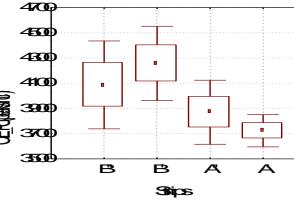
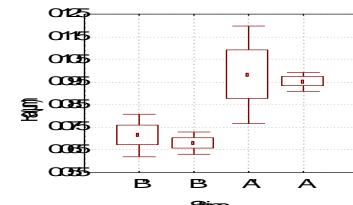
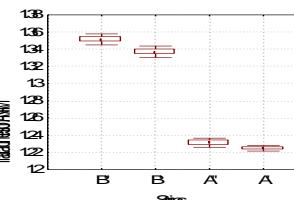
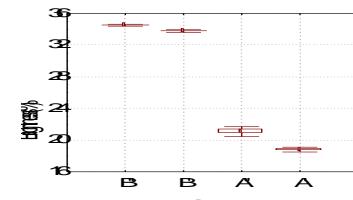
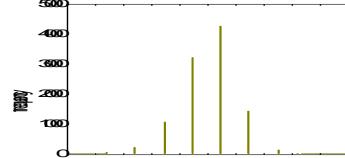
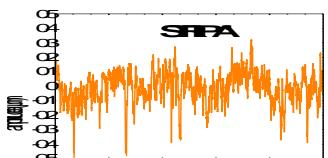
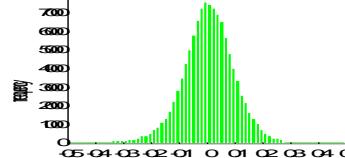
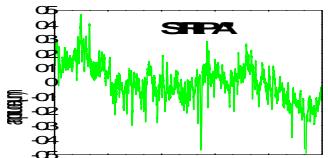
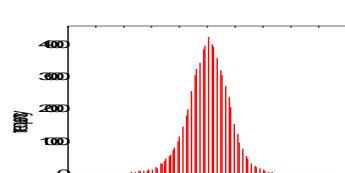
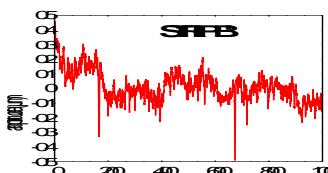
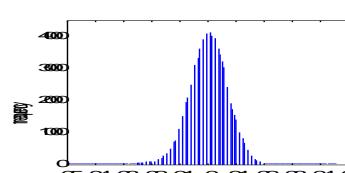
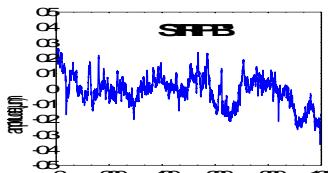
MEASUREMENTS AND
NUMERICAL TREATMENT

$$K_\tau^\alpha(f, a, b) = \frac{1}{b-a} \int_{x=a}^{x=b} \left[\frac{1}{\tau^2} \int_{t_1=0}^{\tau} \int_{t_2=0}^{\tau} |f(x+t_1) - f(x-t_2)|^\alpha dt_1 dt_2 \right]^{\frac{1}{\alpha}} dx$$

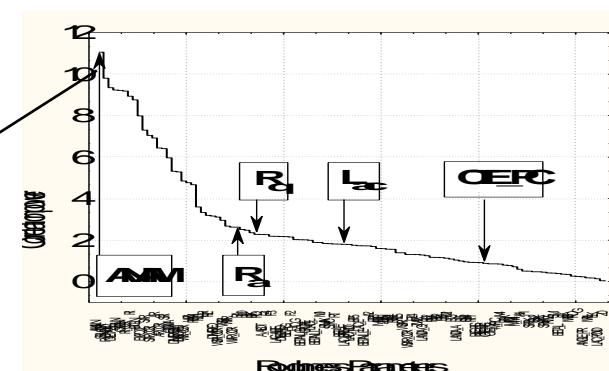
$$K_\tau^\alpha(f, a, b) = c \tau^{H(f, a, b)}$$

$$\Delta(f, a, b) = \limsup_{\tau \rightarrow 0} \left(2 - \frac{\log K_\tau^\alpha(f, a, b)}{\log \tau} \right)$$

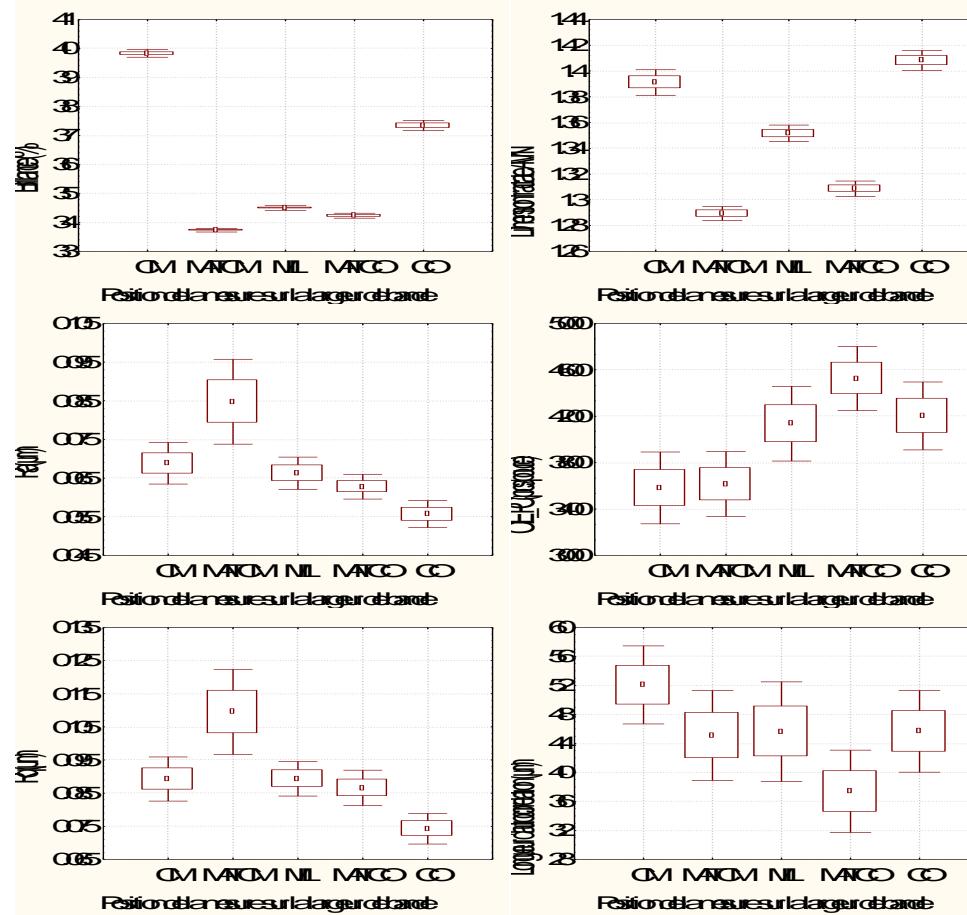
2. Roughness



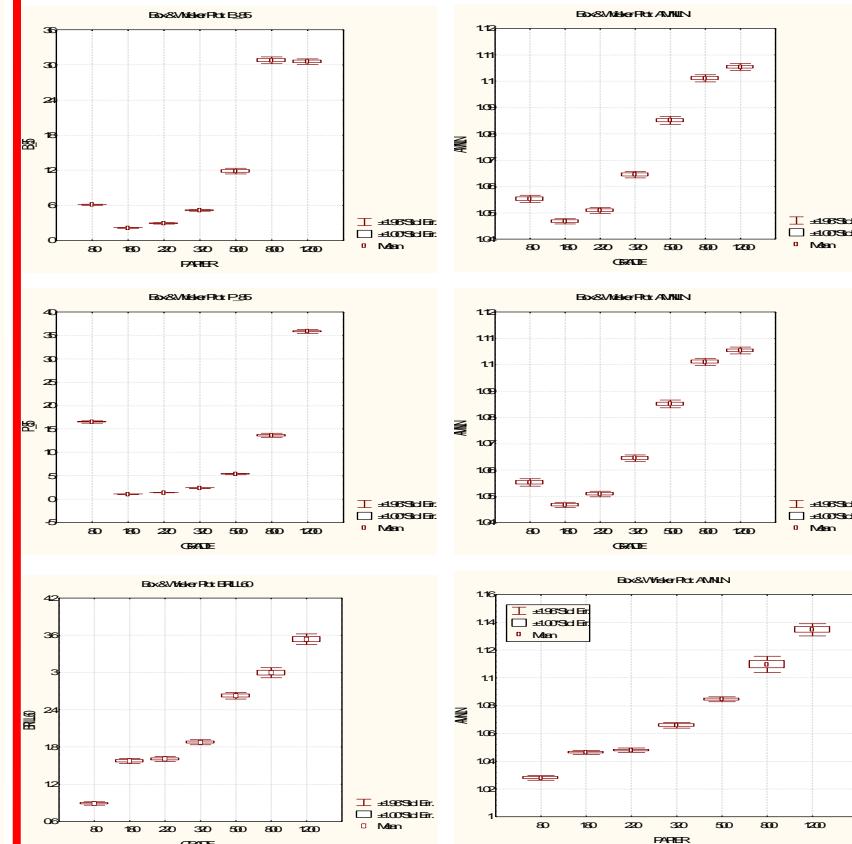
4. Parameters classification



Tooled machined surfaces

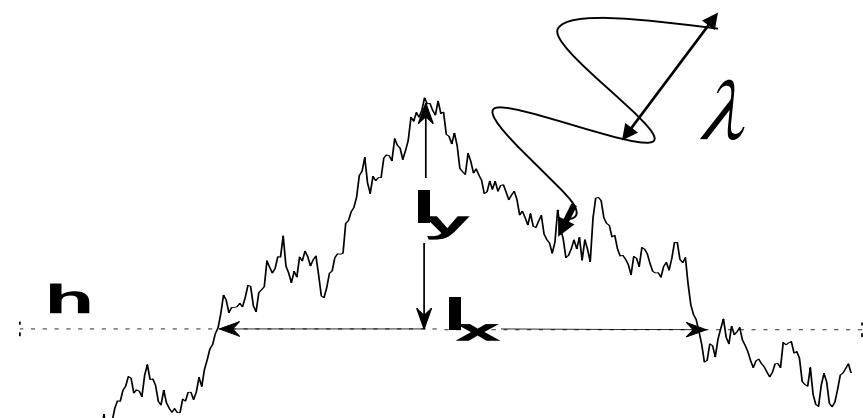
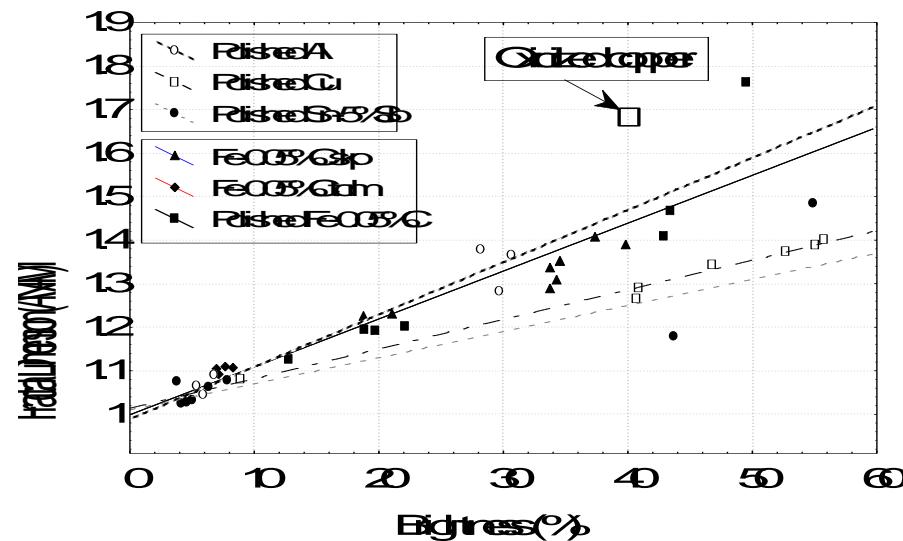


Abrasion on 3 polymers

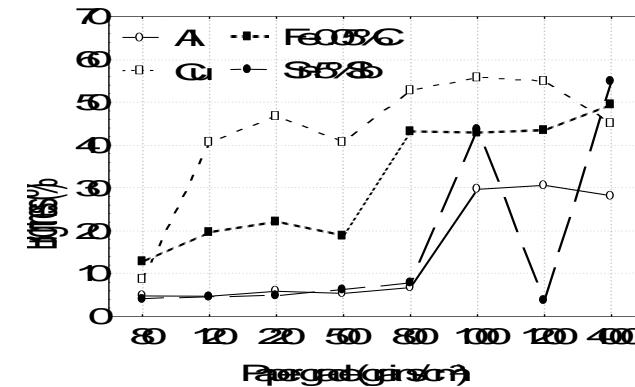
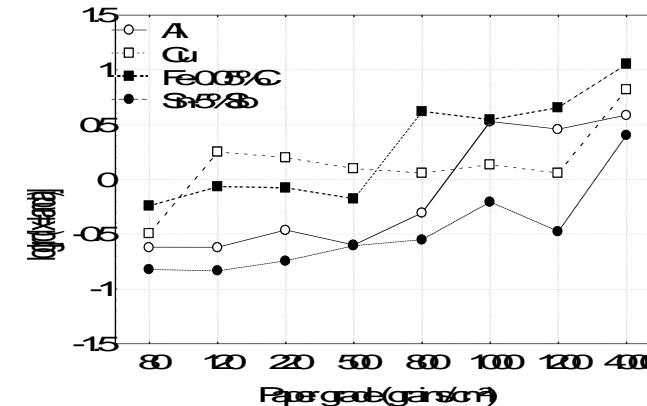


Fractal dimension by AMN method is the best parameter

Physical Explanation of Mesrug Results



$$\Delta(f, a, b) = \limsup_{l_x \rightarrow 0} (\log r_c(l_x) / \log l_x)$$



When peak curvature is evaluated at the scale of wavelength, the curvature radii increases with fractal dimension and surface appears more and more plat