Prediction of Surface Profile in CFRP Machining

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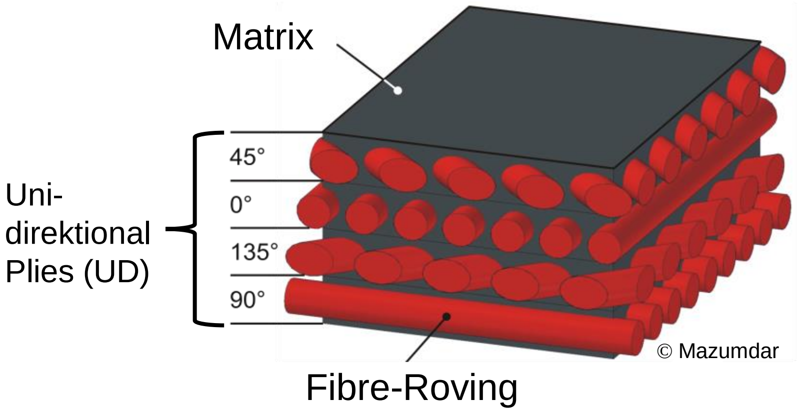
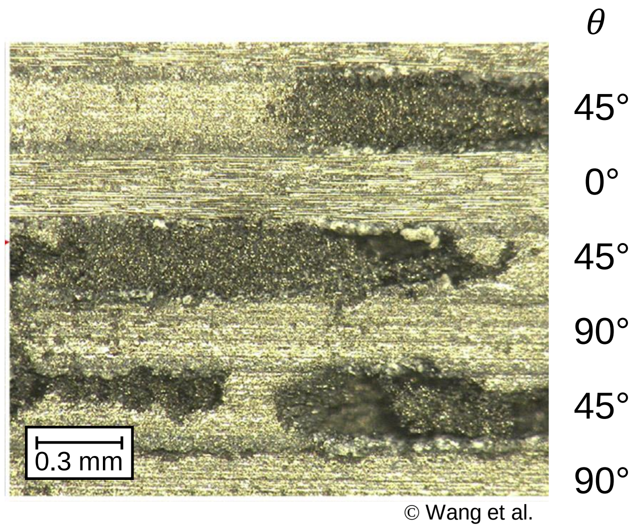
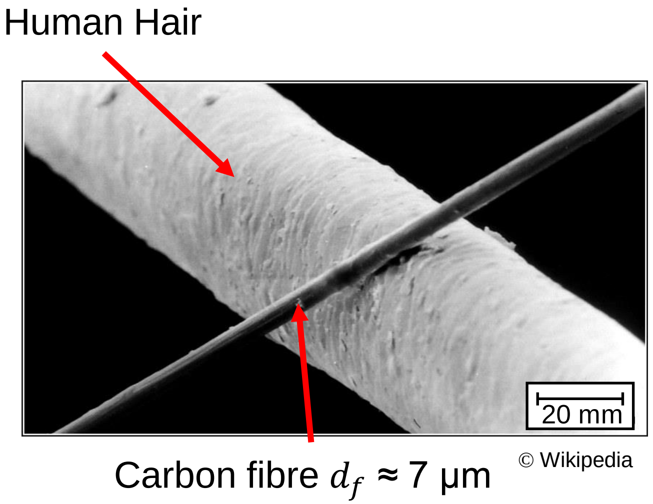
Prediction of Surface Profile in CFRP Machining

Challenges in machining of CFRP

Carbon **F**ibre **R**einforced **P**olymer





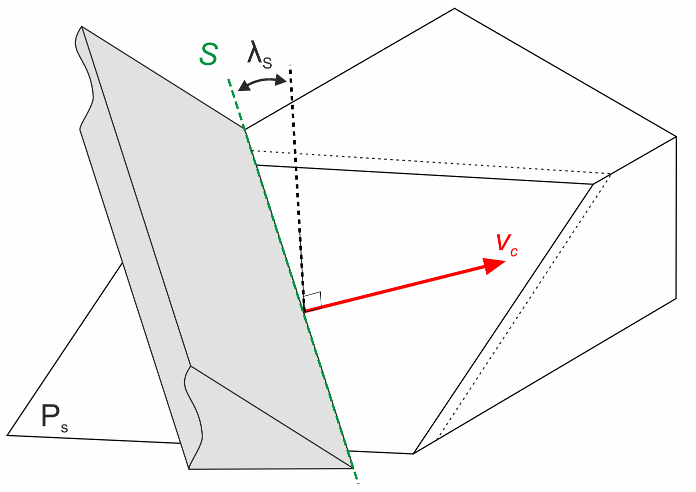


- Composite material
  - Hard fibres
  - Soft polymer matrix
- Anisotropic behaviour
- Surface integrity depends of fibre orientation

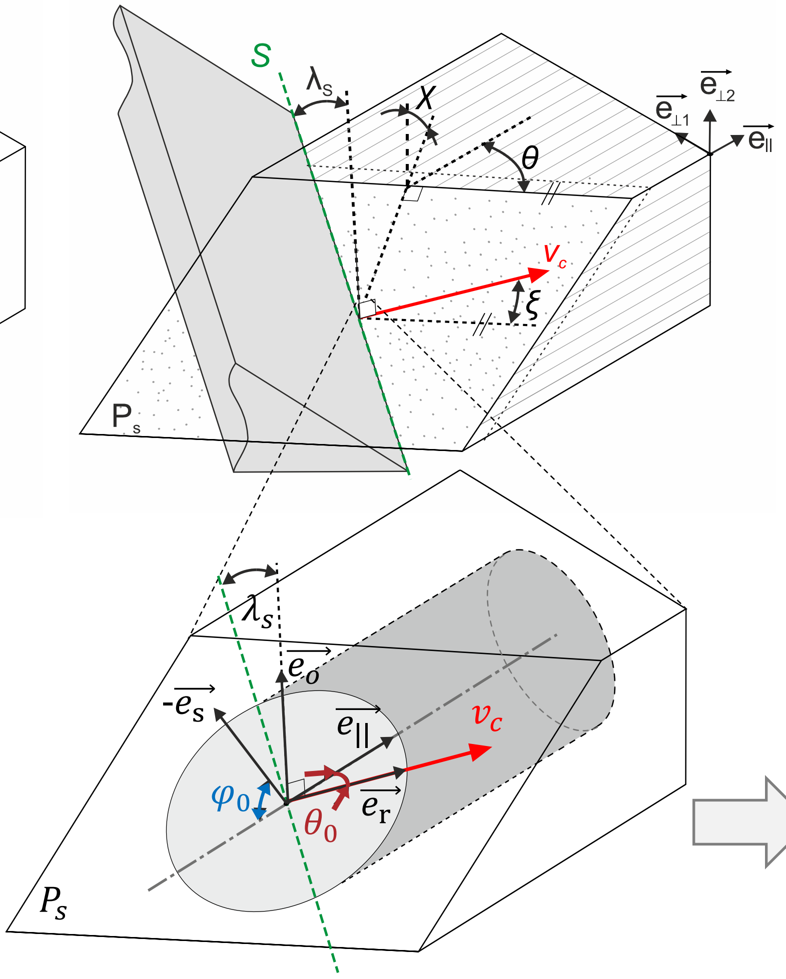
Prediction of Surface Profile in CFRP Machining

Definition of spatial engagement conditions in CFRP

Oblique cutting of **homogeneous** material

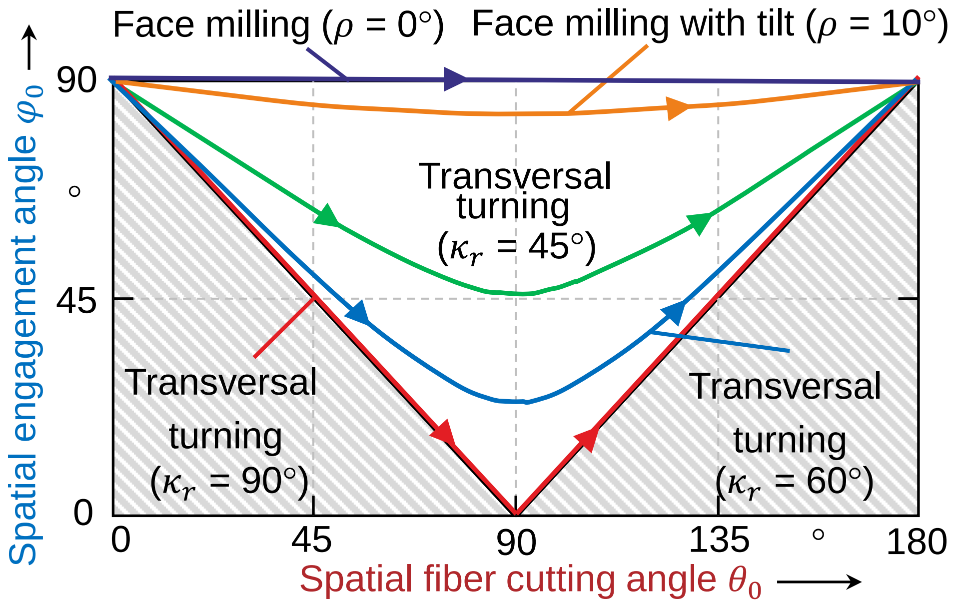


Oblique cutting of **anisotropic** material



Oblique cutting of **orthotropic** material

$\boldsymbol{P_s}$	Cutting plane
$\overrightarrow{\boldsymbol{e_s}}$	Normal vector of the cutting plane
$\overrightarrow{\boldsymbol{v_c}}$	Cutting velocity vector
$\overrightarrow{\boldsymbol{e_{\|\|}}}$	Unit vector in fibre direction
$\overrightarrow{\boldsymbol{e_{\perp 1}}}$	Unit vector in laminate plane
$\overrightarrow{\boldsymbol{e_{\perp 2}}}$	Unit vector in laminate thickness direction



Value ranges of spatial angles

Spatial engagement angle: $0° \leq \boldsymbol{\varphi_0} \leq 90°$

Spatial fiber cutting angle: $0° \leq \boldsymbol{\theta_0} \leq 180°$

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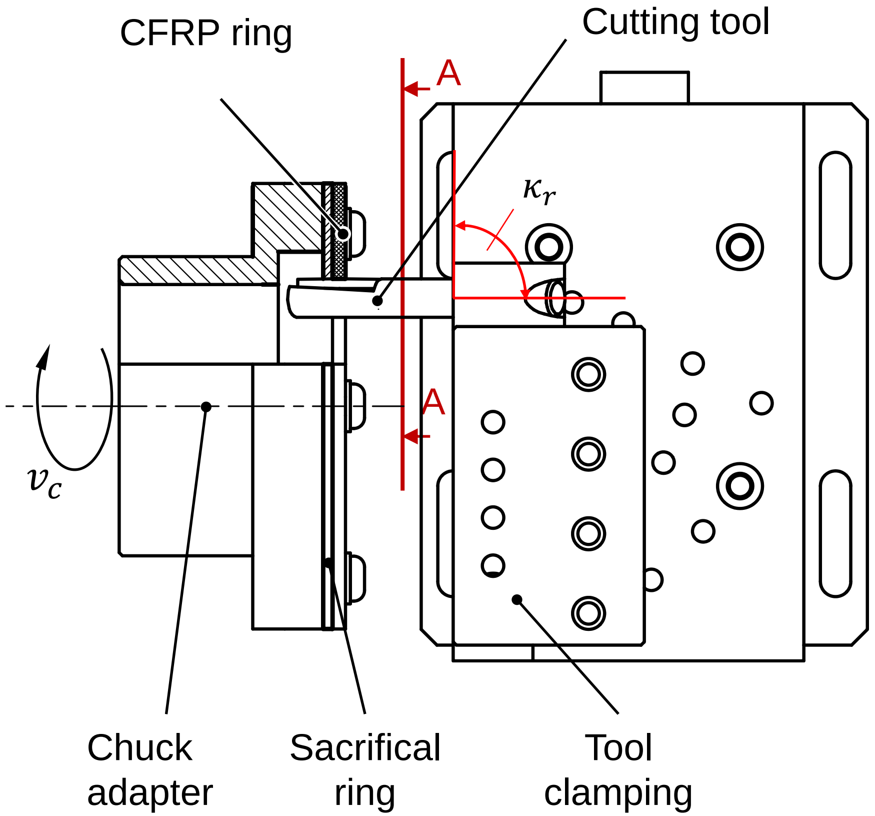
Prediction of Surface Profile in CFRP Machining

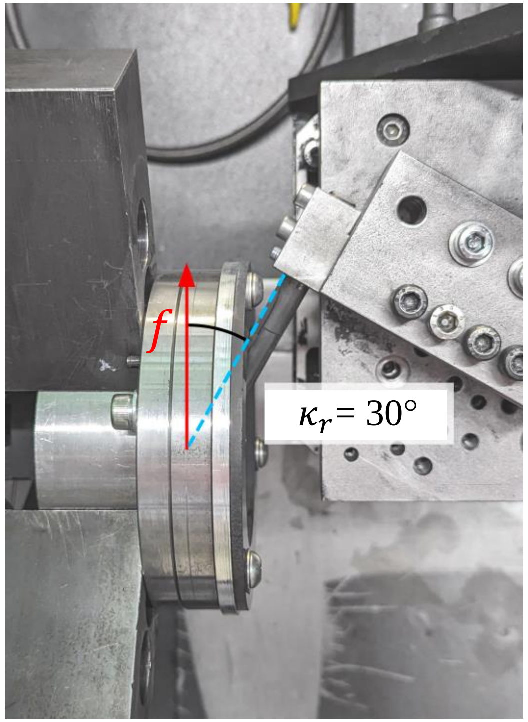
Experimental Set-up: Transversal Internal Turning

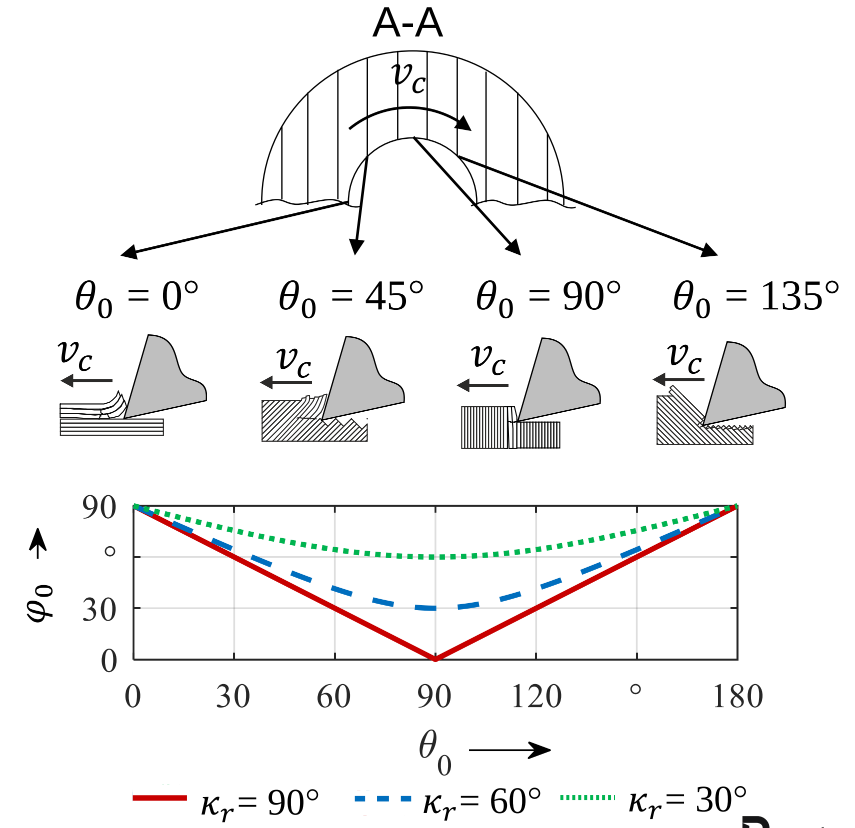
Phenomenological Analysis
Internal turning

Prediction Model
Wavelet-Transformation | Profile(θ_0,φ_0,λ)

Validation
Sidemilling | Comparison







Transversal internal turning: $\theta = 0 \ldots 180°$; $\chi = 90 - \kappa_r$; $\xi = 0°$; $\theta_0 = \theta$; $\varphi_0 = \arccos(\cos(\theta) \cdot \cos(90 - \kappa_r))$

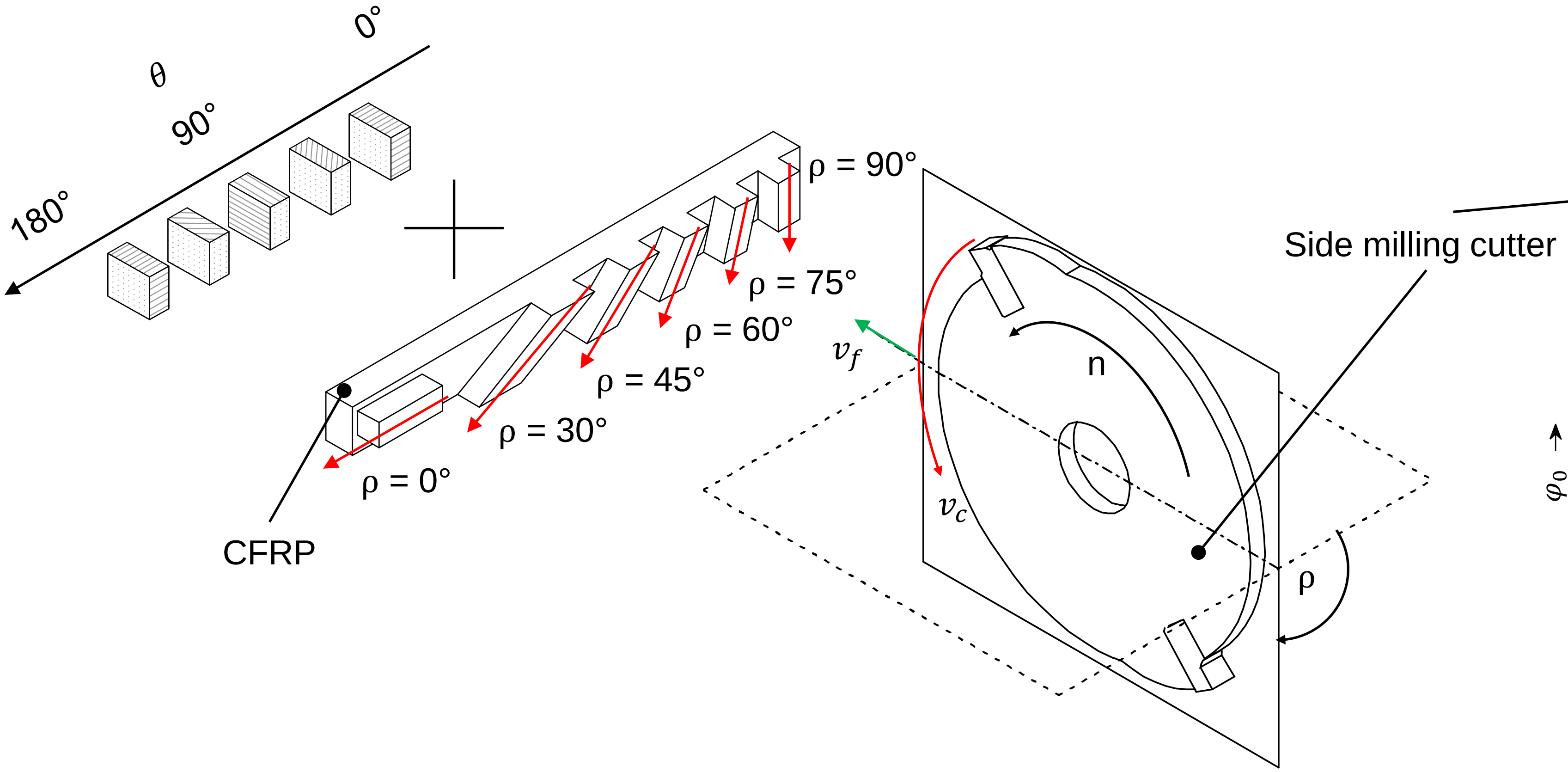
Prediction of Surface Profile in CFRP Machining

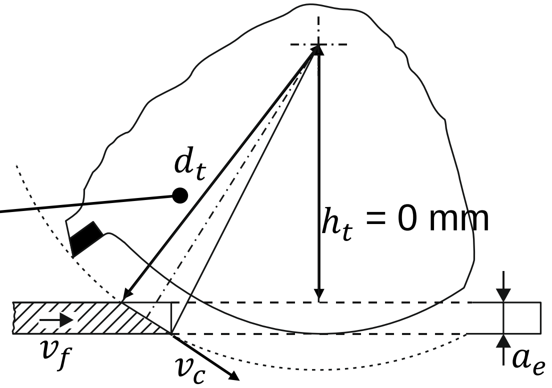
Experimental Set-up: Side milling

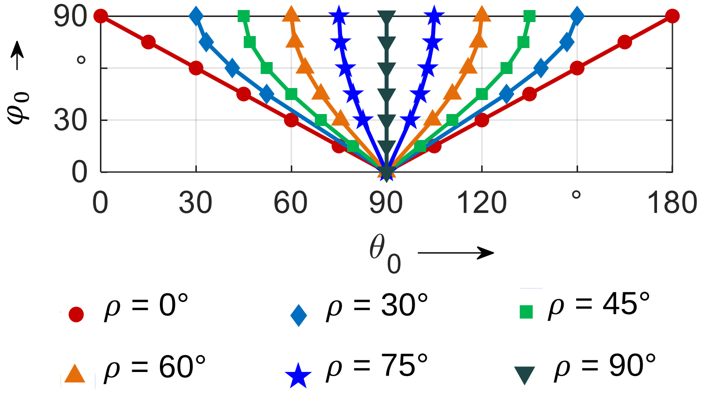
Phenomenological Analysis
Internal turning

Prediction Model
Wavelet-Transformation | Profile(θ_0,φ_0,λ)

Validation
Sidemilling | Comparison







Side milling: $\theta = 0\ldots180°$; $\chi = 0°$; $\xi = \rho$; $\theta_0 = \arccos(\cos(\theta)\cdot\cos(\xi))$; $\varphi_0 = \arccos(\sin(\theta))$

Prediction of Surface Profile in CFRP Machining

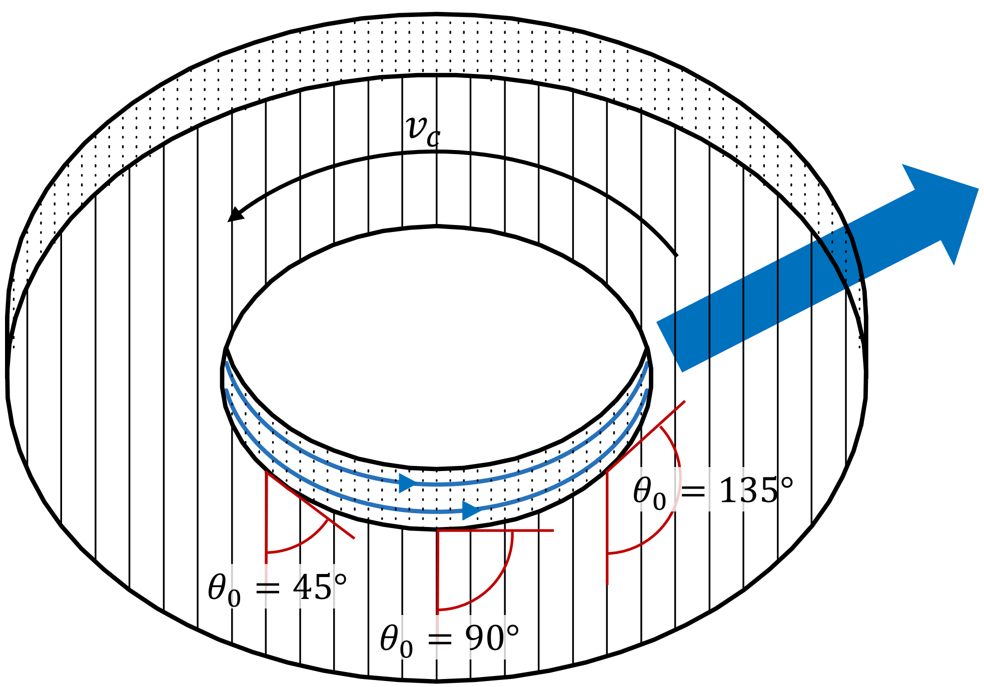
Surface Profile Analysis in dependence of fibre cutting angle θ

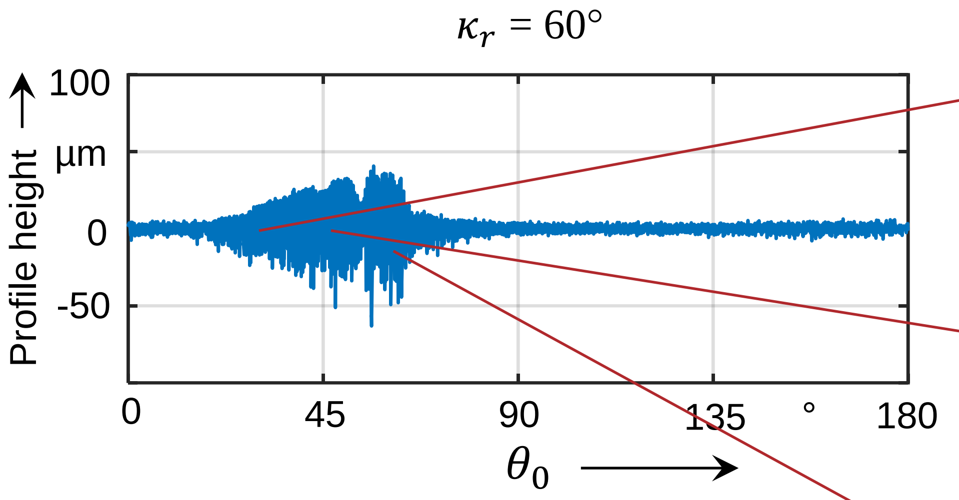
Phenomenological Analysis
Internal turning

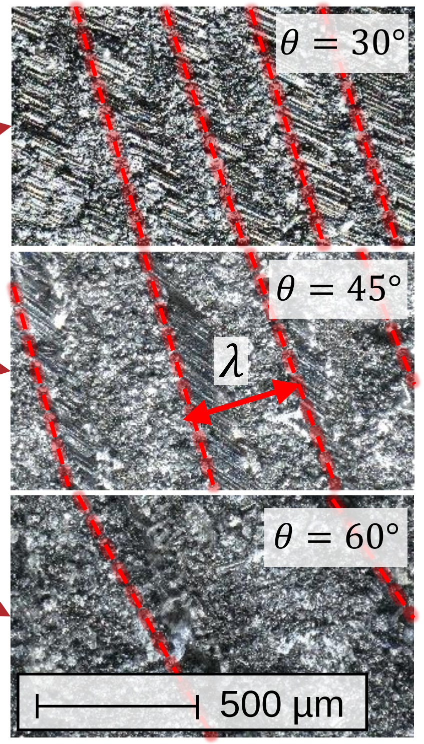
Prediction Model
Wavelet-Transformation | Profile(θ_0,φ_0,λ)

Validation
Sidemilling | Comparison

Tactile measurement







Process:

a_p	=	4	mm
v_c	=	50	m/min
h	=	0.04	mm
κ_r	=	60	°
α_o	=	6	°
γ_o	=	10	°

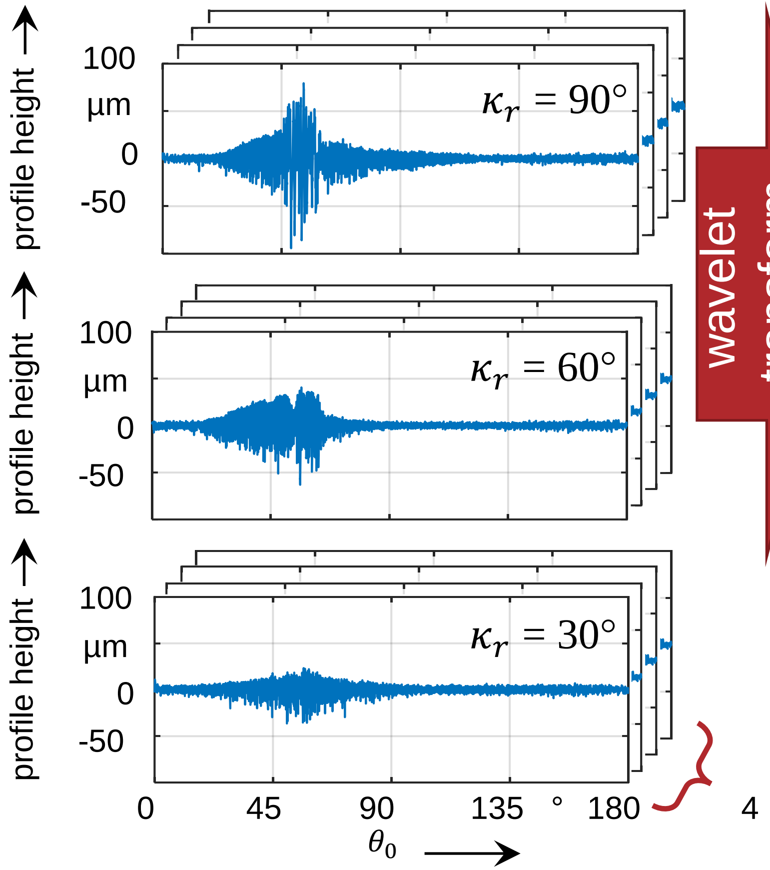
Material:	CFRP
Orientation:	UD
Matrix:	Hexply 6376
Fibre:	HTS (12K)
Substrate:	HF-N10
Coating:	Diamond

→ v_c
maximum profile height

Prediction of Surface Profile in CFRP Machining

Assembly of the prediction model

Phenomenological Analysis
Internal turning

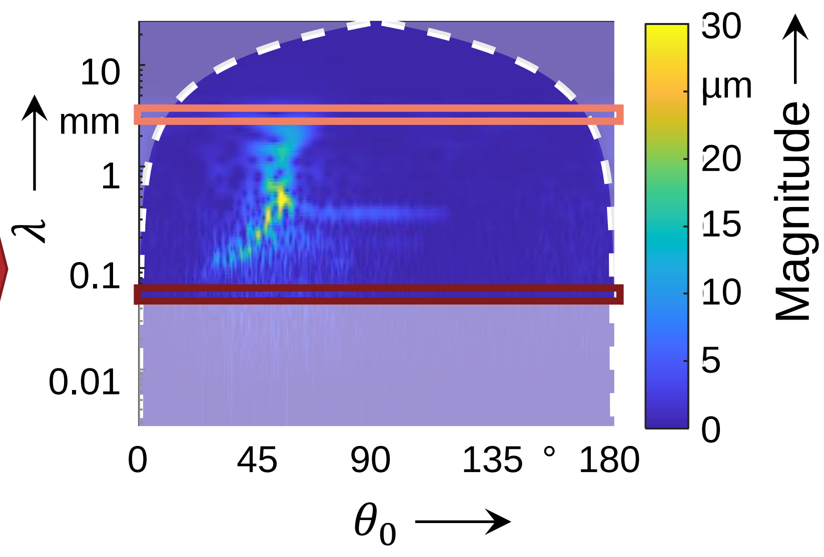


wavelet transform

Prediction Model

Wavelet-Transformation

Profile(θ_0,φ_0,λ)

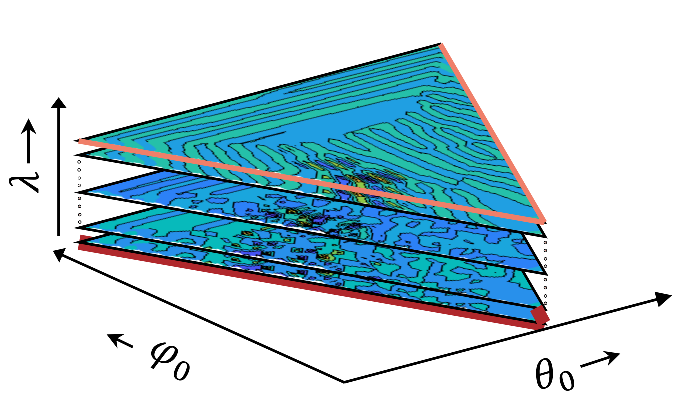


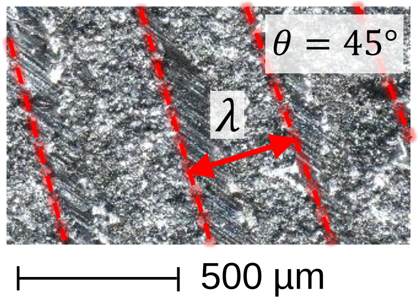
Interpolation for each λ

Validation

Sidemilling

Comparison





Process:

a_p	=	4	mm
v_c	=	50	m/min
h	=	0.04	mm
κ_r	=	var.	°
α_o	=	6	°
γ_o	=	10	°

Material:	CFRP
Orientation:	UD
Matrix:	Hexply 6376
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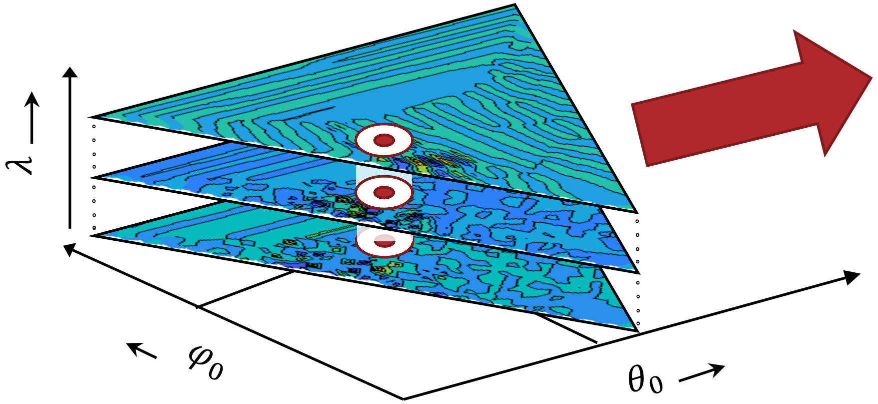
Prediction of Surface Profile in CFRP Machining

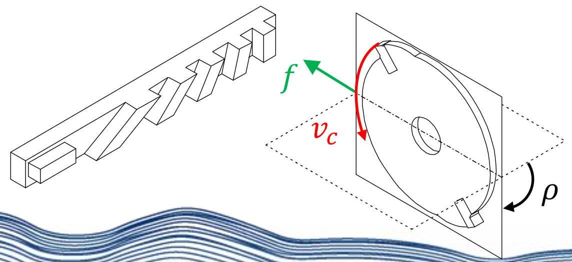
Forecast for specific engagement conditions

Phenomenological Analysis
Internal turning

Selection of the engagement conditons for a specific side milling process



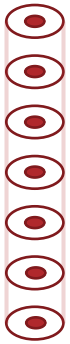
θ = 30°; ρ = 45 °
θ_0 = 54°; φ_0 = 60°



Prediction Model
Wavelet-Transformation

Profile(θ_0,φ_0,λ)

Interpolated data for each λ



Inverse wavelet transform

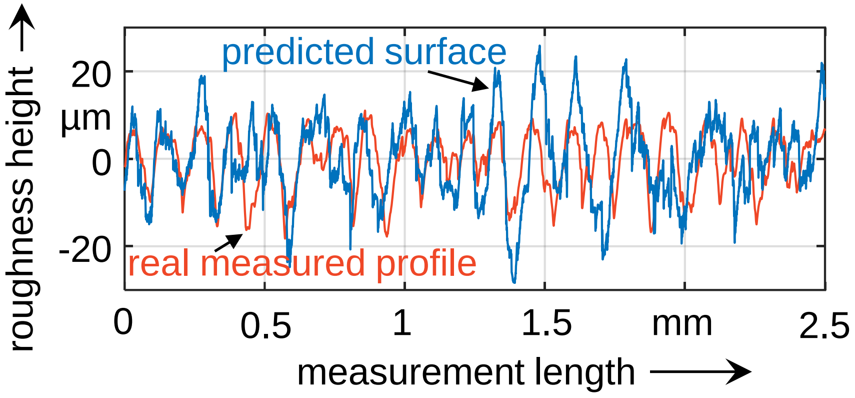
Process:

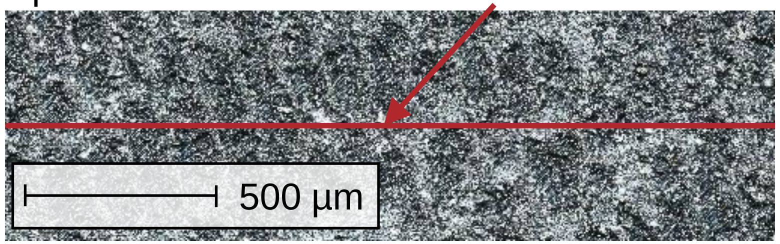
a_p	=	6	mm
v_c	=	50	m/min
h	=	0.04	mm
h_t	=	0	mm
α_o	=	6	°
γ_o	=	10	°

Material:	CFRP
Orientation:	UD
Matrix:	Hexply 6376
Fibre:	HTS (12K)
Substrate:	HF-N10
Coating:	Diamond

Validation
Sidemilling

Comparison





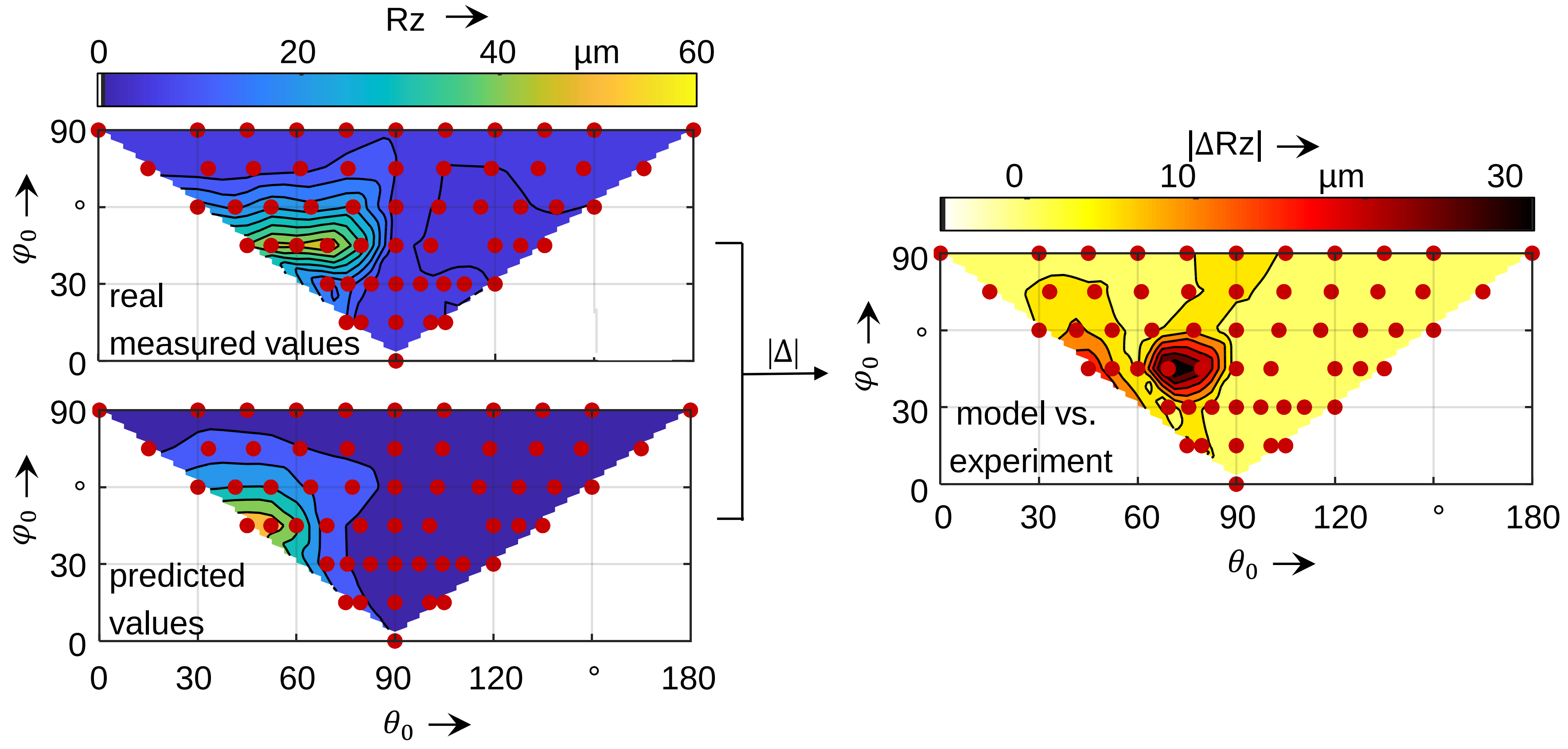
Prediction of Surface Profile in CFRP Machining

Comparison of predicted roughness and measured roughness

Phenomenological Analysis
Internal turning

Prediction Model
Wavelet-Transformation | Profile(θ_0,φ_0,λ)

Validation
Sidemilling | **Comparison**



Process:

a_p	=	6	mm
v_c	=	50	m/min
h	=	0.04	mm
h_t	=	0	mm
ρ	=	var. °	
α_o	=	6	°
γ_o	=	10	°

Material: CFRP
Orientation: UD
Matrix: Hexply 6376
Fibre: HTS (12K)

Substrate: HF-N10
Coating: Diamond

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Conclusions

- Data generated with one process can be used to predict other processes
- Process-independent predictions are feasible
- Good Agreement for process-independent prediction

Outlook

- Inclusion of other process parameters e.g. uncut chip thickness h
- Inclusion of kinematic roughness for milling operations
- Testin the model with different machining processes

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Thank you for your kind attention !

Prediction of Surface Profile in CFRP Machining through Phenomenological Analysis and inverse Continuous Wavelet Transformation

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