Interreg
EVROPSKÁ UNIE
Rakousko-Česká republika
Evropský fond pro regionální rozvoj

ATCZ276 – ROTCUT
„From Linear to Rotary Cutting of Hardwood”

KICK-OFF MEETING 1.12.2021 11:00 MSTeams

MENDELU - Mendel University in Brno
KPLUS - Kompetenzzentrum Holz GmbH
BUT - Brno University of Technology

EVROPSKÁ UNIE

Mendel University in Brno

WOOD KPLUS

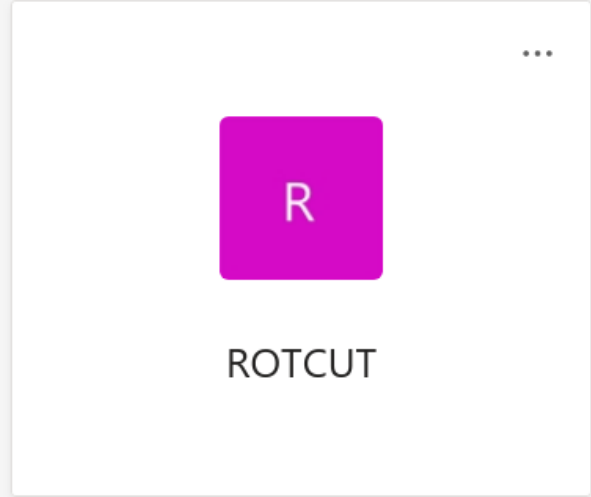
BRNO UNIVERSITY OF TECHNOLOGY

Spolufinancován z prostředků Evropského fondu regionálního rozvoje

From HARDIS to ROTCUT Team (2017-2021)

ROTCUT: **7 @ MENDELU (1+3R, 1M, 2T)**
6 @ KPLUS (1+2R, 1A, 2T)
6 @ BUT (1+5R)

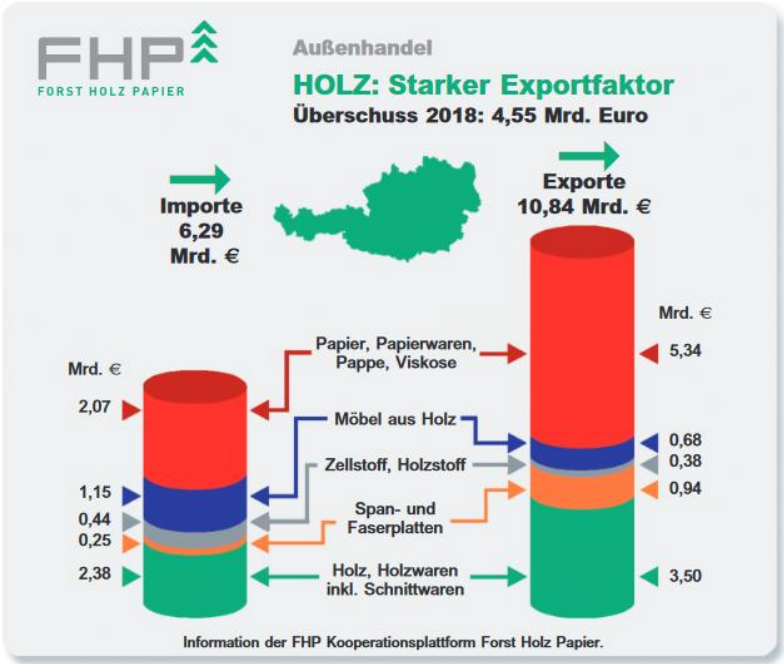
Luďka Hlásková, Petra Krejčí, Ondřej Dvořáček, Daniel Lechowicz, František Šebek, Petr Kubík, Martin Brabec, Jiří Valenta, Jiří Procházka, Jaromír Salák, Pavel Kubáč and Jan Tippner

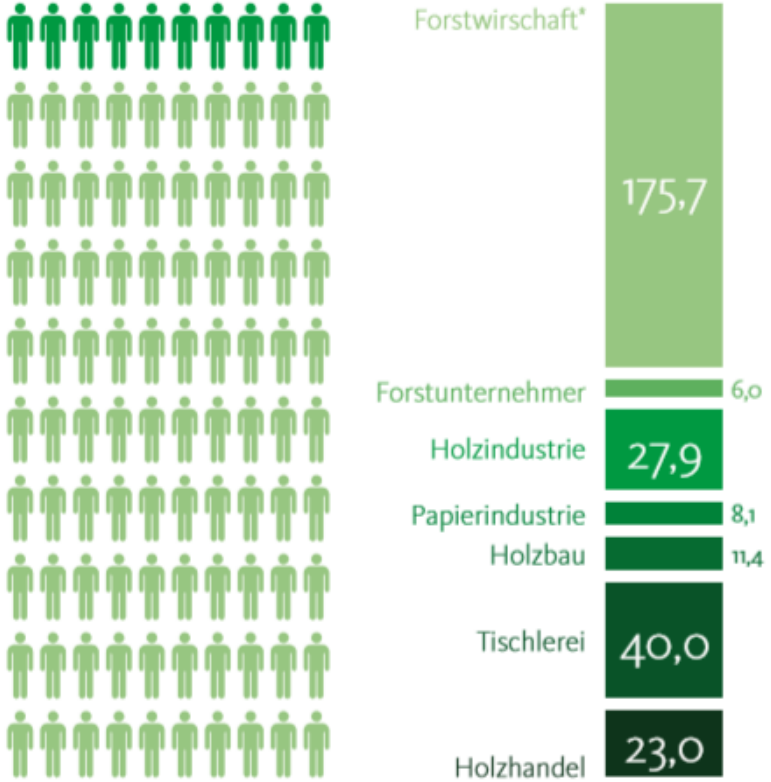


Motivation

The Wood Processing Industry is very important for both regions

(after tourism, the second largest industry in Austria)





*) *Personen, die ganz oder teilweise ihr Einkommen aus der Waldbewirtschaftung erzielen (Waldeigentümer, Angestellte, Arbeiter, öffentlicher Dienst, etc.)*

Quelle: FHP Kooperationsplattform Forst Holz Papier

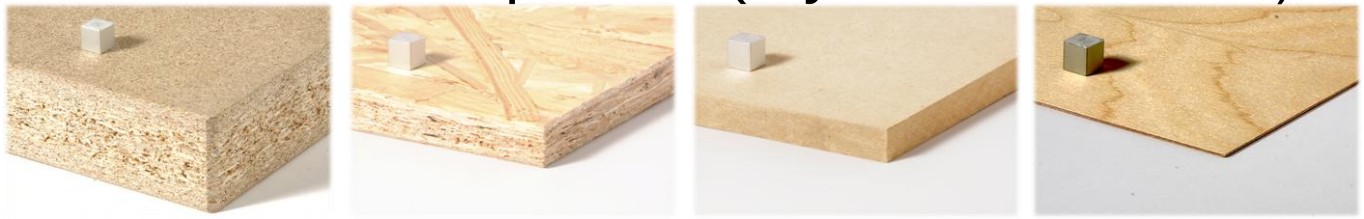
Motivation

… current wood industry specialized in softwood (spruce)

- Sawmills

https://www.egger.com/shop/de_LI/ueber-uns/umwelt/saegewerk

- Wood Based Composites (Plywoods, OSB,…)



http://www.materialarchiv.ch

- Wooden Buildings

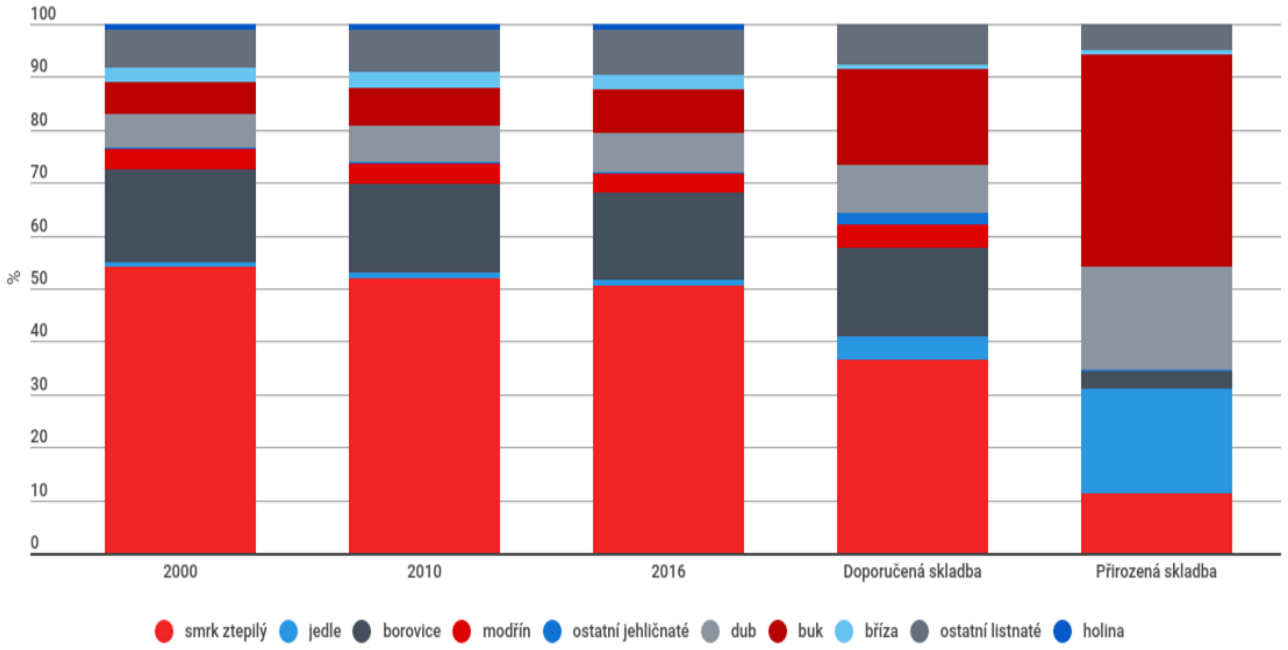
KLH Massivholz GmbH

www.woschitzgroup.com

www.panelsfurnitureasia.com

Due the long-term strategy in forestry policy and the current rapid changes in the forests of Central Europe, the importance of hardwood processing is growing significantly.

Tree species compositions in CZ forests *(source ČSÚ)*



Spruce

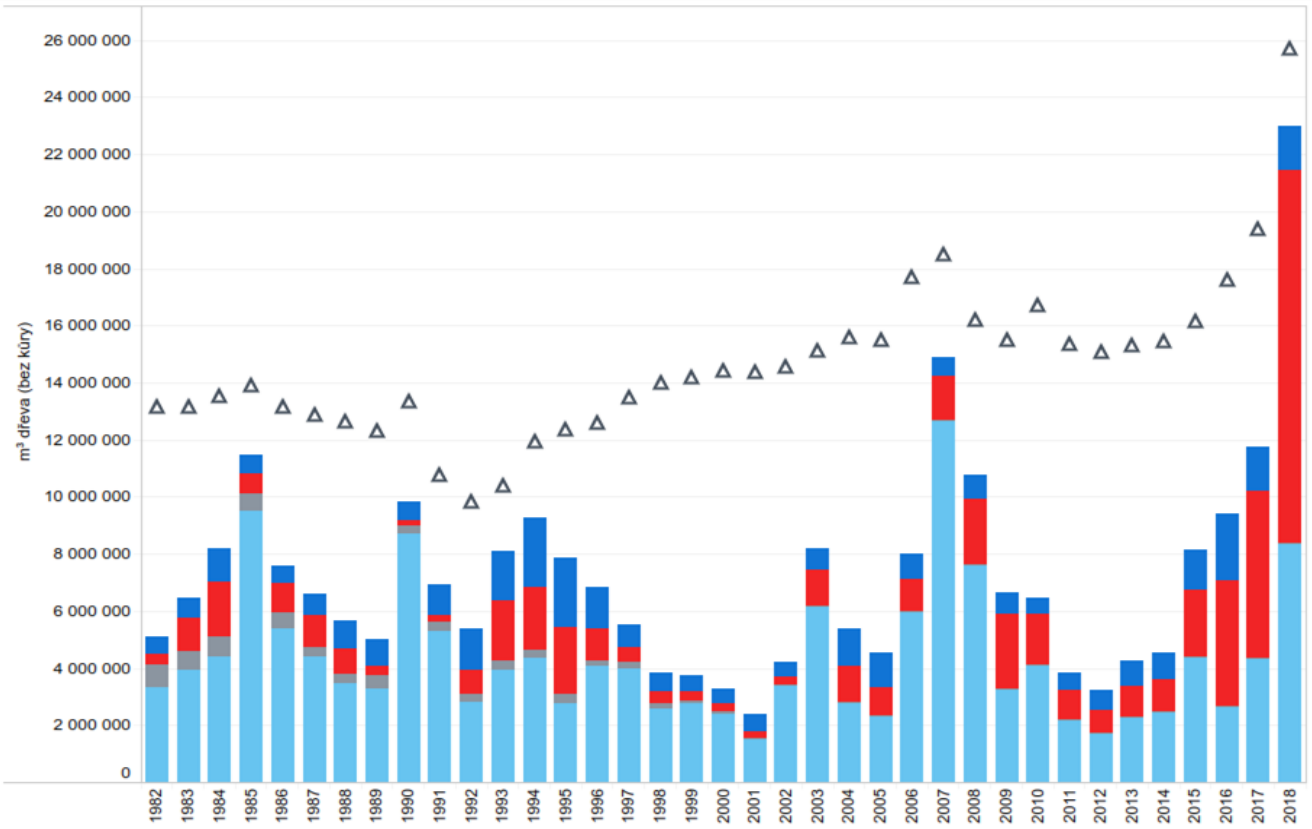
Beech

beech in natural forests: 40.2% vs. now 8.6% with increase (simillar for oak, lime-tree)

Changes accelerated with Bark Beetle Calamity

- synergy with droughts and stormy winds

Increase of logging in CZ forests *(source ČSÚ)*



Bark beetle @ Spruce

The softwood **stocks were destroyed** in the last 4 years.

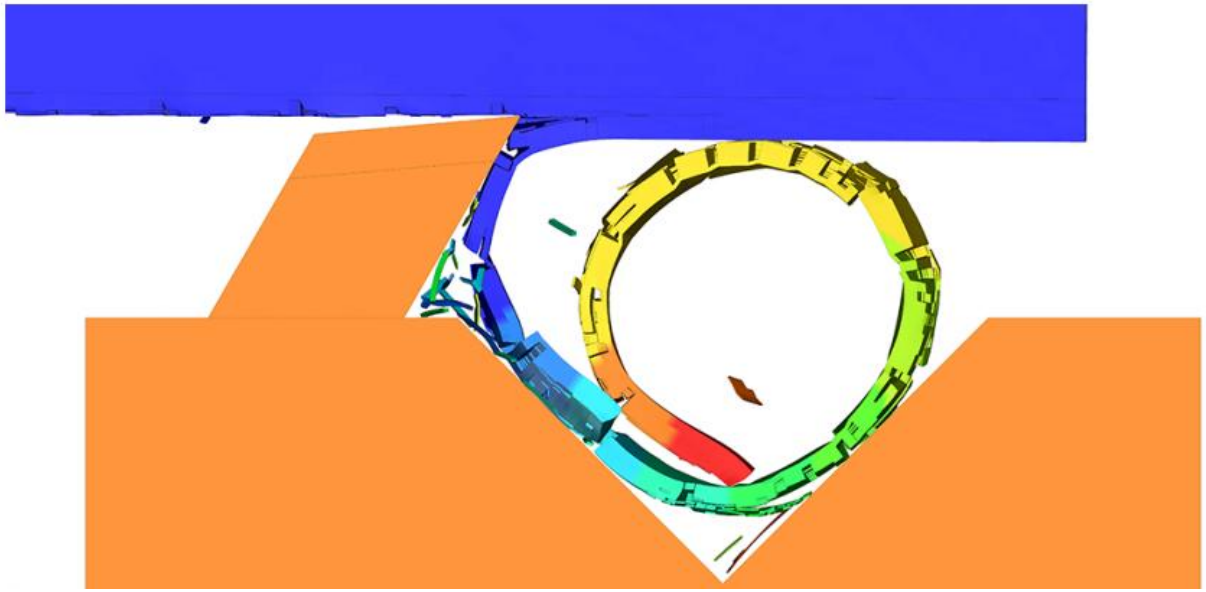
In 2019, for the first time in history**, more deciduous trees** (14.7 ths. ha) were planted than conifers (14.0 ths. ha) in CZ.

At the **same time, the HARDIS team** made a great progress in the high-speed machining of hardwood.

Motivation & Goals

- mechanical disintegration is a **key wood processing process**, forestry: shift away from coniferous monocultures accelerated by **rapid changes** (4yrs. calamity)
- HARDIS: great progress in describing the **high-speed disintegration** of hardwood – almost **LINEAR**
- ROTCUT: more complex **rotary machining** (widespread, CNC etc.), to develop **theoretical and experimental** methods for the analysis
- the **unique equipment** of the HARDIS project will be adapted for new experiments
- influence of rotary **machining factors** - different cutting directions, speed, material, etc.
- **3D force measurement**, **high-speed camera** scanning and deformation image analysis (**DIC**)
- **FE model** for numerical simulation (experimentally **validated**) - identify optimal cutting conditions
- results disseminated: **companies, clusters, educational and research institutions** (digital activities, promotional materials, workshop, article and conference)

To achieve clear research goals, the complex machining had to be **simplified to cases of almost linear** machining.

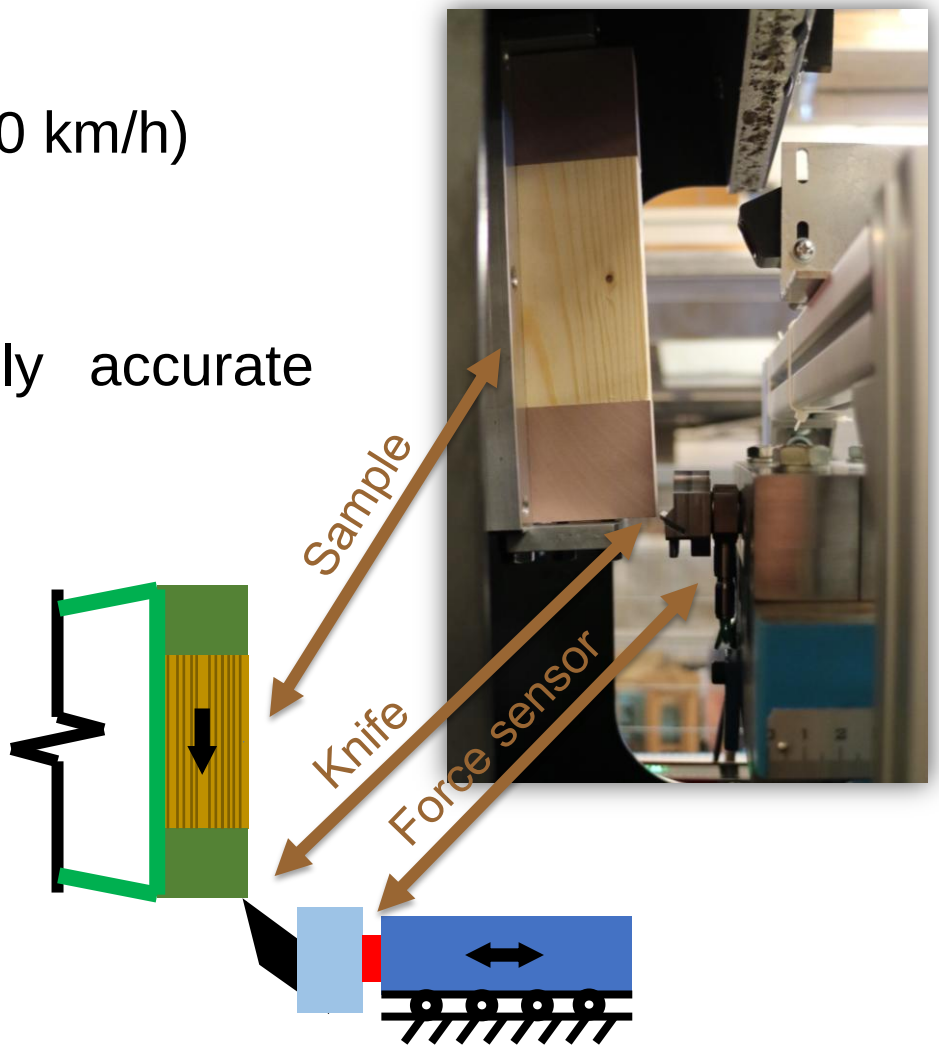


Natural **future step** for the know-how application is to expand the activities to **rotary machining** - much more complex and very common form of machining (incl. CNC in all sizes companies).

Measuring device (HARDIS ATCZ21 2017-2020)

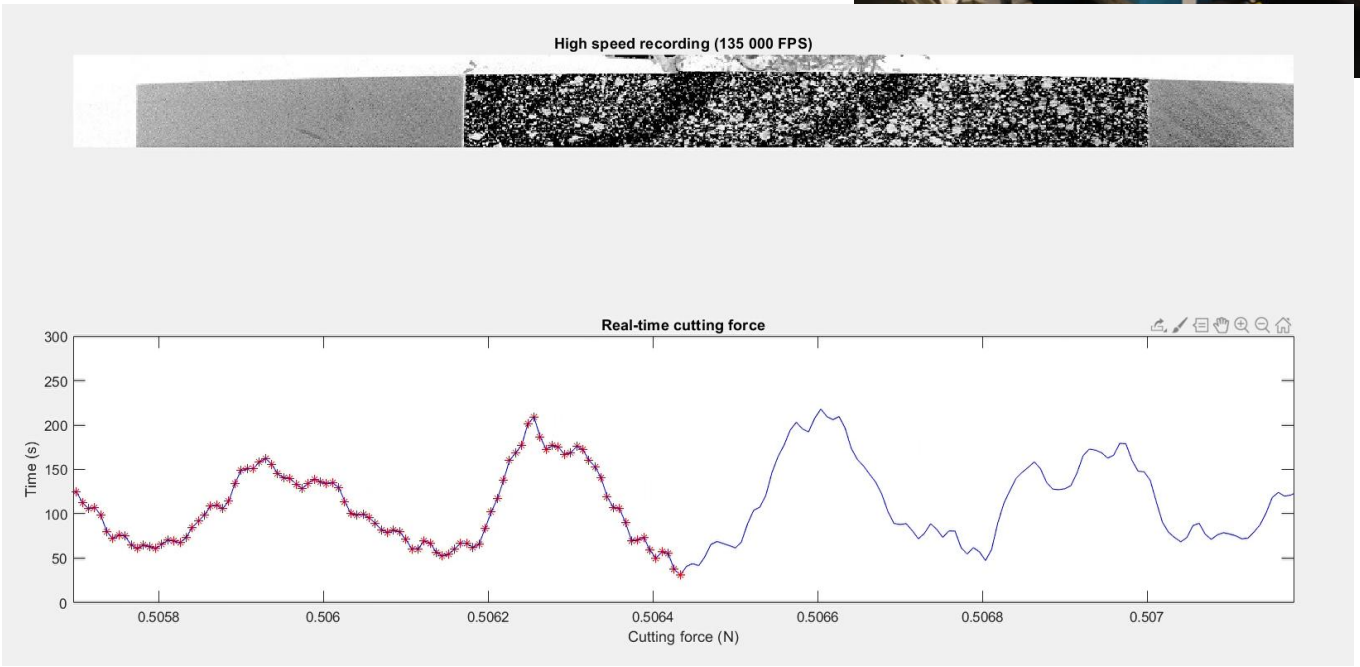
- Approximation of linear cut
- Cutting speed 100 m/s (=360 km/h)
- Stiff construction
- Static tool – knife

→ Ideal conditions for highly accurate measurements



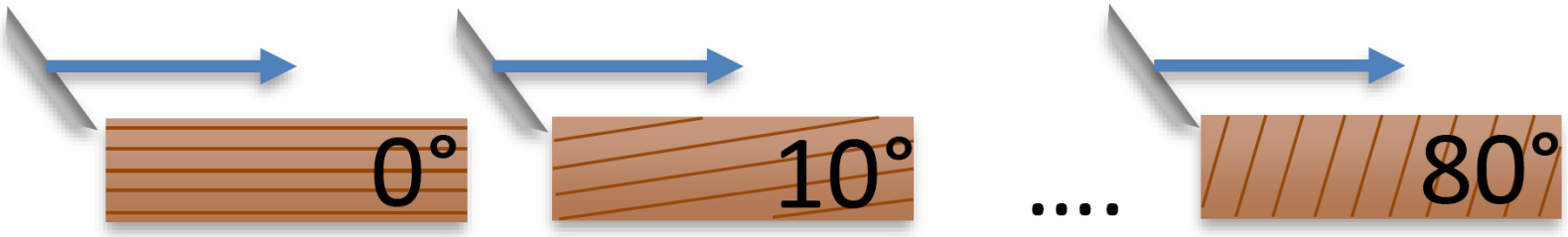
Instrumentation

- Quartz force sensor
- Powerful data acquisition system
- Chip analysis
- Data post-processing
- High-speed cameras

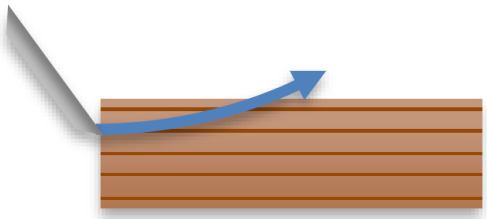


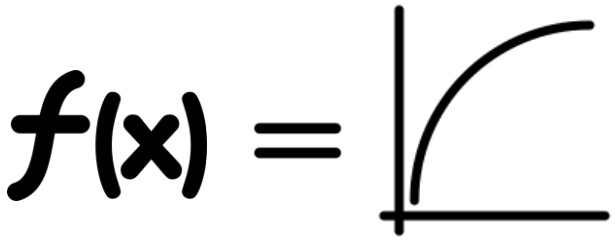
Design of Experiment

1. Discretize problem of rotary cutting



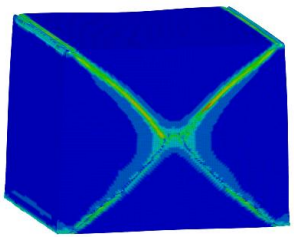
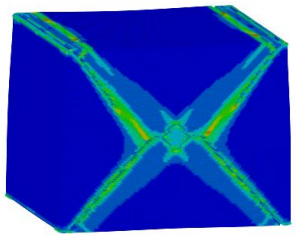
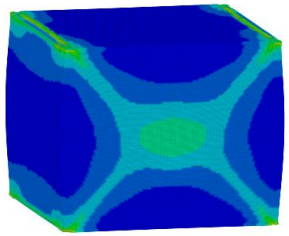
2. Build a F_c model for rotary trajectory

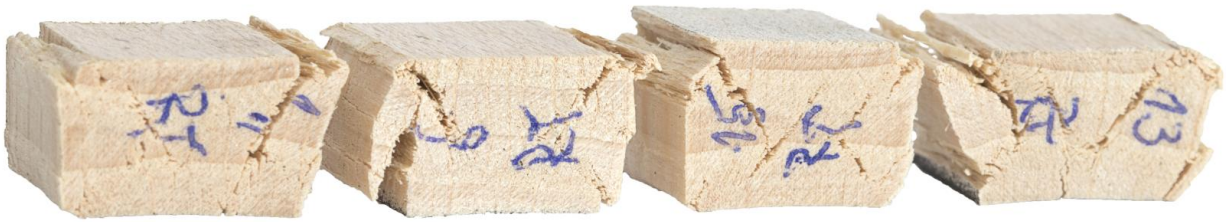
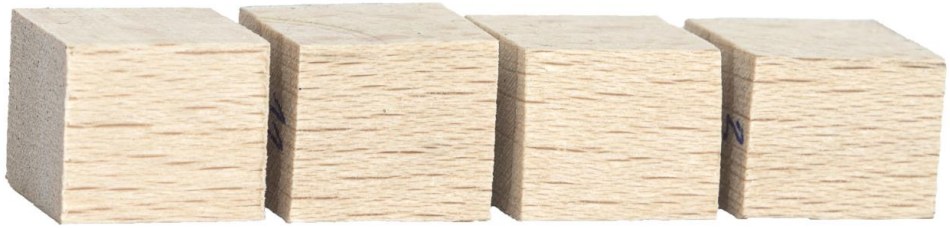




Explicit finite element method

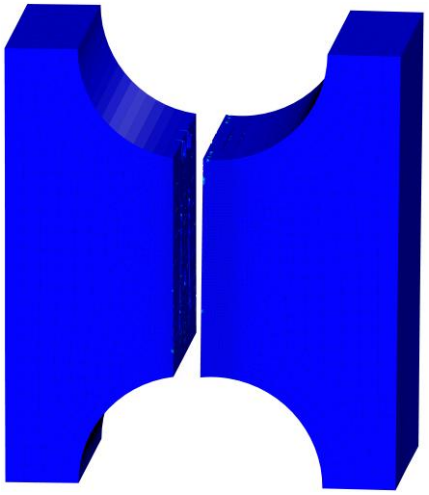
- Allowing crack modelling – suitable for high-strain rate and dynamic applications such as the hardwood disintegration

Model calibration

- Material anisotropy for elasticity, plasticity and fracture considering the tensile–compressive failure asymmetry



$$\bar{\sigma} = \sqrt{F\ \hat{\sigma}_{\mathrm{R}} - \hat{\sigma}_{\mathrm{T}}\ ^2 + G\ \hat{\sigma}_{\mathrm{T}} - \hat{\sigma}_{\mathrm{L}}\ ^2 + H\ \hat{\sigma}_{\mathrm{L}} - \hat{\sigma}_{\mathrm{R}}\ ^2 + 2L\hat{\sigma}_{\mathrm{RT}}^2 + 2M\hat{\sigma}_{\mathrm{LT}}^2 + 2N\hat{\sigma}_{\mathrm{LR}}^2}$$

$$F = \frac{\sigma_0^2}{2}\left(\frac{1}{\tilde{\sigma}_{\mathrm{R}}^2} + \frac{1}{\tilde{\sigma}_{\mathrm{T}}^2} - \frac{1}{\tilde{\sigma}_{\mathrm{L}}^2}\right) \qquad L = \frac{3}{2}\left(\frac{\tau_0}{\tilde{\sigma}_{\mathrm{RT}}}\right)^2 \qquad \tau_0 = \frac{\sigma_0}{\sqrt{3}}$$

$$G = \frac{\sigma_0^2}{2}\left(\frac{1}{\tilde{\sigma}_{\mathrm{L}}^2} + \frac{1}{\tilde{\sigma}_{\mathrm{T}}^2} - \frac{1}{\tilde{\sigma}_{\mathrm{R}}^2}\right) \qquad M = \frac{3}{2}\left(\frac{\tau_0}{\tilde{\sigma}_{\mathrm{LT}}}\right)^2 \qquad \sigma_m = \frac{\sigma_{\mathrm{L}} + \sigma_{\mathrm{R}} + \sigma_{\mathrm{T}}}{3}$$

$$H = \frac{\sigma_0^2}{2}\left(\frac{1}{\tilde{\sigma}_{\mathrm{L}}^2} + \frac{1}{\tilde{\sigma}_{\mathrm{R}}^2} - \frac{1}{\tilde{\sigma}_{\mathrm{T}}^2}\right) \qquad N = \frac{3}{2}\left(\frac{\tau_0}{\tilde{\sigma}_{\mathrm{LR}}}\right)^2 \qquad \eta = \frac{\sigma_m}{\sigma_{eq}}$$

$$\begin{bmatrix} \sigma_{\mathrm{L}} \\ \sigma_{\mathrm{R}} \\ \sigma_{\mathrm{T}} \\ \sigma_{\mathrm{LR}} \\ \sigma_{\mathrm{RT}} \\ \sigma_{\mathrm{LT}} \end{bmatrix} = \begin{bmatrix} 1-D_{\mathrm{L}} & 0 & 0 & 0 & 0 & 0 \\ 0 & 1-D_{\mathrm{R}} & 0 & 0 & 0 & 0 \\ 0 & 0 & 1-D_{\mathrm{T}} & 0 & 0 & 0 \\ 0 & 0 & 0 & 1-0.5\ D_{\mathrm{L}}+D_{\mathrm{R}} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1-0.5\ D_{\mathrm{R}}+D_{\mathrm{T}} & 0 \\ 0 & 0 & 0 & 0 & 0 & 1-0.5\ D_{\mathrm{L}}+D_{\mathrm{T}} \end{bmatrix} \begin{bmatrix} \hat{\sigma}_{\mathrm{L}} \\ \hat{\sigma}_{\mathrm{R}} \\ \hat{\sigma}_{\mathrm{T}} \\ \hat{\sigma}_{\mathrm{LR}} \\ \hat{\sigma}_{\mathrm{RT}} \\ \hat{\sigma}_{\mathrm{LT}} \end{bmatrix}$$

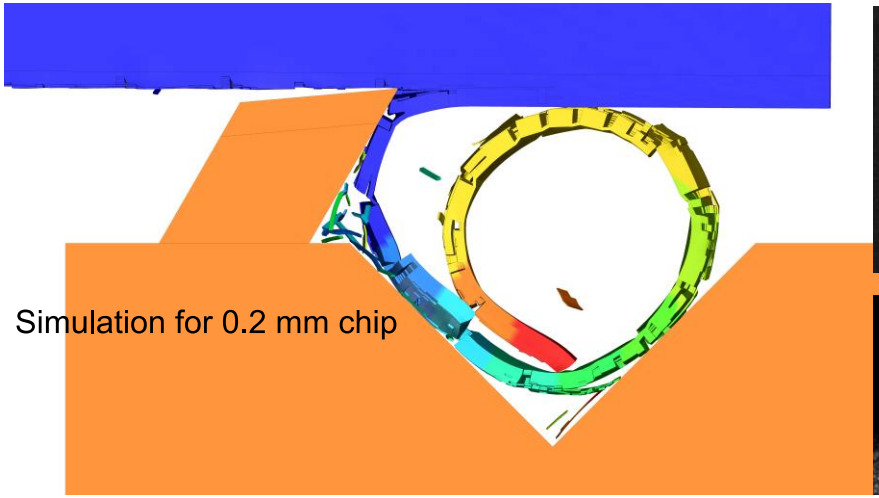
$$D_{\mathrm{L}} = \int_0^{\varepsilon_{\mathrm{L}}^D} \frac{1}{\varepsilon_{\mathrm{L}}^f} \left|\mathrm{d}\varepsilon_{\mathrm{L}}^p\right|$$

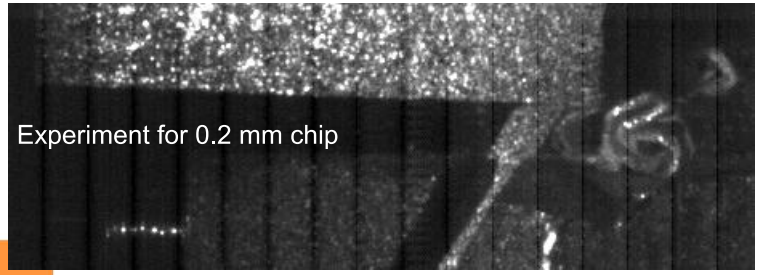
$$D_{\mathrm{R}} = \int_0^{\varepsilon_{\mathrm{R}}^D} \frac{1}{\varepsilon_{\mathrm{R}}^f} \left|\mathrm{d}\varepsilon_{\mathrm{R}}^p\right|$$

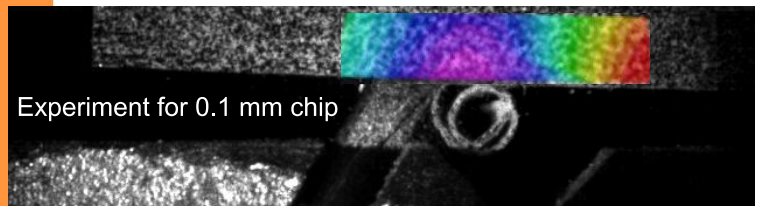
$$D_{\mathrm{T}} = \int_0^{\varepsilon_{\mathrm{T}}^D} \frac{1}{\varepsilon_{\mathrm{T}}^f} \left|\mathrm{d}\varepsilon_{\mathrm{T}}^p\right|$$

Numerical computations of rotary cutting

- Simulations of rotary cutting absent in the literature
- Computations validated against data from high-speed cameras and force sensor
- Virtual design providing cost savings







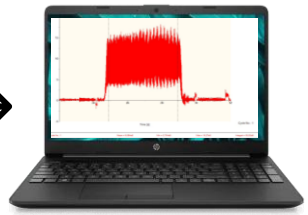
Comparative measurements

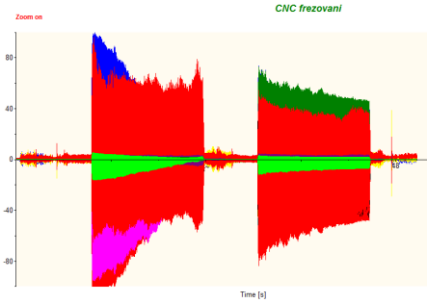
- Comparison of results with measured data of machines with rotary kinematics

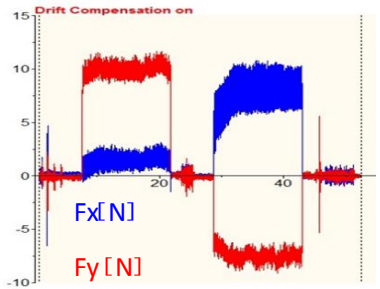
Measurement and calculation of cutting forces

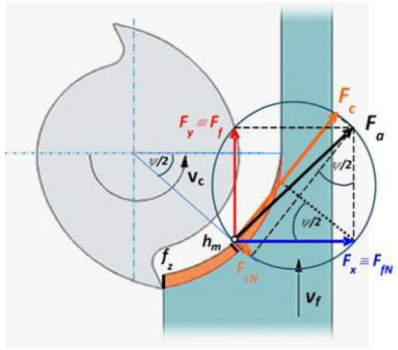
- The cutting force can be determined in two ways: practically, by performing an experiment or theoretically using empirical relationships.

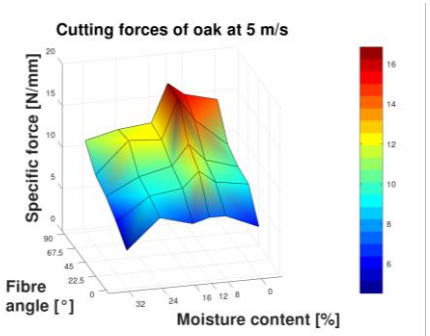
X →
Y →
Z →











Summary of goals and challenges

1) to theoretically and experimentally **analyze the rotary machining** of hard hardwood

2) to use **interdisciplinary approach** (functional team from 3 institutions) for comprehensive description of the rotary disintegration

3) to develop **new rotary machining model** by **a)** combining a simplified **experimental machining cases** (almost linear cutting at different angles with 3D measurement at unique high-speed machining device) and **b)** final implementation of empirical knowledge into an **explicit finite-element model**

4) to **validate the model** by measurement of the total force (3D measurement of the global cutting forces during the rotary machining of a wood sample)

5) to **apply model** in "what-if" scenarios (influence of factors)

SPECIFIC GOALS:

No.1

"Empirical description of the rotary cut"

No.2

"Finite element model of rotary cutting of hardwood"

Implementation (T1)

Lead partner MENDELU will **design/perform rotary cutting testing** together with Wood K Plus to investigate the **effect of various phenomena** (cutting speed, chip thickness or hardwood moisture). The cutting **forces** will be recorded together with **high-speed camera** acquisition by BUT, which will also participate in the **FE modeling**.

MAIN OUTPUT: "Experimental findings and comput. model"

MAIN ACTIVITY: "Experimental and numerical analyzes" with 2 partial ouputs (experimental/numerical)

Context, Synergy & Horizontal principles

A **Biodiversity, Global Climate Strategies and Sustainability**, changes in forestry sector and missing wood industry capacities in Austria Danube regions and joined Czech regions

B **Project Synergy** - former and future **projects** (HARDIS ATCZ21 with unique equipment, measurement techniques, filtration methods, ERDF, COMET, FFG Bridge, Innoscheck, ERC, GAČR, TAČR, OPVVV, NAKI
Paris Agreement (energy efficiency of wood disintegration),
The European Green Deal (decreasing of CO_2)

C Clear **positive impact in Sustainable development**, neutral impact in Gender and equal opportunities / non-discrimination

Target groups & Dissemination

5 **SMP** (small and medium-sized enterprises operating in the field of wood processing)

2 **Clusters** operating in the field of wood processing (eg ADMD, EcoPlus, AUVA)

3 **Enterprises** > SMP

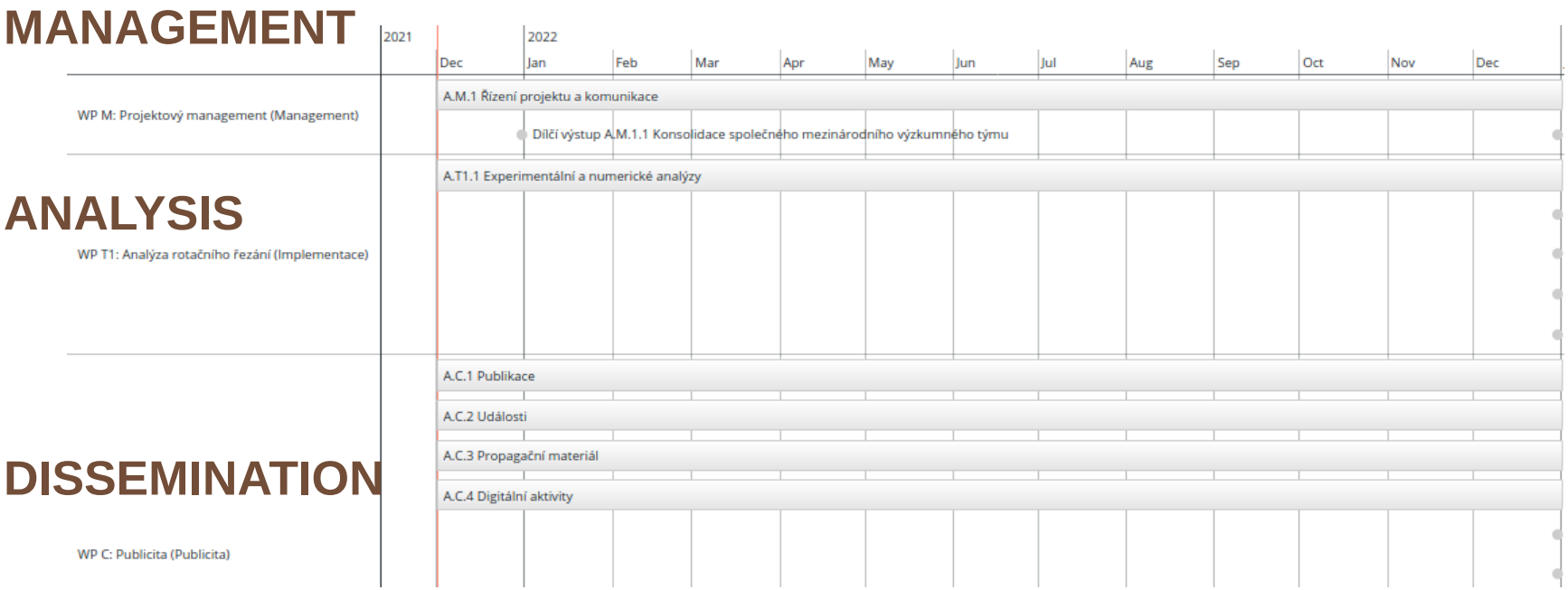
6 **Research inst. & Universities**

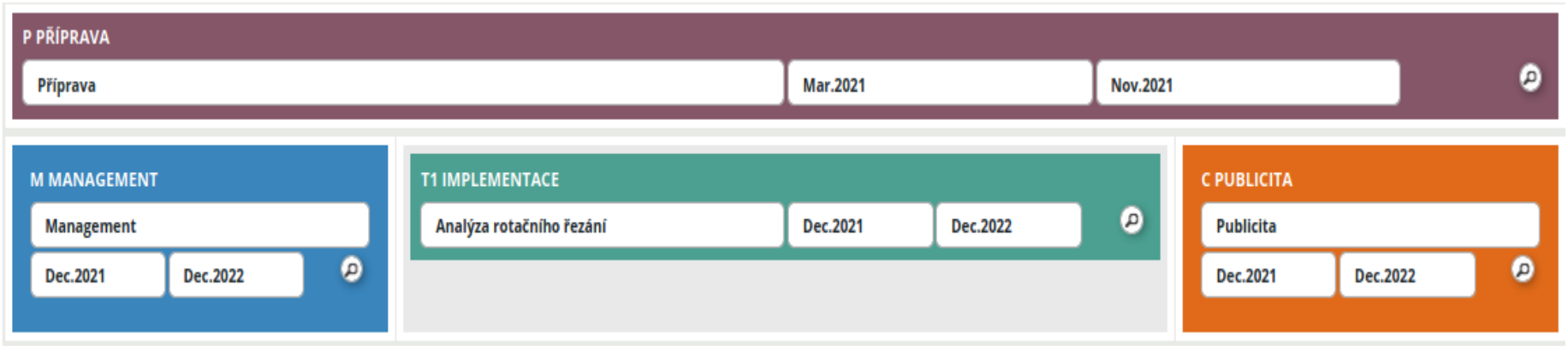
1+6 **Peer-review articles & Conference presentations**

1+3 **Project Web pages & Social network profiles**

1+1 **Online workshop & promotional material**

Time schedule: **Dec 2021 – Dec 2022**





Budget: 299 ths. EUR in total / 13 months

Partner	Zdroj spolufinancování	Monitorovací období 0	Monitorovací období 1	Celkový rozpočet	Čisté příjmy	Celkový způsobilý rozpočet
1 - Mendelova univerzita v Brně	EFRR	€ 5 000.00	€ 123 909.00	€ 128 909.00	€ 0.00	€ 128 909.00
2 - Kompetenzzentrum Holz GmbH	EFRR	€ 0.00	€ 125 030.08	€ 125 030.08	€ 0.00	€ 125 030.08
3 - Vysoké učení technické v Brně	EFRR	€ 0.00	€ 45 281.80	€ 45 281.80	€ 0.00	€ 45 281.80
Celkem		€ 5 000.00	€ 294 220.88	€ 299 220.88	€ 0.00	€ 299 220.88
% z celkového rozpočtu		1.67 %	98.32 %	100.00 %	0.00 %	100.00 %

Contributions of partners & Co-financing

č. PB	Monitorovací období 0	Monitorovací období 1	Celkový rozpočet	Čisté příjmy	Celkový způsobilý rozpočet
PB P	€ 5 000.00	€ 0.00	€ 5 000.00	€ 0.00	€ 5 000.00
PB M	€ 0.00	€ 58 278.25	€ 58 278.25	€ 0.00	€ 58 278.25
PB T1	€ 0.00	€ 152 119.85	€ 152 119.85	€ 0.00	€ 152 119.85
PB C	€ 0.00	€ 83 822.78	€ 83 822.78	€ 0.00	€ 83 822.78
Celkem	€ 5 000.00	€ 294 220.88	€ 299 220.88	€ 0.00	€ 299 220.88

Structure in WPs and MPs

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KICK-OFF MEETING 1.12.2021

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Spolufinancován z prostředků Evropského fondu regionálního rozvoje