FlexiMill Progress report

Module Works SRl

Overview

Activities within the last 19-24 Project months.

	Work packages	Lead	1st year												2nd year											
			I			II			III			IV			I			II			III			IV		
WP1:	**Specification of the requirements**	Camaix	1		3																					
1.1	Detection of technological and economic status quo at the end-users		1	2																						
1.2	Detection of technological and economic targets resulting from industrial demands		1	2																						
1.3	Definition of a demonstrator			2	3																					
1.4	Definition of a case study			2	3																					
WP2:	**Module 1: Tooling**	Fraisa		2												15										
2.1	Classification and design specification of circle-segment-end-mills			2		4																				
2.2	Parametrization of design specifications for CAM programming				3			6																		
2.3	Selection of key tool parameters for experimentation				3			6																		
2.4	Tool grinding trials, optimization and tool deployment for machining investigations					5										15										
WP3:	**Module 2: Process Planning**	ModWorks		2												15										
3.1	Definition of technological specifications for computer-aided machining			2		4																				
3.2	Development of an automated toolpath calculation algorithm			2							10															
3.3	Integration of milling tool parametric design			2							10															
3.4	Development of CAM-module as a component								8							15										
WP4:	**Module 3: Machining**	IPT		2															17							
4.1	Adaption of machining simulation software to circle segment end mill geometries			2					7																	
4.2	Analysis of engagement situation and process characteristics in circle-segment-end-milling						6				10															
4.3	Translation of process knowledge into viable process rules & machining strategies						6				10															
4.4	Verification of process rules & machining strategies							7											17							
WP5:	**Integration of FlexiMILL Process Planning System**	Camaix												13							20					
5.1	Integration of CAM module into a PLM software environment													13		15										
5.2	Implementation of preliminary machining strategies														14				18							
5.3	Integration of the process rules and machining strategies into the CAM module																16			20						
5.4	Integration of the optimized milling tool design into the CAM module																16			20						
WP6:	**Optimization of the Integrated FlexiMILL System**	IPT																		19			22			
6.1	Optimization of the circle-segment-end-mill design																			19			22			
6.2	Optimization of the CAM-module																			19			22			
6.3	Optimization of the process rules and machining strategies																			19			22			
WP7.	**Demonstration and Testing**	Mathys																			20			23		
7.1	Demonstration of FlexiMILL technology in research environment																				20		22			
7.2	Demonstration of FlexiMILL technology at end-user in industrial environment																					21		23		
WP8:	**Intermediate & Subsequent Evaluation**	Camaix	1																							24
8.1	Intermediate economic and technological evaluation of the project progress		1																					23		
8.2	Final economic and technological evaluation of the FlexiMILL technology platform																						22			24
WP9:	**Dissemination, Exploitation and Training**	IPT	1																							24
9.1	Dissemination		1											13												24
9.2	Exploitation medical environment													13												24
9.3	Exploitation in turbo-engine- and tool-die-making environment													13												24
9.4	Training																							23		24
9.5	IPR management		4																							24
WP10:	**Technical Project Management**	Camaix	1																							24
10.1	Project coordination and management		1																							24
10.2	Monitoring progress and information flows		1																							24
10.3	Reporting and Communication to the EUREKA secretariat		1																							24

Figure 1: Project planning

Module Works has been active in Workpackages 5, 6, 7, 8, 9 and 10.

Within the last reporting period, Module Works has finalized the last remaining developments that were focusing of on the optimization of the previous developments in order to facilitate integration of Module Works' software libraries into the Integrated FlexiMill System.

Module Works has developed and improved software interfaces (API) to support integration of software libraries developed in WP3, which include new classes for different definitions of barrel tools and cutter-workpiece engagement computation. Besides, Module Works has developed and improved graphic user interface (GUI) to support Human Machine Interaction for the newly implemented definitions of the barrel tool.

Module Works was also supporting other partners in the testing phase. As part of the developments, a dedicated machine model and postprocessor to convert 3D coordinates into machine commands has been created for computer validation of the developed machining strategies.

WP5 Integration of FlexiMILL Process Planning System

WP5 is the "Integration of FlexiMILL Process Planning System" and managed by Camaix. The basis is the developed CAM-module from WP3.

Module Works has developed and improved software interfaces (API) to support integration of software libraries developed in WP3, which include new classes for different definitions of barrel tools and cutter-workpiece engagement computation, as shown in Fig. 2.

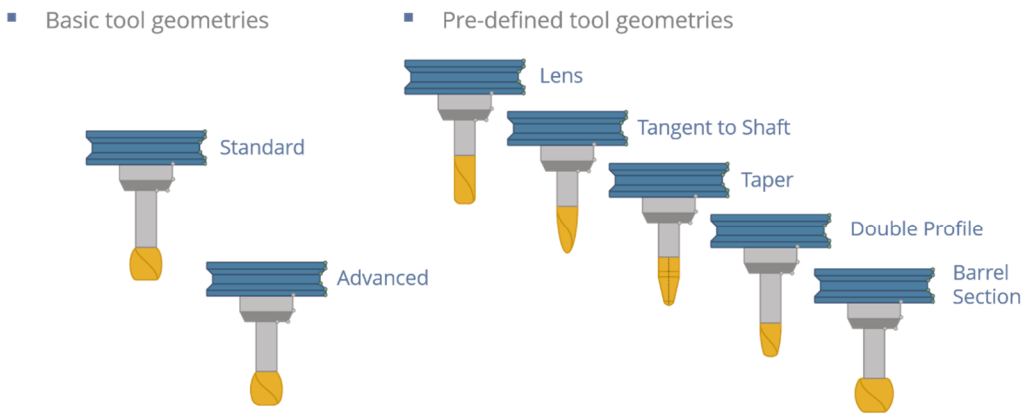


Figure 2: Different definitions for the barrel tool

Figure 3 and Figure 4 show snapshot of the software interface (API) of the barrel tool definitions.

```
//!Constructor
/*!Constructs a barrel mill tool using the given parameters.
\param newUpperDiameter is the upper diameter of the constructed tool.
\param newMaximumDiameter is the maximum diameter of the constructed tool.
\param newHolder is the holder.
\param newShoulderLen is the length of the shoulder.
\param newFluteLen is the flute length.
\param newArbor is the arbor.
\param newCornerRadius is the corner radius of the constructed tool.
\param newProfileRadius is the profile radius of the constructed tool
\param units are the measurement units.
*/
mwBarrelMill( const double& newUpperDiameter,
              const double& newMaximumDiameter,
              const HolderDefinition &newHolder,
              const double& newShoulderLen,
              const double& newFluteLen,
              const ArborDefinition &newArbor,
              const double& newCornerRadius,
              const double& newProfileRadius,
              const Units units);
```

Figure 3: Constructor for the standard barrel tool definition

```
//!Constructor with parameters and user given shoulder definition extender
mwBarrelAdvancedMill(const FluteHeightDefinition& fluteHeightDef,
                     const AxialPositionDefinition& axialPositionDef,
                     const RadialPositionDefinition& radialPositionDef,
                     const cornerRaduisType& cornerRadType,
                     const double& cornerRadius,
                     const double& shoulderLen,
                     const double& profileRadius,
                     const HolderDefinition& holderDef,
                     const ArborDefinition& arborDef,
                     const mwShoulderDefinitionExtender& shoulderDefinition,
                     const Units units);
```

Figure 4: Constructor for the advanced barrel tool definition

WP6 Optimization of the Integrated FlexiMILL System

WP6, "Optimization of the Integrated FlexiMILL System", identified flaws in the technology package due to interface losses and integration in WP5. First machining trials of a simplified demonstrator performed to identify deficits of the FlexiMILL technology package. An optimization of "tooling", "process planning " and "machining" took place on module level.

For the demonstration of the FlexiMILL process planning system (WP7) a high level of autonomous and reliable process planning was desired. In the intermediate evaluation, a simplified demonstrator achieved the required level of automatization. Correction in the user-machine interaction via the user interface was necessary, as shown in Figure 5.

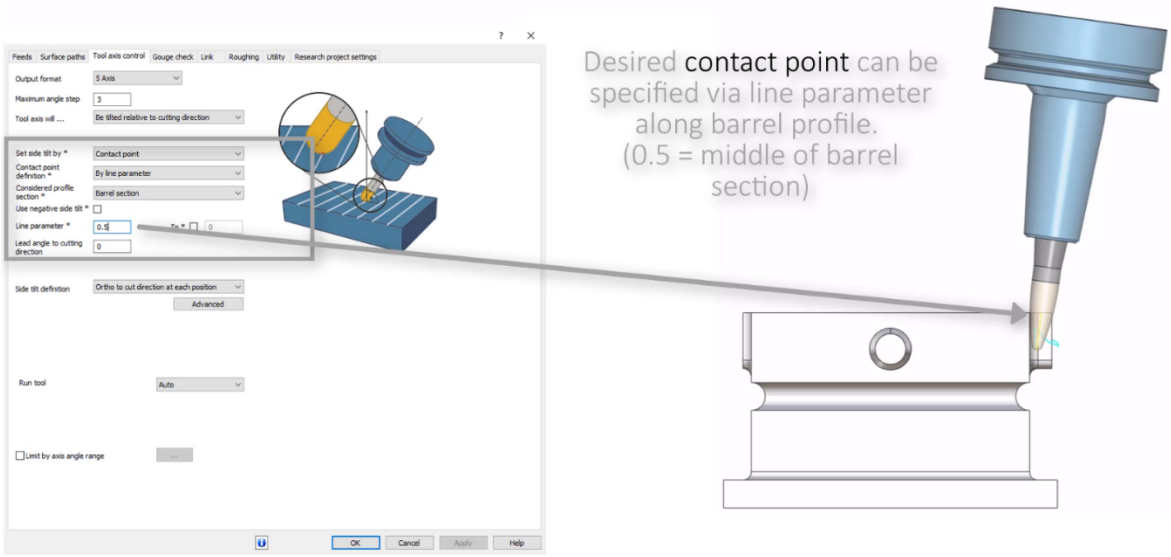


Figure 5: GUI for automated alignment of the barrel tool profile to the machined surface

Module Works has developed and improved graphic user interface (GUI) to support Human Machine Interaction for the newly implemented definitions of the barrel tool, as shown in Figure 6.

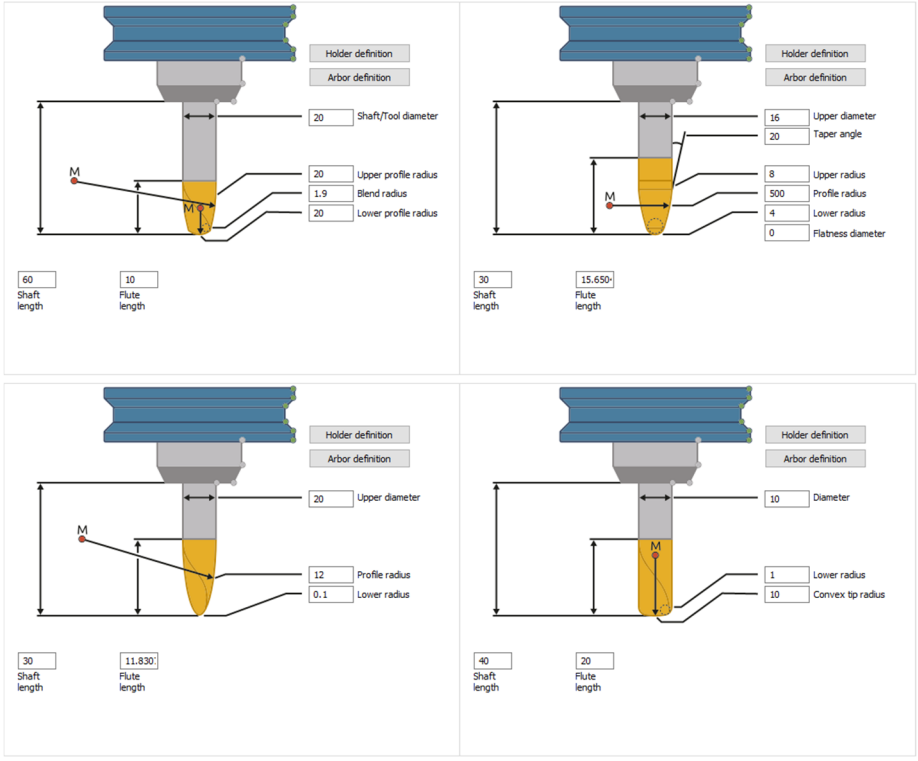


Figure 6: GUI to specify dimensions of the different barrel tool definitions

Module Works has performed extensive debugging and development of software features to optimize integration of Module Works software libraries into the Integrated FlexiMill System. A list of development cases is presented in Figure 7.

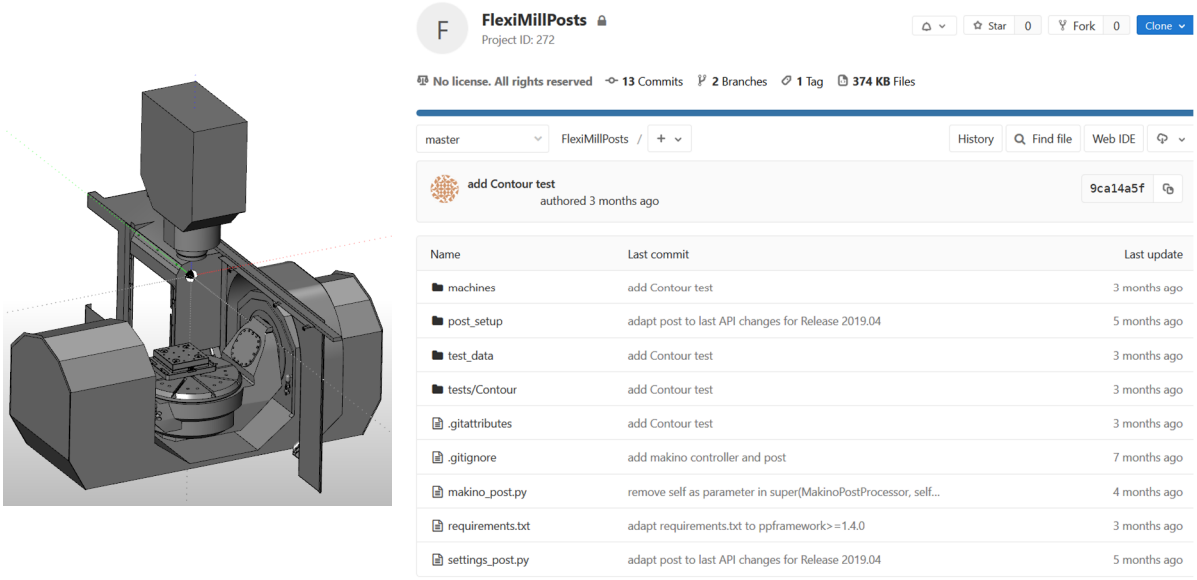
FC-21843	Prototype - FlexiMill Barrel Mill request from IPT
FC-21868	FlexiMill project
FC-22047	FlexiMill - make surface radius based feed optimization available on an exact surface pattern
FC-22057	FlexiMill - Trim tp with contact point out of defined region
FC-22193	SideTilt to degouge doesnt tilt the advanced barrel to tip radius if necessary
FC-22519	FlexiMill - Jitter by side tilt of advanced barrel
FC-22522	BarrelTool angle change not constant
FC-22627	FlexiMill - Feedrate adaption to compensate tool tilting
FC-22718	Extend mwOnTheFly5axDataHandler and add support for fleximill
FC-22819	FlexiMill - Feed adaption by cutSimPro
FC-22820	BarrelTool: Variant of TangentToShaft Barrel with Cyl.+Cone Shaft
FC-23068	Provide progress info to IPT Fleximill
FM-990	FlexiMill - Tilt adaption by SimCutPro

Figure 7: Module Works cases associated with integration tasks of the FlexiMill project

WP7 Demonstration and Testing

To ensure that the FlexiMILL process planning system is operational, demonstration will be performed in a laboratory environment. This testing was performed at Fraunhofer IPT.

Module Works was also supporting other partners in the testing phase. As part of the developments, a dedicated machine model of Makino D500 and postprocessor to convert 3D coordinates into machine commands has been created for computer validation of the developed machining strategies, as shown in Figure 8 and Figure 9. The postprocessor is based on Module Works Post Processor Framework, as referred in Figure 9.



a) 3D model of the workspace of Makino D500

b) internal GIT repository of the Makino D500 postprocessor

Figure 8: FlexiMill machine model and postprocessor (Makino D500)

makino_post.py

```
from ppframework.pplib.post_processor import PostProcessor
from ppframework.pplib.util.ncfilewriter_v3 import NCFileWriter
from post_setup.makino_controller import MakinoController
from ppframework.pplib.machine_v3.controller.controller import Channel, Move
from ppframework.pplib.machine_v3.axis import AxisCharacteristicsController, AxisCharacteristicsPhysical, \
    AxisCharacteristics, TranslationalAxis, RotationalAxis, Spindle
from ppframework.pplib.operation import DrillingOperation, TriangleMeshOperation
from ppframework.pplib.types import AxIsoType, RTCPMode
from ppframework import settings
import os, re
import logging
logger = logging.getLogger(settings.LOGGER_NAME)


class MakinoBasePostProcessor(PostProcessor):
    SAFE_STOP_TOL = 1  # safe stop 1 mm

    def __init__(self):
        super(MakinoBasePostProcessor, self).__init__()
        self.writer = NCFileWriter(has_sequence_numbering=False, start_sequence_number=10, increment_sequence_number=10)
        self.controller = MakinoController(self.writer)
        self.main_file_name = "O001"

    def configure_axes_and_channels(self):
        # Todo Save position

        # x_controller:
        x_controller_id = 0
        x_name = 'X'
        x_tolerance = 0.00000001
        x_home = 10.0
        x_soft_min = -250 + self.SAFE_STOP_TOL # ToDo
        x_soft_max = 300 - self.SAFE_STOP_TOL # ToDo
```

Figure 9: FlexiMill machine model and postprocessor (Makino D500)

WP9 Dissemination

A poster, shown in Figure 10, was presented at the 2019 International Conference on Virtual Machining Process Technology (VMPT 2019) Vancouver, Canada on April 23-25, 2019.

The title of the poster was "Discrete Cutter-Workpiece Engagement for Five-axis Milling using Multi-Dexel Model".

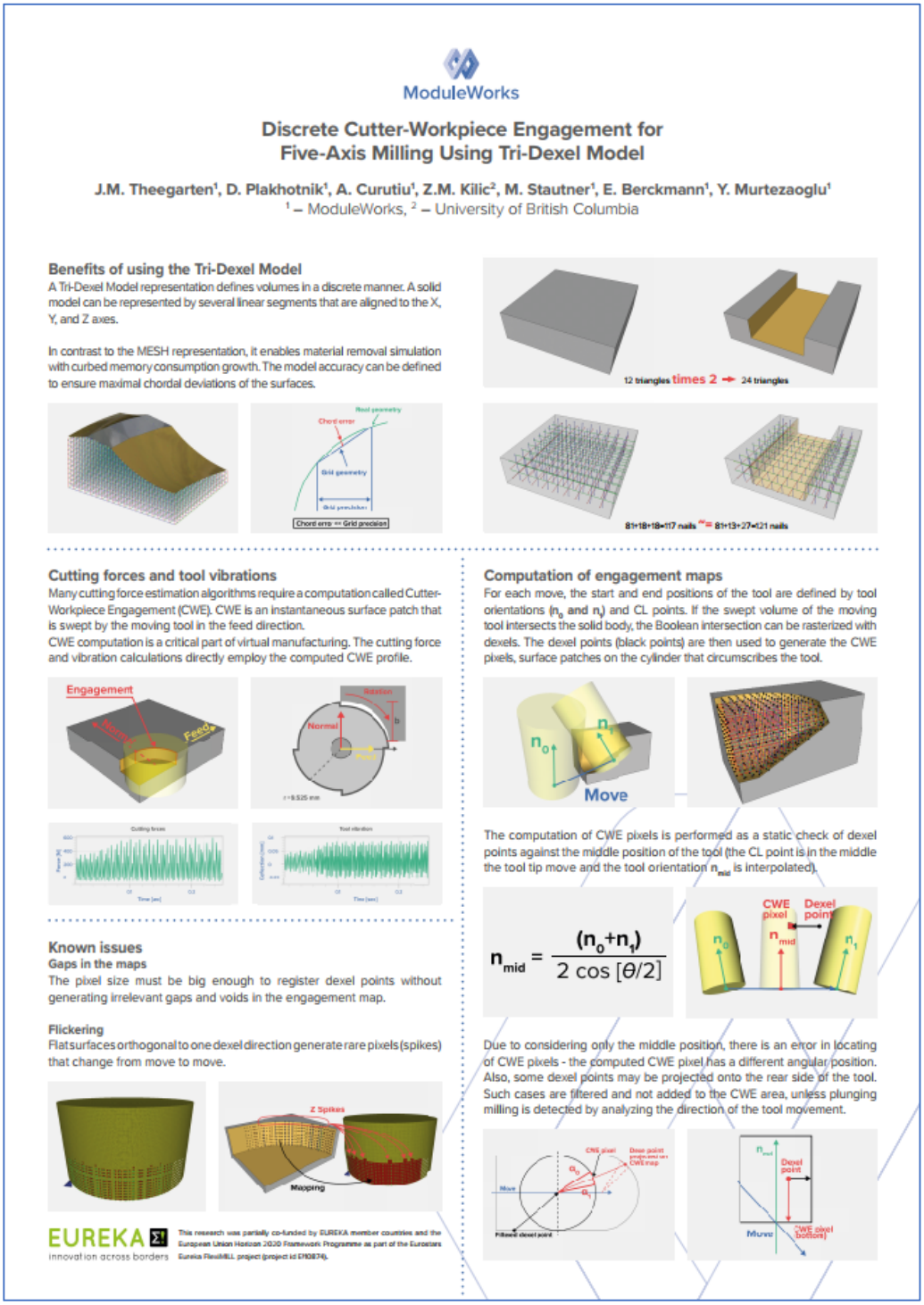


Figure 10: Conference poster