Analysis of machining accuracy during free form surface milling simulation for different milling strategies

Introduction

- CNC machine tools and CAD/CAM systems (Computer Aided Design/ Computer Aided Manufacturing) are used in the production of parts with complex surfaces in the aviation and automotive industry.
- One of the biggest limitations in the use of CNC machine tools and CAD/CAM systems in the production of parts containing free-form surfaces is the considerable time of implementation of the machining process.
- Inappropriate selection of CNC machining process parameters resulting in the manufacture of a part that has incorrect surface roughness and dimensional shape accuracy. Performing part re-processing involves additional costs for prototyping and losses for the manufacturing plant.

Introduction

- In many manufacturing plants the NC program is created by using the CAM software and then prototype is machined on the CNC machine tools.
- The most common selection of process parameters: machining strategy and cutting parameters is made on the basis of measurements of prototypes processed on the machine tool.
- In the CAM software, only process simulation is verified, consisting of checking for possible collisions with the tool or machine components without verifying the accuracy of the machining.

Introduction

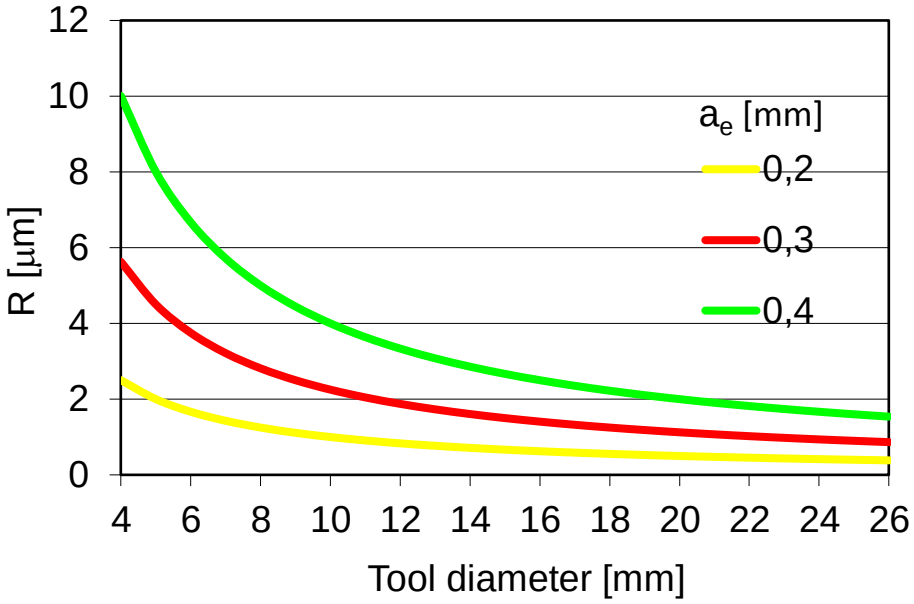
- Due to time consuming of the prototyping, verification of the correctness of the strategy and used cutting parameters, it is necessary to determine the accuracy of part machining at the design stage in the CAM system.
- For this purpose, the 3D solid body obtained in the machining simulation is subjected to the analysis. The nominal and obtained in the CAM simulation part shape is compared. The size of the raw material identifies the machining accuracy of the designed technological process for a given strategy, cutting parameters, type of cutting tool and machine kinematics.

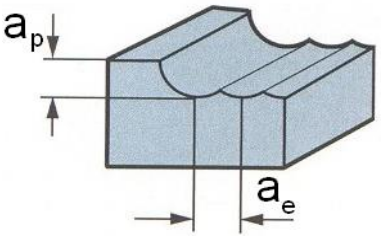
Free form surface machining

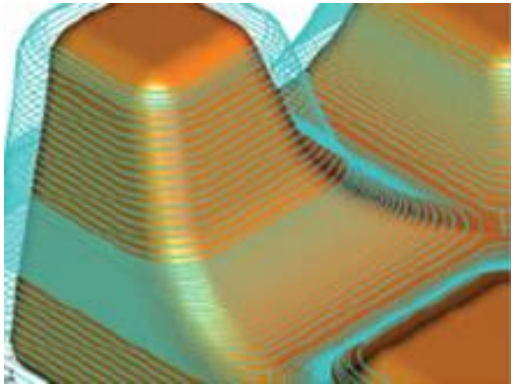
- For the machining of free form surfaces are the most commonly used the ball end mill. Thanks to their application and use of CNC machine tools is possible to make the surface of arbitrarily complex shape.
- As the result of the ball end milling of machined surfaces are created roughness resulting from the geometrical shape of the mapping tool on the machined surface.

Selection of radial depth of cut

- The resulting roughness *R* can be described by the relationship between the used tool diameter and the radially depth of cut a_e. At the height of roughness also affects the inclination of the part surface.
- The use of CAM software enables to calculation of the radial depth of cut a_e, however, in practice, during machining of free form surface machining, the calculated radial depth of cut is incorrect.





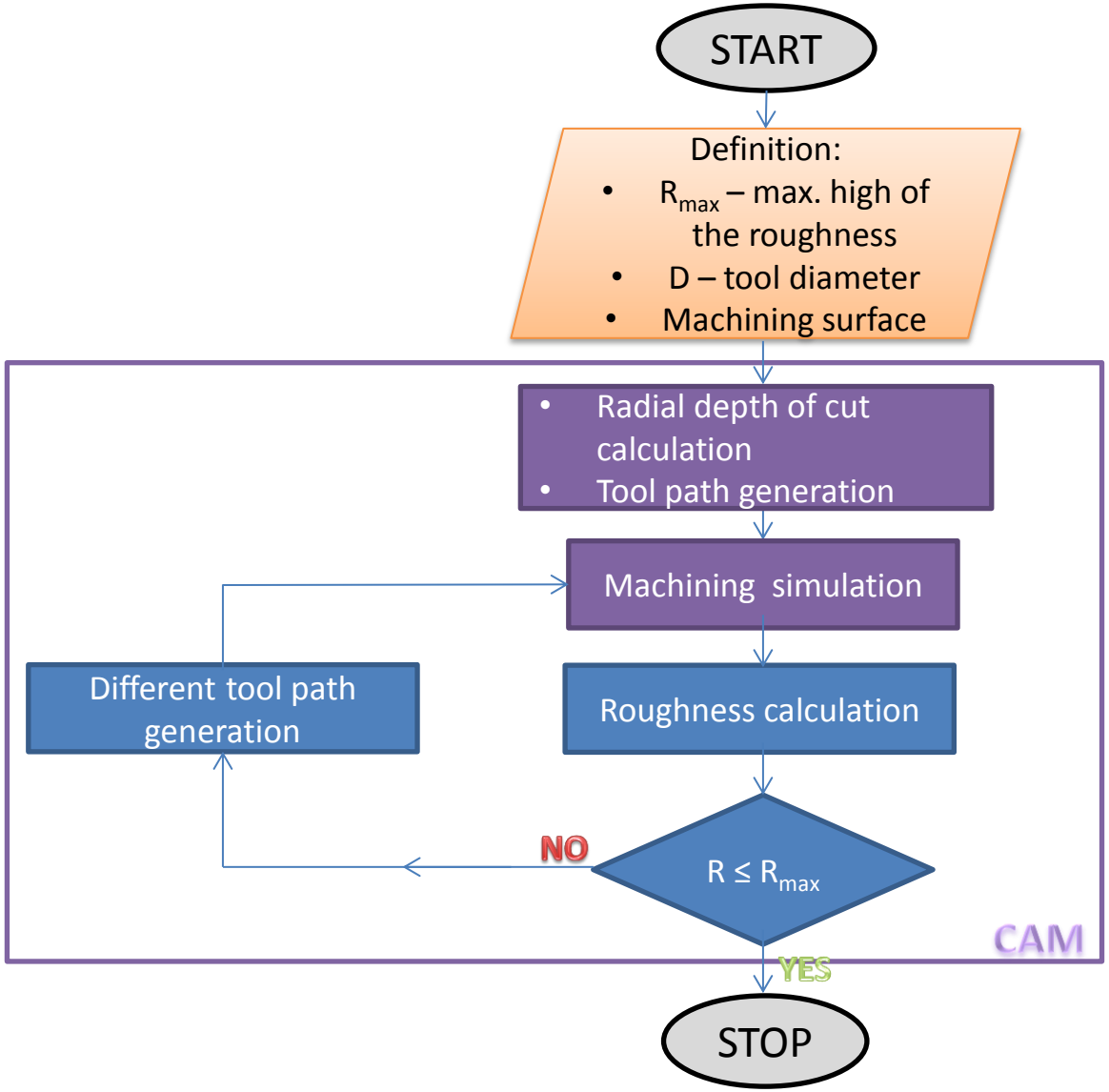


Selection of radial depth of cut

In order to increase the possibility of use CAM software, the method of verifying the correctness of the calculation of the radial depth of cut a_e in the free form surface machining is given.

The proposed method has been illustrated using an algorithm

Tool path selection algorithm



Selection of radial depth of cut

In the first step, the input data are defined:

- the maximum assumed height of the surface roughness resulting from the mapping of the tool shape on the machined surface, R_{max},
- Diameter and shape of the tool used for machining,
- The shape of the machined surface.

Selection of radial depth of cut

- In the next stage, using the CAM system, tool paths are generated and the radial depth of cut a_e is calculated.
- After this stage, a machining simulation is performed, as a result of which it is possible to obtain a geometric model of the machined surface.
- The next stage of design is the calculation of the surface roughness resulting from the mapping of the tool shape on the machined surface. This is done by comparing the nominal surface shape with the model obtained during the CAM simulation.

Selection of radial depth of cut

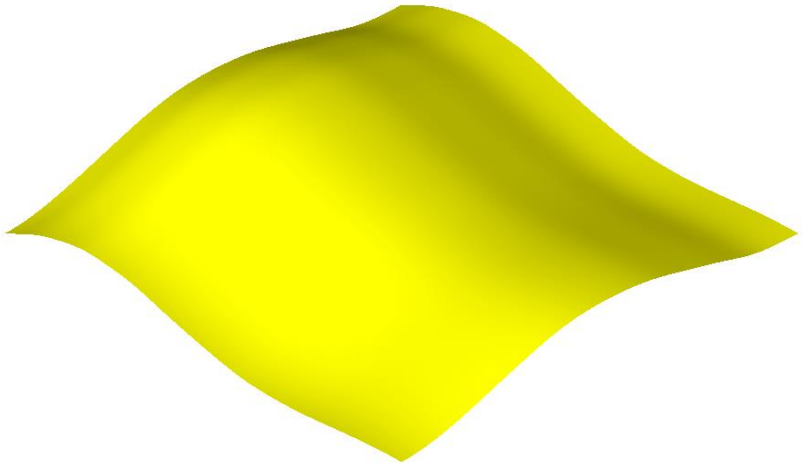
- In the case when the calculated surface roughness does not exceed the maximum allowable value, it is possible to generate the NC code and perform the part machining on the CNC machine.

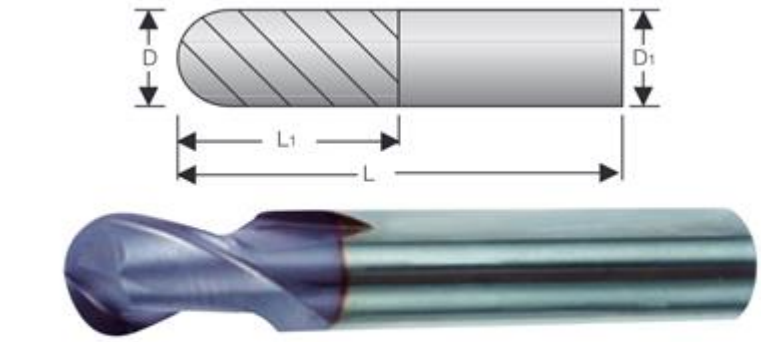
- If the calculated surface roughness exceeds the maximum allowable value, the toolpath must be regenerated using a different radial depth of cut a_e, another tool or a different machining strategy.

Method Verification - experimental researches

Experimental researches

Surface based on the spline curves was prepared for the researches. For different finishing milling strategy (different tool paths) were designed for ball milling tool with diameter *D*=6 mm. The maximum height of profile unevenness should not exceed of the value R_{max}=50 µm.





D [mm]	D_1 [mm]	L [mm]	L_1 [mm]
6	6	64	15

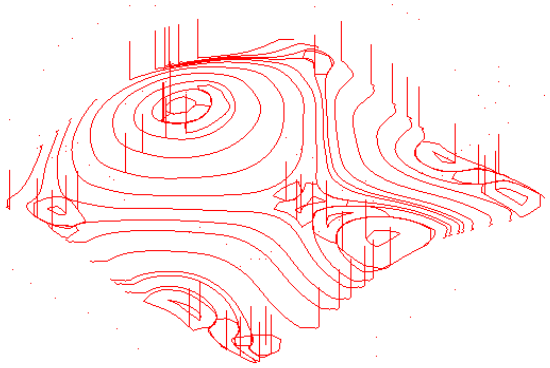
Experimental researches

Tool paths were designed basis of the following strategies:

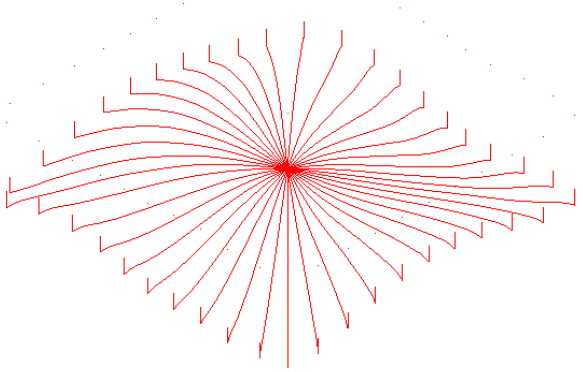
- *Level Z* – tool moves along the contours, created as a result of a surface intersection by surface XY on the different levels Z.
- *Radial* – tool moves along a half surface profile, up-down direction.
- *Square* – tool moves along a square path.
- *Circular* – tool moves along a circular path.

Used milling strategy

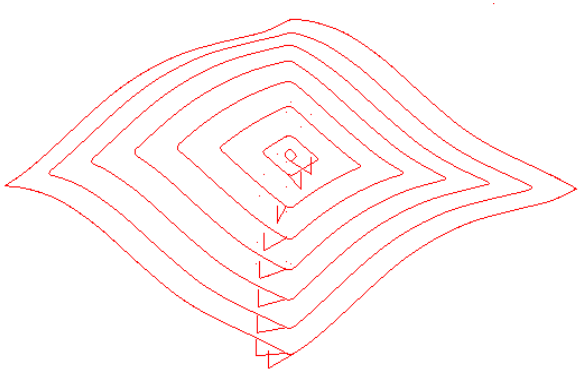
Strategy Level Z



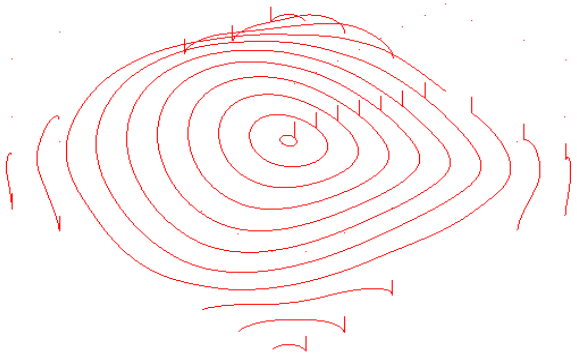
Strategy Radial



Strategy Square

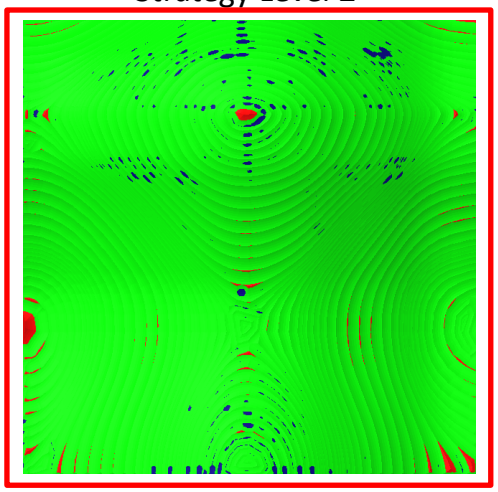


Strategy Circular

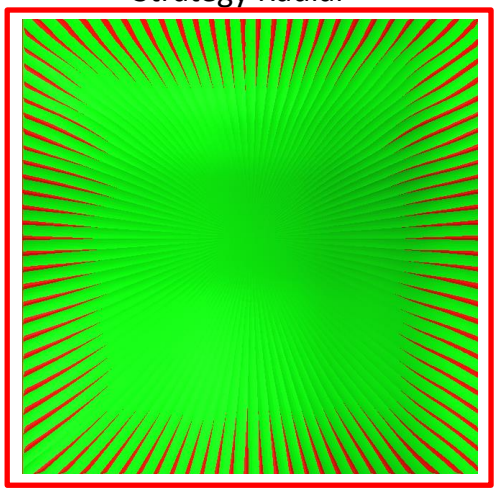


Calculations results

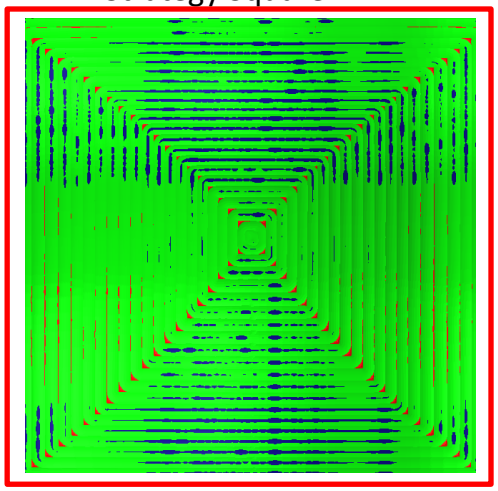
Strategy Level Z



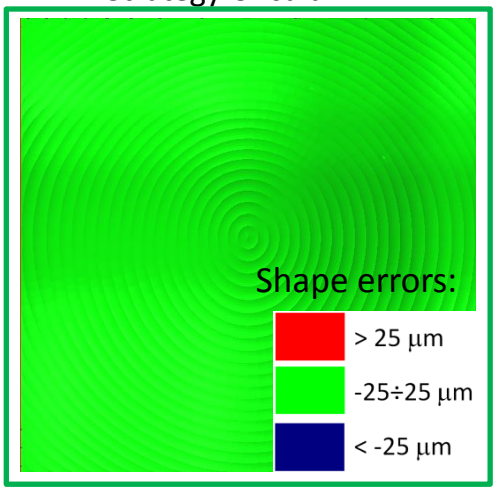
Strategy Radial



Strategy Square



Strategy Circular

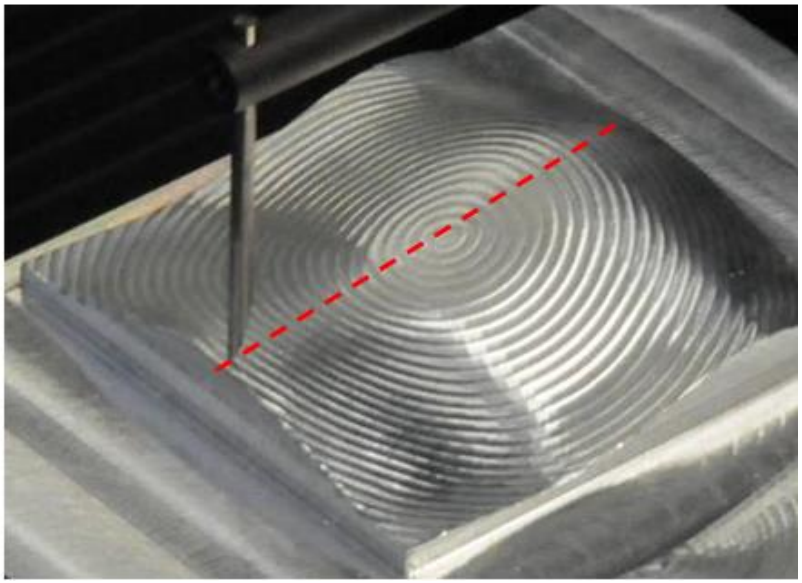


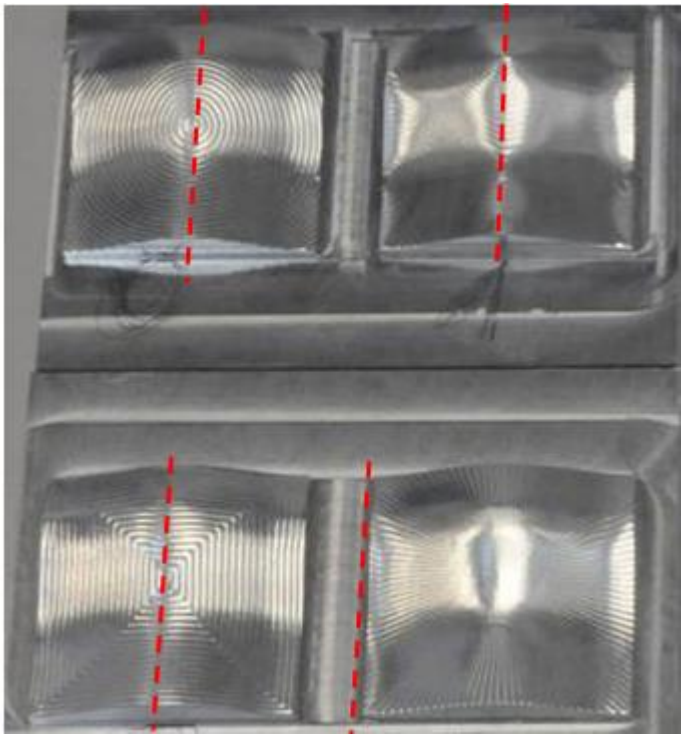
After designing the CAM simulation the surface roughness was calculated.

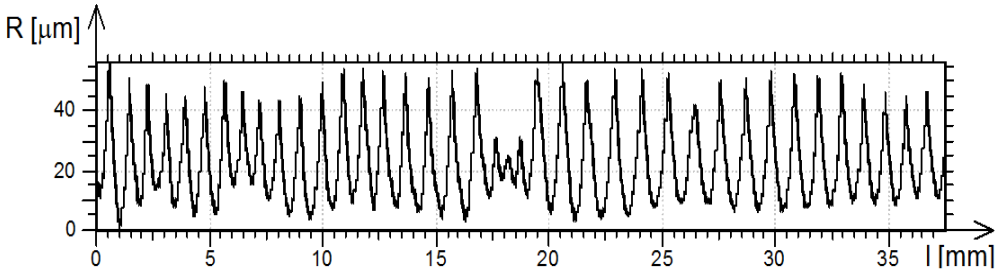
The places in which the surface roughness is higher than the assumed R_{max} are marked with blue and red.

Machined surface

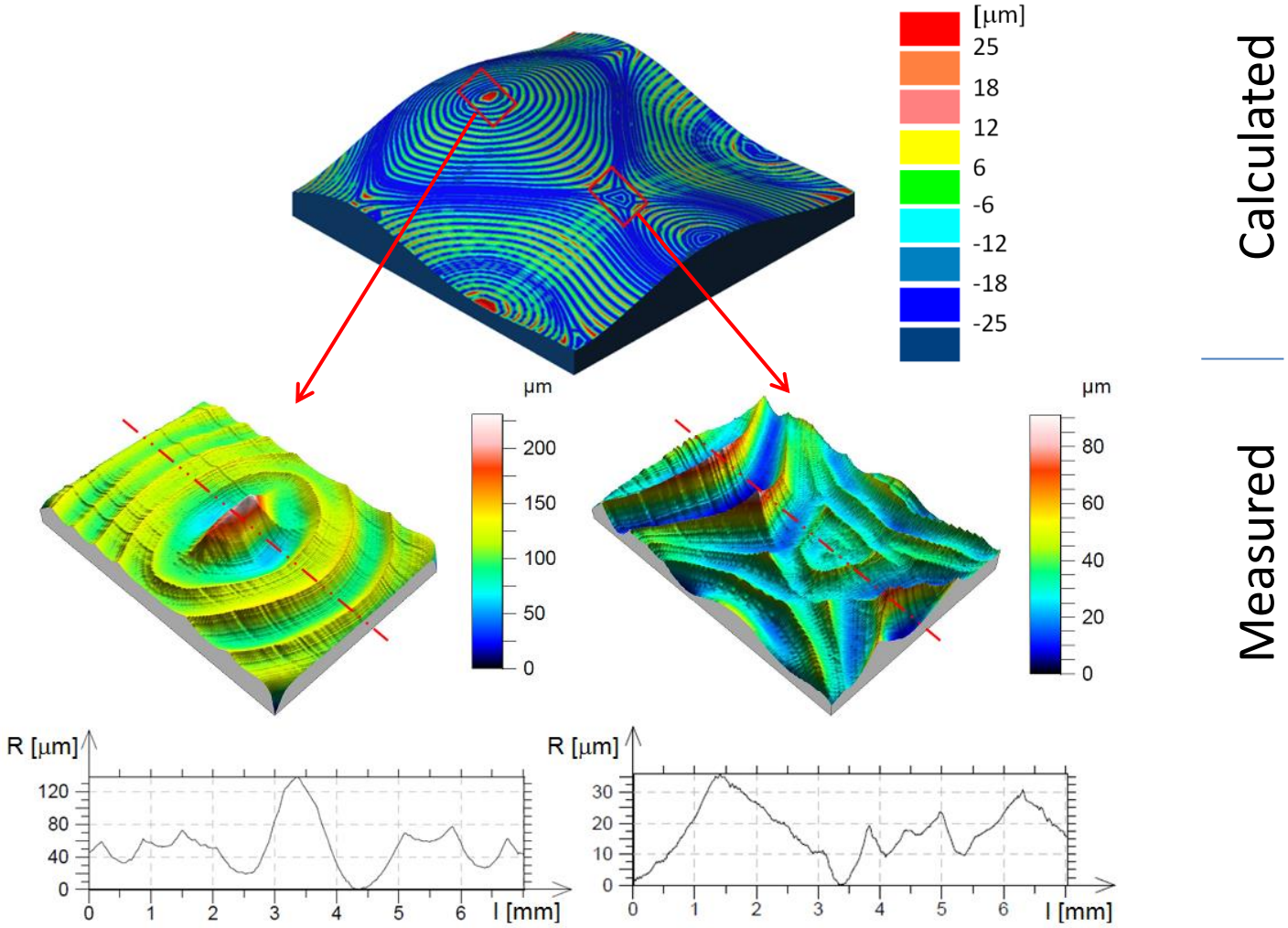
In order to verify the calculations, surface machining was carried out using previously created machining strategies and measurements of the surfaces roughness were made.







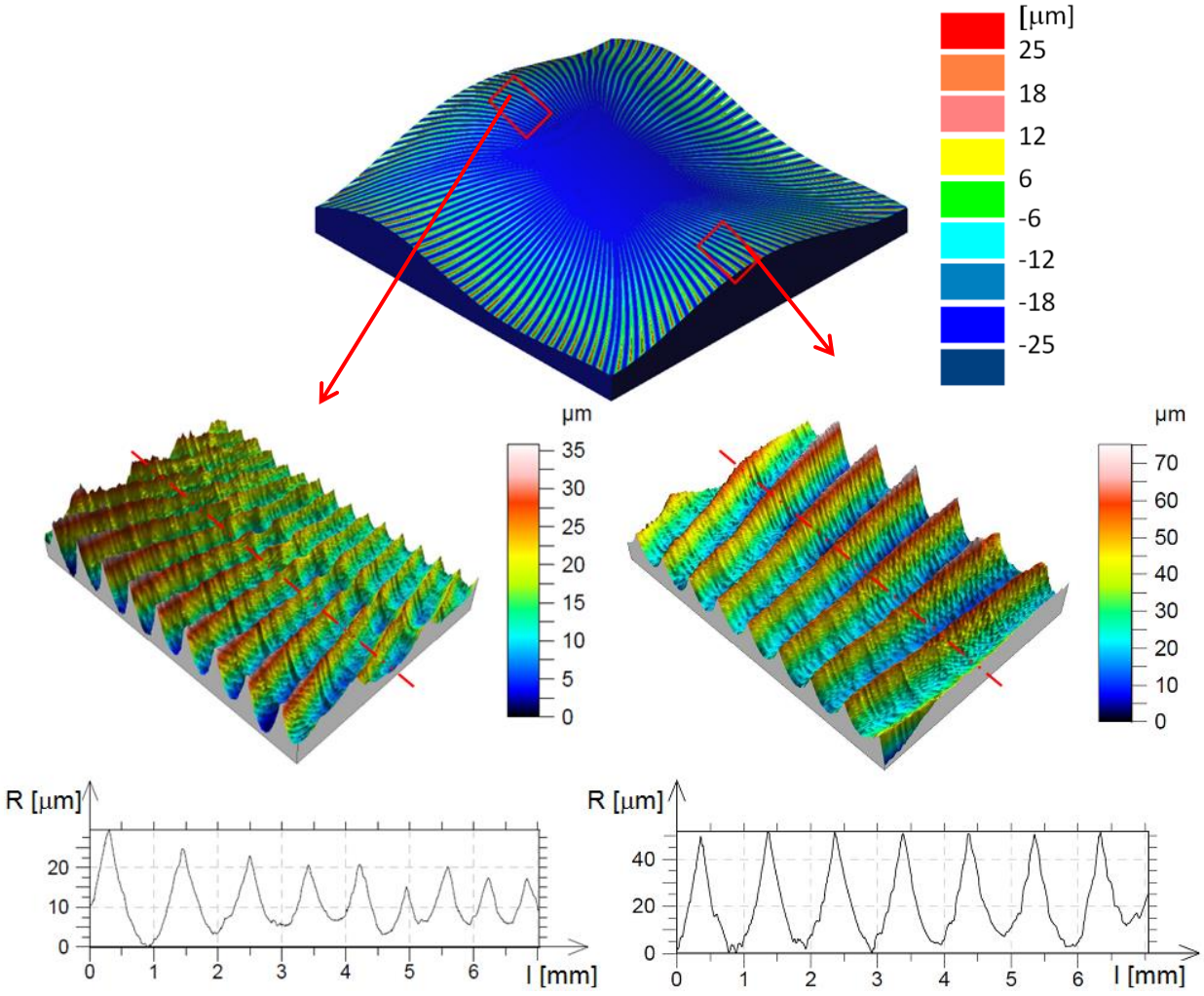
Comparison of the calculated and measured values – strategy Level Z



Calculated

Measured

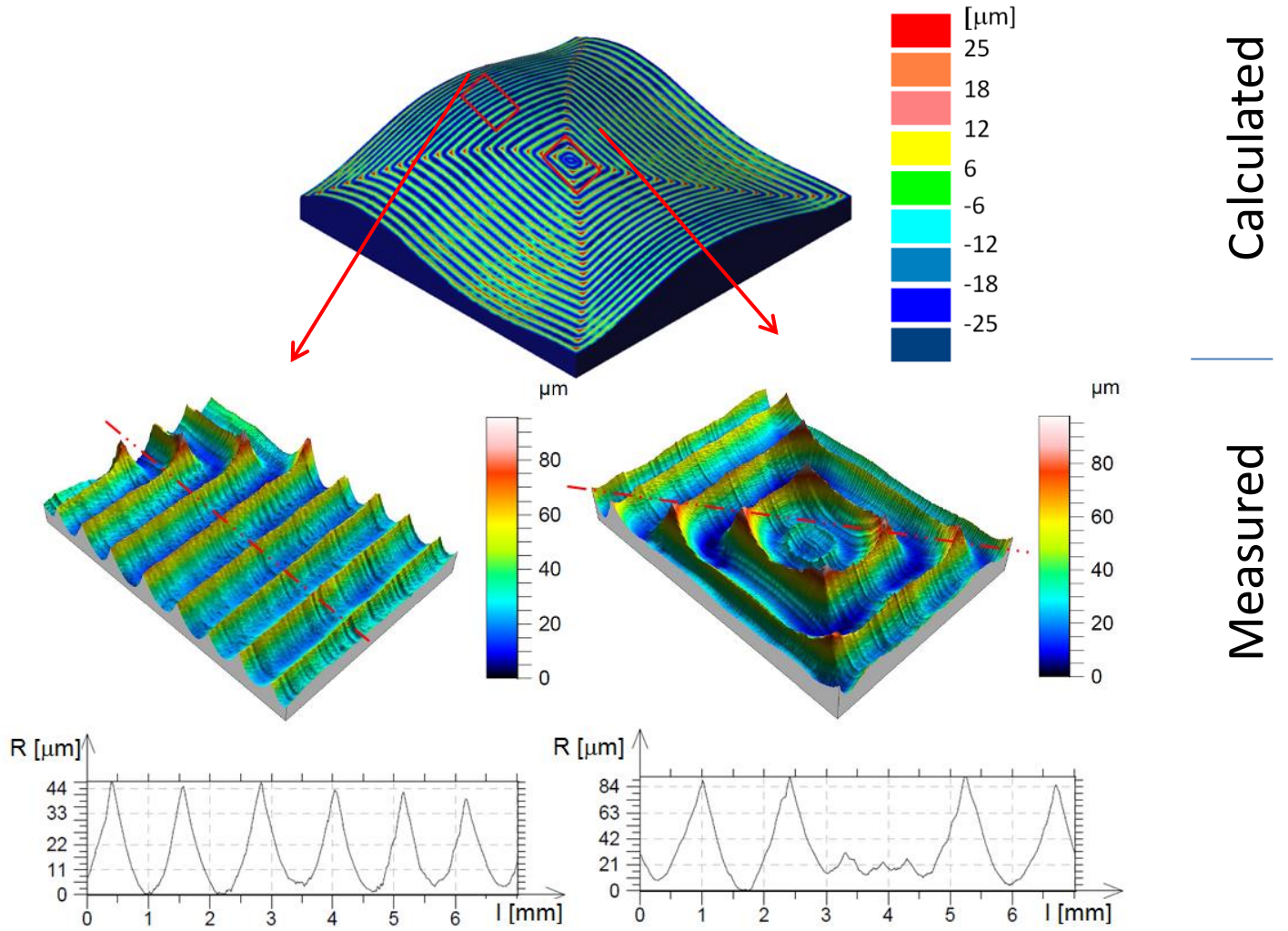
Comparison of the calculated and measured values– strategy Radial



Calculated

Measured

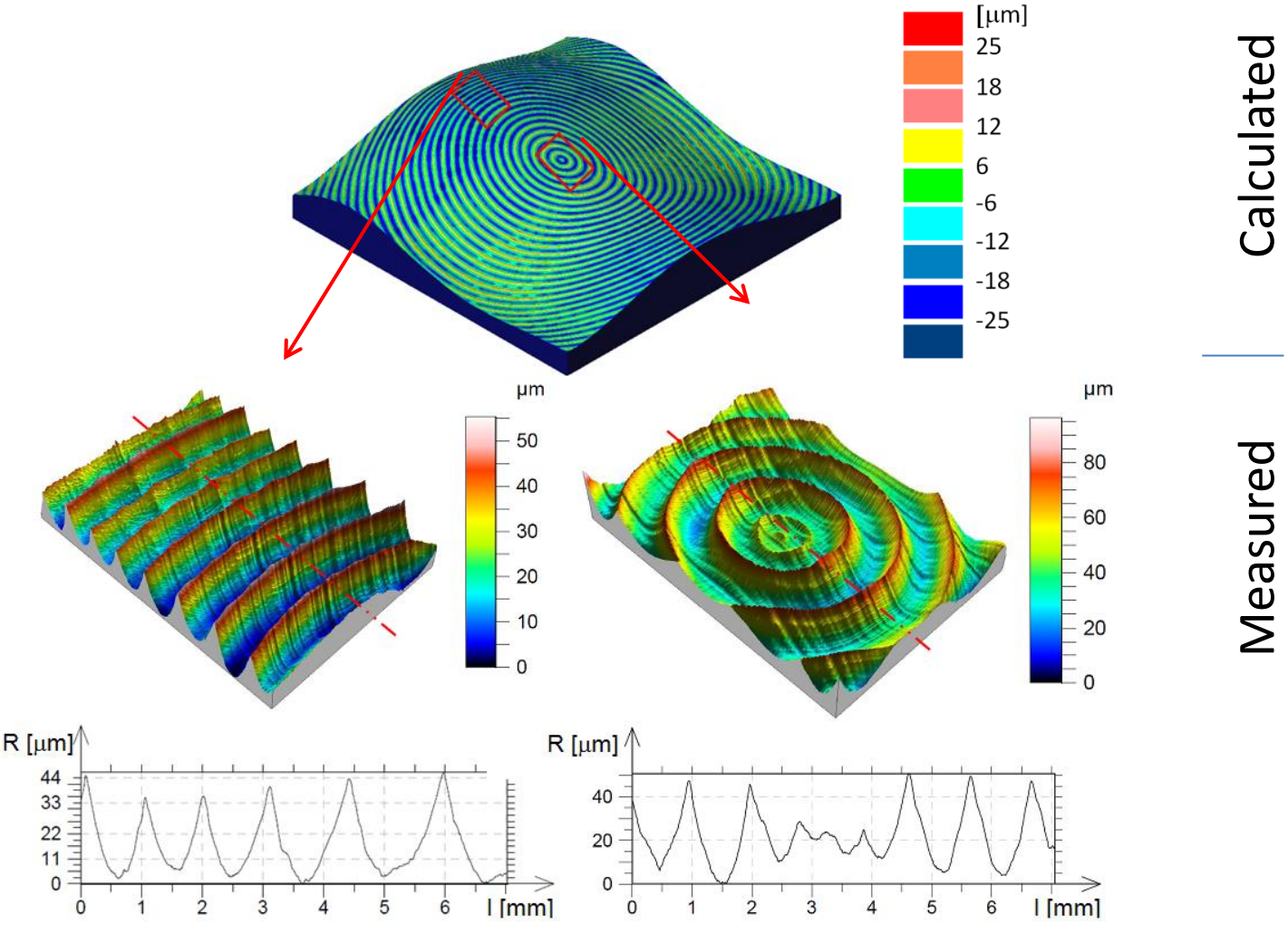
Comparison of the calculated and measured values– strategy Square



Calculated

Measured

Comparison of the calculated and measured values– strategy Circular



Calculated

Measured

Comparison of the calculated and measured values

	Calculation	Measured	
Tool path strategy	Maximum surface roughness [µm]	Maximum surface roughness [µm]	Length of tool path [mm]
Level Z	192	186	6817
Radial	72	64	3447
Square	84	86	1870
Circular	48	46	2251

Conclusions

- As a result of measurement and calculation of surface roughness, it was found that the use of CAM software to determine of the radial cutting depth of cut value does not work for the free form surface machining.
- Application of the proposed method allowed the identification of strategies and radial depth of cut values to enable the correct machining parts.
- Were obtained a good matching surface roughness values resulting from measurement and computer calculations.
- The proposed method could be implemented in CAM systems to improve their ability to application.

Thank you for your attention