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Influence of CNC milling strategies on complex surface machining

T Dodok[1], N Čuboňová[1], M Císar[1], V Ivanov[2] and D Wiecek[3]

[1] Department of Automation and Production systems, Faculty of Mechanical Engineering, University of Žilina, Univerzitná 1, 010 26 Žilina, Slovak Republic

[2] Department of Manufacturing Engineering, Machines and Tools, Sumy State University, 2 Rymskogo-Korsakova St., Sumy, 40007, Ukraine

[3] Faculty of Mechanical Engineering and Computer Science, University of Bielsko-Biala, ul. Willowa 2, 43-309, Bielsko-Biała, Poland

E-mail: tomas.dodok@fstroj.uniza.sk

Abstract. Milling strategies are an integral part of CAD/CAM systems. Every CAD/CAM system offers unique strategies to differentiate itself from the competition. The article deals with analysis of CNC milling strategies in CAD/CAM system Edgecam 2017 R2. Analysis is divided into two parts. In first part are analysed roughing strategies with focus based on time necessary for removal of material. Second part is focused on finishing strategies and achieving the highest quality of surface. In conclusion, the article deals with the analysis of existing milling strategies and the creation of a database for the assignment of optimal roughing and finishing strategies for specified components.

1. Introduction

Creating new strategies, respectively generating and optimizing new ways of tool movement across the surface, is a multidisciplinary issue, requiring knowledge of machining theory, mathematics and computer science. An important area is also the evaluation and comparison of already existing strategies because proper selection can significantly reduce machining times and tool wear [1–3]. Strategies that optimize cutting conditions to achieve a constant tool load are common, contributing to longer tool life and improved surface finish. Modern CAM systems support 2D, 3D to 5D machining. With these programs, simulation, verification and various settings can achieve the desired shape, accuracy, component quality and efficient production. The present article deals with analysis of CNC milling strategies in modern CAD/CAM system Edgecam 2017 R2. Comparison of milling strategy is based on two parameters in terms of machining time and achieved surface quality.
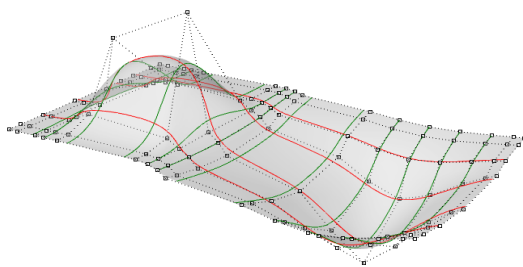
2. Surfaces in CAD/CAM systems

At present, all modern CAD/CAM systems are parametric, which allows to define the dependence between individual components or assembly be using parameters, e.g. edge length is derived from circle radius or creating 2D graphs containing dependencies [4, 5]. However, the problem arises when it is necessary to create a 3D parametric surface that does not have direct modelling support in one of the modern CAD/CAM systems. Typically, complex shapes are created using the "Spline" element, which has different defined properties in each program, so it is impossible to create the same surface in the same way in different programs [6, 7]. Mathematically defined surface does not have such a problem, but it cannot be created in the CAD programs. While programs such as Matlab, MathCad,

Mathematica, etc. are suitable for creating 3D surfaces, their main problem is that the output from them is not supported by any standard format such as STEP and IGES. To import a mathematically described surface, it is necessary to use the reverse engineering modules that are already part of some CAD / CAM systems.CAD / CAM systems use two types of surfaces:

- Standard (general) surfaces – created by rotation (conical, cylindrical, spherical, annular surfaces, etc.) and extruded surfaces. They are created by the EXTRUDE and REVOLVE commands using a closed curve (solid model).
- FreeForm surfaces – represent a complex surface. Basic of these surfaces is created by complex mathematical description. Representative of these surfaces are NURBS surfaces (figure 1) whose definition is not possible by means of polynomial equations, but are based on poles, degrees of freedom and distribution of the surface into segments formed by spline curve [4, 8] (figure 2).

Figure 1. NURBS surface.
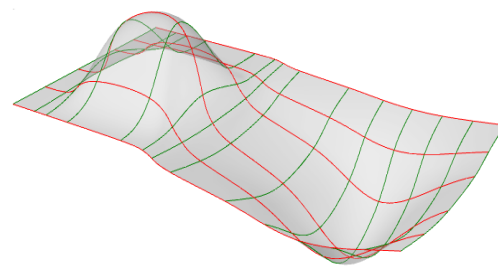
Figure 2. The control structure of a NURBS surface.

3. Milling strategies in CAD/CAM systems

Themilling strategies in CAD/CAM systems are predefined milling tool paths that are designed to machine different types of surfaces. By using suitable machining strategies, it is possible to achieve a reduction in machining time, improve surface quality, increase tool life and affect the dimensional accuracy of machining. In order for high-speed hard machining to be economically applicable in the manufacture of a component, certain technological principles must be strictly observed, not only when choosing cutting conditions, tools, etc., but also when choosing milling strategies. Milling strategies are generally divided into roughing, pre-finishing and finishing. Roughing strategies are used to remove the maximum volume of material in the shortest possible time. Due to the dimensions of the workpiece, the largest possible diameter of the tool is used. The principle of finishing strategies is primarily to achieve the highest possible surface quality. In order to achieve the lowest cutting depths in finishing cycles, production time is reduced. It is necessary to choose suitable tools in order to achieve a high surface quality. CAD/CAM system Edgecam 2017 R2 will be used for the purpose of these articles. In table 1 are chosen strategies for experiments.

Table 1. Edgacam 2017 R2 – Millingstrategies.

Roughing strategies	Finishing strategies
Concentric	Concentric
Waveform	Constant Cups Finishing
Lance	Profiling
Spiral	Lance
	Project Flow Curves

4. Experiments

Various types of the components have been designed for the experiment (figure 3). The components will be manufactured from aluminium alloy – AlMg4,5Mn with workpiece dimensions $100 \times 50 \times 30$ mm. These are mainly components with shaped surfaces that were created by rotation (cylindrical, spherical surfaces, etc.).
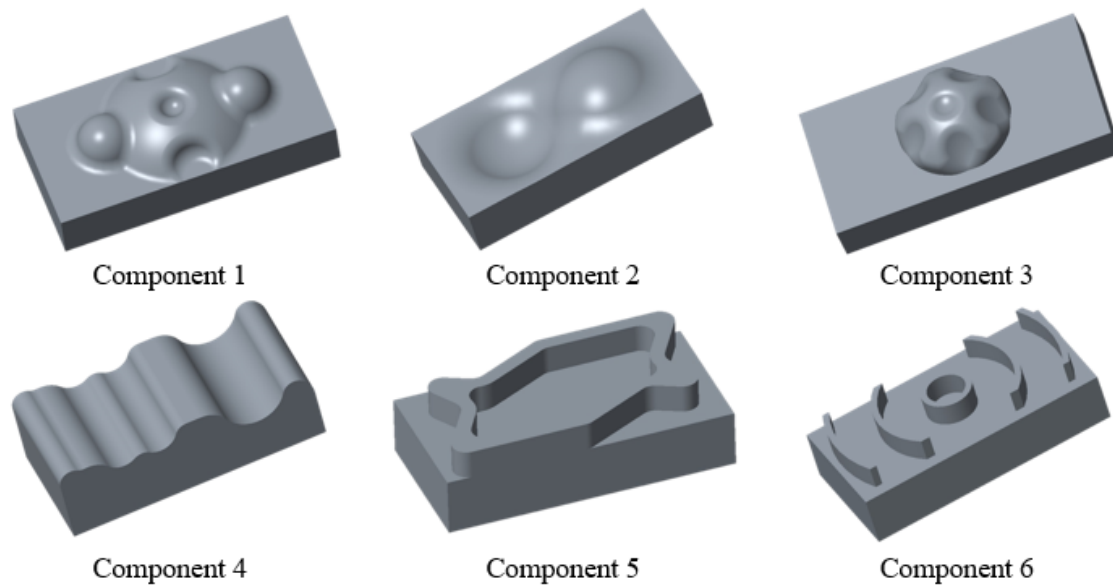

Figure 3. Components designed for the experiment.

For machining was chosen CNC machine EMCO Concept Mill 105 with control system Sinumerik 840D. For roughing strategies were chosen end mill with diameter Ø16 mm and end mill with diameter Ø4 mm. Ball milling cutters with a diameter of Ø5 mm and Ø8 mm were used for finishing. Also proper cutting conditions were chosen based on workpiece material and possibilities of CNC machine.

The aim of the experiment is to analyse the milling strategies generated in the CAD / CAM system Edgecam 2016 R2 and to evaluate their impact on the productivity and quality of the machined surface. Emphasis will be placed on the productivity of machining, i.e. production time and the quality of the machined surface. Attention will also be paid to a parameter that indicates the length of the NC code generated from each strategy. However, this parameter does not affect the machining process itself.

4.1. Time of machining

In the figure 4 is possible to see time required for machining individual components by using selected roughing strategies. Shortest time of machining was achieved with waveform strategy. This strategy focus on utilization of maximal length of the cutting part of End Mill. In the figure 5 is possible to see time required for machining of components by using finishing strategies. For this comparison were chosen only components (no. 1–4) containing complex surfaces. Components no. 5 and 6 contain only flat surfaces with 2D features. For this types of components are not suitable complexive finishing strategies.
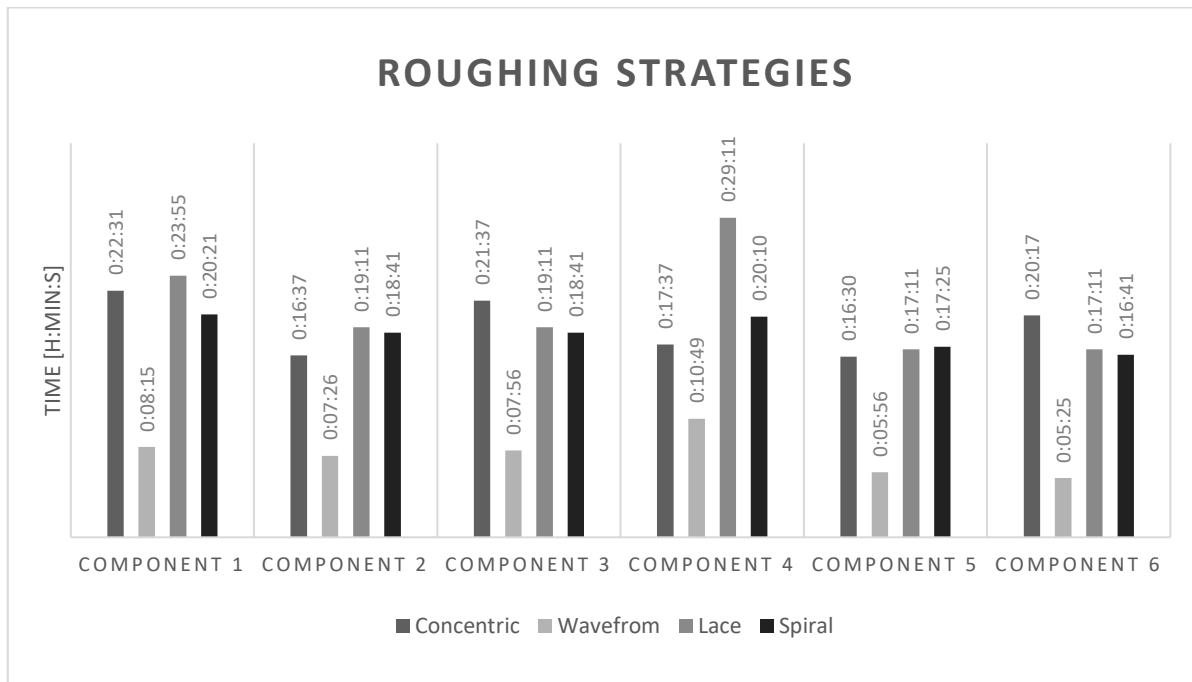
Figure 4. Time of machining for roughing strategies.
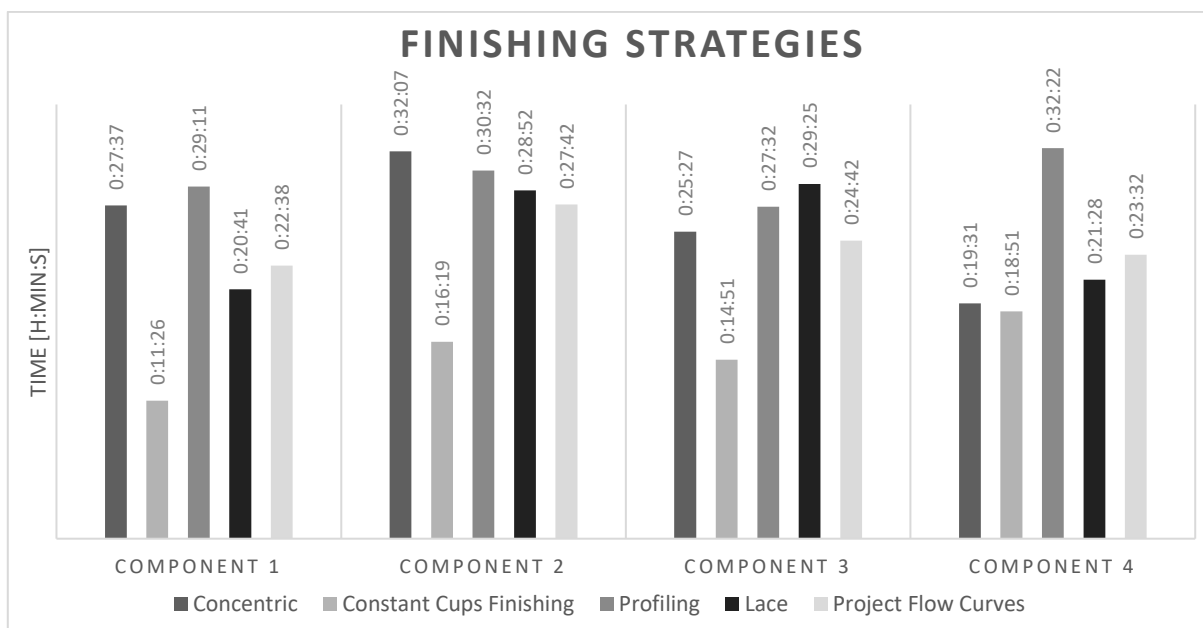
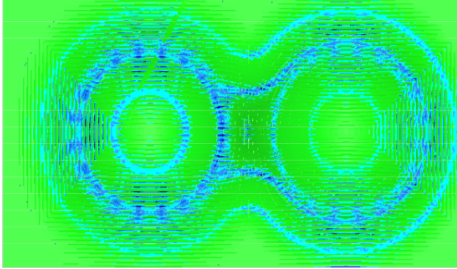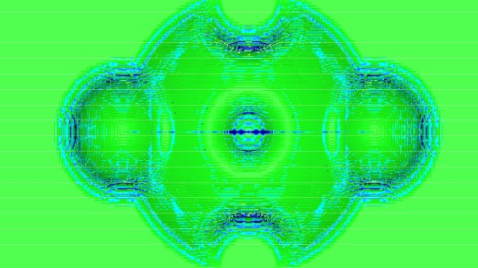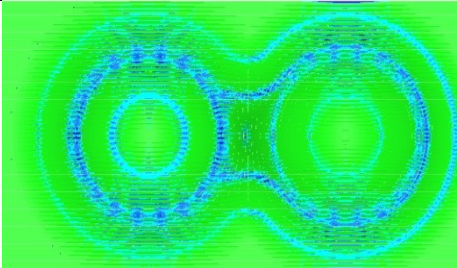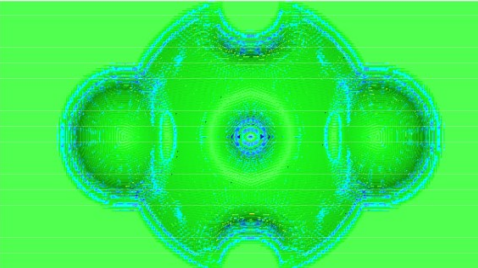**Figure 5.** Time of machining for finishing strategies.
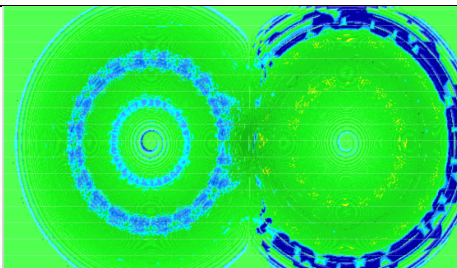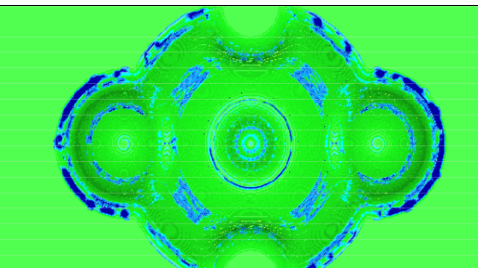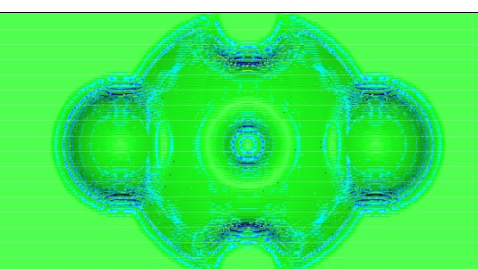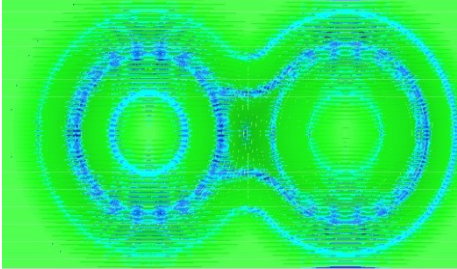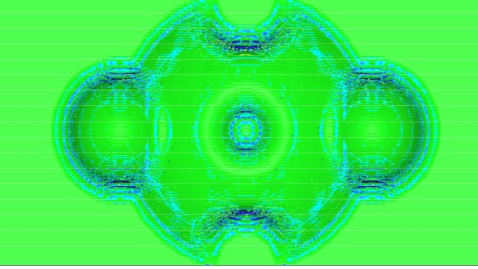
4.2. Surface quality

After completing the analyses of the time required for machining components, a consistent surface quality was chosen for further comparison. Due to machine malfunction, the surface quality was evaluated only based on simulation results. After the production of compone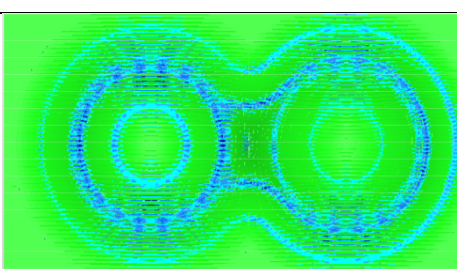nts, it will be necessary to compare the results achieved in the simulation with the results on real components. Table 2 shows an example of achieved quality with finishing strategies. Based on the simulations, it can be said that the

best surface quality was achieved with strategies Constant Cups Finishing and Project Flow Curves. The worst result was achieved using the Profiling strategy. Large amounts of residual material remained on the surface of the component or more material was removed than necessary.

Table 2. A slightly more complex table with a narrow caption.

Strategy	Component 1	Component 2
Concentric		
ConstantCupsFinishing		
Profiling		
Project FlowCurves		
Lace		

5. Conclusion

The aim of the research was to analyse available CNC milling strategies in CAD/CAM system Edgecam 2017 R2 and to create a database to facilitate selection of optimal roughing and finishing strategies for specified types of components. Each of the tested strategies had different toolpaths, machining times and after each strategy the machined surface has different quality. Based on experiments, the following conclusions can be formulated for the milling strategies in CAD/CAM system Edgecam 2017 R2:

- Time of machining – Shortest time of machining was achieved with Waveform strategy. This strategy allow to remove a large amount of materialin a very short time.
- Surface quality – Best surface quality was achieved with strategies Constant Cups Finishing and Project Flow Curves. The worst result was achieved using the Profiling strategy.
- Knowledge database – The creation of a knowledge base will enable a better understanding of the importance of the appropriate selection of milling strategies. The database can be expanded by further knowledge such as appropriate cutting parameters for different types of milling strategies.

The evaluation of milling strategies, knowledge of their possibilities and limitations creates the preconditions for their correct use, which leads to faster creation of NC programs as well as to reducing the occurrence of errors and the need for later fine-tuning of already created programs. Despite the extensive possibilities of current CAD / CAM systems, there is still possibility for further development, e.g. when designing new strategies, or improving simulations and increasing their accuracy.

6. References

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