Automation of Operations Design for Complex-Shaped Surfaces Processing

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Abstract. Research work is aimed at modeling the process of milling surfaces of complex shape in automated CAD/CAM systems. To reduce labour input of this process, an algorithm for designing milling operations is proposed. The algorithm is implemented in the form of software written in the VBA programming language from Office Excel. The software allows to select cutting tools and cutting modes for roughing, semi-finishing and finishing milling. The initial data for this are: processed material, part configuration, profile depth, technical requirements on the surface. The work of the algorithm was tested on the parts of the mold type. It is found that the set of cutting tools for all types of milling surfaces of complex shape is selected taking into account the overall dimensions of the treated surface, its curvature and radii of surfaces rounding. The results of simulation of mold processing in Sprut CAM system according to the assigned set of cutting tools and cutting modes allowed to choose the tool path with minimal processing time.

1 Introduction

Increased production of parts with surfaces of complex shape (SCS) leads to the search for the new ways and improvement of the old ones of their design and processing. If earlier such parts were used in the aviation industry and shipbuilding, now various complex forms are widely used in the automotive industry, agricultural engineering, at machine building enterprises for manufacture of dies, molds, models for precision casting, etc.

Wide use of the parts containing SCS is justified by the availability of modern CAD/CAM systems [1, 2] for their design and the variety of the latest equipment with numerical control for their processing. Quite an important role in processing is the choice of cutting tools and modes for processing [3-5]. Modern companies developing cutting tools (Hoffman, Sandvic Coromant, Iscar, etc.) constantly work on the material of the cutting part of the tool, its geometry and develop a high-performance roughing tool and a high-precision tool for finishing.

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The main equipment for manufacturing parts with complex shape surface area are milling and multi-purpose CNC machines that allow processing quite a large number of very different surfaces. This is ensured by the automatic control of the machine, allowing to move the tool along any path in the operating area of the machine.

The labour input of technological preparation of production and the process of manufacturing SCS is quite volume. This leads to a constant search for new methods of designing and developing a control program (CP) for CNC machine [6]. The search for solutions is aimed at modeling the process of milling SCS in automated CAD/CAM systems [7]: building trajectory according to optimization criteria (equipment selection, assigning cutting tools of increased durability, optimal cutting mode parameters) to reduce machining time [8]; calculation of the tool path on roughing passes taking into account the remainder of the material for finishing [9]; the formation of the trajectory by the criterion of cutting forces conservation at the assigned level, which will ensure the required surface quality [10]. The use of high-speed machining when milling SCS is aimed at improving performance and ensuring high quality surfaces [11].

The production process is improved in all directions, since even with such sufficient automation of the production process the technologist has to make decisions on the choice of tooling, structural and geometrical parameters of the cutting tool used [12], the rational tool movement path, the purpose of cutting modes.

Studies of this work are aimed at reducing the labour [13] input in the operations design for the processing of complex-shaped surfaces in automated CAD/CAM systems. For this, a number of tasks are solved:

- milling operations designing algorithm development for processing SCS;
- the choice of cutting tool constructive and geometric parameters;
- rational tool path modeling.

2 Research methodology

Creating CP for processing SCS is a time consuming process. Designing operations for the processing of SCS in CAD/CAM systems significantly reduces the time to create CP for a CNC machine [14]. However, the design of operations requires additional time-consuming decisions on the toolpaths choice for roughing, semi-finishing and finishing milling, the costs of cutting tool assignment for processing any given surfaces for all assigned types of processing. To solve this problem, milling operations designing algorithm for the SCS processing is proposed (Fig. 1).

Depending on technical requirements for the part (roughness and accuracy of the surfaces) the processing milling type is assigned - roughing, semi-finishing, finishing milling. The definition of the tool path during roughing depends on the configuration of the part. For semi-finishing and finishing processing contour pattern of the toolpath is assigned.

The choice of cutting tools is based on the material being processed, the depth of the profile and the configuration of the part. To implement the algorithm the software was developed in Office Excel, in the embedded VBA language. The cutters for all types of processing are chosen from the created and replenished base of the cutting tools (CT) (Fig. 2), which includes data on the manufacturer, structural and geometric parameters of the tool, recommended processing modes (cutting speed, feed).

Fig. 1. Algorithm for designing milling operations.

Code of cutt tool	Manufacturer	Material of cutt tool	Diameter of cutt tool, mm	Length CP, mm	Tool length, mm	Shank diameter, mm	Number of teeth	Shank type	Processing	feed
191200	Hoffmann	HSS-Co8	1.5	7	51	6	3	cylinder	finishing	0.002
191632	Hoffmann	SPM	6	8	52	6	4	cylinder	semi-finishing	0.008
191630	Hoffmann	HSS-Co5	50	36	100	32	8	cylinder	finishing	0.06
191640	Hoffmann	HSS-Co8	11	22	79	12	3	cylinder	semi-finishing	0.014
205490	Hoffmann	VHM	20	38	104	20	4	cylinder	roughing	0.1
205592	Hoffmann	VHM	8	16	63	8	3	cylinder	roughing	0.04
205718	Hoffmann	VHM	16	32	150	16	5	cylinder	roughing	0.06

Fig. 2. The base of the cutting tool (fragment).

3 Results and discussion

The algorithm was tested on the parts of the mold. One of them is shown in Fig. 3.

Fig. 3. Mold.

All experiments on designing milling operations for SCS processing were carried out in the Sprut CAM system for an imported 3D model of a mold from Compass CAD (Fig. 4).

Fig. 4. 3D model of the mold.

To reduce the processing time of rough milling, it is necessary to remove a sufficiently large volume of the material. Therefore, the overall dimensions of the surface to be machined, its curvature, and the array of rounding radii of surfaces (Fig. 5) [15] were taken into account to assign the milling strategy and a cutting tool.

Fig. 5. Simulation processing.

Modeling at the semi-finishing stage of processing was carried out taking into account the tool pass through all machined surfaces where possible [15]. Experimental data showed that the amount of not selected residual material should be no more than 20% on each pass (Fig. 6).

Fig. 6. Mode "comparison of the processing result with the part" during the semi-finished milling.

To obtain a part with final dimensions and surface quality R_a in the range of $6,3 - 0,32 \mu\text{m}$, finishing milling is carried out. For the finishing milling of SCS, ball-ended cutters are selected. When choosing a cutter diameter, the minimum radius of surfaces rounding on the part is taken into account. The selected cutter geometry will provide high performance and quality of the machined surfaces in the areas of mating surfaces with the smallest radii of surfaces rounding (Fig. 7).

Fig. 7. Mode "comparison of the processing result with the part" in the final milling.

The work of the software algorithm results in two sets of cutting tools with recommended cutting conditions and processing parameters for rough, semi-finishing and finishing milling of the mold (Fig. 8). These recommendations provide an opportunity in the Sprut CAM system to simulate the processing of a part containing SCS, show the total processing time, and then select the tool path with the minimum processing time (Fig. 9).

Roughness (Ra), μm	1.6	To select a tool						
Configuration parts (K)	2							
Profile depth (H), mm	48	Clean						
The processed material	General grades of steel							
Number of mating surfaces radii (Rckp)	6							
The number of radius	1	2	3	4	5	6	7	
	32	25	17.5	15	10	3		

	Code of cutt tool	Material of cutt tool	Diameter of cutt tool, mm	Tool length, mm	Number of teeth	Processing	Type of cutter	feed	V_s , m/min
first complete set	191632	SPM	22	88	4	roughing	endmill	0.044	74
	191640	HSS-Co8	10	72	3	semi-finishing	endmill	0.014	23
	194302	HSS-PM	6	52	2	finishing	spherical milling cutter	0.016	64

second complete set	192970	HSS-Co8	40	95	6	roughing	grinding mill	0.055	23
	1916940	HSS-Co8	15	83	3	semi-finishing	endmill	0.021	23
	207135	VHM	6	100	2	finishing	spherical milling cutter	0.037	40

Fig. 8. Cutting tool set.

Fig. 9. Simulation of treatment process. Treatment time 3 hrs 34 min.

4 Conclusions

The proposed milling operations designing algorithm for SCS processing, implemented in the form of a software product, allows to assign processing types to all the SCS and cutting tools according to the part data with cutting conditions recommendations. Modeling SCS processing in the CAM-system accord.

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