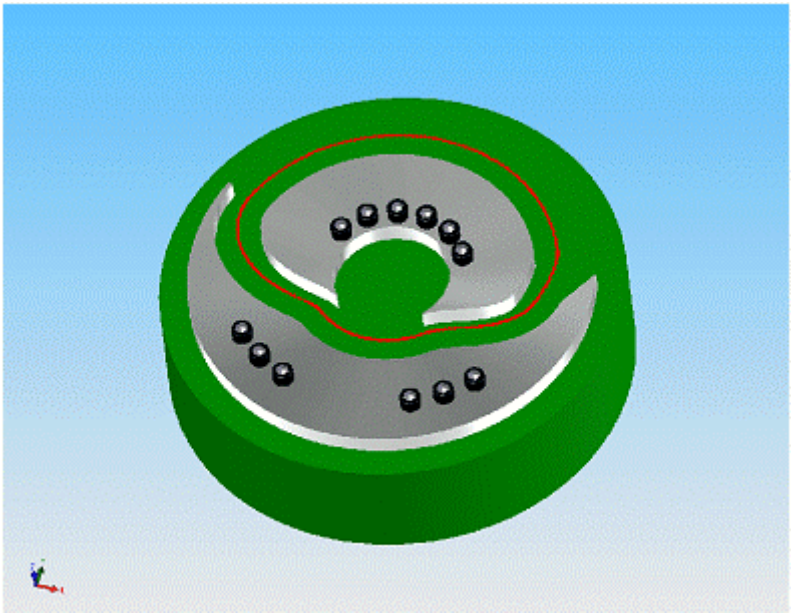
Profile curve processing

from primary to quality-correct NC data



Profile curves appear at various parts. Growing challenges on the production arise by increasing demands of accuracy. Inadequately prepared defaults from the design make it often more difficult to produce profile curves efficiently on a high quality standard. As different as the parts with their various curve forms and their special know-how in the process chain from the design up to the finished part are, as efficient a CAD/CAM system has to be so that an effective support can be given for the way from function-oriented design up to manufacturing-oriented NC control data.

Parts with profile curves are often key parts for the core function of machinery and equipment. They appear in various types like steering curves, fan rotors, camshafts, crankshafts and others **(Fig. 1)**. Complex and mathematically complicated curve runs can arise here.

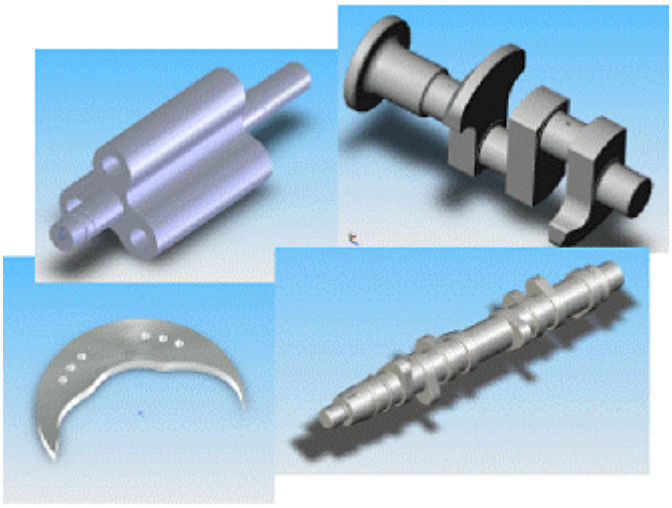


Fig. 1: Part spectrum with profile curves

Increasing standards in accuracy on the profile curves of parts put higher challenges to the manufacturing especially also then, when new manufacturing methods and new NC machinery with complex kinematics have to be used to reach profitability. It should be easy to find a satisfying standard solution under the great variety of system solutions in the CAD/CAM area. But in practice it can be seen that efficient solutions do not only have to orientate towards the specific requirements of the part spectrum, but also they have to cover well the whole engineering chain from the function-oriented interpretation of the profile curve up to the determination of the tool paths and process parameter. Only then manufacturing-, procedure-, CNC- and organisation-oriented results can be reached. To find to a target-leading solution for the NC production of profile curves, the following questions resulted from several application cases in practice have to be clarified:

- Which are the master or primary data (geometry plus attributes) for the determination of a curve resulting from the function requirements?
- In which form are these data available – paper drawing, 2D/3D-CAD model, coordinate table, formula, measured points, interpolation curve or in mixtures?
- How clear, exact and complete are the primary data for a manufacturing in the range of pre-defined tolerances?
- Have the primary data to be segmented, extended or displaced for the tool path determination to be able to produce the target contour at the workpiece?
- Are there demands for optimization of the tool paths under consideration of pre-set tolerances?
- Is an extended simulation with workpiece, tool, device, aggregate, machine model required for result protection of the NC planning?
- Have the interpolation possibilities of the CNC to be considered for control data output?
- Is the data storage of the CNC great enough to take up the control data without other measures?
- Are additional information necessary for the organisation of manufacturing execution (set-up conditions, machining times and others)?
- Is a long-time archiving of the NC manufacturing data required to be able to backtrack e. g. in case of safety-relevant parts or for the production of spare parts?
- Are profile curves to be manufactured belonging to a well-defined part spectrum and offering the possibility to run standardized process sequences in an automated way?

Depending on the answers to these questions there are various requirement profiles on an efficient CAD/CAM solution. Not or insufficiently cleared questions easily lead to underdeveloped solutions or to the compulsion to process in cascades, effort-consuming rework loops.

Because of the increasing accuracy requirement the micro-geometry is decisive for manufacturing a profile curve. It is therefore crucial for the manufacturer to get access to the primary data of the kinematical design of a profile curve. That means often that a sequence of points is the backbone of the functional design of a profile curve **(Fig. 2)**. From such a sequence of points, stored in coordinate tables, profile curves are modelled with CAD systems, which seem at a first view to be reality-near. Frequently those derived profile curves are not sufficient for the demands, either because they are too vague or because they have been interpolated with methods that are unsuitable for the manufacturing-oriented NC planning. A further problem occurs, when the manufacturing-determining attributes are not available in the CAD model of a part. That concerns e. g. details about required accuracies, probably even varying along curve segments and also exposed curve points (supporting points, min/max points, return points) and others resulting from the design with kinematical calculation systems.

Gebläserotor-G19-Koordinatentabelle.txt - Editor

Datei Bearbeiten Format ?

Koordinatentabelle für Profilkurve Gebläserotor

Profilbezeichnung		G19		
Rotoren-Achsabstand		528 mm		
Außendurchmesser Da0 =		792 mm		
Dichtleistenmaß DL =		786 mm		
Spiel einer Rotorflanke		0.4 mm		
T6/29.03.04 LUVO				
I	X	Y	K	Attribute
1	0.000000	-395.600000	0.000000E+00	A1
2	3.558295	-395.559368	2.284113E-02	
3	7.115136	-395.437472	4.570954E-02	
4	10.669071	-395.234317	6.863265E-02	
5	14.218645	-394.949909	9.163820E-02	
6	17.762404	-394.584255	1.147544E-01	
7	21.298892	-394.137367	1.380099E-01	
8	24.826655	-393.609256	1.614344E-01	
9	28.344235	-392.999932	1.850584E-01	C2
10	32.583991	-392.154257	2.139498E-01	
		.		
		.		
		.		
270	32.583991	392.154257	-2.139498E-01	
271	28.344235	392.999932	-1.850584E-01	C8
272	24.826655	393.609256	-1.614344E-01	
273	21.298892	394.137367	-1.380099E-01	
274	17.762404	394.584255	-1.147544E-01	
275	14.218645	394.949909	-9.163820E-02	
276	10.669071	395.234317	-6.863265E-02	
277	7.115136	395.437472	-4.570954E-02	
278	3.558295	395.559368	-2.284113E-02	
279	0.000000	395.600000	-1.224606E-16	A9

Fig. 2: Coordinate table with primary data for the interpretation of a fan rotor profile (extract)

If the NC planning should be based on the primary data, employees are needed that are well skilled in including all design parameter of a profile curve for proper conversion into tool paths. Part of this is e. g. the ability to interpret geometrical boundary conditions correctly and to modify them after a technological viewpoint. An appropriately designed CAM system for this preparing work is required to support such skilled persons efficiently. It must be flexibly usable for the demands of the workpiece spectrum with its specific parameters, for the most diverse data formats for transferring primary data and for the required manufacturing-oriented preparation of the geometry data.

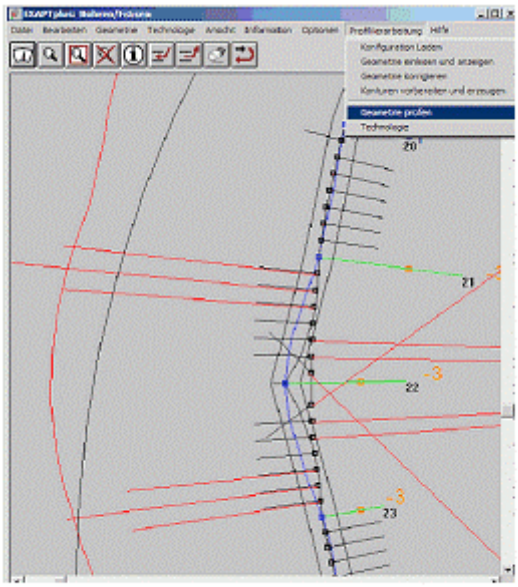


Fig. 3: Curve analysis with display of a point of discontinuity at position 22 by data outlier

The requirements heighten, when the primary data come from an ´impure source`. That occurs when e. g. it is worked with semi-manual determination methods, when a reengineering from existing parts is made over series of measurements or when only an incomplete design of a profile curve is available. A follow-up treatment of the profile curve geometry is essential in these cases and functions for curve analysis, smoothing, extrapolation and others of curves in the CAM system are necessary **(Fig. 3).**

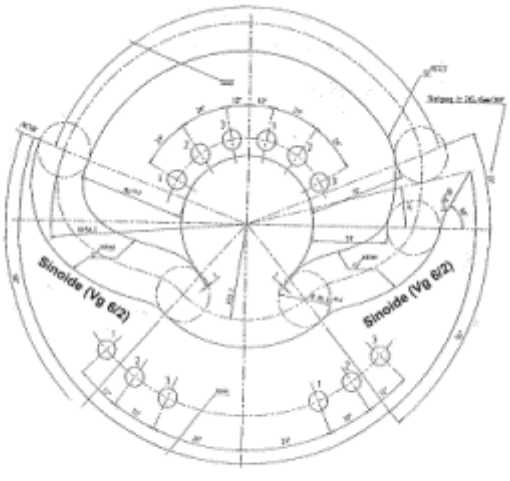


Fig. 4: Primary data in the drawing with data for the curve transitions in sinoid form

It happens that a curve is determined completely or partly by mathematical formulas indicated in drawings and therefore appropriate functions for calculation of the curve transition are necessary **(Fig. 4)**. For transition regions of profile curves with secondary function extensive calculation functions are often required to embed the sections not defined in detail by the design smoothed and tangential to the main areas of a curve.

For manufacturing-oriented engineering normally special functions for the geometrical preparation of profile curves are demanded. This is especially the cutting up of curves into segments for the single machining operations according to the process, tool operation or similar. The normal vectors are calculated for the tool orientation in the cut. The tool paths are optimized under use of the tolerance area, so depending on the situation the tool paths will be laid closer or farther to each other. Normally CNC controls are able only to process linearly or circularly interpolated curve inputs. Consequently the primary data have to be prepared according to the defined tolerance requirements. In case the primary profile curve is not the target curve to be manufactured at the part, the offset for the target curve has to be determined and also additional elements have to be inserted for curve infeeds or approach/withdrawal movements **(Fig. 5)**.

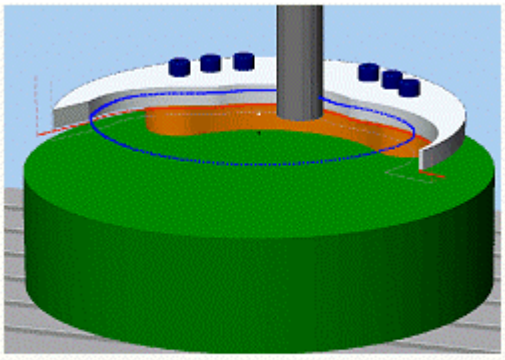


Fig. 5: Primary profile curve (blue) and adjacent target curve for machining (red)

In case of high accuracy requirements the number of tool paths to machine a profile curve consequently leads to high control data amounts. This can lead to difficulties in case of insufficient storage capacity of the CNC. The use of CNC functions like e. g. the parametrical subroutine processing can help in this case. Recurring similar facts must be given only once to the control in a subroutine to process it recurrently according to the necessary amount. The required structuring and formatting has to be solved during the NC planning by a CAM system.

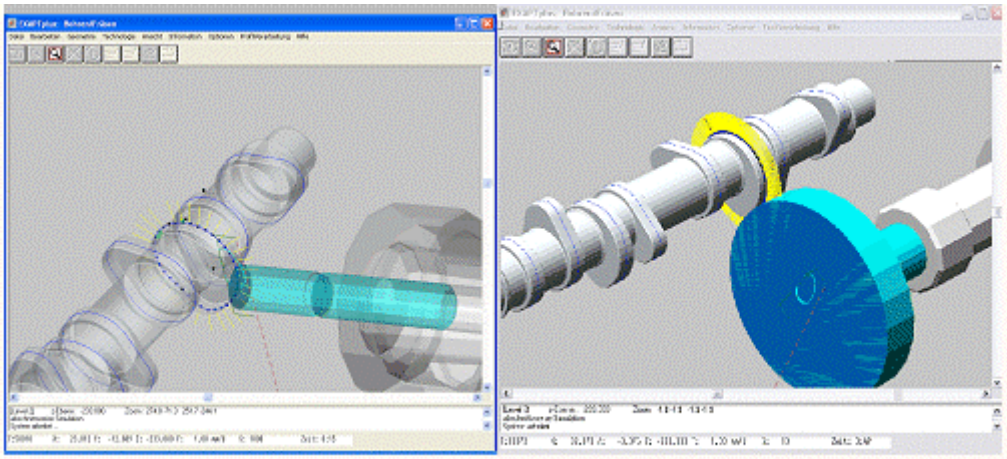


Fig. 6: Alternative turn-milling of a camshaft (orthogonal and axis-parallel tool setting)

To get higher cutting performance even with universal tools and for smaller lots, new machining processes like turn-milling are brought in. With this also revolving profile curves like e. g. camshafts can be manufactured on NC machines that are appropriately kinematically designed for this **(Fig. 6)**. In this way also cylindrical forms can be produced that run eccentric to the part rotation axis, like e. g. crank pins on crank shafts **(Fig. 7)**. For the outside machining of the gas blower rotor the turn-milling is in use besides the line-milling and form-milling for different curve sections. Especially the transition from one section to another must be particularly observed here **(Fig. 8)**.

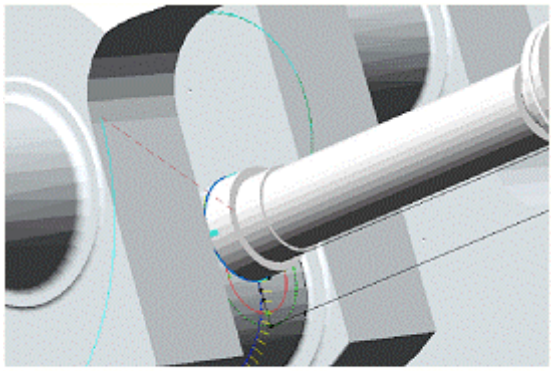


Fig. 7: Turn-milling of a lifting pin with help geometry for tool alignment

The workpiece and tool models can be visualized in different manner as shown in the previous images that give a general view of the process planning. But in the practice of the NC planning it often happens that on the one side the CAD models are not available or not in a suitable form and that the complete definition is taken for too complicated or on the other side the basic geometry elements are more useful for accurate work in the area of the micro geometry in the profile curve processing **(Fig. 8)**. This is very useful especially when geometrical conditions are model-unbound.

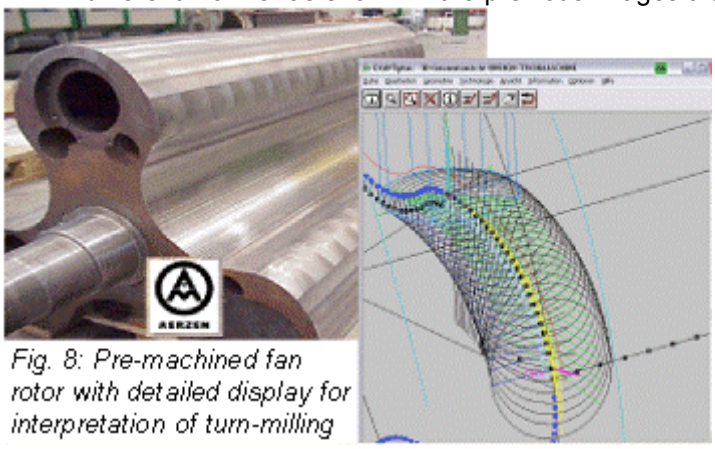


Fig. 8: Pre-machined fan rotor with detailed display for interpretation of turn-milling

The EXAPTplus system of the EXAPT Systemtechnik GmbH is able to meet flexibly the great demand of NC planning even if the requirement profiles of workpieces out of different branches are various as shown before. The EXAPT solution is configurable, extendable and adaptable. In addition the production data organisation system EXAPTpdo in connection with EXAPT-DNC is the surplus in supporting optimally the NC planning up flow up to the fast supply of NC machines with quality-correct NC data.