Rapid Prototyping without re-working

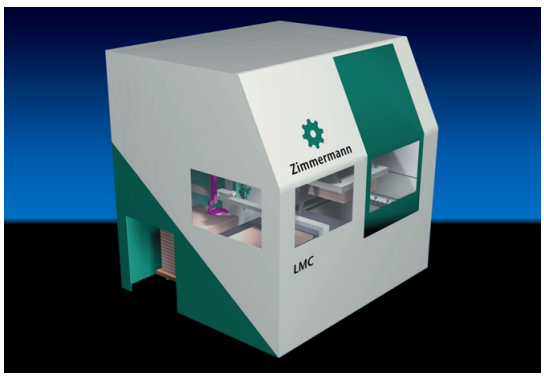
**The Layer Milling Center LMC produced by F. Zimmermann GmbH in Denkendorf combines the known RP-procedures with HSC milling.
The CAM software WorkNC-LMP especially developed for the LMC by SESCOI enables a fast and fully automatic programming.**

Complex geometry and narrow cavities within a normal milling process are possible to be designed only under extensive preparations. The user faces a problem while selecting the cutting strategies and the programming of parts with deep cavities. Additional swivelling axes are required with the milling machine and by that the collision risk is increased at the same time. The surface quality achieved by using long and thin tools is not satisfactory and the obtaining of special tools delays the delivery time even more. Necessary refinishing negatively effects the accuracy and increases the time expenditure.

Most probably a generative technique procedure such as stereolithography, laser sinter or LOM can be performed in order to provide prototypes very quickly. Through this particular layer structure of the work piece, complex contours can be produced. The accuracy and surface quality are impossible to be compared with the cut part. The expenditures for refinishing exceeds the actual production time and the quality is not always satisfactory. Positive, on the other hand, is the fully automatic procedure and the low programming expenditure.

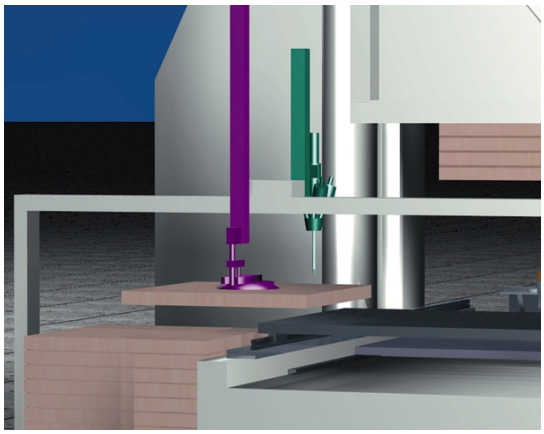
A construction in layers is, in general, practically possible with machined prototypes and pre-production parts. By that the technical cutting problems with deep contours can be eliminated or at least reduced. However, the expenditure for projecting and programming is increased considerably and the manual treating of the adhesives can lead to non-accurate results.

The gap between the above mentioned RP-process and the conventional cutting has been closed by the automatic layer milling process LMP.

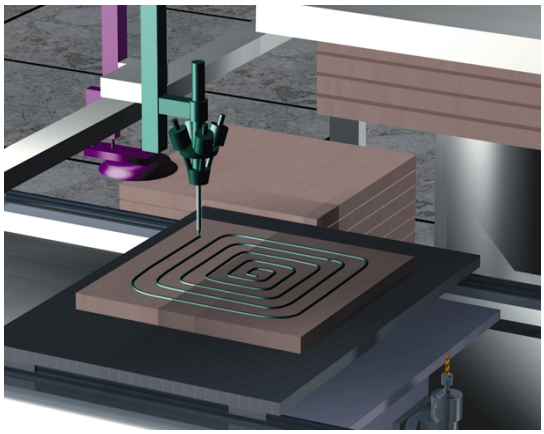


Layer Milling Machine LMC

Thereto raw material boards are taken out of the board storage station by means of a vacuum holder.

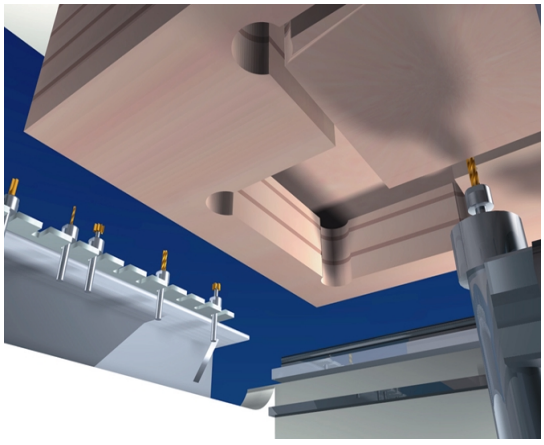


Layer Handling



Gluing Process

The following step is gluing. After a short waiting time the glue has achieved the necessary starting strength and the automatic machining starts consequently. An important fact is that each board is cut and therefore also finished. The next board is glued with the remaining surface with an overlap of approximately 1-2 mm when comparing it with the prior board. Thus it is guaranteed that the surplus adhesive is removed from the edges. As the model is generated in layers the remaining gluing surface gets permanently smaller after each board. As the boards are getting smaller optionally thin-wall frame supporting constructions can be integrated in the layers. The required parameters can be put into the WorkNC LMP CAM-Software.



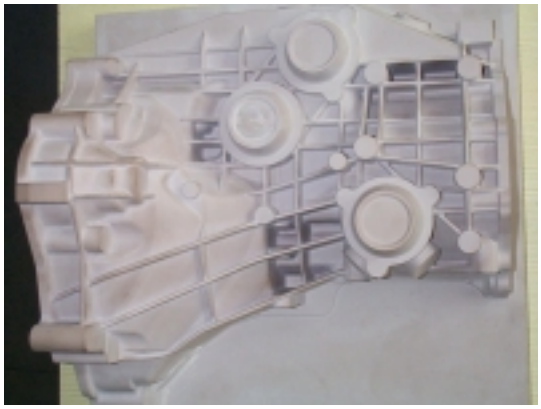
”Top-Layer” Milling

Automation by "top-layer" milling

Milling in the LMC (Layer Milling Center) takes place 'upside-down'. This means that the milling cutter aims from the bottom to the top and that the work piece is hanging on the milling machine table. In that way, chips always drop down and can be extracted. The adhesive surface for the next plate remains clean so that it is possible to automate the entire process. Apart from that, excess ahesive does not run into the already smoothed profile of the preceding plate(s). When glueing together a new plate, the milling machine table descends with the already finished part of the workpiece onto the glueing table, the optimum contact pressure being calculated by the CAM-software WorkNC-LMP in dependance on the remaining adhesive surface and controlled via the motor current consumption. Thanks to a new glueing concept, the waiting period for the processing of block materials has been reduced to only a few minutes. Further machining is automatically started after the adhesive has set.

The first machine working according to this principle has been erected at Modellbau Pauser in Schwäbisch Gmünd, where, apart from the manufacture of customized parts, milling tests are carried out and sample workpieces are made.

For sensible LMC-applications, impressively little time is required for the entire process chain. Strongly ribbed workpieces as e.g. the gearbox case depicted, are very problematic if they are manufactured conventionally especially if 'right at the bottom' of the profile small corner radii are required.



Gearbox Case (Pattern)

When layer milling on the LMC, the gearbox case does not present any difficulties. Once the machine has been set up, the LMC works manless until after approx. 25 hours the finished workpiece can be removed. The surface is of high quality all around so that no manual refinishing is required. The saving on time by far exceeds 50% for this workpiece.

HSC-conditions are always optimal as only short tools are used. This is further supported by the fact that the milling machine table is stationary during machining. The milling spindle is equipped with an additional vertical axle.

High machine dynamics, the milling spindle working at 40.000 l/min and the use of short tools facilitate the economic manufacture of smoothed surfaces which, if aluminium is being processed, are suitable for injection moulding without any further refinishing.

Prior to and after every change of tools, the tool length is measured. Wear on the tool is reliably detected. Due to the layered construction, the milling spindle never needs to dip into the workpiece profile, thus practically excluding the danger of a collision during manless operation.
A drawer has been attached to the milling machine table in order to fasten the first plate and for the easy removal of the finished workpiece. Solid guide rollers ensure the unproblematic handling even of heavy and large workpieces.
Patterns and moulds made of block materials, aluminium and graphite can be manufactured. The working room available measuring 1200x1000x750mm is also suitable for applications for which the use of other rapid prototyping/rapid tooling methods is no longer possible.
The scope of application ranges from illustrative and functional models, synthetic moulds used to cast sample parts, aluminium moulds for wax models and injection moulded parts in standard quality to graphite electrodes for cavity sinking by EDM.

Examples of application: gearbox case (foundry pattern), radiator grille (design model), aluminium injection mould for a housing.

Example gearbox case:

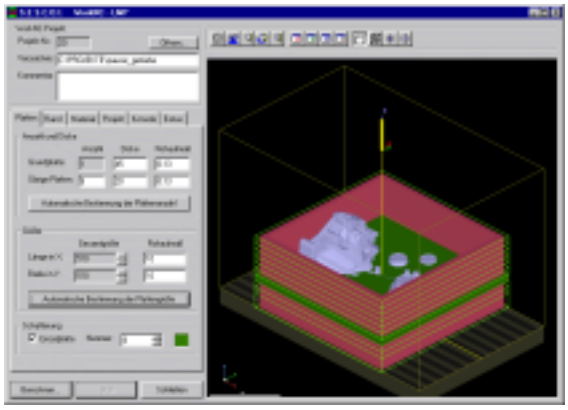
- Material: standard PU-block material (brown)
- Outer dimensions: 450x450x250mm, constructed of 9 plates
- Four milling cutters
- Smoothed with step 0,1 mm
- Time required on the LMC: approx. 25 hours (manless)
- Optimum surface 'all around'
- Refinishing of surface is not necessary
- Use: pattern for sand casting mould

Preparation of data / WorkNC-LMP:

In order to assess a method's economic efficiency, the time required to generate the NC-data also needs to be taken into account. On the part of the CAM-module, the layered structure of the pattern up to now required costly programming. For example, all milling paths required for a layer had to be programmed and calculated individually. In addition, a number of other milling paths had to be generated 'manually' for each layer. For example, strategies for the milling of the area between geometry and supporting edge, the facing of layers to the required height, the milling

of grooves for excess adhesive, the application of the adhesive itself and the possible roughing of the surface to ensure a better bonding had to be generated separately.

As a result of the cooperation between the companies F. Zimmermann GmbH, S.E.S.C.O.I. and Modellbau PAUSER - the inventor of the machine - the auxiliary program *WorkNC-LMP* was developed. With its aid, all milling paths required for all layers are created simultaneously and fully automatically. The procedure is initially the same as for milling from the solid: starting out from the 3D CAD model, a WorkNC project is created and for this the strategies required for milling are defined as if this were a conventional milling process. Afterwards, the new auxiliary module WorkNC-LMP, which is equipped with a graphics user interface and automatically loads the current project, is started directly from within WorkNC (illustration1):

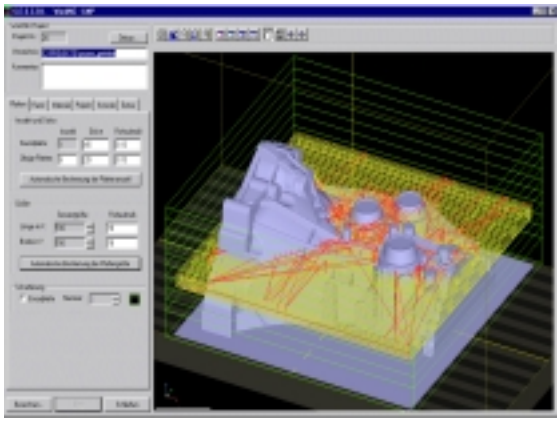


WorkNC-LMP

Illustration 1: The graphics user interface of *WorkNC-LMP*

Once inside WorkNC-LMP, all important parameter for the layer milling process are entered. These are inter alia the plate size, thickness and the number of plates, the required overlapping of milling paths to remove any protruding glue, time and force details for the glueing process and extraction parameter. In addition, important dimensions for the automatic milling of grooves to hold the adhesive residue as well as for the automatic application of the adhesive along these grooves are set. All parameter specific to the material are saved in a material file and are thus also available to other projects.

With the aid of a dialogue it is then explicitly defined which milling and glueing strategies are to be generated, which milling and glueing paths are to be calculated and which of these milling paths are afterwards to be postprocessed to NC-data with simultaneous optimization of return traverses. Because of this procedure, it is possible to purposefully calculate individual milling strategies once more with modified parameters. During the generation and calculation, the user can observe or even interrupt progress through a window in the console. Afterwards it is possible to visually depict and check all milling paths and NC-data generated (illustration 2).



Cutting Paths

Illustration 2: A rough-milling path with optimized return traverses for the third layer of the gearbox case

For the preparation of the machine, the first layer - the so-called base plate - is screwed onto the machine table. Defining the screw positions is normally not without problems, as every wrongly-placed screw could lead to the milling cutter breaking up if it penetrates into an area where a screw has been placed by mistake. In addition, screws need to be placed in the region of the supporting edge. WorkNC-LMP helps the user to define these positions by visualizing the default bores in the LMC-table. With the aid of the mouse it is then possible to interactively position the screws in this project (illustration 3). As both the cut of the base plate with the geometry as well as the supporting edges are visible during this process, selecting the points is very easy. Afterwards, a print-out of the screw positions can be made in order to prepare the LMC for the milling process.

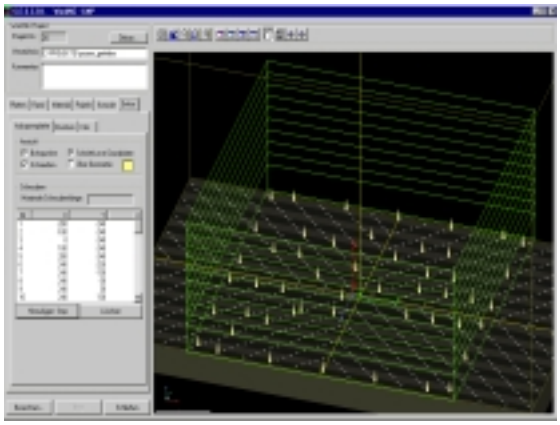


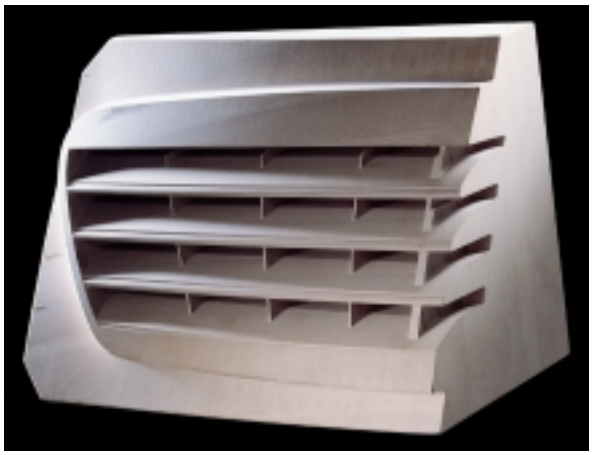
Illustration 3: Defining screw positions in the gearbox case

To further prepare the machine, it is possible to create a print-out containing plate sizes and the number of plates as well as a detailed milling cutter list. On this occasion, a detailed assessment of the expected milling times per plate is determined and printed to facilitate an optimization with regard to machine utilization.

Finally, a macroprogram is generated containing all information required for the control of the layer milling machine. With the aid of this program, the complete milling operation may then be processed.

Summary:

Thanks to the raw material plates which may be standardized and the simple milling tools, it is possible to start with the generation of NC-data very soon after receipt of an order and directly following this with manufacturing. After it has been set up, the LMC works manless until the workpiece is finished. It is not necessary to manually refinish the milled surface. The result is a reduction of machining times and at the same time a very high product quality.



Example Radiator Grille

Technical data:

X, Y, Z	1200x1000x750mm
Plate thickness	5-50 mm
Max. forward feed	40 m/min
Max. axle acceleration	8 m/s_
Spindle output	8 kW
Spindle speed	40.000 l/min
Tool holding fixture	HSK 32
Materials	Synthetics, aluminium, graphite

Illustrations
Radiator grille and aluminium injection mould
Gearbox case