Five-Axis Milling—
The Key to High-Tech Products

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When developing new components and products, it is important to consider production aspects as early as possible. This concern frequently requires the fabrication of one-of-a-kind models, whereas the manufacturer's know-how usually lies in the mass production of components. Sulzer Innotec, a specialist for variant production, has an efficient infrastructure and resources in the field of five-axis milling. Its service offering extends from component modeling and CNC programming to production on milling centers. In this setting, it is possible to carry out the entire product development process from the idea to finished component.

Sulzer Innotec does not manufacture its own products, but rather concentrates on process development and production as a service. Its offering range includes pure milling jobs, manufacturing jobs including CNC programming, up to the development of sophisticated production technologies (Fig. 1). The latter assignments often begin with a feasibility study and include prototype fabrication and, on a case-by-case basis, training of customers who wish to produce these parts themselves.

Shorter setting-up times

Five-axis milling technology, as used by Sulzer Innotec, allows the machining of complicated workpieces with a single or very few

1 A workshop can be laid out either for series production or for variant production. With its customers, Sulzer Innotec, as variant manufacturer, develops five-axis milling processes for exacting applications.

chuckings on one machine; this ability to work on one machine substantially reduces the setting-up, or secondary processing, times. Since the orientation of the workpiece with respect to the milling spindle is variable, it is possible to produce surfaces with undercuts as well as workpieces with narrow clear openings. Additionally, the tools can work with favorable blade angles—and thus with higher cutting speeds—which shortens the net machining time, i.e., the primary processing time (Fig. 2). These advantages allow Sulzer Innotec to offer its services at prices in line with the market.

Sulzer Innotec has gained considerable experience through the development of a multitude of production processes. By outsourcing prototype and small batch production, customers can profit from this experience and the knowledge transfer from other projects. If in-house production is strategically important to a company, it will acquire the production know-how and manufacture the product itself. The collaboration with Sulzer Innotec also offers decisive advantages in reduction of cost and risk or in shortening the time to market.

2 In this mixer from Sulzer Chemtech, which Sulzer Innotec produces on a five-axis milling center, the component's internal surfaces can be machined with short tools at an optimal cutting angle. Milling vibrations are thereby reduced, and the cutting speeds can be increased.

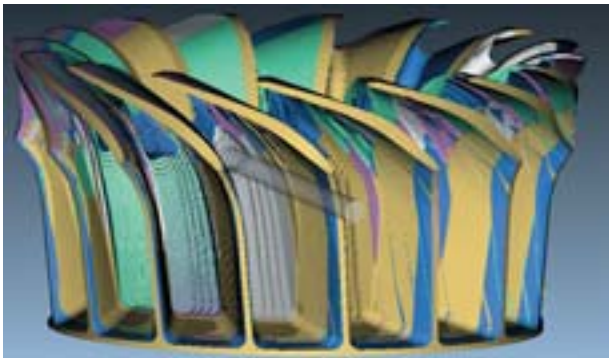
Technology Transfer

If customers want to have in-house manufacturing, Sulzer Innotec conducts a technology project. Frequently, in the scope of such a project, the customer purchases a milling center, which will subsequently be operated by the company's own employees.

If only one specific component is to be machined, the project comprises the milling machine, the machine tools, and the CNC programming. If the customer wishes to program and produce similar components independently, a more extensive technology transfer must take place and training for the operation of the control software for the milling machine (NC software) will be provided.

One current example of such a technology project at Sulzer Innotec is the design of a milling process for model turbine runners used in the development of water turbines. In water-turbine projects, model test rigs are used to prove the guaranteed performance levels. Therefore, the acceptable tolerances for model production are very tight. The production of these model turbine runners is very exacting; the three-dimensional shapes have to be transferred from the computer-aided runner development onto the workpiece without any deviation. The tight schedules for large-scale projects cause the manufacturers of water turbines to look for processes with which the model runners can be produced as quickly as possible.

3 Within the scope of the feasibility study, the accessibility, the required swiveling path, and the collision situation on the machine are investigated with the help of a CAD program.



4 The milling of the blade channels is extremely difficult due to the possibility of collision of the tool with the workpiece. It requires special NC software for five-axis simultaneous milling. The ripple structure, which results from the crescent-shaped cutting surfaces, is typical for plunge milling.

Feasibility Study

The biggest challenge in this project, which Sulzer Innotec performed on commission of a water-turbine manufacturer, was the machining of the blade channels, because the access from inside was very constricted due to the collision of the milling spindle with the opposite wheel side. Access from the outside required the use of very long tools, which tend to vibrate and are thus difficult to control. The length of the blades and the susceptibility of the blades themselves to vibration were additional critical points.

5 Not all milling parameters, e.g., cutting values, cutter deflection, and vibrations, can be checked on the computer. For this reason, the running-in process on the machine is required. As a rule, running in is performed on a real workpiece and not on a lost specimen.

Therefore, a feasibility study was initially performed, and with the help of a computer model the accessibility of the blade channels for milling tools was verified. The traversing regions, the chuckings and the clearances on the machine—the latter describing the working space in which a pivoting workpiece can be moved without collision—were also examined with the help of a CAD program (Fig. 3). In addition, a concept for the machining was developed at an early processing stage, so that the tight dimensional tolerances and surface quality could be met.

New Machining Strategy

Subsequently, the course of the project was planned. It was extremely important to keep the processes as simple as possible. Therefore, the customer's machine was set up directly at Sulzer Innotec, and the components were run in on this machine. The sequences could thereby be tested and improved on-site.

While writing the milling program, a direct collaboration with the NC program developers is established if necessary. In order to implement the milling strategy for the model turbine runner, it was even necessary to use a variety of NC programming software codes. Sometimes, Sulzer Innotec pushed the boundaries of established machining strategies to their limits and beyond. In this case, plunge milling turned out to be the most controllable technology (Fig. 4). In plunge milling, primarily axial forces act on the tool. This fact allows greater machining forces and thus higher cutting rates, particularly with long tools, such as those required for the blades of the model runner. The machining times were shortened as a result (Fig. 5). Although the machining times were to be kept as short as possible, a robust milling strategy, which does not approach the performance limits of tool and machine, is adhered to in such projects. This approach provides the scope required to optimize the NC programs on the machine.

Production Procedure Implemented

The customer's acceptance of the milling work, the machine, and the milling and production processes conclude a project. Sulzer Innotec is responsible for the milling quality and the production process.

The customer's experts were also trained to program the NC software. Since June 2005, water turbines for model tests have been produced in accordance with the process developed by Sulzer Innotec. The customer now has a modern production process that would have required substantially more time and money to develop without the support of Sulzer Innotec's experts. ◀

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