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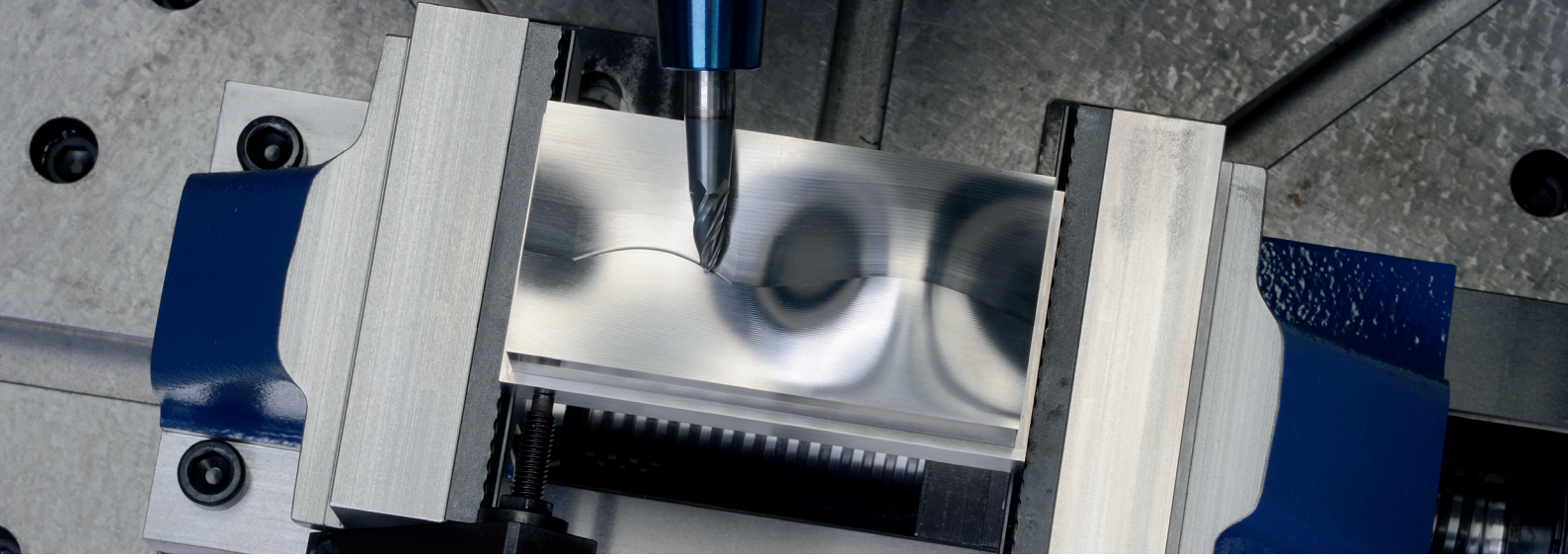
FLEXIMILL

A TECHNOLOGY PLATFORM FOR THE FAST AND FLEXIBLE MACHINING OF FREEFORM SURFACES USING CIRCLE SEGMENT END MILLS

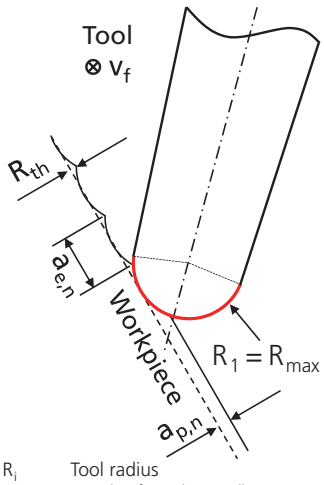


TECHNOLOGY

According to Eurostat, the fabricated metal products manufacturing sector in the EU-27 comprised 388,000 enterprises in 2010, making it the largest manufacturing sector in Europe. The 3.6 million employees generated EUR 149 billion of value added, which is the third highest level of value added, after the manufacture of machinery and equipment and food products. Milling is one of the most important technologies used in the sector. According to figures published by the German Machine Tool Builders' Association, VDW milling machines and machining centers accounted for approximately 35% of all machine types in production in 2013.

The manufacture of geometrically complex metal products relies heavily nowadays on the extensive use of five axis-machining operations, supported by advanced computer-aided manufacturing software for process planning. State-of-the-art tool technology used to machine complex geometries, such as freeform surfaces, includes milling with ball end type milling tools. However, the ball end-milling process is very time consuming due to the required small step-over distance between adjacent tool path passes.

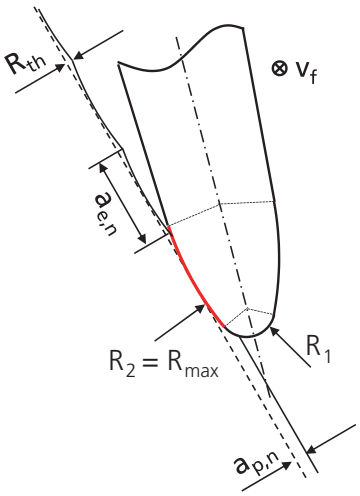
One approach to increasing productivity in finish milling is to utilize new cutting tool technologies. A major trend in this area is the use of so-called circle segment end mills, also known as barrel tools. Circle segment end mills are characterized by a contour consisting of a circle segment, apparent in the side view, with a considerably larger radius than the actual ball end radius of a comparable ball end mill. Consequently, the step-over distance in finish milling can be increased significantly, resulting in a reduction of the required cutting time by up to 80%.

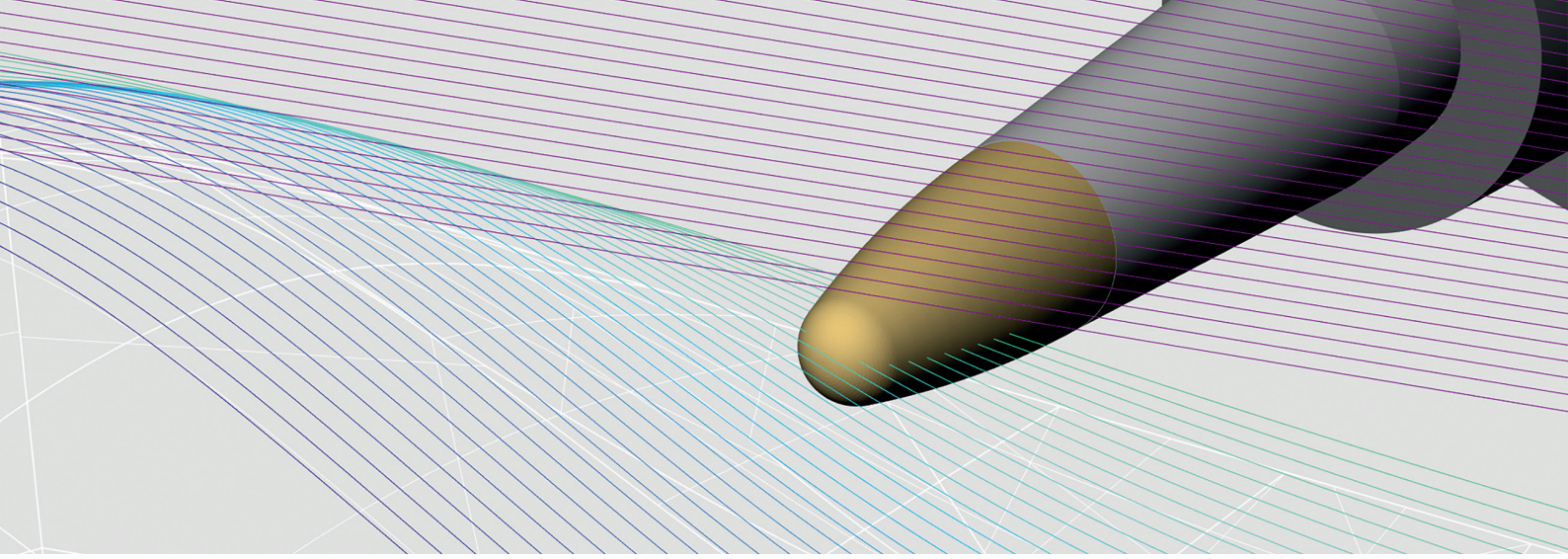


R_i	Tool radius
$a_{p,n}$	Depth of cut (normal)
$a_{e,n}$	Width of cut (normal)
R_{th}	Theoretical roughness
v_f	Feed direction

Ball End	Parameter	CSEM
3	Max. tool radius R_{max} [mm]	75
1.7	Theor. roughness R_{th} [µm]	1.7
0.2	Width of cut $a_{e,n}$ [mm]	1.0

Factor 5



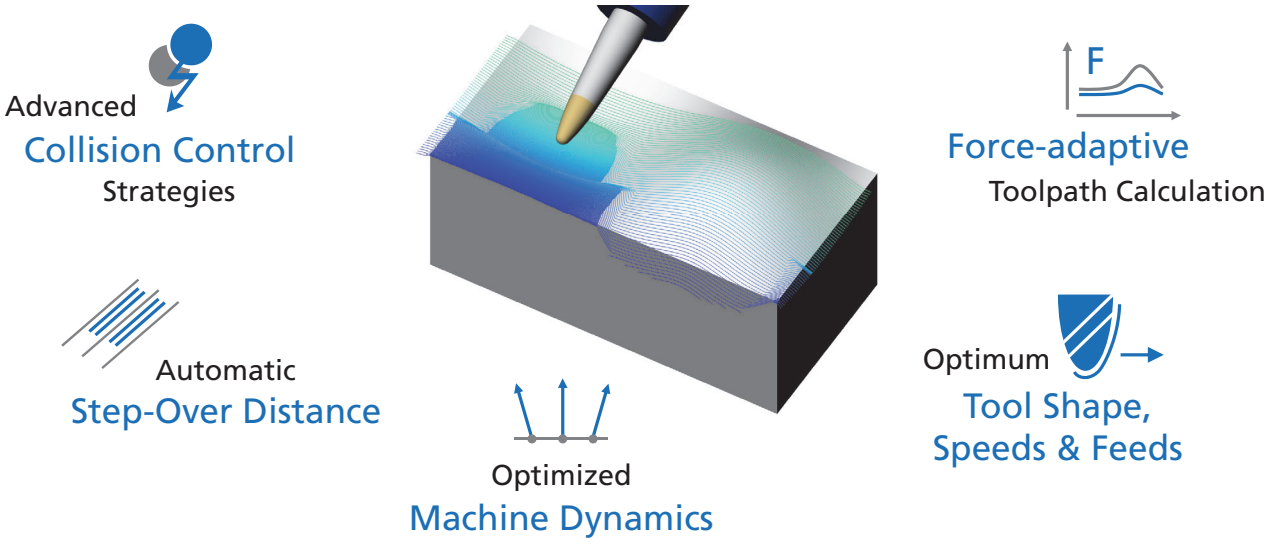


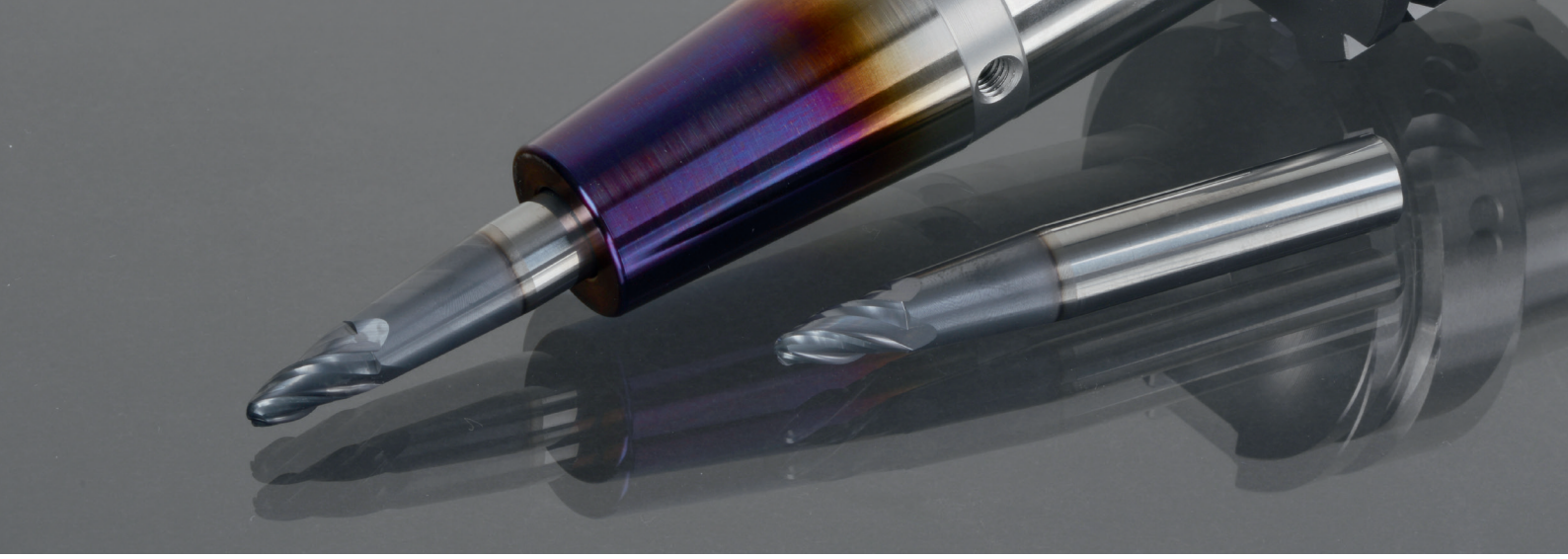
PROJECT AIM

Increased productivity, surface quality and economy are three major advantages of circle segment end mills over the state-of-the-art ball end milling technology. In recent years customers have been able to choose from a wide range of circle segment end mills which are readily available on the market and are now being produced by an increasing number of cutting tool manufacturers. However, during process planning in the production environment, aspects like suitable tool choice, geometrical flexibility and tool path design can be challenging.

During process planning of a circle segment end milling operation it becomes obvious to the end user that the capabilities of the computer-aided manufacturing software frequently struggle to keep up with the demands of the specific characteristics and complicated mathematical handling of the cutting tool geometry. This deficit is less noticeable when simple surface geometries like flat or ruled surfaces are machined, but becomes especially evident in five-axis machining of more complex freeform surfaces. Against this background, the aim of the FlexiMILL project is to provide a technology platform for the fast and flexible finish machining of freeform surfaces with circle segment end mills.

The aim of the FlexiMILL project is to develop tailor made innovative and adaptive machining strategies, especially designed for machining complex workpiece geometries with circle segment end mills. The project adopts a threefold approach, addressing the three major research areas "Cutting Tool Technology", "Process Planning and Toolpath Calculation Technologies" and "Fundamentals and Technology Development". As a result, FlexiMILL will enable more flexible use of circle segment end mills in a wide range of applications in businesses ranging from tool and die making and medical industries through to turbo engine manufacturing.





RESEARCH AREAS

Cutting Tool Technology

Due to the specific cutting conditions prevalent in the milling operations conducted using circle segment end mills, it is crucial that the appropriate tool geometry for a specific machining task is selected carefully at the process planning stage. Appropriate cutting tool design combines a maximum of process efficiency with a high level of geometric flexibility, allowing as large as possible an area of the workpiece to be machined within a short period of time. Once suitable tool geometry is in place, cutting conditions are highly dependent on the combination of tool path and workpiece geometry. The tool design must enable adaptive process control in order to compensate for the influences listed. Finally, it is vital to ensure economic tool life time via classic optimization of cutting-edge geometry, substrate, coating, as well as through optimum speed and feed rates.

Process Planning and Toolpath Calculation

Nowadays manufacturing engineers and technicians can choose from a wide range of machining strategies for a specific machining task. Those strategies are easily implemented via a wide range of commercially available CAM software packages and are industry-proven in numerous applications. However, when it comes to milling complex geometries such as freeform surfaces, strategies usually focus on the point contact of the state-of-the-art ball-end milling process. The simple transfer of such existing machining strategies onto the milling with circle segment end mills is often not sufficient. The eccentric position of the circle segment center point, along with the limitations in tool orientation and the differing cutting conditions require adaption of existing tool path calculation algorithms. FlexiMILL will therefore focus on the development of suitable machining strategies which take account of the mentioned specific characteristics of circle segment end mills. The R&D results will be incorporated into the market-leading multi axis calculation core and in one of the major CAM software products readily available on the market today.

Fundamentals and Technology Development

The cutting conditions in milling, i.e. the engagement between the cutting tool and the workpiece, largely determine the overall performance of the cutting process. In milling operations conducted using circle segment end mills, the resulting cutting conditions are generally different from the point contact, which occurs in milling with ball end mills. As a result, there may be significant variations in the machinability criteria such as cutting force, tool wear, process stability and surface quality within a single process. FlexiMILL will focus on the detailed analysis of cutting conditions in terms of different surface topographies, process parameters and machining strategies, when using circle segment end mills. The goal of these research activities is to deduce adequate process rules and to translate these into viable machining strategies. The innovative approaches in machining strategies will be directly integrated into the tool path calculation core and subsequently into the major CAM software product. Ultimately the developments will be demonstrated within the process planning and machining of a full demonstrator component from the medical sector.

PARTNERS

Camaix GmbH

Camaix specializes in CNC-Technology, Computer-aided Design CAD and Computer aided Manufacturing CAM with customers worldwide. Camaix has been successfully developing sophisticated software for 5-axis-toolpath creation, machine verification and other purposes in the CAM/NC/CNC area since 1997. The staff working at Camaix facilities are project engineers with the experience ranging from 5 to 30 years. Almost all of this experience is in developing solutions for computer-aided manufacturing related problems and in utilizing these solutions both in R&D and in industrial practice.

Fraisa SA

Fraisa produces cutting tools for metal cutting processes throughout the global market. The Swiss-based company, founded in 1934, currently employs more than 500 people and is one of the leading manufacturers in the industry. The core business activity of Fraisa is the production and sales of cutting tools like solid end mills, drills and taps for the machining of metal and its alloys. The customer range comprises the medical and watch industry in Switzerland as well as the automotive, the aerospace, the medical and the die and mold industry in Europe. A further key factor in the company´s success is the after sales-service worldwide including tool regrinding and recoating.

Fraunhofer Institute for Production Technology IPT

The Fraunhofer IPT combines knowledge and experience from all areas of production technology. Located in Aachen, it offers customers and partners applied research and development for networked, adaptive production. The Fraunhofer IPT does not only understand production in its individual steps, but also considers the entirety of the processes and the and the interconnections among various elements of the process chain. Its range of services is oriented towards the current challenges of specific industries, technologies and product areas such as tool and mould making, the optical industry, turbomachinery manufacturing, life sciences engineering and lightweight production technology. Currently about 460 employees work at the Fraunhofer IPT on an area of 9000 m². About 5000 m² of this are used as laboratories and machine shop floors.

Mathys AG

As a globally active Swiss family business founded in 1946, Mathys core business activities focus on the development, production and distribution of artificial joint replacements for the areas of hip, knee and shoulder, as well as on synthetic bone replacement materials and sports orthopedics. Mathys applies innovative 5-axis machining technologies in the manufacture of complex implant geometries, providing high quality products to clinical customers worldwide.

ModuleWorks S.R.L.

ModuleWorks S.R.L. is a leading Software Component Provider for CAM Industry. The products are 3-5-axis machining and simulation technology as used by many of the leading CAM systems and by specialized manufacturing companies. ModuleWorks delivers no CAM-products directly to end users, which allows them to focus on meeting the specific needs of the OEM companies like Siemens, Mastercam, etc. in CAM-core algorithms. ModuleWorks S.R.L was funded in 2004. The development teams are made up of CAD/CAM industry experts with special knowledge of 5-axis machining, simulation and graphics technologies."

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The Eurostars Programme is powered by EUREKA and the European Community

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The presented work is powered by Eurostars, a joint program between EUREKA and the European Commission, co-funded from the national budgets of 36 Eurostars Participating States and Partner Countries and by the European Union through Horizon 2020 (E!10874 FlexiMill).