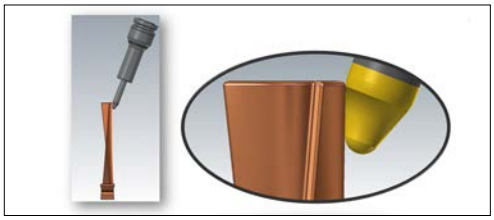
An Introduction to 5-Axis Machining with Circle Segment End Mills

INTRODUCTION

Reducing cycle time and achieving a superior surface finish are two key goals when 5-Axis machining. Manufacturers in aerospace, die and mold, medical and many other industries that machine parts traditionally with a ball nose end mill have access to a powerful alternative: Circle Segment End Mills from EMUGE. Increased tool life, superb finishes and significantly reduced cycle times are all easily achieved when using Circle SegmentEnd Mills.

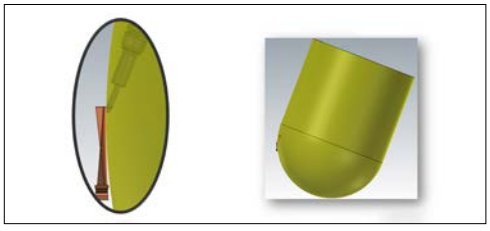
The unique differentiator of Circle Segment End Mills is their shape. A Circle Segment End Mill uses a cutting edge with large profile radii, which leads to a wider stepover when cutting. The surface quality of a machined part is directly related to the effective width of cut of the end mill. The width of cut is referred to as the stepover length. Each stepover creates a small cusp on the part surface. The greater the milling stepover length, the better the surface finish and the lower the cycle time for milling.

Contrastingly, a ball nose end mill's stepover is small, between 3 to 5 percent of the diameter of the tool, reducing the amount of surface area that the tool is in contact with the material. This means more passes are required to obtain an optimum surface finish, putting the tool through excessive stress and wear. Additional tool passes due to the reduced stepover length also increases the manufacturing cycle time.



Circle Segment End Mill shown at a 1,500 mm radius profile.

To achieve the same stepover length as a Circle Segment End Mill (shown above), an enormous Ball Nose End Mill (shown below) would be required.



Close-up of exaggerated 3,000 mm Ball Nose End Mill with a 1,500 mm radius profile.

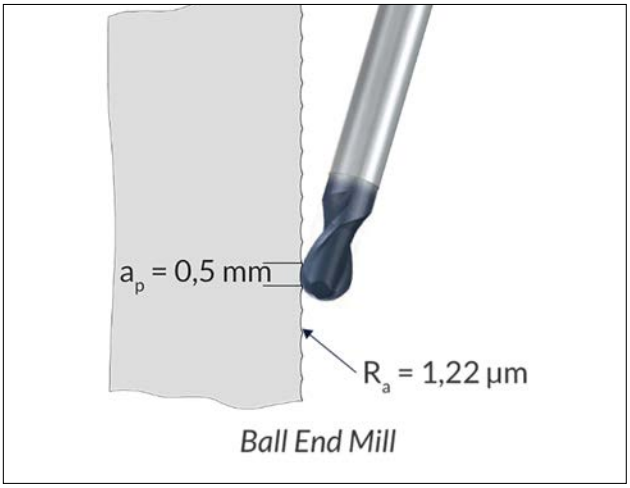
REDUCING CYCLE TIME, IMPROVING SURFACE FINISH WITH CIRCLE SEGMENT END MILLS

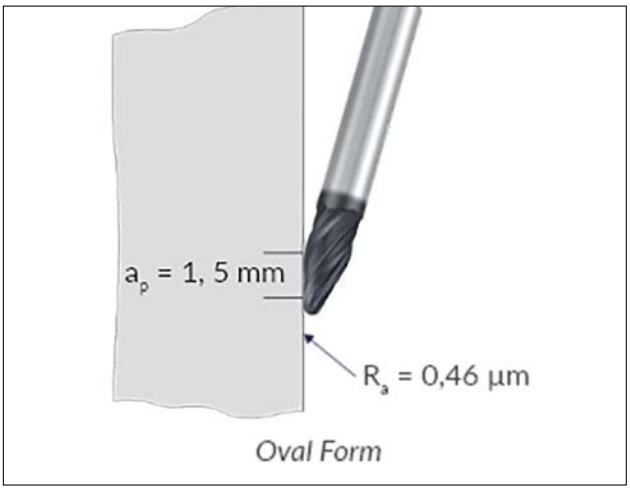
A solution was developed to solve these issues and a superb surface finish quality can now be achieved by mapping only a part of the circle (a circle segment) on the end mill. This end mill design features unique forms with large profile radii in the cutting area of the end mills to enable large stepovers that cut wider swaths of material removal enabling shorter tool paths, while maximizing tool life, efficiency, and minimizing cusps. The large stepover produces higher cutting forces than standard ball nose cutters due to the large radii on both the face and radial cutting edges. The large radius simulates a ball-nose end mill with a cutting diameter of 12 to 3,000 mm and even larger.

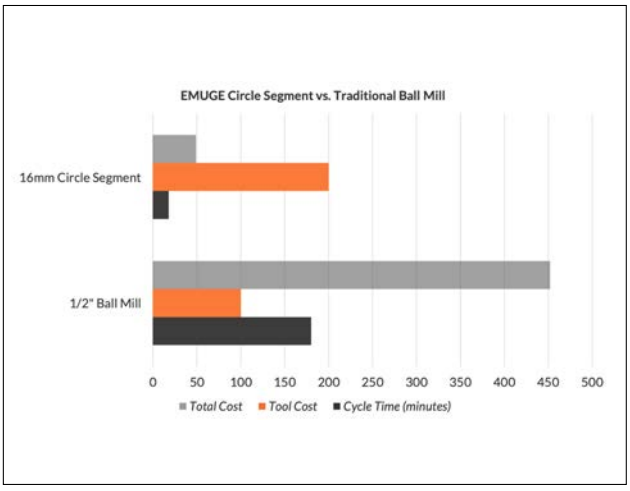
By combining advanced cutting-edge geometries with expansive radius profiles, EMUGE Circle Segment End Mills mimic large diameter cutter profiles with standard tooling sizes. For example, a 16 mm diameter end mill can have a 500 mm radius profile. This significantly increases the stepover width of the end mill and reduces the milling cycle time by up to 90%.

Specific CAM system software, such as the latest versions of hyperMILL® (OPEN MIND Technologies) or Mastercam® (CNC Software), is required to support and compute the geometries of EMUGE Circle Segment End Mills to achieve the performance levels the tools were designed for.

To see Circle Segment End Milling in action, view a video which shows finishing a surface with a standard ball nose end mill strategy and the new EMUGE Circle Segment strategy, showing a 90% cycle time reduction with an improved finish.







THE PROOF IS IN THE PASSES

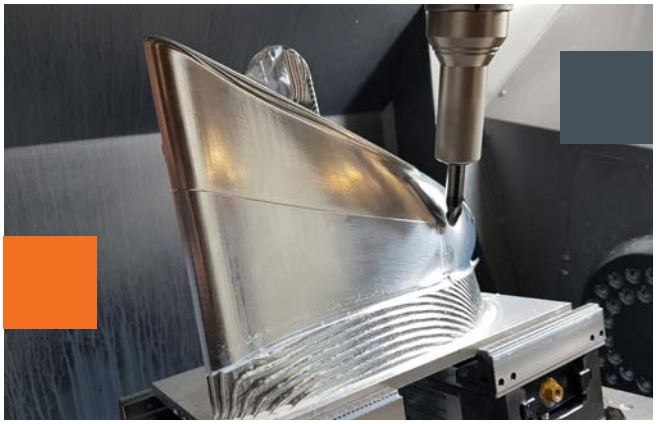
The true test of the success in milling is in the reduction of cycle times and the resulting part quality. An example of a challenging finishing application that demonstrated the advantages of EMUGE Circle Segment technology is a turbo intake header with steep sides and a continuously changing contour comprised of aluminum alloy.

The manufacturer was running a 2-flute, 0.500" ball nose end mill at 800 SFM with 0.010" stepover to complete the job in over 10 hours. The end mill lasted for 15 parts before needing replacement. To reduce cutting time, a Circle Segment end mill was introduced with an EMUGE FPC milling chuck.

Using a 12 mm Circle Segment Taper Form end mill with 3-flutes and a 250 mm radius, the cutting speed was increased to 1,900 SFM with 0.060" stepover to complete the job in only 27 minutes. Thirty parts can be milled with one Circle Segment end mill compared to 15 parts with the conventional ball nose end mill.

Both tool types produced an average surface finish of Ra 63, but the Emuge Circle Segment end mill freed hours of machine time on each job run.

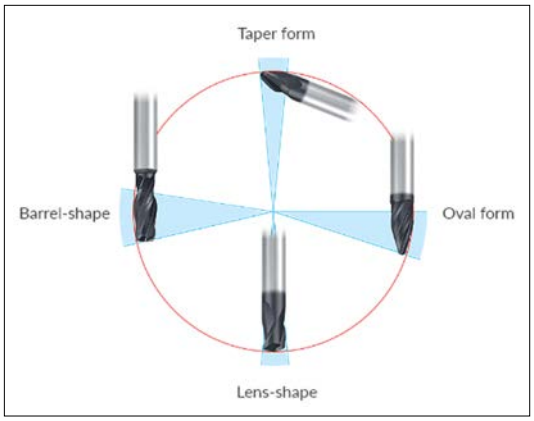
The result: a $1,000 per part cost savings. Even though the Circle Segment tool cost was more than the conventional tool, it still resulted in a per job cost saving of 95.1%.



In a large fascia mold example, some surfaces could be machined using tangent plane machining. The greatest benefit is achieved in areas that cannot easily be machined by side milling with an end mill, since these pockets are quite deep. Traditionally, they would have to be machined using a ball nose end mill with a tight stepover. The larger the ball end mill, the greater the amount of material that will need to be removed in the corners. Circle Segment End Mills can easily access these vertical corners, as well as the floors of deeper pockets. The appropriate CAM software enables Circle Segment tools to not only get access to the vertical and steep areas with tangent plane machining, but also on any flat or shallow areas. It is important to note that the ball nose end mill took approximately 9 hours and 36 minutes to complete, whereas the **Circle Segment End Mills took an estimated machining time of only one hour and 10 minutes. This accounts for an 88% reduction in machining cycle time.**

TOOL OPTIONS

Circle Segment End Mills excel in machining turbine blades, impellers and blisks, as well as molds, and are offered in four geometries: barrel-shape, oval form, taper form and lens-shape. Oval and taper form mills are ideal for curved shapes such as blades or straight-walled pockets, freely engaging more of the cutting edge. Barrel design mills provide highly effective flank milling to the sides of spiral grooves and similar applications, while lens shape mills excel in narrow channels or in lands on molds. Each type is available in various diameters and lengths depending on the type of application.



THE EMUGE DIFFERENCE

EMUGE recognizes that the growth in popularity of Circle Segment end milling (also known as conical barrel cutters) has led to a number of similar tools on the market.

Why should your company choose EMUGE?

EMUGE pioneered the tool technology! This deep knowledge of and experience with Circle Segment End Mills offers manufacturers unsurpassed levels of successes with a broad range of applications.

In-depth customer service. EMUGE partners with manufacturers, providing a personalized level of attention you can count on. At EMUGE's advanced Technology Center in West Boylston, Massachusetts, two services are available to ensure your success with EMUGE high performance cutting tools such as Circle Segment End Mills.

EMUGE FRANKEN

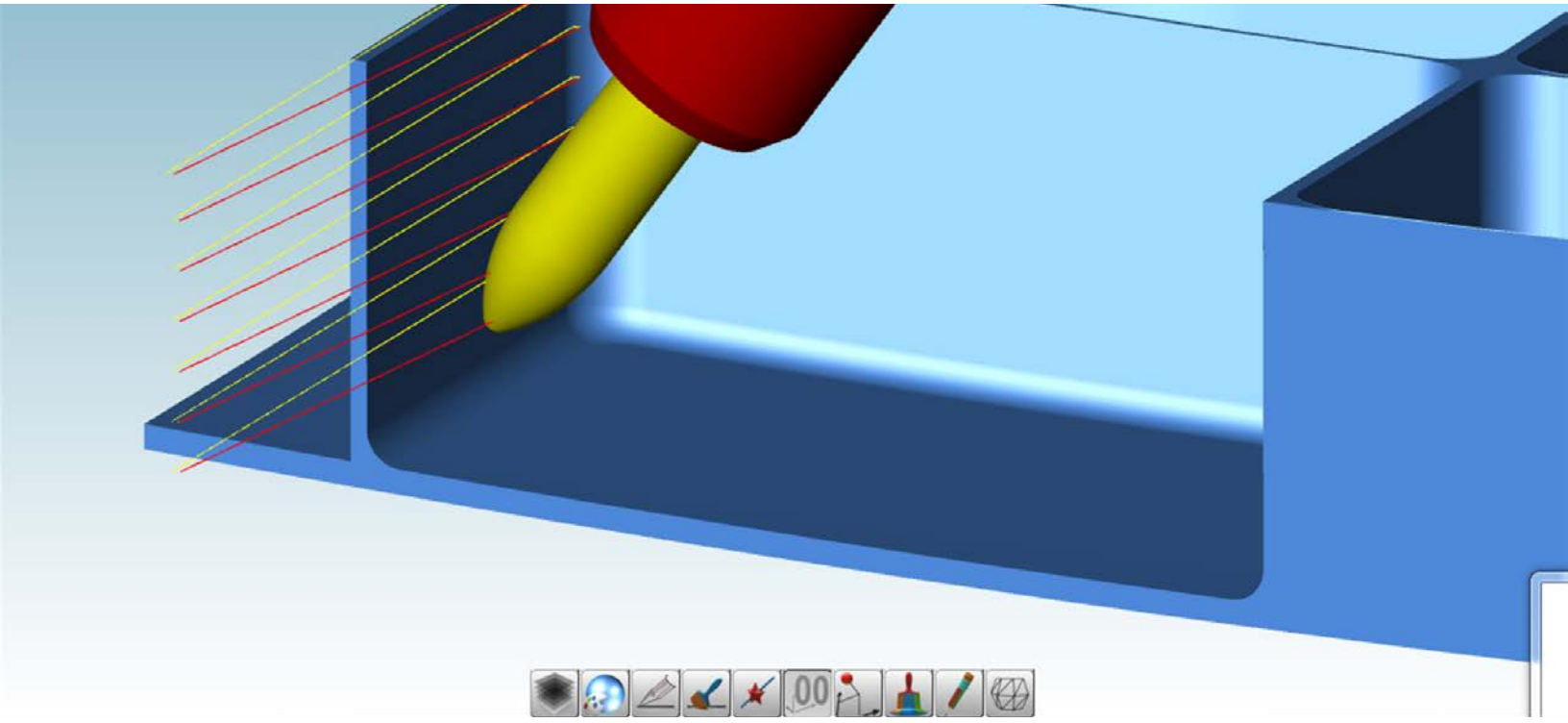


Image courtesy of OPEN MIND Technologies

EMUGE CNC PROGRAMMING ASSISTANCE

A cutting tool can only perform as well as the CNC controller and software allow. Since specialized programming is sometimes required for Circle Segment End Milling, EMUGE works closely with today's leading CNC software companies such as CNC Software (Mastercam®) and OPEN MIND Technologies (hyperMILL®) to offer programming assistance and process recommendations.
EMUGE tooling engineers can offer simple programming suggestions or actual program codes along with optimized tooling recommendations. EMUGE can also provide detailed reports with programming instructions and where applicable, actual sample test cuts with video documentation.

Download the New Circle Segement Brochure

EMUGE TEST CUTS PROGRAM

Exploring new technology and tooling designs is the best way for progressive manufacturers to stay ahead of the competition. New tooling solutions such as Circle Segment End Mills are an ideal way to reduce cycle times and improve product quality. However, breaking into production or tying up critical machines for testing new tool styles is not always an option.

EMUGE's Technology Center offers a test cut service that allows manufacturers to run test cuts on actual parts or sample materials on state-of-the-art 5-Axis machining centers. When it comes to implementing Circle Segment End Mills, the EMUGE team can be involved from the outset of the process to provide advice and education. EMUGE tooling design engineers and skilled machinists will work with manufacturers to explore the optimum tooling solution at EMUGE's' facility without tying up a customer's costly production equipment. Tooling specialists provide tooling solutions, programming suggestions along with detailed reports on operating parameters and results. Manufacturers adopting Circle Segment End Mills do not have to go it alone - EMUGE can provide support and guidance to ensure success.

EMUGE has a century-long history of offering innovative high performance cutting tools, and remains on the cutting edge through continuous research and development. Its commitment to craftsmanship, innovation and quality is evident in its new class of tools – Circle Segment End Mills. **Learn more about Circle Segment End Mills and get in touch** with the team at EMUGE today.