FRANKEN

CIRCLE SEGMENT & TURBINE END MILLS FOR **MACHINING BLADES AND OTHER COMPLEX PARTS**

Circle Segment and Turbine End Mills for Aerospace and Turbine Machining Strategies

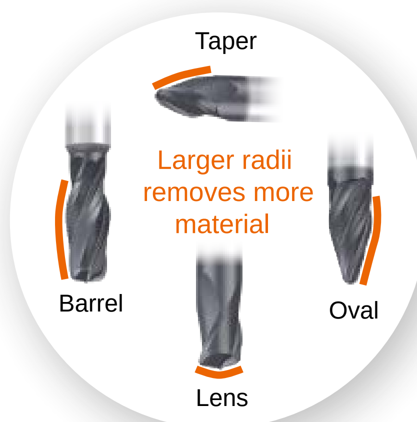
Unique Geometry Designed for High Performance Machining

Circle Segment End Mills – an Emuge Innovation

Circle Segment end mills feature unique design forms with large radii, allowing a much larger axial depth of cut during pre-finish and finishing. This generates higher cutting forces than conventional ball-nose cutters due to the large radii on the face and radial cutting edges. These tools enable substantially more material removal with fewer passes in 5-Axis machining, generating **cycle time reductions of over 80% and up to 50% smoother surface finishes.**

Circle Segment solid-carbide end mills are ideal for mold making, machining turbine blades, impellers and blisks, and are offered in four geometries. Oval and taper form mills are ideal for curved shapes, 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. Specific CAM system software such as hyperMill® or Mastercam® is required to support and compute the geometries of Circle Segment end mills to achieve optimum performance.

Over 80% Cycle time Reductions!

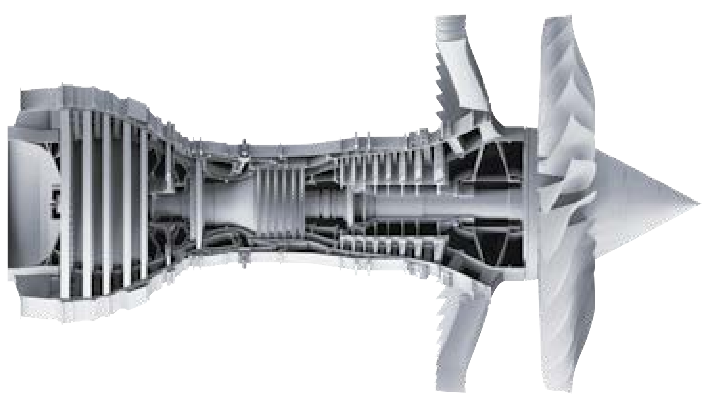


Turbine End Mills

Emuge Turbine Solid Carbide End Mills were developed to meet the requirements of materials and complex component geometry design found in aerospace and turbine industries. In addition to turbine parts, these tools are also widely used in the die and mold industry.

Complex shapes including wide sweeping radii and deep pocketed cavities present a broad range of challenges for machinists and programmers. The Emuge turbine milling program was developed to provide standard solutions to special problems.

Realize unprecedented cycle time reductions and tool life in challenging forms and materials, including Ti, Ni and more.



The Emuge Turbine end mill range is comprised of solid carbide tools for the roughing and finishing of components on turbines or other complex 5-Axis parts.

Product nder

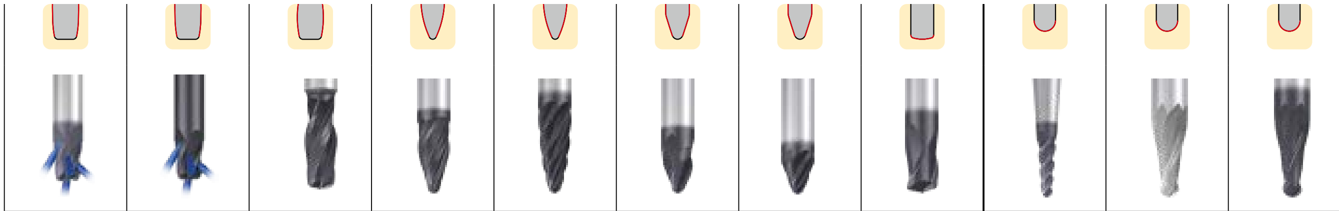
Please note:
The suitability is indicated as follows:

$ = very suitable
) = suitable

Please find the cutting conditions on pages 9 up to 49.

		Applications – Materials	Hardness Range HRC	BHN	N/mm2	Material – Examples
P		Steel materials				
P	1.1	Cold-extrusion steels, Construction steels, Free-cutting steels, etc.		180	600	1010 / 1018 / 1020 / 12L14 / 12L15 / A36 / T1
P	2.1	Construction steels, Cementation steels, Steel castings, etc.	22	235	800	A36 / T1 / 1030-1095 / 4140 / 4340 / 8620
P	3.1	Cementation steels, Heat-treatable steels, Cold work steels, etc.	31	295	1000	4140 / 4340 / 8620 / P20 / H13 / D2 / A2 / S7 / H1150
P	4.1	Heat-treatable steels, Cold work steels, Nitriding steels, etc.	38	355	1200	4140 / 4340 / 8620 / P20 / H13 / D2 / 300M / 52100 / M1-M42
P	5.1	High-alloyed steels, Cold work steels, Hot work steels, etc.	44	415	1400	4140 / 4340 / 8620 / P20 / H13 / D2 / 300M / 52100
M		Stainless steel materials				
M	1.1	Ferritic, martensitic	29	280	950	410 / 440 / 440C / 17-4 PH
M	2.1	Austenitic	29	280	950	303 / 304 / 316 / 316L / 321
M	3.1	Austenitic-ferritic (Duplex)	35	325	1100	
M	4.1	Austenitic-ferritic heat-resistant (Super Duplex)	39	370	1250	
K		Cast materials				
K	1.1	Cast iron with lamellar graphite (GJL)		30 - 75	100 - 250	Grey cast irons G10-GG40
K	1.2			75 - 135	250 - 450	
K	2.1	Cast iron with nodular graphite (GJS)		105 - 150	350 - 500	Nodular GGG40-GGG70
K	2.2			150 - 265	500 - 900	
K	3.1	Cast iron with vermicular graphite (GJV)		90 - 120	300 - 400	
K	3.2			120 - 150	400 - 500	Compact graphite iron (CGI)
K	4.1	Malleable cast iron (GTMW, GTMB)		70 - 145	250 - 500	
K	4.2			150 - 235	500 - 800	White iron
N		Non-ferrous materials				
N		Aluminium alloys				
N	1.1	Wrought aluminium alloys		60	200	7075
N	1.2			105	350	6061-T6 / 2024-T4
N	1.3			165	550	
N	1.4	Aluminium cast alloys Si ≤ 7%				
N	1.5	Aluminium cast alloys 7% < Si ≤ 12%				
N	1.6	Aluminium cast alloys 12% < Si ≤ 17%				
N		Copper alloys				
N	2.1	Pure copper, low-alloyed copper		120	400	
N	2.2	Copper-zinc alloys (brass, long-chipping)		165	550	
N	2.3	Copper-zinc alloys (brass, short-chipping)		165	550	
N	2.4	Copper-aluminium alloys (alu bronze, long-chipping)		235	800	
N	2.5	Copper-tin alloys (tin bronze, long-chipping)		205	700	
N	2.6	Copper-tin alloys (tin bronze, short-chipping)		120	400	
N	2.7	Special copper alloys		180	600	
N	2.8		44	415	1400	
N		Magnesium alloys				
N	3.1	Magnesium wrought alloys		150	500	
N	3.2	Magnesium cast alloys		150	500	
N		Synthetics				
N	4.1	Duroplastics (short-chipping)				
N	4.2	Thermoplastics (long-chipping)				
N	4.3	Fibre-reinforced synthetics (fibre content ≤ 30%)				
N	4.4	Fibre-reinforced synthetics (fibre content > 30%)				
N		Special materials				
N	5.1	Graphite				
N	5.2	Tungsten-copper alloys				
N	5.3	Composite materials				
S		Special materials				
S		Titanium alloys				
S	1.1	Pure titanium		135	450	CP1 / CP2
S	1.2	Titanium alloys	27	265	900	6AL4V
S	1.3		39	370	1250	
S		Nickel alloys, cobalt alloys and iron alloys				
S	2.1	Pure nickel		180	600	
S	2.2	Nickel-based alloys	31	295	1000	Monel 500 / Hastelloy / 625 Inconel
S	2.3		49	475	1600	718 Inconel
S	2.4	Cobalt-based alloys	31	295	1000	
S	2.5		49	475	1600	Haynes 25
S	2.6	Iron-based alloys	46	445	1500	Incoloy 925
H		Hard materials				
H	1.1	High strength steels, hardened steels, hard castings	44 - 50			
H	1.2		50 - 55			
H	1.3		55 - 60			
H	1.4		60 - 63			
H	1.5		63 - 66			

FRANKEN CIRCLE SEGMENT & TURBINE END MILLS



Circle Segment								Turbine				
NR	N							NR	NF			
ø 8 - 16 mm	ø 8 - 16 mm	r_2 = 50 mm	r_2 = 50 - 95 mm	ø 10 - 16 mm	$\angle_2$=12.5 - 70° r_2=50 - 1500 mm	$\angle_2$=12.5 - 70° r_2=200 - 1500 mm	r_2 = 6 - 25 mm	$\angle_2$ = 4° r = 2 - 4 mm	$\angle_2$ = 3 - 8° r = 0.5 - 2 mm	$\angle_2$ = 3 - 8° r = 0.5 - 2 mm		
4	4	4	3 - 4	6	2 - 3	4 - 6	3	3	2	2	# Flutes	
3552LZ	3554LZ	3542L	3538L	3539L	3540L	3541L	3544L	3546L	3446 / 3447	3446L		
–	–	–	–	–	–	–	–	–	–	–		
8	10	12	14	16	18	20	22	24	26	26	Page	
9	11	13	15	17	19	21	23	25	27	27	v_c / f_z	
$	$	$	$	$	$	$	$	$		$	1.1	P
$	$	$	$	$	$	$	$	$		$	2.1	
$	$	$	$	$	$	$	$	$		$	3.1	
$	$	$	$	$	$	$	$	$		)	4.1	
$	$	$	$	$	$	$	$	$		)	5.1	
$	$	$	$	$	$	$	$	$		$	1.1	M
$	$	$	$	$	$	$	$	$		$	2.1	
$	$	)	)	)	)	)	)	$			3.1	
$	$	)	)	)	)	)	)	$			4.1	
		$	$	$	$	$	$			$	1.1	K
		$	$	$	$	$	$			$	1.2	
		$	$	$	$	$	$			$	2.1	
		)	)	)	)	)	)			$	2.2	
		$	$	$	$	$	$			)	3.1	
		$	$	$	$	$	$			)	3.2	
		$	$	$	$	$	$			)	4.1	
		)	)	)	)	)	)			)	4.2	
$	$	$	$	$	$	$	$	$	$	$	1.1	N
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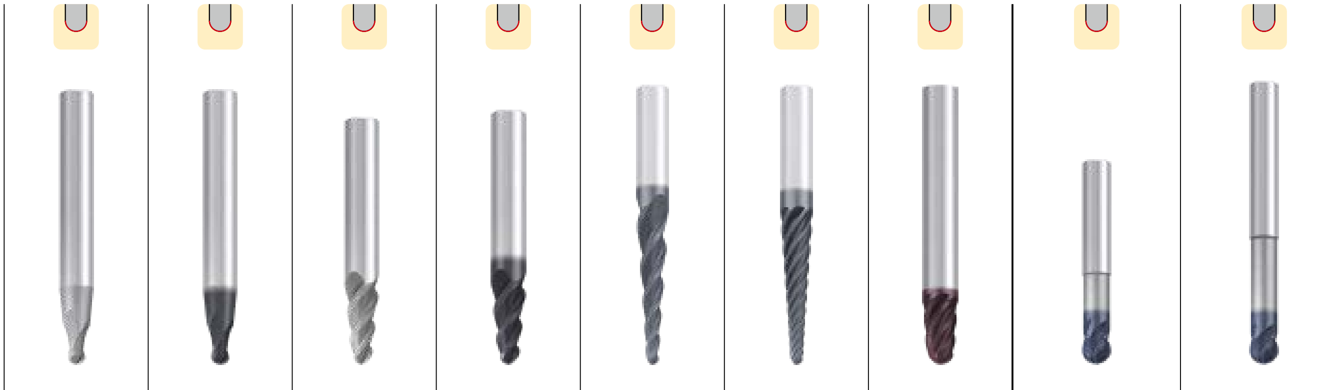
$	$	$	$	$	$	$	$	$	$	$	1.3	
		$	$	$	$	$	$			$	1.4	
										)	1.5	
											1.6	
		$	$	$	$	$	$			$	2.1	
		$	$	$	$	$	$			$	2.2	
		$	$	$	$	$	$			$	2.3	
		$	$	$	$	$	$			$	2.4	
		$	$	$	$	$	$			$	2.5	
		$	$	$	$	$	$			$	2.6	
		$	$	$	$	$	$			)	2.7	
		$	$	$	$	$	$			)	2.8	
		$	$	$	$	$	$			$	3.1	
		$	$	$	$	$	$			$	3.2	
		)	)	)	)	)			$	$	4.1	
		)	)	)	)	)			$	$	4.2	
										$	4.3	
										$	4.4	
											5.1	
		)	)	)	)	)	)			$	5.2	
										$	5.3	
$	$	$	$	$	$	$	$	$		$	1.1	S
$	$	$	$	$	$	$	$	$		$	1.2	
$	$	$	$	$	$	$	$	$		)	1.3	
		$	$	$	$	$	$			$	2.1	
$	$	$	$	$	$	$		$		$	2.2	
$	$	)	)	)	)	)		$		)	2.3	
$	$	$	$	$	$	$		$		)	2.4	
$	$	)	)	)	)	)		$		)	2.5	
$	$	)	)	)	)	)		$		)	2.6	
		)	)	$	)	$					1.1	H
		)	)	$	)	$					1.2	
				$		$					1.3	
											1.4	
											1.5	

$ = very suitable) = suitable



		Turbine						Hard-Cut	
		N						H	
	$\measuredangle_2$ = 3 - 8° r = 1.5 - 3 mm	$\measuredangle_2$ = 3 - 8° r = 1.5 - 3 mm	$\measuredangle_2$ = 3 - 17.5° r = 0.5 - 3 mm	$\measuredangle_2$ = 3 - 17.5° r = 0.5 - 3 mm	$\measuredangle_2$ = 4° r = 2 - 4 mm	$\measuredangle_2$ = 4° r = 2 - 4 mm	$\measuredangle_2$ = 4° r = 3 - 8 mm	ø 3 - 12 mm	ø 6 - 12 mm
# Flutes	2	2	2	2	3	3/6	3/6	4	4
	3442 / 3443	3442L	3440 / 3441	3440L	3550L	3548L	2679A	2834A	2842A
	–	–	–	–	–	–	–	–	–
Page	28	28	30	30	32	33	34	36	38
v_c / f_z	29	29	31	31	32	33	35	37	39
P									
1.1		$		$	$	$	$	)	)
2.1		$		$	$	$	$	)	)
3.1		$		$	$	$	$	$	$
4.1		)		)	$	$	$	$	$
5.1		)		)	$	$	$	$	$
M									
1.1		$		$	$	$	$		
2.1		$		$	$	$	$		
3.1					$	$	$		
4.1					$	$	$		
K									
1.1		$		$			$	$	$
1.2		$		$			$	$	$
2.1		$		$			$	$	$
2.2		$		$			$	$	$
3.1		)		)			$	$	$
3.2		)		)			$	$	$
4.1		)		)			$	$	$
4.2		)		)			$	$	$
N									
1.1	$	$	$	$					
1.2	$	$	$	$					
1.3	$	$	$	$	$	$			
1.4		$		$	$	$			
1.5		)		)	$	$			
1.6									
2.1		$		$			$		
2.2		$		$			$	)	)
2.3		$		$			$	$	$
2.4		$		$			$	)	)
2.5		$		$			$	)	)
2.6		$		$			$	$	$
2.7		)		)			$	$	$
2.8		)		)			$	$	$
3.1		$		$					
3.2		$		$					
4.1	$	$	$	$					
4.2	$	$	$	$					
4.3		$		$					
4.4		$		$					
5.1									
5.2		$		$					
5.3		$		$					
S									
1.1		$		$	$	$	$		$
1.2		$		$	$	$	$		$
1.3		)		)	$	$	$		$
2.1		$		$			$		$
2.2		$		$	$	$	$		$
2.3		)		)	$	$	$		$
2.4		)		)	$	$	$		$
2.5		)		)	$	$	$		$
2.6		)		)	$	$	$		$
H									
1.1								$	$
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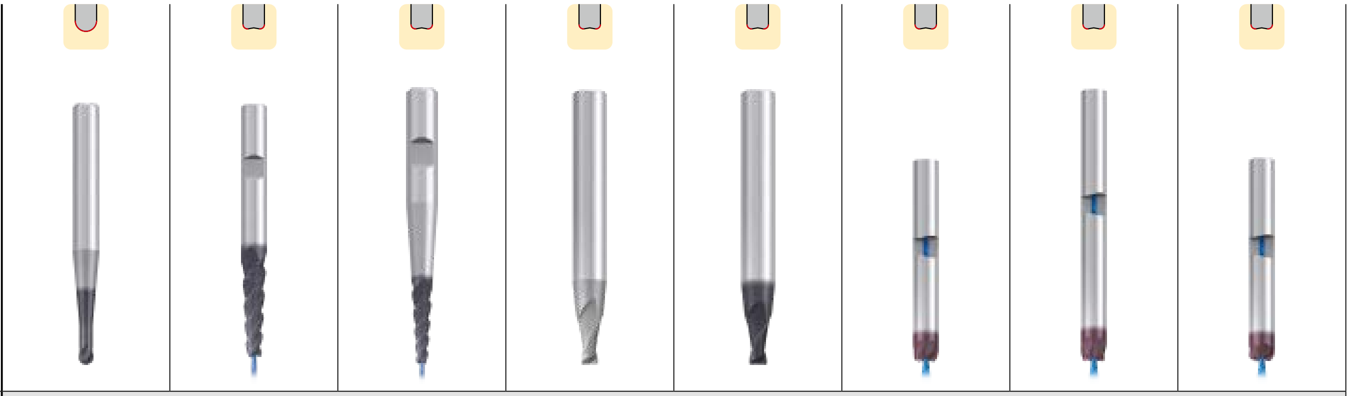
1.5								$	$

$ = very suitable) = suitable



Turbine								
N	NR		N					
ø4 - 10 mm	∠2 = 3° ø 6.5 - 8.5 mm	∠2 = 3° ø 5 - 8.5 mm	∠2 = 3 - 8° ø d1 = 3 - 5 mm	∠2 = 3 - 8° ø d1 = 3 - 5 mm	∠2 = 8° ø d1 = 8 - 11 mm	∠2 = 8° ø d1 = 9 - 19 mm	ø d1 = 8 - 16 mm	
4	4	3	2	2	7 - 9	5 - 13	5 - 9	# Flutes
2564L	–	–	3444 / 3445	3444L	2677AZ	2678AZ	2676AZ	
–	3534LZ	3532LZ	–	–	–	–	–	
40	42	42	44	44	46	46	48	Page
41	43	43	45	45	47	47	49	v_c / f_z

								Code	Group
$	$	$		$	$	$	$	1.1	P
$	$	$		$	$	$	$	2.1	P
$	$	$		$	$	$	$	3.1	P
$	$	$		)	$	$	$	4.1	P
$	$	$		)	$	$	$	5.1	P
$	$	$		$	$	$	$	1.1	M
$	$	$		$	$	$	$	2.1	M
$	$	$			$	$	$	3.1	M
$	$	$			$	$	$	4.1	M
)				$	$	$	$	1.1	K
)				$	$	$	$	1.2	K
)				$	$	$	$	2.1	K
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)				)	$	$	$	3.1	K
)				)	$	$	$	3.2	K
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)				)	$	$	$	4.2	K
	$	$	$	$				1.1	N
	$	$	$	$				1.2	N
	$	$	$	$				1.3	N
				$				1.4	N
				)				1.5	N
								1.6	N
$				$	$	$	$	2.1	N
$				$	$	$	$	2.2	N
$				$	$	$	$	2.3	N
$				$	$	$	$	2.4	N
$				$	$	$	$	2.5	N
$				$	$	$	$	2.6	N
$				)	$	$	$	2.7	N
$				)	$	$	$	2.8	N
				$				3.1	N
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			$	$				4.1	N
			$	$				4.2	N
				$				4.3	N
				$				4.4	N
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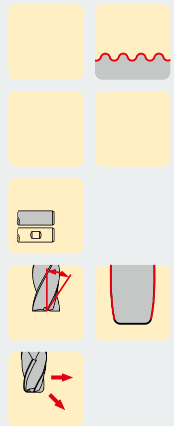
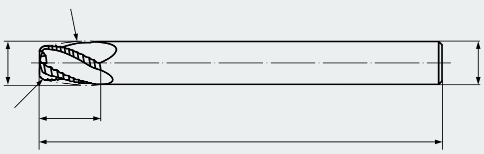
				$				5.2	N
				$				5.3	N
$	$	$		$	$	$	$	1.1	S
$	$	$		$	$	$	$	1.2	S
$	$	$		)	$	$	$	1.3	S
$				$	$	$	$	2.1	S
$	$	$		$	$	$	$	2.2	S
$	$	$		)	$	$	$	2.3	S
$	$	$		)	$	$	$	2.4	S
$	$	$		)	$	$	$	2.5	S
$	$	$		)	$	$	$	2.6	S
)								1.1	H
)								1.2	H
)								1.3	H
								1.4	H
								1.5	H

$ = very suitable) = suitable

- High performance tool
- With 4 utes
- Variable spacing
- Low-vibration machining
- Highly ef cient roughing





Icon Descriptions (see page 51)

Oval Form – ER

Universal

COATING: ALCR

Applications – materials (see page 5)

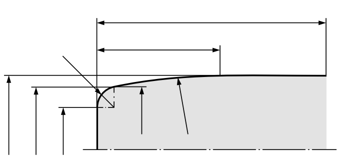
- Especially suitable for high-strength materials
- Also suitable in Nickel-based alloys
- For the machining of titanium alloys
- Suitable in all turbine materials
- Optimized for pre-finishing Impellers and Integrated Bladed Rotors (IBR) made from aluminum, titanium and Inconel

P 1.1-5.1
M 1.1-4.1
N 1.1-1.3
S 1.1-1.3
S 2.2-2.6

Tool Dimensions / mm

d_1	r_1	r_2	l_2	l_1	ø d_2 h6	# Flutes	Tool No.
8	1	40	12	80	8	4	3552LZ.08040A
10	1.5	45	12	95	10	4	3552LZ.10045A
12	2	50	14	100	12	4	3552LZ.12050A
16	2	60	18	128	16	4	3552LZ.16060A

Dimensions for tool database



d_1	r_1	r_2	l_2	l_r	ø d_5	ø d_6	ø d_7
8	1	40	12	10	3.895	5.841	5.895
10	1.5	45	12	10	5.323	8.265	8.323
12	2	50	14	12	5.894	9.806	9.894
16	2	60	18	16	8.570	12.452	12.570

l_r = r_2 is tangential to d_1

d_6 = Tangent point of r_1 and r_2

$d_7 = d_5 + 2 \times r_1$