End mill – GM series

Material group		Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						5501R302GM 5601R302GM 5502R302GM 5602R302GM				GM-2E GM-2EFP GM-2F			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD
						3≤x≤20	0,8xD			3≤x≤20	0,8xD		
						KMG303				KMG303			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	150	200	270	2	150	200	270	2
		approx. 0,45 % C	annealed	190	2	145	190	260	2	145	190	260	2
		approx. 0,45 % C	tempered	250	3	105	140	190	2	105	140	190	2
		approx. 0,75 % C	annealed	270	4	90	120	165	2	90	120	165	2
		approx. 0,75 % C	tempered	300	5	85	110	150	2	85	110	150	2
	Low-alloyed steel		annealed	180	6	115	150	205	2	115	150	205	2
			tempered	275	7	90	120	165	2	90	120	165	2
			tempered	300	8	85	110	150	2	85	110	150	2
			tempered	350	9	80	105	145	2	80	105	145	2
	High-alloyed steel and high-alloyed tool steel		annealed	200	10	105	140	190	2	105	140	190	2
			hardened and tempered	325	11	80	110	145	2	80	110	145	2
M	Stainless steel	ferritic/martensitic	annealed	200	12	50	65	90	2	50	65	90	2
		martensitic	tempered	240	13	45	60	80	2	45	60	80	2
		austenitic	quench hardened	180	14	55	70	95	2	55	70	95	2
		austenitic-ferritic		230	15	45	60	80	2	45	60	80	2
K	Grey cast iron	perlitic/ferritic		180	16	110	150	200	2	110	150	200	2
		perlitic (martensitic)		260	17	90	120	165	2	90	120	165	2
	Cast iron with spheroidal graphite	ferritic		160	18	135	180	245	2	135	180	245	2
		perlitic		250	19	105	140	190	2	105	140	190	2
	Malleable cast iron	ferritic		130	20	150	200	270	2	150	200	270	2
		perlitic		230	21	120	160	220	2	120	160	220	2
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24								
		≤ 12% Si, hardenable	hardened	90	25								
		> 12% Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
			hardened	280	31								
		Ni or Co bass	annealed	250	32								
			hardened	350	33								
			cast	320	34								
	Titanium alloys	pure titanium		R_m 400	35								
		α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
			hardened and tempered	60 HRC	38								
	Hard cast iron		cast	400	39								
	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]																			
	GM-2EL GM-2EX GM-2FL				GM-2EP GM-2ES				GM-3E GM-4E GM-4E-G				GM-2EL GM-4EL-G				5501R303GM 5601R303GM 5502R303GM 5602R303GM			
	Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling	
	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
	0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD
	3≤x≤20	0,8xD			3≤x≤20	0,8xD			3≤x≤20	0,8xD			3≤x≤20	0,8xD			3≤x≤20	0,8xD		
	KMG303				KMG303				KMG303				KMG303				KMG303			
	a_e / D				a_e / D				a_e / D				a_e / D				a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
	130	170	230	2	150	200	270	2	150	200	270	2	130	170	230	2	140	185	245	2
	125	165	220	2	145	190	260	2	145	190	260	2	125	165	220	2	135	180	235	2
	95	120	165	2	105	140	190	2	105	140	190	2	95	120	165	2	100	130	175	2
	80	105	140	2	90	120	165	2	90	120	165	2	80	105	140	2	85	115	150	2
	75	95	130	2	85	110	150	2	85	110	150	2	75	95	130	2	80	105	135	2
	100	130	175	2	115	150	205	2	115	150	205	2	100	130	175	2	105	140	185	2
	80	105	140	2	90	120	165	2	90	120	165	2	80	105	140	2	85	115	150	2
	75	95	130	2	85	110	150	2	85	110	150	2	75	95	130	2	80	105	135	2
	70	90	120	2	80	105	145	2	80	105	145	2	70	90	120	2	75	100	130	2
	95	120	165	2	105	140	190	2	105	140	190	2	95	120	165	2	100	130	175	2
	70	95	125	2	80	110	145	2	80	110	145	2	70	95	125	2	75	100	130	2
	45	55	75	2	50	65	90	2	50	65	90	2	45	55	75	2	45	60	80	2
	40	50	65	2	45	60	80	2	45	60	80	2	40	50	65	2	40	55	70	2
	45	60	80	2	55	70	95	2	55	70	95	2	45	60	80	2	50	65	85	2
	40	50	65	2	45	60	80	2	45	60	80	2	40	50	65	2	40	55	70	2
	95	125	170	2	110	150	200	2	110	150	200	2	95	125	170	2	105	140	180	2
	80	105	140	2	90	120	165	2	90	120	165	2	80	105	140	2	85	115	150	2
	120	155	210	2	135	180	245	2	135	180	245	2	120	155	210	2	130	170	225	2
	95	120	165	2	105	140	190	2	105	140	190	2	95	120	165	2	100	130	175	2
	130	170	230	2	150	200	270	2	150	200	270	2	130	170	230	2	140	185	245	2
	105	140	185	2	120	160	220	2	120	160	220	2	105	140	185	2	115	150	200	2

End mill – GM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						5501R304GF 5601R304GF 5502R304GF 5602R304GF				GM-4F-G GM-4EFP			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<3	0,1xD	0<x≤20	<0,5xD	0<x<3	0,1xD	0<x≤20	<0,5xD
						3≤x≤20	0,8xD			3≤x≤20	0,8xD		
						KMG303				KMG303			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	155	200	265	2	150	200	270	2
		approx. 0,45 % C	annealed	190	2	150	190	255	2	145	190	260	2
		approx. 0,45 % C	tempered	250	3	110	140	190	2	105	140	190	2
		approx. 0,75 % C	annealed	270	4	95	120	160	2	90	120	165	2
		approx. 0,75 % C	tempered	300	5	90	110	150	2	85	110	150	2
	Low-alloyed steel		annealed	180	6	120	150	200	2	115	150	205	2
			tempered	275	7	95	120	160	2	90	120	165	2
			tempered	300	8	90	110	150	2	85	110	150	2
			tempered	350	9	85	105	140	2	80	105	145	2
	High-alloyed steel and high-alloyed tool steel		annealed	200	10	110	140	190	2	105	140	190	2
			hardened and tempered	325	11	85	110	145	2	80	110	145	2
M	Stainless steel	ferritic/martensitic	annealed	200	12	50	65	85	2	50	65	90	2
		martensitic	tempered	240	13	45	60	75	2	45	60	80	2
		austenitic	quench hardened	180	14	55	70	95	2	55	70	95	2
		austenitic-ferritic		230	15	45	60	75	2	45	60	80	2
K	Grey cast iron	perlitic/ferritic		180	16	115	150	195	2	110	150	200	2
		perlitic (martensitic)		260	17	95	120	160	2	90	120	165	2
	Cast iron with spheroidal graphite	ferritic		160	18	140	180	240	2	135	180	245	2
		perlitic		250	19	110	140	190	2	105	140	190	2
	Malleable cast iron	ferritic		130	20	155	200	265	2	150	200	270	2
		perlitic		230	21	125	160	215	2	120	160	220	2
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
		≤ 12 % Si, hardenable	hardened	90	25								
		> 12 % Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
			hardened	280	31								
		Ni or Co bass	annealed	250	32								
			hardened	350	33								
			cast	320	34								
	Titanium alloys	pure titanium		R_m 400	35								
		α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
			hardened and tempered	60 HRC	38								
	Hard cast iron		cast	400	39								
	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

ZCC·CT

	Starting values for cutting speed v_c [m/min]																			
	GM-4FL-G GM-4EX-G				GM-6E				GM-6E 5589R45MGFR				5565R302GF 5565R302GM 5566R302GF				GM-2B GM-4B GM-2BS GM-2BP			
	Slot milling		Shoulder milling				Shoulder milling				Shoulder milling		Slot milling		Shoulder milling					
	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$			Ø [mm]	$a_{e\,max}$			Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$				
	$0 < x < 3$	0,1 x D	$0 < x \leq 20$	< 0,5 x D			$0 < x \leq 20$	< 0,5 x D			$0 < x \leq 20$	< 0,5 x D	$0 < x < 3$	0,1 x D	$0 < x \leq 20$	< 0,5 x D				
	$3 \leq x \leq 20$	0,8 x D											$3 \leq x \leq 20$	0,8 x D						
	KMG303				KMG303				KMG303				KMG303				KMG303			
	a_e / D				a_e / D				a_e / D				a_e / D				a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group	1/1	1/10	1/20	f-group
	130	170	230	2	–	–	270	2	–	–	230	2	–	250	280	5	–	250	280	5
	125	165	220	2	–	–	260	2	–	–	220	2	–	240	270	5	–	240	270	5
	95	120	165	2	–	–	190	2	–	–	165	2	–	175	200	5	–	175	200	5
	80	105	140	2	–	–	165	2	–	–	140	2	–	150	170	5	–	150	170	5
	75	95	130	2	–	–	150	2	–	–	130	2	–	140	155	5	–	140	155	5
	100	130	175	2	–	–	205	2	–	–	175	2	–	190	210	5	–	190	210	5
	80	105	140	2	–	–	165	2	–	–	140	2	–	150	170	5	–	150	170	5
	75	95	130	2	–	–	150	2	–	–	130	2	–	140	155	5	–	140	155	5
	70	90	120	2	–	–	145	2	–	–	120	2	–	130	150	5	–	130	150	5
	95	120	165	2	–	–	190	2	–	–	165	2	–	175	200	5	–	175	200	5
	70	95	125	2	–	–	145	2	–	–	125	2	–	135	150	5	–	135	150	5
	45	55	75	2	–	–	90	2	–	–	75	2	–	80	90	5	–	80	90	5
	40	50	65	2	–	–	80	2	–	–	65	2	–	70	80	5	–	70	80	5
	45	60	80	2	–	–	95	2	–	–	80	2	–	85	100	5	–	85	100	5
	40	50	65	2	–	–	80	2	–	–	65	2	–	70	80	5	–	70	80	5
	95	125	170	2	–	–	200	2	–	–	170	2	–	185	205	5	–	185	205	5
	80	105	140	2	–	–	165	2	–	–	140	2	–	150	170	5	–	150	170	5
	120	155	210	2	–	–	245	2	–	–	210	2	–	225	255	5	–	225	255	5
	95	120	165	2	–	–	190	2	–	–	165	2	–	175	200	5	–	175	200	5
	130	170	230	2	–	–	270	2	–	–	230	2	–	250	280	5	–	250	280	5
	105	140	185	2	–	–	220	2	–	–	185	2	–	200	225	5	–	200	225	5

End mill – GM series

Material group		Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						GM-2BL GM-4BL GM-2BFP				GM-2R GM-4R			
										Slot milling		Shoulder milling	
										Ø [mm]	$a_{p\ max}$	Ø [mm]	$a_{e\ max}$
										0 < x < 3	0,1 x D	0 < x ≤ 20	< 0,5 x D
										3 ≤ x ≤ 20	0,8 x D		
						KMG303				KMG303			
						a_e / D				a_e / D			
						1/1	1/10	1/20	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	–	220	250	5	160	215	275	2
		approx. 0,45 % C	annealed	190	2	–	210	240	5	155	205	265	2
		approx. 0,45 % C	tempered	250	3	–	155	175	5	115	155	195	2
		approx. 0,75 % C	annealed	270	4	–	135	150	5	100	130	165	2
		approx. 0,75 % C	tempered	300	5	–	125	140	5	90	120	155	2
	Low-alloyed steel		annealed	180	6	–	165	190	5	120	165	210	2
			tempered	275	7	–	135	150	5	100	130	165	2
			tempered	300	8	–	125	140	5	90	120	155	2
			tempered	350	9	–	115	130	5	85	115	145	2
	High-alloyed steel and high-alloyed tool steel		annealed	200	10	–	155	175	5	115	155	195	2
			hardened and tempered	325	11	–	120	135	5	85	115	150	2
M	Stainless steel	ferritic/martensitic	annealed	200	12	–	75	80	5	55	70	90	2
		martensitic	tempered	240	13	–	65	70	5	45	65	80	2
		austenitic	quench hardened	180	14	–	75	85	5	55	75	95	2
		austenitic-ferritic		230	15	–	65	70	5	45	65	80	2
K	Grey cast iron	perlitic/ferritic		180	16	–	165	185	5	120	160	205	2
		perlitic (martensitic)		260	17	–	135	150	5	100	130	165	2
	Cast iron with spheroidal graphite	ferritic		160	18	–	200	225	5	145	195	250	2
		perlitic		250	19	–	155	175	5	115	155	195	2
	Malleable cast iron	ferritic		130	20	–	220	250	5	160	215	275	2
		perlitic		230	21	–	180	200	5	130	175	220	2
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
		≤ 12 % Si, hardenable	hardened	90	25								
		> 12 % Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
			hardened	280	31								
		Ni or Co bass	annealed	250	32								
			hardened	350	33								
			cast	320	34								
	Titanium alloys	pure titanium		R_m 400	35								
		α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
			hardened and tempered	60 HRC	38								
	Hard cast iron		cast	400	39								
	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]							
	GM-4RL				5602R303GR 5602R304GR 5602R305GR GM-4W			
	Slot milling		Shoulder milling		Slot milling		Shoulder milling	
	Ø [mm]	$a_{p\ max}$	Ø [mm]	$a_{e\ max}$	Ø [mm]	$a_{p\ max}$	Ø [mm]	$a_{e\ max}$
	0 < x < 3	0,1 x D	0 < x ≤ 20	< 0,5 x D	0 < x < 3	0,1 x D	0 < x ≤ 20	< 0,5 x D
	3 ≤ x ≤ 20	0,8 x D			3 ≤ x ≤ 20	0,8 x D		
	KMG303				KMG303			
	a_e / D				a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
	145	200	240	2	135	180	240	2
	140	190	230	2	130	175	230	2
	105	140	170	2	95	130	170	2
	90	120	145	2	85	110	145	2
	80	110	135	2	75	100	135	2
	110	150	180	2	105	135	180	2
	90	120	145	2	85	110	145	2
	80	110	135	2	75	100	135	2
	80	105	125	2	75	95	125	2
	105	140	170	2	95	130	170	2
	80	110	130	2	75	100	130	2
	50	65	80	2	45	60	80	2
	45	60	70	2	40	55	70	2
	50	70	85	2	50	65	85	2
	45	60	70	2	40	55	70	2
	110	150	180	2	100	135	180	2
	90	120	145	2	85	110	145	2
	135	180	220	2	125	165	220	2
	105	140	170	2	95	130	170	2
	145	200	240	2	135	180	240	2
	120	160	195	2	110	145	195	2

End mill – HM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min] HM-2E, HM-2EP, HM-2ES, HM-4E (Shoulder milling: Ø [mm] 0<x≤20, $a_{e\,max}$ 0,05xD; KMG555) a_e/D 1/1	1/2	1/10	f-group	HM-2EFP, HM-4EL, HM-4EFP (Shoulder milling: Ø [mm] 0<x≤20, $a_{e\,max}$ 0,05xD; KMG555) a_e/D 1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
		approx. 0,45 % C	annealed	190	2								
		approx. 0,45 % C	tempered	250	3								
		approx. 0,75 % C	annealed	270	4								
		approx. 0,75 % C	tempered	300	5								
	Low-alloyed steel		annealed	180	6								
			tempered	275	7								
			tempered	300	8								
			tempered	350	9								
	High-alloyed steel and high-alloyed tool steel		annealed	200	10								
			hardened and tempered	325	11								
M	Stainless steel	ferritic/martensitic	annealed	200	12								
		martensitic	tempered	240	13								
		austenitic	quench hardened	180	14								
		austenitic-ferritic		230	15								
K	Grey cast iron	perlitic/ferritic		180	16								
		perlitic (martensitic)		260	17								
	Cast iron with spheroidal graphite	ferritic		160	18								
		perlitic		250	19								
	Malleable cast iron	ferritic		130	20								
		perlitic		230	21								
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
		≤ 12 % Si, hardenable	hardened	90	25								
		> 12 % Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
			hardened	280	31								
		Ni or Co bass	annealed	250	32								
			hardened	350	33								
			cast	320	34								
	Titanium alloys	pure titanium		R_m 400	35								
		α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	55	100	125	3	50	95	115	3
			hardened and tempered	60 HRC	38	55	95	120	3	50	95	110	3
	Hard cast iron		cast	400	39	70	125	160	3	65	120	145	3
	Hardened cast iron		hardened and tempered	55 HRC	40	55	100	125	3	50	95	115	3
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]																			
	HM-6E				HM-6EL				HM-2B HM-2BP HM-2BS HM-4B				HM-2BL HM-4BL				HM-4R HM-4RP HM-4RF			
			Shoulder milling				Shoulder milling												Shoulder milling	
			Ø [mm]	$a_{e\ max}$			Ø [mm]	$a_{e\ max}$											Ø [mm]	$a_{e\ max}$
			0 < x ≤ 20	0,05 x D			0 < x ≤ 20	0,05 x D											0 < x ≤ 20	0,05 x D
	KMG555				KMG555				KMG555				KMG555				KMG555			
	a_e / D				a_e / D				a_e / D				a_e / D				a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group	1/1	1/10	1/20	f-group	1/1	1/2	1/10	f-group
	–	–	125	3	–	–	115	3	–	130	145	7	–	125	140	7	55	100	125	3
	–	–	120	3	–	–	110	3	–	80	90	7	–	80	90	7	55	95	120	3
	–	–	160	3	–	–	145	3	–	163	181	7	–	156	175	7	70	125	160	3
	–	–	125	3	–	–	115	3	–	109	145	7	–	105	140	7	55	100	125	3

End mill – NM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						5502R402NM NM-2E NM-4E NM-2EP				NM-2B NM-4BP			
						Slot milling		Shoulder milling					
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$				
						0<x<12	0,5xD	0<x≤20	<0,5xD				
						12≤x≤20	1,0xD						
						KMG309				KMG309			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2								
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3								
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4								
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5								
P	Low-alloyed steel		annealed	180	6								
P	Low-alloyed steel		tempered	275	7								
P	Low-alloyed steel		tempered	300	8								
P	Low-alloyed steel		tempered	350	9								
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10								
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11								
M	Stainless steel	ferritic/martensitic	annealed	200	12								
M	Stainless steel	martensitic	tempered	240	13								
M	Stainless steel	austenitic	quench hardened	180	14								
M	Stainless steel	austenitic-ferritic		230	15								
K	Grey cast iron	perlitic/ferritic		180	16								
K	Grey cast iron	perlitic (martensitic)		260	17								
K	Cast iron with spheroidal graphite	ferritic		160	18								
K	Cast iron with spheroidal graphite	perlitic		250	19								
K	Malleable cast iron	ferritic		130	20								
K	Malleable cast iron	perlitic		230	21								
N	Aluminium wrought alloys	cannot be hardened		60	22	920	1100	1200	4	–	1400	1550	4
N	Aluminium wrought alloys	hardenable	hardened	100	23	555	660	720	4	–	840	930	4
N	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24	370	440	480	4	–	560	620	4
N	Cast aluminium alloys	≤ 12 % Si, hardenable	hardened	90	25	460	550	600	4	–	700	775	4
N	Cast aluminium alloys	> 12 % Si, cannot be hardened		130	26	140	165	180	4	–	210	235	4
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27	280	330	360	4	–	420	465	4
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28	325	385	420	4	–	490	545	4
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29	280	330	360	4	–	420	465	4
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
H	Hardened steel		hardened and tempered	60 HRC	38								
H	Hard cast iron		cast	400	39								
H	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

ZCC·CT

A Turning
B Milling
C Drilling
D Technical Information
E Index

End mill – AL series, ALP/ALG series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						ALP-1EP				AL-1E AL-2E AL-3E (W) ALG-2E			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD
						12≤x≤20	1,0xD			12≤x≤20	1,0xD		
						YK40F / KMD401				YK30F / YK40F			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2								
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3								
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4								
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5								
P	Low-alloyed steel		annealed	180	6								
P	Low-alloyed steel		tempered	275	7								
P	Low-alloyed steel		tempered	300	8								
P	Low-alloyed steel		tempered	350	9								
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10								
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11								
M	Stainless steel	ferritic/martensitic	annealed	200	12								
M	Stainless steel	martensitic	tempered	240	13								
M	Stainless steel	austenitic	quench hardened	180	14								
M	Stainless steel	austenitic-ferritic		230	15								
K	Grey cast iron	perlitic/ferritic		180	16								
K	Grey cast iron	perlitic (martensitic)		260	17								
K	Cast iron with spheroidal graphite	ferritic		160	18								
K	Cast iron with spheroidal graphite	perlitic		250	19								
K	Malleable cast iron	ferritic		130	20								
K	Malleable cast iron	perlitic		230	21								
N	Aluminium wrought alloys	cannot be hardened		60	22	300	345	375	12	920	1100	1200	4
N	Aluminium wrought alloys	hardenable	hardened	100	23	250	290	315	12	555	660	720	4
N	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24	250	280	315	12	370	440	480	4
N	Cast aluminium alloys	≤ 12 % Si, hardenable	hardened	90	25	210	240	265	12	460	550	600	4
N	Cast aluminium alloys	> 12 % Si, cannot be hardened		130	26	180	210	225	12	140	165	180	4
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27	280	320	350	12	280	330	360	4
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28	310	360	390	12	325	385	420	4
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29	280	320	350	12	280	330	360	4
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
H	Hardened steel		hardened and tempered	60 HRC	38								
H	Hard cast iron		cast	400	39								
H	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

Starting values for cutting speed v_c [m/min]																			
AL-2EL AL-3EL				ALG-3E ALP-3E ALP-4E				ALG-3E (W) ALP-3E (W) ALP-4E (W)				5566R302NH AL-2B				AL-2R-AIR AL-3R-AIR			
Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling	
Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD
12≤x≤20	1,0xD			12≤x≤20	1,0xD			12≤x≤20	1,0xD			12≤x≤20	1,0xD			12≤x≤20	1,0xD		
YK30F				YK40F				KMD401				YK30F / YK40F				YK40F			
a_e / D				ae / D				a_e / D				a_e / D				ae / D			
1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
830	990	1080	4	920	1100	1200	4	1200	1430	1560	4	–	1400	1550	4	1150	1380	1500	8
500	595	650	4	555	660	720	4	725	860	940	4	–	840	930	4	690	830	900	8
335	400	435	4	370	440	480	4	485	575	625	4	–	560	620	4	460	555	600	8
415	495	540	4	460	550	600	4	600	715	780	4	–	700	775	4	575	690	750	8
125	150	165	4	140	165	180	4	185	215	235	4	–	210	235	4	175	210	225	8
250	300	325	4	280	330	360	4	365	430	470	4	–	420	465	4	345	415	450	8
295	350	380	4	325	385	420	4	425	505	550	4	–	490	545	4	405	485	525	8
250	300	325	4	280	330	360	4	365	430	470	4	–	420	465	4	345	415	450	8

A Turning
B Milling
C Drilling
D Technical Information
E Index

ZCC·CT

A Turning
B Milling
C Drilling
D Technical Information
E Index

End mill – AL series, ALP/ALG series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						ALG-2R (W)				AL-2RL-AIR AL-3RL-AIR			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<12	0,5xD	0<x≤20	<0,5xD	0<x<12	0,5xD	0<x≤20	<0,5xD
						12≤x≤20	1,0xD			12≤x≤20	1,0xD		
						KMD401				YK40F			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2								
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3								
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4								
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5								
P	Low-alloyed steel		annealed	180	6								
P	Low-alloyed steel		tempered	275	7								
P	Low-alloyed steel		tempered	300	8								
P	Low-alloyed steel		tempered	350	9								
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10								
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11								
M	Stainless steel	ferritic/martensitic	annealed	200	12								
M	Stainless steel	martensitic	tempered	240	13								
M	Stainless steel	austenitic	quench hardened	180	14								
M	Stainless steel	austenitic-ferritic		230	15								
K	Grey cast iron	perlitic/ferritic		180	16								
K	Grey cast iron	perlitic (martensitic)		260	17								
K	Cast iron with spheroidal graphite	ferritic		160	18								
K	Cast iron with spheroidal graphite	perlitic		250	19								
K	Malleable cast iron	ferritic		130	20								
K	Malleable cast iron	perlitic		230	21								
N	Aluminium wrought alloys	cannot be hardened		60	22	1495	1795	1950	8	1035	1250	1350	8
N	Aluminium wrought alloys	hardenable	hardened	100	23	900	1080	1170	8	625	750	810	8
N	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24	600	725	780	8	415	500	540	8
N	Cast aluminium alloys	≤ 12% Si, hardenable	hardened	90	25	750	900	975	8	520	625	675	8
N	Cast aluminium alloys	> 12% Si, cannot be hardened		130	26	230	275	295	8	160	190	205	8
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27	450	540	585	8	315	375	405	8
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28	530	635	685	8	365	440	475	8
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29	450	540	585	8	315	375	405	8
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37								
H	Hardened steel		hardened and tempered	60 HRC	38								
H	Hard cast iron		cast	400	39								
H	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

ZCC·CT

A Turning
B Milling
C Drilling
D Technical Information
E Index

End mill – TM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						TM-4R / TM-4RP TM-5R / TM-5RP TM-7R / TM-7RP TM-9R / TM-9RP				TM-4B / TM-4BP TM-5B / TM-5BP			
						Slot milling		Shoulder milling					
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$				
						0 < x < 3	0,3 x D	0 < x < 3					
						3 ≤ x < 12	0,7 x D	3 ≤ x < 20	0,3 x D				
						12 ≤ x ≤ 20	1,5 x D						
						KMS405				KMS405			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
		approx. 0,45 % C	annealed	190	2								
		approx. 0,45 % C	tempered	250	3								
		approx. 0,75 % C	annealed	270	4								
		approx. 0,75 % C	tempered	300	5								
	Low-alloyed steel		annealed	180	6								
			tempered	275	7								
			tempered	300	8								
			tempered	350	9								
	High-alloyed steel and high-alloyed tool steel		annealed	200	10								
			hardened and tempered	325	11								
M	Stainless steel	ferritic/martensitic	annealed	200	12								
		martensitic	tempered	240	13								
		austenitic	quench hardened	180	14								
		austenitic-ferritic		230	15								
K	Grey cast iron	perlitic/ferritic		180	16								
		perlitic (martensitic)		260	17								
	Cast iron with spheroidal graphite	ferritic		160	18								
		perlitic		250	19								
	Malleable cast iron	ferritic		130	20								
		perlitic		230	21								
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
		≤ 12 % Si, hardenable	hardened	90	25								
		> 12 % Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30	45	55	85	10	–	85	90	10
			hardened	280	31	25	30	45	10	–	45	50	10
		Ni or Co bass	annealed	250	32	45	55	85	10	–	85	90	10
			hardened	350	33	25	30	45	10	–	45	50	10
			cast	320	34	25	30	45	10	–	45	50	10
	Titanium alloys	pure titanium		R_m 400	35	75	90	135	10	–	135	145	10
		α and β alloys	hardened	R_m 1050	36	45	55	85	10	–	85	90	10
H	Hardened steel		hardened and tempered	55 HRC	37								
			hardened and tempered	60 HRC	38								
	Hard cast iron		cast	400	39								
	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

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Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

ZCC·CT

End mill – PM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						PM-2E PM-2ES / PM-2EP / PM-2RP PM-4E PM-4E-G				PM-4EL PM-4EL-G PM-4EX-G			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<3	0,15xD	0<x≤20	0,15xD	0<x<3	0,15xD	0<x≤20	0,15xD
						3≤x<6	0,3xD			3≤x<6	0,3xD		
						6≤x≤20	0,5xD			6≤x≤20	0,5xD		
						KMG405				KMG405			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	165	220	300	1	140	190	255	1
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2	160	210	285	1	135	185	245	1
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3	120	155	210	1	100	135	180	1
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4	100	135	180	1	85	115	155	1
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5	95	125	165	1	80	105	145	1
P	Low-alloyed steel		annealed	180	6	125	165	225	1	110	145	195	1
P	Low-alloyed steel		tempered	275	7	100	135	180	1	85	115	155	1
P	Low-alloyed steel		tempered	300	8	95	125	165	1	80	105	145	1
P	Low-alloyed steel		tempered	350	9	90	115	160	1	75	100	135	1
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10	120	155	210	1	100	135	180	1
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11	90	120	160	1	75	105	140	1
M	Stainless steel	ferritic/martensitic	annealed	200	12	55	75	100	1	45	65	85	1
M	Stainless steel	martensitic	tempered	240	13	50	65	85	1	40	55	75	1
M	Stainless steel	austenitic	quench hardened	180	14	60	75	105	1	50	65	90	1
M	Stainless steel	austenitic-ferritic		230	15	50	65	85	1	40	55	75	1
K	Grey cast iron	perlitic/ferritic		180	16	125	165	220	1	105	140	190	1
K	Grey cast iron	perlitic (martensitic)		260	17	100	135	180	1	85	115	155	1
K	Cast iron with spheroidal graphite	ferritic		160	18	150	200	270	1	130	175	230	1
K	Cast iron with spheroidal graphite	perlitic		250	19	120	155	210	1	100	135	180	1
K	Malleable cast iron	ferritic		130	20	165	220	300	1	145	190	255	1
K	Malleable cast iron	perlitic		230	21	135	180	240	1	115	155	205	1
N	Aluminium wrought alloys	cannot be hardened		60	22								
N	Aluminium wrought alloys	hardenable	hardened	100	23								
N	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24								
N	Cast aluminium alloys	≤ 12% Si, hardenable	hardened	90	25								
N	Cast aluminium alloys	> 12% Si, cannot be hardened		130	26								
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28								
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	80	105	140	1	65	90	120	1
H	Hardened steel		hardened and tempered	60 HRC	38	–	–	–	–	–	–	–	–
H	Hard cast iron		cast	400	39	105	140	185	1	85	120	160	1
H	Hardened cast iron		hardened and tempered	55 HRC	40	–	–	–	–	–	–	–	–
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.
Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]																			
	PM-6E				PM-6EL				PM-2B PM-2BS / PM-2BP PM-4B				PM-2BL PM-2BFP PM-4BL				PM-2BC			
			Shoulder milling				Shoulder milling													
			Ø [mm]	$a_{p\,max}$			Ø [mm]	$a_{p\,max}$												
			0 < x ≤ 20	0.15 x D			0 < x ≤ 20	0.15 x D												
	KMG405				KMG405				KMG405				KMG405				KMG405			
	a_e / D				a_e / D				a_e / D				a_e / D				a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/10	1/20	f-group	1/1	1/10	1/20	f-group	1/1	1/10	1/20	f-group
	–	220	300	1	–	190	255	1	–	270	300	5	–	230	255	5	–	230	255	5
	–	210	285	1	–	185	245	1	–	260	285	5	–	220	245	5	–	220	245	5
	–	155	210	1	–	135	180	1	–	190	210	5	–	165	180	5	–	165	180	5
	–	135	180	1	–	115	155	1	–	165	180	5	–	140	155	5	–	140	155	5
	–	125	165	1	–	105	145	1	–	150	165	5	–	130	145	5	–	130	145	5
	–	165	225	1	–	145	195	1	–	205	225	5	–	175	195	5	–	175	195	5
	–	135	180	1	–	115	155	1	–	165	180	5	–	140	155	5	–	140	155	5
	–	125	165	1	–	105	145	1	–	150	165	5	–	130	145	5	–	130	145	5
	–	115	160	1	–	100	135	1	–	145	160	5	–	120	135	5	–	120	135	5
	–	155	210	1	–	135	180	1	–	190	210	5	–	165	180	5	–	165	180	5
	–	120	160	1	–	105	140	1	–	145	160	5	–	125	140	5	–	125	140	5
	–	75	100	1	–	65	85	1	–	90	100	5	–	75	85	5	–	75	85	5
	–	65	85	1	–	55	75	1	–	80	85	5	–	65	75	5	–	65	75	5
	–	75	105	1	–	65	90	1	–	95	105	5	–	80	90	5	–	80	90	5
	–	65	85	1	–	55	75	1	–	80	85	5	–	65	75	5	–	65	75	5
	–	165	220	1	–	140	190	1	–	200	220	5	–	170	190	5	–	170	190	5
	–	135	180	1	–	115	155	1	–	165	180	5	–	140	155	5	–	140	155	5
	–	200	270	1	–	175	230	1	–	245	270	5	–	210	230	5	–	210	230	5
	–	155	210	1	–	135	180	1	–	190	210	5	–	165	180	5	–	165	180	5
	–	220	300	1	–	190	255	1	–	270	300	5	–	230	255	5	–	230	255	5
	–	180	240	1	–	155	205	1	–	220	240	5	–	185	205	5	–	185	205	5
	–	105	140	1	–	90	120	1	–	125	140	5	–	110	120	5	–	110	120	5
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	–	140	185	1	–	120	160	1	–	165	185	1	–	145	160	1	–	145	160	1
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

A Turning

B Milling

C Drilling

D Technical Information

E Index

End mill – PM series, VPM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						PM-2R PM-4R				PM-4RL			
						Slot milling: Ø [mm] 0<x<3 – $a_{p\,max}$ 0,15xD; 3≤x<6 – 0,3xD; 6≤x≤20 – 0,5xD		Shoulder milling: Ø [mm] 0<x≤20 – $a_{e\,max}$ 0.15xD		Slot milling: Ø [mm] 0<x<3 – $a_{p\,max}$ 0,15xD; 3≤x<6 – 0,3xD; 6≤x≤20 – 0,5xD		Shoulder milling: Ø [mm] 0<x≤20 – $a_{e\,max}$ 0.15xD	
						KMG405				KMG405			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	165	220	300	1	150	200	265	1
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2	160	210	285	1	145	190	255	1
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3	120	155	210	1	105	140	190	1
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4	100	135	180	1	90	120	160	1
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5	95	125	165	1	85	110	150	1
P	Low-alloyed steel		annealed	180	6	125	165	225	1	115	150	200	1
P	Low-alloyed steel		tempered	275	7	100	135	180	1	90	120	160	1
P	Low-alloyed steel		tempered	300	8	95	125	165	1	85	110	150	1
P	Low-alloyed steel		tempered	350	9	90	115	160	1	80	105	140	1
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10	120	155	210	1	105	140	190	1
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11	90	120	160	1	80	110	145	1
M	Stainless steel	ferritic/martensitic	annealed	200	12	55	75	100	1	50	65	85	1
M	Stainless steel	martensitic	tempered	240	13	50	65	85	1	45	60	75	1
M	Stainless steel	austenitic	quench hardened	180	14	60	75	105	1	55	70	95	1
M	Stainless steel	austenitic-ferritic		230	15	50	65	85	1	45	60	75	1
K	Grey cast iron	perlitic/ferritic		180	16	125	165	220	1	110	150	195	1
K	Grey cast iron	perlitic (martensitic)		260	17	100	135	180	1	90	120	160	1
K	Cast iron with spheroidal graphite	ferritic		160	18	150	200	270	1	135	180	240	1
K	Cast iron with spheroidal graphite	perlitic		250	19	120	155	210	1	105	140	190	1
K	Malleable cast iron	ferritic		130	20	165	220	300	1	150	200	265	1
K	Malleable cast iron	perlitic		230	21	135	180	240	1	120	160	215	1
N	Aluminium wrought alloys	cannot be hardened		60	22								
N	Aluminium wrought alloys	hardenable	hardened	100	23								
N	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24								
N	Cast aluminium alloys	≤ 12% Si, hardenable	hardened	90	25								
N	Cast aluminium alloys	> 12% Si, cannot be hardened		130	26								
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28								
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	85	110	145	1	70	95	125	1
H	Hardened steel		hardened and tempered	60 HRC	38	–	–	–	–	–	–	–	–
H	Hard cast iron		cast	400	39	115	145	190	1	95	125	165	1
H	Hardened cast iron		hardened and tempered	55 HRC	40	–	–	–	–	–	–	–	–
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.
Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

ZCC·CT

Starting values for cutting speed v_c [m/min]							
PM-4H PM-4HL				VPM-4E			
		Shoulder milling					
		Ø [mm]	$a_{e\,max}$				
		0 < x ≤ 20	0.15 x D	0 < x < 3	0,5 x D	0 < x < 3	0.15 x D
				3 ≤ x < 12	1,5 x D	3 ≤ x < 20	0,5 x D
				12 ≤ x ≤ 20	2,0 x D		
KMG405				KMG406			
a_e / D				a_e / D			
1/1	1/2	1/10	f-group	1/1	1/2	1/10	
–	210	270	6	230	280	350	9
–	200	260	6	220	270	340	9
–	150	190	6	160	190	250	9
–	130	165	6	140	160	210	9
–	120	150	6	130	150	200	9
–	160	205	6	180	215	270	9
–	130	165	6	130	170	220	9
–	120	150	6	125	150	190	9
–	110	145	6	120	150	190	9
–	150	190	6	160	190	250	9
–	115	145	6	115	140	190	9
–	70	90	6	70	90	110	9
–	60	80	6	60	80	100	9
–	75	95	6	75	90	120	9
–	60	80	6	65	80	100	9
–	155	200	6	160	200	260	9
–	130	165	6	140	170	220	9
–	190	245	6	215	250	330	9
–	150	190	6	160	200	250	9
–	210	270	6	230	280	360	9
–	170	220	6	180	230	290	9
–	100	125	1	100	120	150	9
–	–	–	–	–	–	–	–
–	130	165	1	110	150	180	9
–	–	–	–	–	–	–	–

End mills – EPM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						EPM-2E EPM-4E				EPM-2EL EPM-4EL			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<3	0,15xD	0<x≤20	0,15xD	0<x<3	0,15xD	0<x≤20	0,15xD
						3≤x<6	0,3xD			3≤x<6	0,3xD		
						6≤x≤20	0,5xD			6≤x≤20	0,5xD		
						KMG406				KMG406			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	165	220	300	1	140	190	255	1
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2	160	210	285	1	135	185	245	1
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3	120	155	210	1	100	135	180	1
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4	100	135	180	1	85	115	155	1
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5	95	125	165	1	80	105	145	1
P	Low-alloyed steel		annealed	180	6	125	165	225	1	110	145	195	1
P	Low-alloyed steel		tempered	275	7	100	135	180	1	85	115	155	1
P	Low-alloyed steel		tempered	300	8	95	125	165	1	80	105	145	1
P	Low-alloyed steel		tempered	350	9	90	115	160	1	75	100	135	1
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10	120	155	210	1	100	135	180	1
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11	90	120	160	1	75	105	140	1
M	Stainless steel	ferritic/martensitic	annealed	200	12	55	75	100	1	45	65	85	1
M	Stainless steel	martensitic	tempered	240	13	50	65	85	1	40	55	75	1
M	Stainless steel	austenitic	quench hardened	180	14	60	75	105	1	50	65	90	1
M	Stainless steel	austenitic-ferritic		230	15	50	65	85	1	40	55	75	1
K	Grey cast iron	perlitic/ferritic		180	16	125	165	220	1	105	140	190	1
K	Grey cast iron	perlitic (martensitic)		260	17	100	135	180	1	85	115	155	1
K	Cast iron with spheroidal graphite	ferritic		160	18	150	200	270	1	130	175	230	1
K	Cast iron with spheroidal graphite	perlitic		250	19	120	155	210	1	100	135	180	1
K	Malleable cast iron	ferritic		130	20	165	220	300	1	145	190	255	1
K	Malleable cast iron	perlitic		230	21	135	180	240	1	115	155	205	1
N	Aluminium wrought alloys	cannot be hardened		60	22								
N	Aluminium wrought alloys	hardenable	hardened	100	23								
N	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
N	Cast aluminium alloys	≤ 12 % Si, hardenable	hardened	90	25								
N	Cast aluminium alloys	> 12 % Si, cannot be hardened		130	26								
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28								
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	80	105	140	1	65	90	120	1
H	Hardened steel		hardened and tempered	60 HRC	38	–	–	–	–	–	–	–	–
H	Hard cast iron		cast	400	39	105	140	185	1	85	120	160	1
H	Hardened cast iron		hardened and tempered	55 HRC	40								
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.
Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]							
	EPM-2B EPM-4B				EPM-2BL EPM-4BL			
	KMG406				KMG406			
	a_e / D				a_e / D			
	1/1	1/10	1/20	f-group	1/1	1/10	1/20	f-group
	–	270	300	5	–	230	255	5
	–	260	285	5	–	220	245	5
	–	190	210	5	–	165	180	5
	–	165	180	5	–	140	155	5
	–	150	165	5	–	130	145	5
	–	205	225	5	–	175	195	5
	–	165	180	5	–	140	155	5
	–	150	165	5	–	130	145	5
	–	145	160	5	–	120	135	5
	–	190	210	5	–	165	180	5
	–	145	160	5	–	125	140	5
	–	90	100	5	–	75	85	5
	–	80	85	5	–	65	75	5
	–	95	105	5	–	80	90	5
	–	80	85	5	–	65	75	5
	–	200	220	5	–	170	190	5
	–	165	180	5	–	140	155	5
	–	245	270	5	–	210	230	5
	–	190	210	5	–	165	180	5
	–	270	300	5	–	230	255	5
	–	220	240	5	–	185	205	5
	–	125	140	5	–	110	120	5
	–	–	–	–	–	–	–	–
	–	165	185	1	–	145	160	1

End mill – HPC series, UM/UMC series, VSM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						5501R38414GM (-R) 5502R38414GM (-R) 5602R38414GM (-R)				5501R38414GM 5502R38414GM 5602R38414GM			
						Slot milling		Shoulder milling		Slot milling		Shoulder milling	
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
						0<x<3	0,3xD	0<x<3	0.15xD	0<x<3	0,3xD	0<x<3	0.15xD
						3≤x<12	0,7xD	3≤x<20	0,3xD	3≤x<12	0,7xD	3≤x<20	0,3xD
						12≤x≤20	1,5xD			12≤x≤20	1,5xD		
						KMG405				KMG406			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	250	300	380	9	230	280	350	9
		approx. 0,45 % C	annealed	190	2	240	285	365	9	220	270	340	9
		approx. 0,45 % C	tempered	250	3	175	210	270	9	160	190	250	9
		approx. 0,75 % C	annealed	270	4	150	180	230	9	140	160	210	9
		approx. 0,75 % C	tempered	300	5	140	165	210	9	130	150	200	9
	Low-alloyed steel		annealed	180	6	190	225	285	9	180	215	270	9
			tempered	275	7	150	180	230	9	130	170	220	9
			tempered	300	8	140	165	210	9	125	150	190	9
			tempered	350	9	130	160	200	9	120	150	190	9
	High-alloyed steel and high-alloyed tool steel		annealed	200	10	175	210	270	9	160	190	250	9
			hardened and tempered	325	11	135	160	205	9	115	140	190	9
M	Stainless steel	ferritic/martensitic	annealed	200	12	80	100	125	9	70	90	110	9
		martensitic	tempered	240	13	70	85	110	9	60	80	100	9
		austenitic	quench hardened	180	14	85	105	130	9	75	90	120	9
		austenitic-ferritic		230	15	70	85	110	9	65	80	100	9
K	Grey cast iron	perlitic/ferritic		180	16	185	220	280	9	160	200	260	9
		perlitic (martensitic)		260	17	150	180	230	9	140	170	220	9
	Cast iron with spheroidal graphite	ferritic		160	18	225	270	345	9	215	250	330	9
		perlitic		250	19	175	210	270	9	160	200	250	9
	Malleable cast iron	ferritic		130	20	250	300	380	9	230	280	360	9
		perlitic		230	21	200	240	305	9	180	230	290	9
N	Aluminium wrought alloys	cannot be hardened		60	22								
		hardenable	hardened	100	23								
	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24								
		≤ 12% Si, hardenable	hardened	90	25								
		> 12% Si, cannot be hardened		130	26								
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
		CuZn, CuSnZn		90	28								
		CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
			hardened	280	31								
		Ni or Co bass	annealed	250	32								
			hardened	350	33								
			cast	320	34								
	Titanium alloys	pure titanium		R_m 400	35								
		α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	115	140	175	9	100	120	150	9
			hardened and tempered	60 HRC	38	–	–	–	–	–	–	–	–
	Hard cast iron		cast	400	39	135	165	205	9	110	150	180	9
	Hardened cast iron		hardened and tempered	55 HRC	40	–	–	–	–	–	–	–	–
X	Non-metallic materials	Thermoplasts			41								
		Thermosetting plastics			42								
		Plastic, glass-fibre reinforced GFRP			43								
		Plastic, carbon fibre reinforced CFRP			44								
		Graphite			45								
		Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.
Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

Starting values for cutting speed v_c [m/min]																			
UM-4E UM-4E-W UM-4R UM-5EP				UM-4EL UM-4EL-W UM-4ELP UM-4EFP				UM-4RL UM-4RFP				UMC-4E UMC-4E-W				VSM-4E VSM-4R			
Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling		Slot milling		Shoulder milling	
Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$	Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$
0<x<3	0,3xD	0<x<3	0.15xD	0<x<3	0,3xD	0<x<3	0.15xD	0<x<3	0,3xD	0<x<3	0.15xD	0<x<3	0,3xD	0<x<3	0.15xD	0<x<3	0,3xD	0<x<3	0.15xD
3≤x<12	0,7xD	3≤x<20	0,3xD	3≤x<12	0,7xD	3≤x<20	0,3xD	3≤x<12	0,7xD	3≤x<20	0,3xD	3≤x<12	0,7xD	3≤x<20	0,3xD	3≤x<12	0,7xD	3≤x<20	0,3xD
12≤x≤20	1,5xD			12≤x≤20	1,5xD			12≤x≤20	1,5xD			12≤x≤20	1,5xD			12≤x≤20	1,5xD		
KMG405				KMG405				KMG405				KMG405				KMG405			
a_e / D				a_e / D				a_e / D				a_e / D				a_e / D			
1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group	1/1	1/2	1/10	
250	300	380	9	150	180	230	9	150	180	230	9	–	–	300	9	145	180	250	10
240	285	365	9	145	175	220	9	145	175	220	9	–	–	285	9	140	175	240	10
175	210	270	9	105	130	165	9	105	130	165	9	–	–	210	9	105	130	175	10
150	180	230	9	90	110	140	9	90	110	140	9	–	–	180	9	90	110	150	10
140	165	210	9	85	100	130	9	85	100	130	9	–	–	165	9	80	100	140	10
190	225	285	9	115	135	175	9	115	135	175	9	–	–	225	9	110	135	190	10
150	180	230	9	90	110	140	9	90	110	140	9	–	–	180	9	90	110	150	10
140	165	210	9	85	100	130	9	85	100	130	9	–	–	165	9	80	100	140	10
130	160	200	9	80	95	120	9	80	95	120	9	–	–	160	9	80	95	130	10
175	210	270	9	105	130	165	9	105	130	165	9	–	–	210	9	105	130	175	10
135	160	205	9	80	100	125	9	80	100	125	9	–	–	160	9	80	100	135	10
80	100	125	9	50	60	75	9	50	60	75	9	–	–	100	9	50	60	80	10
70	85	110	9	45	55	65	9	45	55	65	9	–	–	85	9	45	55	70	10
85	105	130	9	55	65	80	9	55	65	80	9	–	–	105	9	50	65	85	10
70	85	110	9	45	55	65	9	45	55	65	9	–	–	85	9	45	55	70	10
185	220	280	9	110	135	170	9	110	135	170	9	–	–	220	9				
150	180	230	9	90	110	140	9	90	110	140	9	–	–	180	9				
225	270	345	9	135	165	210	9	135	165	210	9	–	–	270	9				
175	210	270	9	105	130	165	9	105	130	165	9	–	–	210	9				
250	300	380	9	150	180	230	9	150	180	230	9	–	–	300	9				
200	240	305	9	120	145	185	9	120	145	185	9	–	–	240	9				
																45	55	85	10
																25	30	45	10
																45	55	85	10
																25	30	45	10
																25	30	45	10
																75	90	135	10
																45	55	85	10
115	140	175	9	70	85	110	9	70	85	110	9								
–	–	–	–	–	–	–	–	–	–	–	–								
135	165	205	9	85	100	130	9	85	100	130	9								
–	–	–	–	–	–	–	–	–	–	–	–								

A

Turning

B

Milling

C

Drilling

D

Technical Information

E

Index

ZCC·CT

A Turning
B Milling
C Drilling
D Technical Information
E Index

Deburring cutters – FM series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]			
						5501 / 5601 5501 / 5601 5601			
						KMG303			
						a_e / D			
						1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1	–	–	230	11
		approx. 0,45 % C	annealed	190	2	–	–	220	11
		approx. 0,45 % C	tempered	250	3	–	–	165	11
		approx. 0,75 % C	annealed	270	4	–	–	140	11
		approx. 0,75 % C	tempered	300	5	–	–	130	11
	Low-alloyed steel		annealed	180	6	–	–	175	11
			tempered	275	7	–	–	140	11
			tempered	300	8	–	–	130	11
			tempered	350	9	–	–	120	11
	High-alloyed steel and high-alloyed tool steel		annealed	200	10	–	–	165	11
			hardened and tempered	325	11	–	–	125	11
M	Stainless steel	ferritic/martensitic	annealed	200	12	–	–	75	11
		martensitic	tempered	240	13	–	–	65	11
		austenitic	quench hardened	180	14	–	–	80	11
		austenitic-ferritic		230	15	–	–	65	11
K	Grey cast iron	perlitic/ferritic		180	16	–	–	170	11
		perlitic (martensitic)		260	17	–	–	140	11
	Cast iron with spheroidal graphite	ferritic		160	18	–	–	210	11
		perlitic		250	19	–	–	165	11
	Malleable cast iron	ferritic		130	20	–	–	230	11
		perlitic		230	21	–	–	185	11
N	Aluminium wrought alloys	cannot be hardened		60	22	–	–	1200	11
		hardenable	hardened	100	23	–	–	720	11
	Cast aluminium alloys	≤ 12% Si, cannot be hardened		75	24	–	–	480	11
		≤ 12% Si, hardenable	hardened	90	25	–	–	600	11
		> 12% Si, cannot be hardened		130	26	–	–	180	11
	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27	–	–	360	11
		CuZn, CuSnZn		90	28	–	–	420	11
		CuSn, Pb-free copper, electrolytic copper		100	29	–	–	360	11
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30				
			hardened	280	31				
		Ni or Co bass	annealed	250	32				
			hardened	350	33				
			cast	320	34				
	Titanium alloys	pure titanium		R_m 400	35				
		α and β alloys	hardened	R_m 1050	36				
H	Hardened steel		hardened and tempered	55 HRC	37				
			hardened and tempered	60 HRC	38				
	Hard cast iron		cast	400	39				
	Hardened cast iron		hardened and tempered	55 HRC	40				
X	Non-metallic materials	Thermoplasts			41				
		Thermosetting plastics			42				
		Plastic, glass-fibre reinforced GFRP			43				
		Plastic, carbon fibre reinforced CFRP			44				
		Graphite			45				
		Wood			46				

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

A Turning
B Milling
C Drilling
D Technical Information
E Index

End mills – QCH series

	Material group	Composition / structure / heat treatment		Brinell hardness HB	Machining group	Starting values for cutting speed v_c [m/min]							
						Q**-PM-4E Q**-PM-4R Q**-VPM-4E				Q**PM-2B Q**PM-4B			
						Slot milling		Shoulder milling					
						Ø [mm]	$a_{p\,max}$	Ø [mm]	$a_{e\,max}$				
						0<x<3	0,3xD	0<x<20	0,15xD				
						3≤x<6	0,3xD						
						6≤x≤20	0,5xD						
						KMG405				KMG405			
						a_e / D				a_e / D			
						1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
P	Unalloyed steel	approx. 0,15 % C	annealed	125	1								
P	Unalloyed steel	approx. 0,45 % C	annealed	190	2	165	220	300	1	–	270	300	5
P	Unalloyed steel	approx. 0,45 % C	tempered	250	3	160	210	285	1	–	260	285	5
P	Unalloyed steel	approx. 0,75 % C	annealed	270	4	120	155	210	1	–	190	210	5
P	Unalloyed steel	approx. 0,75 % C	tempered	300	5	100	135	180	1	–	165	180	5
P	Low-alloyed steel		annealed	180	6	95	125	165	1	–	150	165	5
P	Low-alloyed steel		tempered	275	7	125	165	225	1	–	205	225	5
P	Low-alloyed steel		tempered	300	8	100	135	180	1	–	165	180	5
P	Low-alloyed steel		tempered	350	9	95	125	165	1	–	150	165	5
P	High-alloyed steel and high-alloyed tool steel		annealed	200	10	90	115	160	1	–	145	160	5
P	High-alloyed steel and high-alloyed tool steel		hardened and tempered	325	11	120	155	210	1	–	190	210	5
M	Stainless steel	ferritic/martensitic	annealed	200	12	90	120	160	1	–	145	160	5
M	Stainless steel	martensitic	tempered	240	13	55	75	100	1	–	90	100	5
M	Stainless steel	austenitic	quench hardened	180	14	50	65	85	1	–	80	85	5
M	Stainless steel	austenitic-ferritic		230	15	60	75	105	1	–	95	105	5
K	Grey cast iron	perlitic/ferritic		180	16	50	65	85	1	–	80	85	5
K	Grey cast iron	perlitic (martensitic)		260	17	125	165	220	1	–	200	220	5
K	Cast iron with spheroidal graphite	ferritic		160	18	100	135	180	1	–	165	180	5
K	Cast iron with spheroidal graphite	perlitic		250	19	150	200	270	1	–	245	270	5
K	Malleable cast iron	ferritic		130	20	120	155	210	1	–	190	210	5
K	Malleable cast iron	perlitic		230	21	165	220	300	1	–	270	300	5
N	Aluminium wrought alloys	cannot be hardened		60	22	135	180	240	1	–	220	240	5
N	Aluminium wrought alloys	hardenable	hardened	100	23								
N	Cast aluminium alloys	≤ 12 % Si, cannot be hardened		75	24								
N	Cast aluminium alloys	≤ 12 % Si, hardenable	hardened	90	25								
N	Cast aluminium alloys	> 12 % Si, cannot be hardened		130	26								
N	Copper and copper alloys (bronze/brass)	machining steel, PB> 1%		110	27								
N	Copper and copper alloys (bronze/brass)	CuZn, CuSnZn		90	28								
N	Copper and copper alloys (bronze/brass)	CuSn, Pb-free copper, electrolytic copper		100	29								
S	Heat-resistant alloys	Fe-based alloys	annealed	200	30								
S	Heat-resistant alloys	Fe-based alloys	hardened	280	31								
S	Heat-resistant alloys	Ni or Co bass	annealed	250	32								
S	Heat-resistant alloys	Ni or Co bass	hardened	350	33								
S	Heat-resistant alloys	Ni or Co bass	cast	320	34								
S	Titanium alloys	pure titanium		R_m 400	35								
S	Titanium alloys	α and β alloys	hardened	R_m 1050	36								
H	Hardened steel		hardened and tempered	55 HRC	37	–	–	–	–				
H	Hardened steel		hardened and tempered	60 HRC	38	80	105	140	1				
H	Hard cast iron		cast	400	39	–	–	–	–				
H	Hardened cast iron		hardened and tempered	55 HRC	40	105	140	185	1				
X	Non-metallic materials	Thermoplasts			41								
X	Non-metallic materials	Thermosetting plastics			42								
X	Non-metallic materials	Plastic, glass-fibre reinforced GFRP			43								
X	Non-metallic materials	Plastic, carbon fibre reinforced CFRP			44								
X	Non-metallic materials	Graphite			45								
X	Non-metallic materials	Wood			46								

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.
Feed rate recommendations on page B522.
For examples of material for cutting tool groups view page D11.

	Starting values for cutting speed v_c [m/min]							
	Q**-HMX-4E Q**-HMX-4R				Q**-HMX-2B Q**-HMX-4B			
			Shoulder milling					
	Ø [mm]	$a_{p\ max}$	Ø [mm]	$a_{e\ max}$	Ø [mm]	$a_{p\ max}$	Ø [mm]	$a_{e\ max}$
			0 < x ≤ 20	0.15 x D				
	KMG5515 a_e / D				KMG5515 a_e / D			
	1/1	1/2	1/10	f-group	1/1	1/2	1/10	f-group
	–	–	–	–	–	–	–	–
	55	100	125	3	–	130	145	7
	55	95	120	3	–	80	90	7
	70	125	160	3	–	163	181	7
	55	100	125	3	–	109	145	7

A

Turning

B

Milling

C

Drilling

D

Technical Information

E

Index

A Turning
B Milling
C Drilling
D Technical Information
E Index

Recommended feed rate

Solid carbide milling group 1 – Square shoulder mills PM series, QCH series, EPM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]																			
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20					
P	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,07	0,08	0,08	0,09	0,09	0,10					
	1/2	0,01	0,03	0,03	0,03	0,03	0,03	0,04	0,04	0,06	0,09	0,10	0,10	0,12	0,12	0,13					
	1/10	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,20					
M	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,05	0,06	0,06	0,07	0,07	0,08					
	1/2	0,01	0,02	0,02	0,02	0,02	0,02	0,04	0,04	0,05	0,07	0,08	0,08	0,10	0,10	0,11					
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,07	0,11	0,13	0,13	0,15	0,15	0,16					
K	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,05	0,07	0,08	0,08	0,09	0,09	0,10					
	1/2	0,01	0,03	0,03	0,03	0,03	0,03	0,04	0,04	0,06	0,09	0,10	0,10	0,12	0,12	0,13					
	1/10	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,20					
H	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,05	0,06	0,06	0,07	0,07	0,08					
	1/2	0,01	0,02	0,02	0,02	0,02	0,02	0,04	0,04	0,05	0,07	0,08	0,08	0,10	0,10	0,11					
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,07	0,11	0,13	0,13	0,15	0,15	0,16					

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 2 – Square shoulder mills GM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]																			
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20					
P	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09					
	1/2	0,01	0,03	0,03	0,03	0,03	0,03	0,04	0,04	0,05	0,08	0,09	0,09	0,10	0,10	0,12					
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,06	0,06	0,08	0,12	0,14	0,14	0,16	0,16	0,18					
M	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,05	0,06	0,06	0,06	0,06	0,07					
	1/2	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09					
	1/10	0,02	0,03	0,03	0,03	0,03	0,03	0,05	0,05	0,06	0,10	0,11	0,11	0,13	0,13	0,15					
K	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09					
	1/2	0,01	0,03	0,03	0,03	0,03	0,03	0,04	0,04	0,05	0,08	0,09	0,09	0,10	0,10	0,12					
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,06	0,06	0,08	0,12	0,14	0,14	0,16	0,16	0,18					

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 3 – Square shoulder mills HM series, QCH series

	a_e / D	Feed rate per cutting edge (f_z) [mm]																			
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20					
H	1/1	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,03	0,05	0,06	0,06	0,06	0,06	0,07					
	1/2	0,01	0,02	0,02	0,02	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09					
	1/10	0,02	0,03	0,03	0,03	0,03	0,03	0,05	0,05	0,06	0,10	0,11	0,11	0,13	0,13	0,15					

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 4 – Square shoulder mills AL series, NM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]																			
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20					
N	1/1	0,02	0,03	0,03	0,03	0,03	0,03	0,05	0,05	0,06	0,09	0,11	0,11	0,12	0,12	0,14					
	3/4	0,02	0,04	0,04	0,04	0,04	0,04	0,06	0,06	0,08	0,12	0,14	0,14	0,16	0,16	0,18					
	1/10	0,03	0,06	0,06	0,06	0,06	0,06	0,09	0,09	0,12	0,19	0,22	0,22	0,25	0,25	0,28					
	1/20	0,04	0,08	0,08	0,08	0,08	0,08	0,12	0,12	0,16	0,23	0,27	0,27	0,31	0,31	0,35					

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Recommended feed rate

Solid carbide milling group 5 – Ball nose cutters GM series, QCH series, EPM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]														
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20
P	1/1															
	1/10	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,20
	1/20	0,03	0,06	0,06	0,06	0,06	0,06	0,08	0,08	0,11	0,17	0,20	0,20	0,23	0,23	0,25
M	1/1															
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,07	0,11	0,13	0,13	0,15	0,15	0,16
	1/20	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,21
K	1/1															
	1/10	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,20
	1/20	0,03	0,06	0,06	0,06	0,06	0,06	0,08	0,08	0,11	0,17	0,20	0,20	0,23	0,23	0,25
H	1/1															
	1/10	0,02	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,07	0,11	0,13	0,13	0,15	0,15	0,16
	1/20	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,21

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 6 – High feed mills PM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]						
		Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12
P	1/1							
	1/10							
	1/20	0,15	0,25	0,28	0,33	0,44	0,55	0,66
M	1/1							
	1/10							
	1/20	0,12	0,22	0,25	0,30	0,41	0,52	0,63
K	1/1							
	1/10							
	1/20	0,15	0,25	0,28	0,33	0,44	0,55	0,66
H	1/1							
	1/10							
	1/20	0,12	0,22	0,25	0,30	0,41	0,52	0,63

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 7 – Ball nose cutters HM series, QCH series

	a_e / D	Feed rate per cutting edge (f_z) [mm]														
		Ø0,5	Ø0,8	Ø 1	Ø 2	Ø 3	Ø 4	Ø 5	Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20
H	1/1															
	1/2	0,02	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,07	0,11	0,13	0,13	0,15	0,15	0,16
	1/10	0,02	0,05	0,05	0,05	0,05	0,05	0,07	0,07	0,09	0,14	0,16	0,16	0,18	0,18	0,21

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 8 – High feed mills AL series, ALP/ALG series

	a_e / D	Feed rate per cutting edge (f_z) [mm]							
		Ø 6	Ø 8	Ø 10	Ø 12	Ø 14	Ø 16	Ø 18	Ø 20
N	1/1	0,04	0,05	0,08	0,09	0,11	0,13	0,16	0,18
	3/4	0,05	0,07	0,10	0,12	0,14	0,16	0,20	0,23
	1/10	0,08	0,11	0,16	0,19	0,22	0,25	0,31	0,36

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Recommended feed rate

Solid carbide milling group 9 – Square shoulder mills UM/UMC series, VPM series HSC/HPC

	a_e / D	Feed rate per cutting edge (f_z) [mm]									
		Ø 4	**Ø 5**	**Ø 6**	**Ø 8**	**Ø 10**	**Ø 12**	**Ø 14**	**Ø 16**	**Ø 18**	**Ø 20**
P	1/1	0,06	0,06	0,06	0,07	0,07	0,07	0,07	0,08	0,08	0,08
	1/2	0,08	0,08	0,08	0,09	0,09	0,09	0,09	0,10	0,10	0,10
	1/10	0,14	0,14	0,16	0,18	0,22	0,25	0,27	0,3	0,32	0,36
M	1/1	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,06	0,06	0,06
	1/2	0,06	0,06	0,06	0,07	0,07	0,07	0,07	0,08	0,08	0,08
	1/10	0,10	0,10	0,10	0,12	0,12	0,14	0,16	0,16	0,18	0,18
K	1/1	0,06	0,06	0,06	0,07	0,07	0,07	0,07	0,08	0,08	0,08
	1/2	0,08	0,08	0,08	0,09	0,09	0,09	0,09	0,10	0,10	0,10
	1/10	0,14	0,14	0,16	0,18	0,22	0,25	0,27	0,3	0,32	0,36
H	1/1	0,045	0,045	0,045	0,053	0,053	0,053	0,053	0,06	0,06	0,06
	1/2	0,06	0,06	0,06	0,07	0,07	0,07	0,07	0,08	0,08	0,08
	1/10	0,10	0,10	0,10	0,12	0,12	0,14	0,16	0,16	0,18	0,18

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 10 – Square shoulder mills VSM series, TM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]									
		Ø 4	**Ø 5**	**Ø 6**	**Ø 8**	**Ø 10**	**Ø 12**	**Ø 14**	**Ø 16**	**Ø 18**	**Ø 20**
P	1/1	0,03	0,04	0,05	0,05	0,05	0,05	0,06	0,06	0,07	0,08
	1/2	0,04	0,06	0,07	0,07	0,07	0,07	0,08	0,09	0,10	0,11
	1/10	0,05	0,08	0,09	0,09	0,09	0,09	0,11	0,12	0,14	0,15
M	1/1	0,02	0,03	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,06
	1/2	0,03	0,05	0,05	0,05	0,05	0,05	0,06	0,07	0,08	0,08
	1/10	0,04	0,06	0,07	0,07	0,07	0,07	0,08	0,09	0,10	0,11
S	1/1	0,02	0,03	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,06
	1/2	0,03	0,05	0,05	0,05	0,05	0,05	0,06	0,07	0,08	0,08
	1/10	0,04	0,06	0,07	0,07	0,07	0,07	0,08	0,09	0,10	0,11

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Solid carbide milling group 11 – Deburring cutters FM series

	a_e / D	Feed rate per cutting edge (f_z) [mm]										
		Ø 3	**Ø 4**	**Ø 5**	**Ø 6**	**Ø 8**	**Ø 10**	**Ø 12**	**Ø 14**	**Ø 16**	**Ø 18**	**Ø 20**
P	1/1											
	1/2											
	1/10	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09
M	1/1											
	1/2											
	1/10	0,02	0,02	0,02	0,02	0,03	0,05	0,06	0,06	0,06	0,06	0,07
K	1/1											
	1/2											
	1/10	0,02	0,02	0,03	0,03	0,04	0,06	0,07	0,07	0,08	0,08	0,09
N	1/1											
	1/2											
	1/10	0,03	0,03	0,05	0,05	0,06	0,09	0,11	0,11	0,12	0,12	0,14

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

Recommended feed rate

Solid carbide milling group 12 – ALP-1EP single-edged cutters

	a_e / D	Feed rate per cutting edge (f_z) [mm]						
		Ø 2	**Ø 3**	**Ø 4**	**Ø 5**	**Ø 6**	**Ø 8**	**Ø 10**
N	**1/1**	0,03	0,05	0,07	0,09	0,11	0,14	0,18
	1/2	0,04	0,07	0,10	0,13	0,15	0,20	0,25
	1/10	0,06	0,11	0,15	0,19	0,23	0,29	0,38

Note: The given cutting values are guide values, which were determined under ideal conditions.
The values have to be adapted in individual cases.

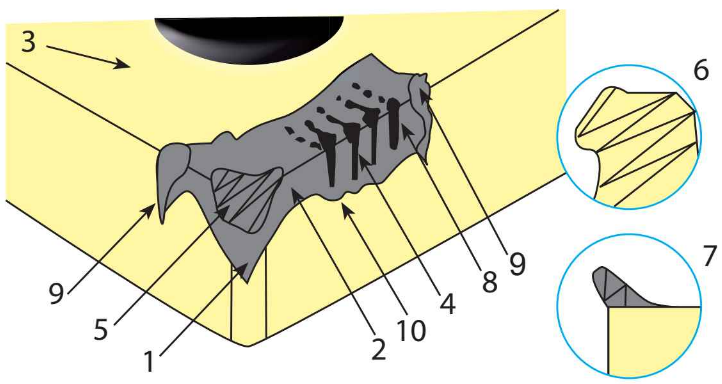
Notes

Technical information

B

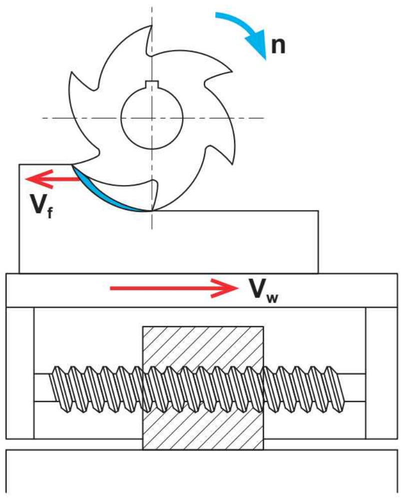
Trouble shooting – indexable milling

Fig.	Type of wear	Effects	Reason	Countermeasure
1+2	Flank wear	– Bad surface quality and dimensional stability – Increase of cutting force	– Grade not wear-resistant enough – Cutting speed too high – Clearance angle too small – Feed rate too low	– Grade with higher wear-resistance – Reduce cutting speed – Increase clearance angle – Reduce feed rate
3	Crater wear	– Bad surface quality and chip control	– Grade not wear-resistant enough – Cutting speed too high – Feed rate too low	– Grade with higher wear-resistance – Reduce cutting speed – Reduce feed rate
4	Chipping	– Unstable tool life – Sudden breakage of cutting edge	– Grade too hard – Feed rate too high – Cutting edge not stable enough – Stability of the holder or tension insufficient	– Grade with higher toughness – Reduce feed rate – Change honing of cutting edge – Use a more stable tool holder
5	Breakage	– Increase of cutting force – Bad surface quality and dimensional stability	– Grade too hard – Feed rate too high – Cutting edge not stable enough – Stability of the holder or tension insufficient	– Grade with higher toughness – Reduce feed rate – Change honing of cutting edge – Use a more stable tool holder
6	Plastic deformation	– Bad dimensional stability – Damage to cutting edge	– Grade not wear-resistant enough – Cutting speed too high – Cutting depth and/or feed rate too high – Temperature on the cutting edge too high	– Grade with higher toughness – Reduce cutting speed – Reduce cutting depth and feed rate – Grade with higher heat-resistance
7	Welding	– Increase of cutting force – Bad surface quality	– Cutting speed too low – Cutting edge not sharp enough – Grade not suitable	– Increase cutting speed – Increase rake angle – Use a more suitable grade
8	Thermal cracks	– Breakage due to thermal interaction, often caused when cutting is interrupted (milling)	– Temperature fluctuation when machining – Grade too hard	– Dry machining – Grade with higher toughness
9	Notch wear	– Burr formation – Increase of cutting force	– Damage through chips (jagged edges) – Feed rate and cutting speed too high	– Grade with higher wear-resistance – Increase rake angle to get a sharper cutting edge – Reduce cutting speed
10	Flaking (coating)	– Often appears when machining hardened materials or caused by vibration	– Cutting edge adhesion and chipping – Bad chip removal	– Increase rake angle to get a sharper cutting edge – Chip breaker with bigger chip space

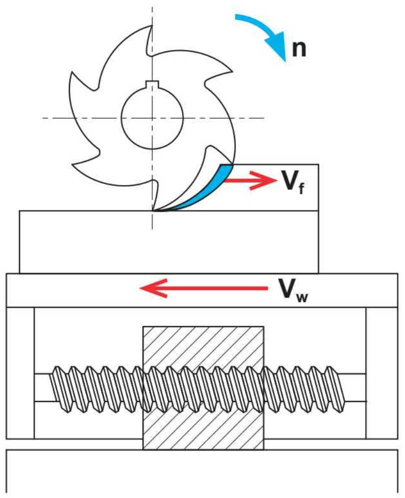


Indexable milling

Difference between up-milling and down-milling



Up-milling



Down-milling

V_f Feed rate tool
V_w Feed rate work piece
n Rotation

Up-milling: the feed direction of the work piece is opposite to that of the milling rotation at the connecting position.	Down-milling: the feed direction of the work piece is the same as that of the milling rotation at the connecting position.

Advantages and disadvantages

Direction	Advantages	Disadvantages
Up-milling	– Prevents hooking of tool – More smooth cut	– Bigger stress on cutting edge – Shorter tool life
Down-milling	– Higher tool life – Less thermal stress	– Hooking of tool possible

Indexable milling

Pitch selection

The pitch is the distance between one point on one cutting edge and the same point on the next edge.
Milling cutters are mainly classified into wide, normal and fine pitches.

Operational stability		
L (low)	M (medium)	H (high)
Wide pitch	Normal pitch	Fine pitch
		
When the milling width is equal to the diameter of the cutter, the machining system is stable and main power of machine is sufficient, selecting a wide pitch can achieve high productive efficiency.	General milling function and multiple mixed productions.	When the milling width is less than the diameter of cutter, cutting by maximum edges can achieve high productive efficiency.

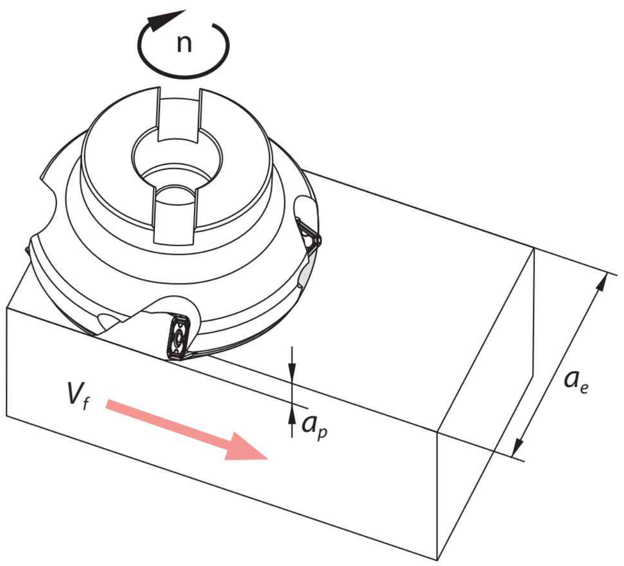
Approach angle

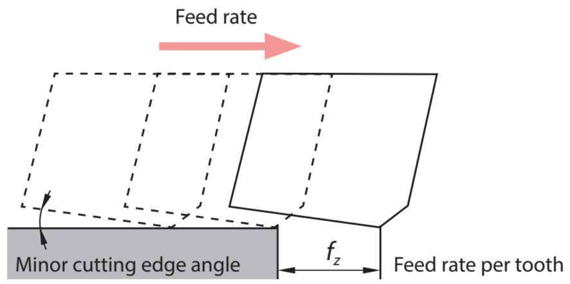
The approach angle is composed by insert. Tool body, chip thickness, cutting forces and tool life are affected especially by the approach angle. Decreasing the approach angle reduces chip thickness and spreads the cutting area between cutting edge and work piece for a given feed rate.
A smaller approach angle also guarantees stable entering or exiting the work piece, to protect the cutting edge and extend tool life. However this will increase higher axial cutting forces on the work piece, thus it is not suitable for machining thin work piecees such as thin plates.

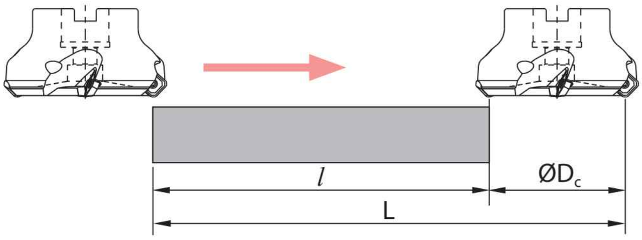
Approach angle	Feed rate per tooth	Max. cutting depth
90°	f_z	$h_{ex} = f_z \times sin_{kr}$
75°		$h_{ex} = 0{,}96 \times f_z$
60°		$h_{ex} = 0{,}86 \times f_z$
45°		$h_{ex} = 0{,}707 \times f_z$
Round		$h_{ex} = \frac{\sqrt{iC^2 \times (iC - 2a_p)^2}}{iC} \times f_z$

Indexable milling

General formulas







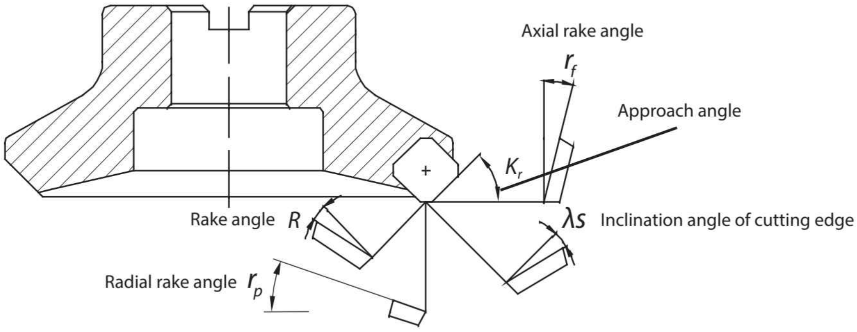
V_c: Feed rate [m/min]
D_c: Nominal diameter of milling tool [mm]
n: Spindle speed [u/min]
z_n: Number of teeth
Q: Metal removal rate [cm^3/min]

V_f: Feed rate of worktable (feed speed) [mm/min]
f_z: Feed rate per tooth [mm/z]
π: ~3,14
T_c: Machining time [min]
f_n: Feed rate per revolution [mm/u]

Cutting speed	$V_c = \frac{\pi \times D_c \times n}{1000}$ [m/min]
Spindle speed	$n = \frac{1000 \times V_c}{\pi \times D_c}$ [rev/min]
Feed rate of work table	$V_f = f_z \times n \times z_n$ [mm/min]
Feed rate per tooth	$f_z = \frac{V_f}{n \times Z_n}$ [mm/z]
Feed rate per revolution	$f_n = \frac{V_f}{n}$ [mm/rev]
Machining time	$T_c = \frac{1000 \times V_c}{\pi \times D_c}$ [min]
Metal removal rate	$Q = \frac{a_p \times a_e \times V_f}{1000}$ [cm^3/min]

Indexable milling

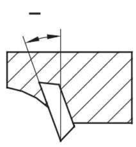
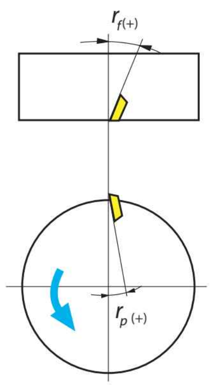
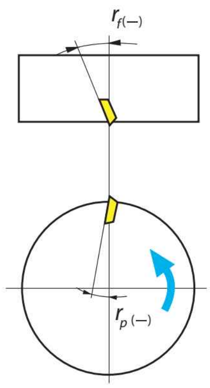
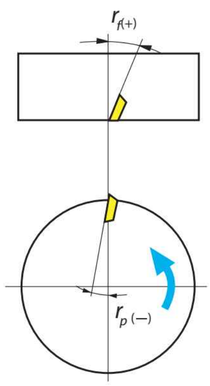
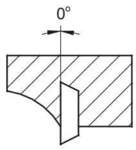
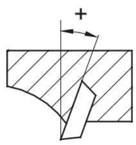
Function of angles when face milling



Main angles

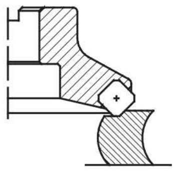
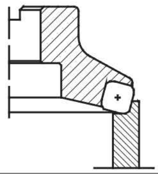
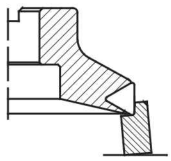
Angle	Feature	Effet		
Axial rake angle r_f	Influences chip direction	Negative angle, good chip removal		
Radial rake angle r_p	Influences cutting edge sharpness	Positive angle, good cutting performance		
Approach angle *Kr*	Influences chip thickness	Kr↑, chip thickness↑, Kr↓, chip thickness↓;		
Rake angle *R*	Influences cutting force	Poor cutting performance, stable cutting edge	(−)←0→(+)	Good cutting performance, unstable cutting edge
Inclination angle *λs*	Influences chip flow direction	Poor cutting performance, stable cutting edge	(−)←0→(+)	Good cutting performance, unstable cutting edge

Combination of different rake angles

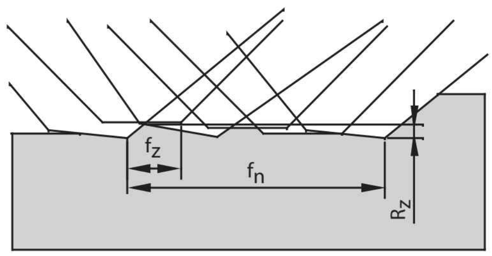
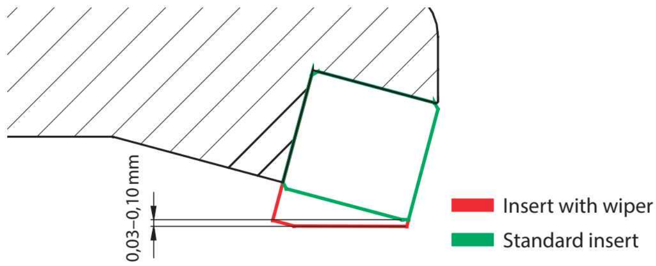
		Double positive	Double negative	Positive/Negative
Negative rake angle				
Neutral angle				
Positive angle				
Axial rake angle r_f		+	–	+
Radial rake angle r_p		+	–	–
Application field	**P**	√		√
	M	√		√
	K		√	√
	N	√		
	S	√		√

Indexable milling

Cutting performances of different approach angles

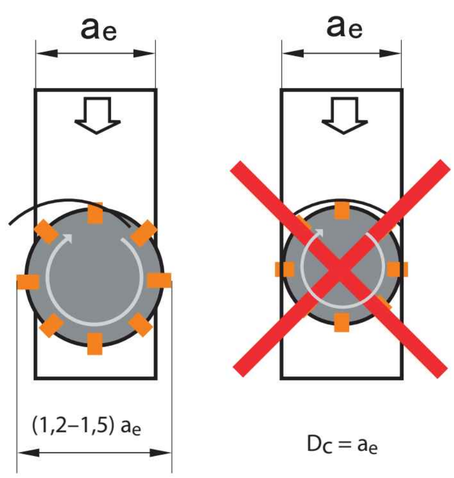
Approach angle	Depiction	Explanation
45°		Axial force is largest. It will bend when machining thin-wall work piece, and reduces the precision of work piece. It is benefit to avoid fringe breakage of work piece when machining cast iron.
75°		The main purpose is to resolve the radial cutting force, it is often used for general face milling.
90°		The axial force is zero in theory, suitable for milling thin plate workpiece.

Inserts with wiper

Using standard inserts	Using inserts with wiper
	
Normal surface quality	High surface quality

The wiper insert must protrude below the other inserts by 0.03–0.10 mm at axial direction, only that the wiping function can take into effect. Generally speaking, a cutter can assemble only one wiper insert. If the diameter of cutter is much bigger or cutter's feed rate per revolution is bigger than the length of wiper edge, 2 to 3 wiper inserts can be assembled.

Cutting width



Generally speaking, the relation between cutting width and tool cutting diameter is $D_c = (1.2–1.5)\ a_e$.

In the machining practice, it needs to avoid coincidence of tool center and workpiece center as much as possible.

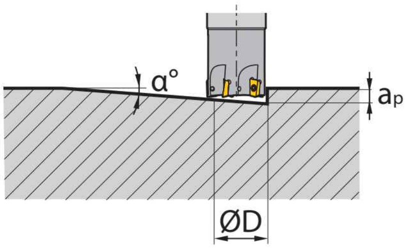
D_c: Tool diameter
a_e: Lateral infeed

A Turning B Milling C Drilling D Technical Information E Index

Indexable milling

Plunging and circular milling with insert APKT

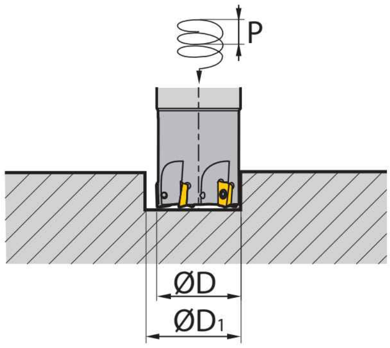
Plunging



$$L_m = \frac{a_p}{\tan_\alpha}$$

α : Angle de plongée

Circular milling



$$P = \tan_\alpha \times \pi \times D_1$$

α : Angle d'hélice

Insert	Diameter ØD [mm]	Max. cutting depth a_p [mm]	Max. plunge angle α°	Min. diameter $ØD_1$ [mm]	Max. diameter [mm]
AP**11**	16	10	10	20	30
	20	10	5	28	38
	25	10	4	40	48
	32	10	3	56	60
	40	10	2	70	76

Reduce the feed rate when plunging and circular milling.
For drilling operations (axial) set the feed rate under 0.2 mm.
„Attention“ – drilling can form long chips.

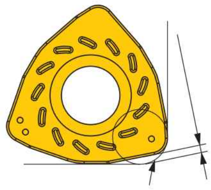
Indexable milling

Plunging and circular milling with insert WPGT or SDMT

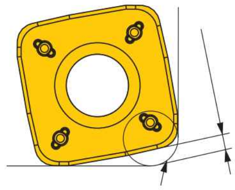
Approx. programmed radius

Insert	approx. R [mm]	Residual material K [mm]
WPGT050315ZSR	2	0,5
WPGT060415ZSR	2,5	0,7
WPGT080615ZSR	2,5	0,7
WPGT090725ZSR	4,5	1,2
SDMT06T208	1,6	0,5
SDMT09T312	2,5	0,87
SDMT120412	4,0	0,93
SDMT150620	4,0	1,38

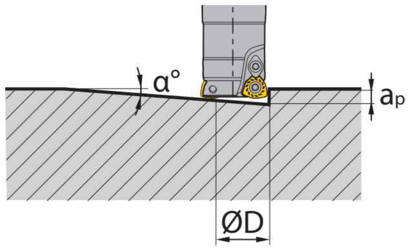
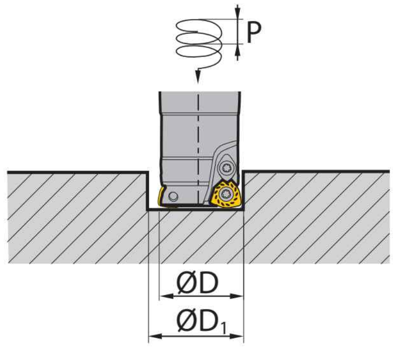
WPGT



SDMT



Insert WPGT

Plunging	Circular milling
	
$L_m = \frac{a_p}{\tan_\alpha}$	$P = \tan_\alpha \times \pi \times D_1$
α : Angle de plongée	α : Angle d'hélice

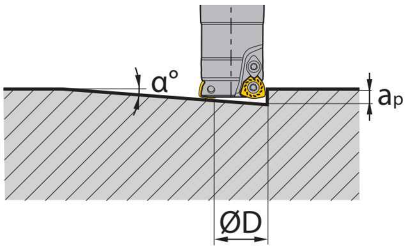
Insert	Diameter ØD [mm]	Max. cutting depth a_p [mm]	Max. plunge angle α°	Min. diameter $ØD_1$ [mm]	Max. diameter [mm]
WP**05**	20	1,5	12	24	37
WP**06**	25	1,5	8,8	31	47
	32	1,5	5	45	61
	40	1,5	3,2	61	77
	50	1,5	2,8	81	97
WP**08**	40	1,5	9	52	77
	50	1,5	5,4	71	97
	63	1,5	4,3	97	123
	80	1,5	2,9	131	157
	100	1,5	2,1	171	197
	125	1,5	1,3	221	247
	160	1,5	1,1	291	317
WP**09**	50	3,0	7,2	70	96
	63	3,0	4,5	96	122
	80	3,0	2,8	130	156
	100	3,0	2,2	170	196
	125	3,0	1,6	220	246
	160	3,0	1,2	290	316

Reduce the feed rate when plunging and circular milling.
For drilling operations (axial) set the feed rate under 0.2 mm.
„Attention" – drilling can form long chips.

Indexable milling

Insert SDMT

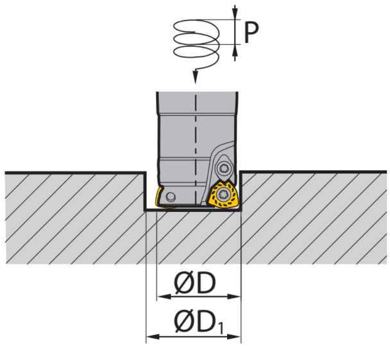
Plunging



$$L_m = \frac{a_p}{\tan_\alpha}$$

α: Plunge angle

Circular milling



$$P = \tan_\alpha \times \pi \times D_1$$

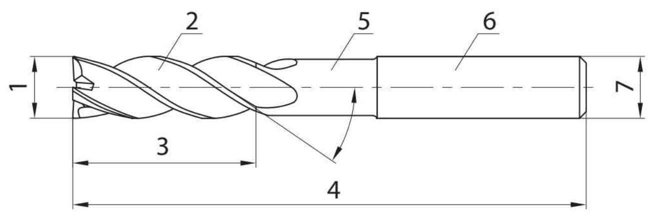
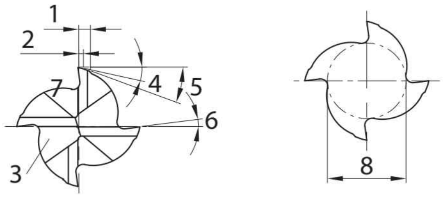
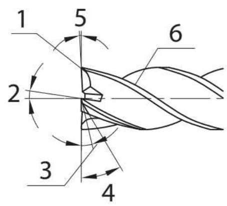
α: Helix angle

Insert	Diameter ØD (mm)	Max. cutting depth a_p [mm]	Max. plunge angle α°	Min. diameter $ØD_1$ [mm]	Max. diameter [mm]
SD**06**	20	0,8	3,6	30	38
	25	0,8	2,8	40	48
	32	0,8	1,6	52	60
	40	0,8	1,1	70	78
	50	0,8	0,8	90	98
	63	0,8	0,7	114	122
SD**09**	25	1,4	6,5	34	48
	32	1,4	4,5	48	62
	35	1,4	3,6	54	68
	50	1,4	1,8	84	98
	63	1,4	1,3	110	124
SD**12**	32	1,8	10,4	44	60
	40	1,8	5,7	60	76
	50	1,8	3,5	80	96
	63	1,8	2,5	106	122
	80	1,8	1,6	140	156
	100	1,8	1,2	180	196
SD**15**	40	2,2	7,3	54	76
	80	2,2	1,4	134	156
	100	2,2	1,0	174	196
	125	2,2	0,9	234	246
	160	2,2	0,6	304	316

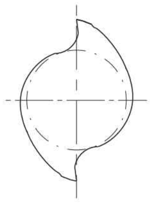
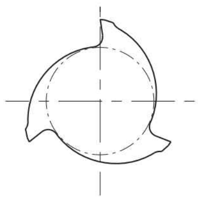
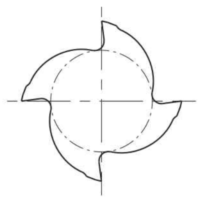
Reduce the feed rate when plunging and circular milling.
For drilling operations (axial) set the feed rate under 0,2 mm.
„Attention" – drilling can form long chips.

Solid carbide mills

Terminology

A		1. Cutting edge diameter 2. Chip pocket 3. Length of cutting edge 4. Total length 5. Neck 6. Shank 7. Shank diameter
B		1. Chamfer width, main cutting edge 2. Chamfer width, diameter 3. Neck, front side 4. Primary radial clearance angle 5. Secondary radial clearance angle 6. Radial rake angle 7. Axial main cutting edge 8. Core diameter
C		1. Cutting edge 2. Axial rake angle 3. Primary axial clearance angle 4. Secondary axial clearance angle 5. Inclination angle 6. Radial cutting edge

Teeth, chip pocket and tool rigidity

Teeth	2 flutes	3 flutes	4 flutes
Cross section			
Cutting edge ratio	54 %	56 %	60 %
Advantages	– Large chip pocket – Good chip removal	– Good chip removal – Good surface quality	– Good rigidity – Good surface
Application	– Slot milling – Square shoulder milling – Drilling	– Slot milling – Square shoulder milling – Finishing	– Slot milling (flat) – Square shoulder milling – Finishing

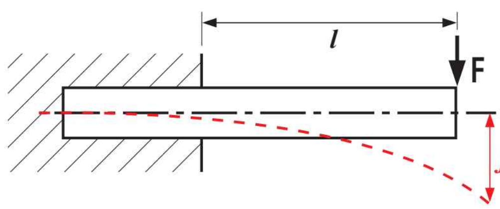
Length of cutting edge (overhang) and cutting diameter

The shorter the overhang, the stronger the rigidity. Thus isn't easy to generate. Bend and vibration in the cutting process may occur.

Length (overhang) increases by 1 time, the deflection degree (f) will be 8 times of the former one.

Reduce the overhang by 20 %
the deflection degree (f) will decrease by 50 %

Increase the diameter by 20 %
the deflection degree (f) will decrease by 50 %

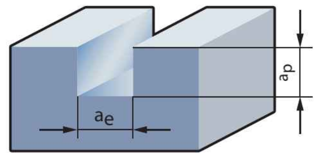


$$f = \frac{F \times l^3}{3 \times E \times I} = \frac{F \times l^3 \times 64}{3 \times E \times I}$$

Solid carbide mills

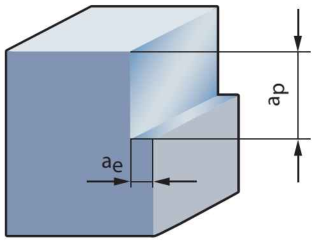
Machining strategy – HPC/UM (HSC) milling cutters

HPC = High Performance Cutting
Machining with significantly increased metal removal rate through higher cutting speeds and feed rates compared with conventional machine cutting processes.



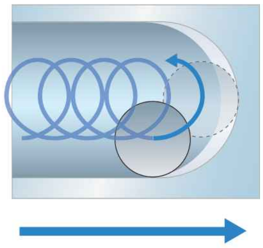
Full-slot milling

HSC (UM) = High Speed Cutting
High cutting speeds and feed rates in combination with low cutting depths lead to lower chip thickness as in normal machining.



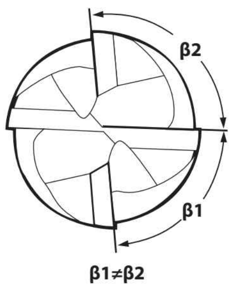
a_e <15 %
a_p = max

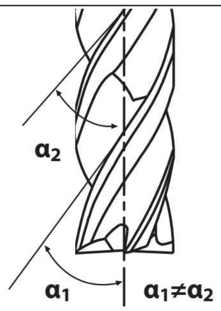
Profiling



Trochoidal milling

The UM milling cutter is specifically optimised for HSC machining.



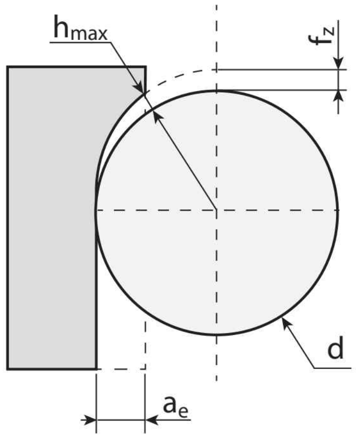


High metal removal rates can be realised with this tool.
Especially on highly dynamic machines with optimised tool paths this milling cutter shows its full potential.

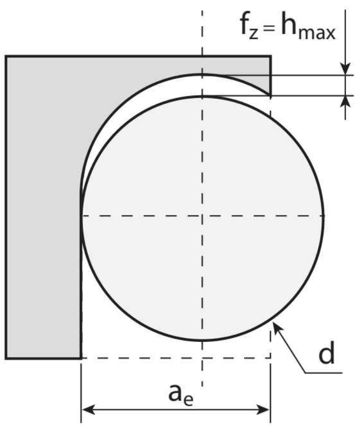
Solid carbide mills

HSC strategy

It's important to use the right strategy. When programming make sure the width of cut is kept. The width of cut is usually not higher than 15 %. Regarding the depth of cut, the total length of the cutting edge can be used.



$a_e < d/2 \quad h_{max} < f_z$

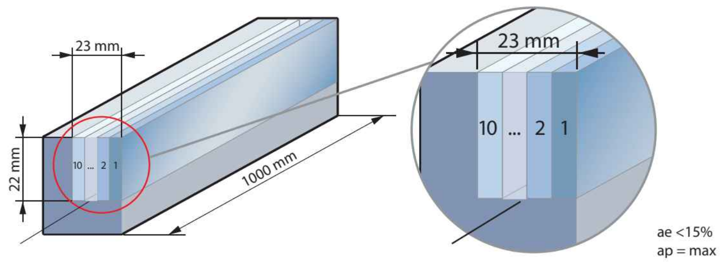


$a_e \geq d/2 \quad h_{max} = f_z$

$$h_{max} = 2f_z\sqrt{\frac{a_e}{d}(1-\frac{a_e}{d})}$$

When changing the width of cut the cutting data needs to be adjusted.
As calculatory size applies a chip thickness from approx. 0.15 –0.2 mm on basis of the usual steel types.

Example

Tool	Machining
 UM-4E-D20.0-W KMG405	 HSC strategy

Workpiece material
16MnCr5 (1.7131) ca. 700 N/mm³

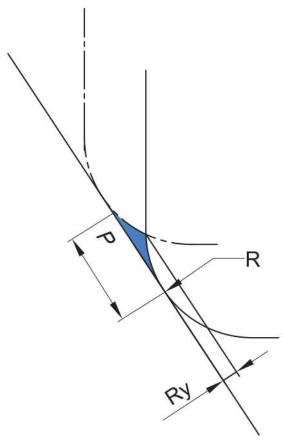
Cutting data	
V_c	550 m/min
n	8750 1/min
f_z	0,3 mm (**h_{max} = 0,19 mm**)
V_f	10500 mm/min
a_p	22 mm
a_e	2,3 mm

Result
Chip removal rate **530 cm³/min**! Machining time 58 seconds! The maximum chip thickness is 0.19 mm.

A
Turning
B
Milling
C
Drilling
D
Technical Information
E
Index

Solid carbide mills

Feed rate selecting table for profile machining with ball nose cutters and torus mills



$$Ry = R \times \{1\text{-}\cos[\arcsin(fr/2R)]\}$$

Ry: Theoretical values of surface quality
P: Feed rate
R: Radius of the ball nose cutter or torus mill

R \ Ry	Feed rate									
	0,1	**0,2**	**0,3**	**0,4**	**0,5**	**0,6**	**0,7**	**0,8**	**0,9**	**1,0**
0,5	0,003	0,010	0,023	0,042	0,067	0,100				
1,0	0,001	0,005	0,011	0,020	0,032	0,046	0,063	0,083	0,107	
1,5	0,001	0,003	0,008	0,013	0,021	0,030	0,041	0,054	0,069	0,086
2,0	0,001	0,003	0,006	0,010	0,015	0,023	0,031	0,040	0,051	0,064
2,5	0,001	0,002	0,005	0,008	0,013	0,018	0,025	0,032	0,041	0,051
3,0		0,001	0,004	0,007	0,010	0,015	0,020	0,027	0,034	0,042
4,0		0,001	0,003	0,005	0,008	0,011	0,015	0,020	0,025	0,031
5,0		0,001	0,002	0,004	0,006	0,009	0,012	0,016	0,020	0,025
6,0			0,002	0,003	0,005	0,008	0,010	0,013	0,017	0,021
8,0			0,001	0,003	0,004	0,006	0,008	0,010	0,013	0,016
10,0			0,001	0,002	0,003	0,005	0,006	0,008	0,010	0,013
12,5			0,001	0,002	0,003	0,004	0,005	0,006	0,008	0,010

R \ Ry	Feed rate									
	1,1	**1,2**	**1,3**	**1,4**	**1,5**	**1,6**	**1,7**	**1,8**	**1,9**	**2,0**
0,5										
1,0										
1,5	0,104									
2,0	0,077	0,092	0,109							
2,5	0,061	0,073	0,086	0,100						
3,0	0,051	0,061	0,071	0,083	0,095	0,109				
4,0	0,038	0,045	0,053	0,062	0,071	0,081	0,091	0,103		
5,0	0,030	0,036	0,042	0,049	0,057	0,064	0,073	0,082	0,091	0,101
6,0	0,025	0,030	0,035	0,041	0,047	0,054	0,061	0,068	0,076	0,084
8,0	0,019	0,023	0,026	0,031	0,035	0,040	0,045	0,051	0,057	0,063
10,0	0,015	0,018	0,021	0,025	0,028	0,032	0,036	0,041	0,045	0,050
12,5	0,012	0,014	0,017	0,020	0,023	0,026	0,029	0,032	0,036	0,040

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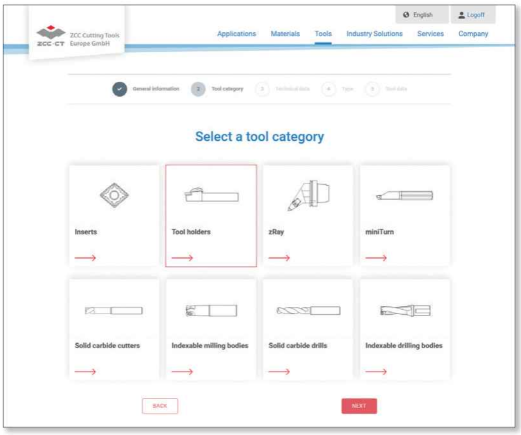
Are there milling applications at your company where having custom tools tailored to your unique needs would deliver real benefits both in terms of logistics and at a technical and commercial level? ZCC Cutting Tools Europe is there to advise and assist you during the planning, development and ordering process. Use our new online tool to request a special tool and get your personal quotation in just a few short steps (https://www.zccct-europe.com/en/tools/special-tools).



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Selecting the tool category

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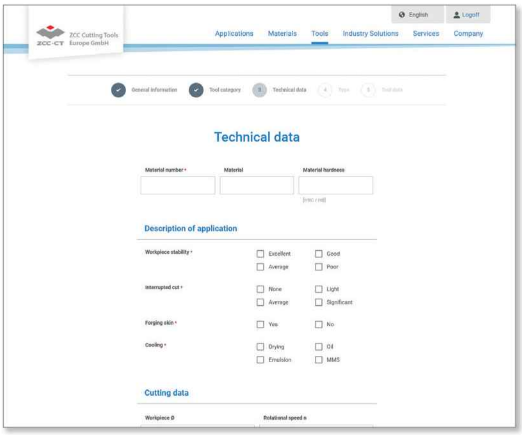

Define the relevant tool parameters.

Defining the tool parameters

You are now guided step by step through the process. You can also securely upload your drawings, diagrams and 3D models (where available).

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