WORKSHOP REFERENCE · 12

# Milling Speeds & Feeds

Starting cutting speeds and feeds per tooth for end mills, chip thinning, and a spindle speed ready-reckoner.

## Cutting speed by material

Vc in m/min · starting values

| ISO | Material | Hardness | HSS / HSS-Co | Solid carbide, coated |
|---|---|---|---|---|
| P | Low-carbon & free-cutting steel | < 180 HB | 30–40 | 150–250 |
| P | Medium-carbon & alloy steel, annealed | 180–280 HB | 20–30 | 120–180 |
| P | Alloy & tool steel, hardened & tempered | 280–350 HB | 10–18 | 80–120 |
| M | Austenitic stainless (304, 316) | < 200 HB | 12–20 | 80–120 |
| M | Duplex & super-duplex stainless | < 300 HB | 10–15 | 60–90 |
| K | Grey cast iron | < 250 HB | 20–30 | 120–200 |
| K | Ductile (SG) cast iron | < 300 HB | 15–25 | 100–150 |
| N | Wrought aluminium | < 120 HB | 150–300 | 300–1000 |
| N | Cast aluminium, high silicon | < 120 HB | 100–200 | 200–500 |
| N | Brass, bronze & copper | < 200 HB | 40–80 | 150–300 |
| S | Titanium alloys | < 350 HB | 10–20 | 40–80 |
| S | Nickel superalloys (Inconel, Hastelloy) | < 350 HB | 5–10 | 20–40 |
| H | Hardened steel | 45–55 HRC | — | 60–120 |
| H | Hardened steel | 55–65 HRC | — | 40–80 |

For side milling with radial engagement up to half the diameter. Full slotting: use about 70% of these speeds. Aluminium figures are usually capped by spindle speed.

## Feed per tooth in steel

fz in mm · end mills

| Cutter Ø mm | HSS | Solid carbide |
|---|---|---|
| 3 | 0.005–0.012 | 0.010–0.020 |
| 6 | 0.012–0.025 | 0.020–0.040 |
| 8 | 0.015–0.030 | 0.030–0.050 |
| 10 | 0.020–0.035 | 0.040–0.060 |
| 12 | 0.025–0.040 | 0.050–0.070 |
| 16 | 0.030–0.050 | 0.060–0.090 |
| 20 | 0.035–0.060 | 0.070–0.100 |
| 25 | 0.040–0.070 | 0.080–0.120 |

Stainless: about 80%. Aluminium: up to 150%. Titanium and nickel alloys: about 60%. Hardened steel: about 50%.

## Chip thinning

light radial cuts

| ae ÷ D | Raise fz by |
|---|---|
| 50% | × 1.00 |
| 40% | × 1.02 |
| 30% | × 1.09 |
| 25% | × 1.15 |
| 20% | × 1.25 |
| 15% | × 1.40 |
| 10% | × 1.67 |
| 5% | × 2.29 |
| 2% | × 3.57 |

With light radial engagement the real chip is thinner than fz. Raise the feed by this factor to keep the chip load right, as in high-efficiency milling.

### Formulas

Table feed $vf = fz \times z \times n$ (mm/min)
Metal removal $Q = ap \times ae \times vf \div 1000$ ($cm^3$/min)
Chip thinning $fz' = fz \times D \div (2\sqrt{(ae \cdot D - ae^2)})$

z number of teeth · ap axial depth · ae radial width (mm)

## Spindle speed (RPM) by cutter diameter and cutting speed

n = Vc × 1000 ÷ (π × D)

| Cutter Ø mm | 10 | 20 | 30 | 40 | 60 | 80 | 100 | 120 | 150 | 200 | 250 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cutting speed Vc (m/min) → | | | | | | | | | | | | | |
| 1 | 3,200 | 6,350 | 9,550 | 12,700 | 19,100 | 25,500 | 31,800 | 38,200 | 47,700 | 63,700 | 79,600 | 95,500 | 127,300 | 159,200 |
| 1.5 | 2,100 | 4,250 | 6,350 | 8,500 | 12,700 | 17,000 | 21,200 | 25,500 | 31,800 | 42,400 | 53,100 | 63,700 | 84,900 | 106,100 |
| 2 | 1,590 | 3,200 | 4,750 | 6,350 | 9,550 | 12,700 | 15,900 | 19,100 | 23,900 | 31,800 | 39,800 | 47,700 | 63,700 | 79,600 |
| 3 | 1,060 | 2,100 | 3,200 | 4,250 | 6,350 | 8,500 | 10,600 | 12,700 | 15,900 | 21,200 | 26,500 | 31,800 | 42,400 | 53,100 |
| 4 | 800 | 1,590 | 2,400 | 3,200 | 4,750 | 6,350 | 7,950 | 9,550 | 11,900 | 15,900 | 19,900 | 23,900 | 31,800 | 39,800 |
| 5 | 640 | 1,270 | 1,910 | 2,550 | 3,800 | 5,100 | 6,350 | 7,650 | 9,550 | 12,700 | 15,900 | 19,100 | 25,500 | 31,800 |
| 6 | 530 | 1,060 | 1,590 | 2,100 | 3,200 | 4,250 | 5,300 | 6,350 | 7,950 | 10,600 | 13,300 | 15,900 | 21,200 | 26,500 |
| 8 | 400 | 800 | 1,190 | 1,590 | 2,400 | 3,200 | 4,000 | 4,750 | 5,950 | 7,950 | 9,950 | 11,900 | 15,900 | 19,900 |
| 10 | 320 | 640 | 950 | 1,270 | 1,910 | 2,550 | 3,200 | 3,800 | 4,750 | 6,350 | 7,950 | 9,550 | 12,700 | 15,900 |
| 12 | 270 | 530 | 800 | 1,060 | 1,590 | 2,100 | 2,650 | 3,200 | 4,000 | 5,300 | 6,650 | 7,950 | 10,600 | 13,300 |
| 14 | 230 | 450 | 680 | 910 | 1,360 | 1,820 | 2,250 | 2,750 | 3,400 | 4,550 | 5,700 | 6,800 | 9,100 | 11,400 |
| 16 | 200 | 400 | 600 | 800 | 1,190 | 1,590 | 1,990 | 2,400 | 3,000 | 4,000 | 4,950 | 5,950 | 7,950 | 9,950 |
| 20 | 160 | 320 | 480 | 640 | 950 | 1,270 | 1,590 | 1,910 | 2,400 | 3,200 | 4,000 | 4,750 | 6,350 | 7,950 |
| 25 | 130 | 250 | 380 | 510 | 760 | 1,020 | 1,270 | 1,530 | 1,910 | 2,550 | 3,200 | 3,800 | 5,100 | 6,350 |
| 32 | 100 | 200 | 300 | 400 | 600 | 800 | 990 | 1,190 | 1,490 | 1,990 | 2,500 | 3,000 | 4,000 | 4,950 |
| 40 | 80 | 160 | 240 | 320 | 480 | 640 | 800 | 950 | 1,190 | 1,590 | 1,990 | 2,400 | 3,200 | 4,000 |
| 50 | 60 | 130 | 190 | 250 | 380 | 510 | 640 | 760 | 950 | 1,270 | 1,590 | 1,910 | 2,550 | 3,200 |
| 63 | 50 | 100 | 150 | 200 | 300 | 400 | 510 | 610 | 760 | 1,010 | 1,260 | 1,520 | 2,000 | 2,550 |
| 80 | 40 | 80 | 120 | 160 | 240 | 320 | 400 | 480 | 600 | 800 | 990 | 1,190 | 1,590 | 1,990 |

Rounded to the nearest 10 RPM (50 above 2,000 and 100 above 10,000). Speeds above 30,000 RPM are greyed out.

Reference values compiled from the cited standards and published manufacturer data. Always confirm against the tool maker's recommendations for your machine, tool and set-up. Speeds and feeds are general starting values for end mills.