

Table 1. Conventional machining operations with parameters

Operation/condition	Parameters			Alloy	Cutting tool	Reference
Cutting/Wet	Cutting speed: 120 mmin ⁻¹	Depth of cut: 1 mm	Feed rate: 0.1 mmrev ⁻¹	Ti54M Ti6246	WC/Co	[33]
Cutting/Wet	Cutting speed: 100-250 mmin ⁻¹	Depth of cut: 0.5 mm	Feed rate: 0.1-0.2 mm/rev	Ti5Al5V5Mo3Cr	Diamond	[93]
Micro-Milling/Wet (oil as coolant lubricant)	Cutting speed: 35, 60 and 80 mmin ⁻¹	Depth of cut: 1mm	Feed per tooth: 1.25-50 µm/ tooth	Ti-6Al-4V	TiAlN,	[41]
	Width of cut: 0.3 mm	Uncut Chip Thickness: 0.9-37.3 µm				
Face Milling	Cutting speed: 50 mmin ⁻¹	Feed rate: 0.1 mmrev ⁻¹	Depth of cut: 1 mm	Ti6242S Ti555.3	PVD: (Ti, Al) N +TiN CVD: Ti (C, N) +Al ₂ O ₃ +TiN	[55]
End Milling/Hybrid Cryogenic MQL cooling/Lubrication	Axial depth of cut: 1mm	Radial depth of cut: 4 mm	Chip load: 0.03 mm/tooth	Ti-6Al-4V	TiSiN	[94]
	Tool overhang: 50 mm					
Cutting/Dry	Cutting speed: 50, 75 and 100 mmin ⁻¹	Feed rate: 0.1, 0.15 and 0.2 mmrev ⁻¹	Depth of cut: 0.2, 0.4 and 0.6 mm	Ti-6Al-4V	WC	[53]
Cutting/Dry	Cutting speed: 50, 75 and 100 mmin ⁻¹	Depth of cut: 0.2, 0.4 and 0.6 mm	Feed rate: 0.10, 0.15, and 0.2 mmre v ⁻¹	Ti-6Al-4V	WC	[53]
Cutting/Coolant and Dry conditions	Cutting speed: 200-350 mmin ⁻¹	Depth of cut: 0.15 mm	Feed rate: 0.1 mmrev ⁻¹	Ti6Al-4V	Cubic Boron Nitride (cBN)/ TiC Particles/ SiC Whiskers/ Al ₂ O ₃	[47]

Laser-Assisted Machining/Dry	Cutting speed: 80-140 mmmin^{-1}	Laser power: 650-1382 W	Feed rate: 0.3-0.8 mm/tooth	BTi6431S	Uncoated WC	[80]
High Pressure Water Jet Machining/Wet (water jet)	Cutting speed: 60, 68 and 75, 80 mmmin^{-1}	Depth of cut: 1.5, 2 and 2.5 mm	Feed rate: 0.1, 0.2, 0.25 and 0.3 mmrev^{-1}	Ti5553	Uncoated WC	[64]
Turning /Dry	Cutting speed: 35-72 mmmin^{-1}	Depth of cut: 1.5 mm	Feed rate: 0.1 mmrev^{-1}	Ti 10VFe3Al	WC/Co	[56]
Cryogenic machining/CO ₂ -Snow-Cooling and Minimum Quantity Lubrication (MQL)	Cutting speed: 70 and 90 mmmin^{-1}	Feed rate: 0.2 mmrev^{-1} .		Ti-6Al-4V Ti6Al2Sn4Zr6Mo	Fine Grained and Uncoated Cemented Carbide	[54]
Cryogenic-Assisted Machining/Liquid Nitrogen	Cutting speed: 80 mmmin^{-1}	Depth of cut: 1 mm	Feed rate: 0.2 mmrev^{-1}	Ti-6Al-4V	Uncoated H13A carbide	[83]
Laser-Assisted Machining/Dry	Cutting speed: 20-90 mmmin^{-1}	Depth of cut: 0.1,0.3,0.5, 0.7 and 1 mm	Feed rate: 0.1, 0.15, 0.2, 0.25 and 0.3	Ti5553	PCNL	[52]
Water Jet Machining/Wet	Traverse speed: 20-90 mmmin^{-1}	Flow rate: 0 and 1.9 l.min^{-1}		TiNb	Australian Garnet (Almandine)	[95]
Orthogonal Machining/Chlorinated Water-Soluble oil	Cutting speed: 10-50 mmmin^{-1}	Spindle speed: 5-1500 revmin^{-1}	Feed rate: 0.0025 mmrev^{-1}	Ti6Al2Sn4Zr2Mo	WC Grade C3	[96]
Cutting/Dry	Cutting depths: 0.3, 0.6, and 0.9 mm	Spindle rotation speed: 600 revmin^{-1}	Feed rate: 0.0029, 0.0047, and 0.0063 mmrev^{-1}	CP Ti (Grade 2)	High Speed Tool Steel (HSS)	[97]

	Surface velocity: 675 mms ⁻¹					
Coupling Response Surface Methodology (CRSM)/ Minimum Quantity Lubrication (MQL) condition (vegetable oil)	Cutting speed: 40,80,120 and 160 mmin ⁻¹	Depth of cut: 0.3,0.6, 0.9 and 1.2 mm	Feed Rate: 0.05, 0.1, 0.15 and 0.2 mmrev ⁻¹	Ti6Al4V	WC inserts with Nano-Multilayer Coatings	[98]
Cutting/ Dry	Cutting speed :125.6 mmin ⁻¹	Depth of cut: 2 mm	Feed rate: 0.23 mmrev ⁻¹	Ti-6Al-4V	WC	[89]
Face Milling/ Dry, Flood Cooling (water-soluble lubricant), MQL, Cryogenic, and LAM	Cutting speed: 50 and 80 mmin ⁻¹	Depth of cut: 2 mm radial Depth of cut: 16.7mm	Feed per tooth: 0.15 mm/tooth	Ti-6Al-4V	Coated (PVD TiAlN) and Uncoated Carbide	[70]
End Milling/ MQL oil and Liquid nitrogen	Cutting speed: 72-86 mmin ⁻¹	Spindle speed: 1430-1711 rpm	Feed per tooth: 0.1 mm/tooth	Ti-6Al-4V	Aluminum Chromium Nitride (AlCrN)	[99]
	Table speed 860-1026 mmin ⁻¹	Axial depth of cut: 24.5mm	Radial depth of cut: 1.2mm			
	Cutting length :1200 mm ,12 passes, 100 mm length/pass					
Milling/ Cryogenic Cooling and Minimum Quantity Lubrication (MQL)	Cutting speed: 47.7,76.4,100 and 120 mmin ⁻¹	Depth of cut: 2 mm Width of cut: 16.7 mm	Feed rate: 0.15 mmrev ⁻¹	Ti-6Al-4V	Uncoated Insert (R245-12T3M)	[49]
Machining /Minimum Quantity Cooling Lubrication (MQCL)	Cutting speed: 90,120 and 150 mmin ⁻¹	Depth of cut: 0.8 mm	Feed rate: 0.1, 0.2 and 0.3	Ti-6Al-4V	Carbide	[68]
Cutting/Dry Mist, Flood	Depth of cut: 0.8 mm	Cutting Speed: 30,60 and 90	Feed rate: 0.1 and 0.2	Ti6Al 4V	TiAlN Coated and Uncoated Carbide Inserts	[59]

		mmmin^{-1}	mmrev^{-1}			
	Length to machine: 120 mm					
Cutting/Dry	Cutting speed: 62.8 mmmin^{-1}	Depth of cut: 1.0 mm	Feed rate: 0.67 mmrev^{-1}	CP-Ti (Grade 2)	HSS Tool Under Usual Conditions and Electrical Insulation Conditions	[39]
High Speed Milling/Dry	Cutting Speed: 600,900,1200, 1500 and 1800 mmmin^{-1}	Depth of cut: 2.0 mm	Feed rate: 0.1 mmrev^{-1}	TC17	BN and Ceramics	[100]
	Main Shaft Speed: 1910, 2866, 3821, 4777 and 5732 rmin^{-1}					
Turning Operation/Dry	Cutting speed PCBN: 30, 40, 50 and 60 mmmin^{-1} PCD: 40, 60, 80 and 100 mmmin^{-1}	Depth of cut PCBN: 0.5, 0.75,1.0 and 1.25 mm PCD: 0.5, 0.75, 1.0, 1.25 and 1.5 mm	Feed Rate: PCBN: 0.05, 0.1, 0.125 and 0.15 mmrev^{-1} PCD: 0.05, 0.1, 0.125 and 0.15 mmrev^{-1}	Ti6Al0.6Cr0.4Fe0.4Si0.01 B	PCD and PCBN	[9]
Turning Operation/ MQL (Soybean oil-based lubricants)	Cutting speed 70, 90 and 110 mmmin^{-1}	Depth of cut: 0.5, 0.75 and 1 mm	Feed rate: 0.30, 0.35 and 0.40 mmrev^{-1}	Ti-6Al-4V	PVD Coated Carbide	[10]
High-Speed Drilling/ Dry and Wet	Cutting speed 20, 40 and 60 mmmin^{-1}	Machining environment (dry and wet)	Feed rate: 0.1, 0.2 and 0.3 mmrev^{-1}	Ti-6Al-4V	TiAlN-Coated Solid Carbide	[40]

Ultra-Precision Machining/ Lubricant compressed air and mineral oil to form a mist	Spindle speed:2000 rpm	Depth of cut: 0.5 mm	Feeding speed:15 mmin ⁻¹	Ti-6Al-4V	Diamond	[75]
Milling/Dry	Cutting speed: 90 mmin ⁻¹	Feed rate: 0.1 mmrev ⁻¹		Ti-6Al-4V	Uncoated Carbide Tools	[46]
Ultra- Precision Machining/dry	Depth of cut: 0.4 mm	Cutting speed: 200 mmin ⁻¹		Ti-6Al-4V TC4	Diamond	[43]

Table 2: Non-conventional machining techniques

Machining Techniques	Machining Parameters		Alloys	Electrode Tool	Reference
Vibrating Feed Electrochemical Machining	Cathode vibration frequency: 20 Hz	Cathode vibration amplitude: 0.2 mm	TC4	Diamond tool electrode	[110]
	Electrolyte temperature: 25°C	Electrolyte composition: 20% NaCl+ 10% NaNO ₃ Electrolyte			
Electrochemical Machining	Electrolyte flow velocity: 19 ms ⁻¹	Applied Voltage: 26 V	Ti-99.2%, Fe-0.35%, O-0.3%, C-0.1%, N-0.05%.	Copper tool	[115]
	Concentration of Electrolyte = 20 g/l of Sodium bromide (NaBr)	Tool feed rate: 0.1 mm.min ⁻¹			
Electrochemical Machining	Vibration frequency: 50 Hz	Vibration amplitude: 0.05 mm	TB6 titanium alloy	Sliced Cathode	[111]
	Average Voltage: 24 V	Feed rate: 22 mm.min ⁻¹			
	Electrolyte temperature: 40°C NaCl+NaNO ₃				
Wire Electrochemical Micromachining	Average Voltage: 11 V	Spindle rotation speed: 4000 rpm	CP-Ti	Helical wire tool	[116]
	Pulse frequency: 200 kHz	Electrode feed rate: 0.3 mm. s ⁻¹			
	Electrolyte NaCl- ethylene glycol				
Jet- Electrochemical Machining	Machining voltage: 24 V	Inter-electrode gap, IEG: 0.6 mm	TB6 (Ti-10V-2Fe-3Al)	Jet of electrolyte	[112]

	Electrolyte flow rate: 2.1 L.min ⁻¹	Electrolyte concentration :15wt% NaCl				
	Electrolyte: NaCl					
Electrolyte Jet Machining	Applied Voltage: 40 V	Electrolyte concentration: 20% NaCl	Electrolyte temperature: 40°CNaCl	TB6	Tool with upward sloping structure	[117]
Jet Electrochemical Machining	Applied Voltage: 24V	IEG: 0.6 mm		Ti-1023	Platinum and Standard Calomel Electrodes	[118]
	Electrolyte flow rate: 2.1 L.min ⁻¹	Nozzle traveling rate: 25 μms ⁻¹				
	Electrolyte: NaCl					
Wire Electrical Discharge Machining	Pulse on time: 0.8, 1.1 and 1.6 μs	Pulse off time: 14, 20 and 30 μs	Peak current: 120, 170 and 220 A	γ TiAl		[119]
	Servo reference voltage: 2,6 and 10 V	Dielectric flow rate: 7, 8.5 and 10 kg/cm ²	Wire tension: 900,1140 and 1380 gm			
Electrical Discharge micromachining	Peak current: 0.5-1.5 A	Duty factor: 60-90%.	Pulse on time: 1-20 μs	Ti-6Al-4V	Brass tool	[120]
	Kerosene					
Electrical Discharge Machining	Power: 413 W	Pulse on time: 1600 μs.	Distilled water	CP-Ti–porcelain composite.	Copper electrode	[121]
Wire Electrical Discharge Machining	Pulse on time: 112 μs	Pulse off time: 56 μs		CP-Ti (Grade 2).	Brass wire	[122]
	Peak current: 120 A	Spark gap voltage: 60 V				
Electrical Discharge Machining (using Cryogenically treated Ti alloy)	Pulse on time: 30 - 45 μs	Peak off time: 90 – 150 μs		(i) Ti alloy, ASTM grade II, TITAN 15 (ii)Ti-5Al-2.5Sn titanium alloy, ASTM grade VI, TITAN 21	Cu, Cu-Cr & Cu-W electrodes	[123]

	Peak current: 6-14 A	Manganese and Tungsten powder		and (iii) Ti-6Al-4V titanium alloy, ASTM grade V, TITAN 31		
Wire Electrical Discharge Machining	Pulse on time: 0.7-1.1 μ s	Pulse off time: 17-38 μ s		carbon: 0.10 % nitrogen: 0.03 % oxygen: 0.25 % hydrogen: 0.015 % iron: 0.30 % and titanium: 99.03 %.	Brass wire	[124]
	Peak current: 120-200A	Spark gap voltage: 40-50 V				
Wire Electrical Discharge Machining	Peak on time: 0.2 μ s	Peak off time: 36 μ s	Servo voltage :75 V	CP-Ti	Zinc and Brass electrode	[125]
	Peak current: 40 A	Wire feed rate: 10 mm.min ⁻¹	Deionized water			
Powder-Mixed Dielectric Ultrasonic Assisted Electrical Discharge Machining	Peak current: 6-48 A	Pulse off time: 6.4 μ s		Ti-6Al-4V	Copper bar	[126]
	Pulse duration: 6.4-400 μ s	Open circuit voltage: 200 V				
	Oil flux					
Power Mixed Electrical Discharge Machining	Pulse on time: 90-150 μ s		Pulse off time:30-45 μ s	Titan 15 ASTM Gr. 2 (Ti 99.83 %), TITAN 21 ASTM Gr. 6 (5.32 % Al, 2.76 % Sn, and 91.8 % Ti) and TITAN 31 ASTM Gr. 5 (6.19 % Al, 4.04 % V, and 89.6 % Ti)	Cu, Cu-Cr and Cu-W electrodes.	[127]
	Peak current: 6-14 A		Depth of cut:1.0 mm			
Electrical Discharge Machining	Pulse on time: 40 μ s		Pulse off time: 120 μ s	TA 15	Cu electrode.	[103]

	Peak current: 10 A			Voltage: 230 V					
	Servo voltage: 20 V								
Electrical Discharge Machining	Pulse on time: 150 μ s			Peak current: 18 A		Ti-6Al-4V -ELI (Gr. 23)	Cu electrode	[128]	
	Voltage: 40V			EDM oil grade 4					
Vibration Assisted Electrical discharge Machining	Pulse on time: 60-90 μ s			Pulse off time: 40-50 μ s		Ti-6Al-4V	Cu &Cu-W electrode	[129]	
	Peak current: 8-12A			Work time: 0.6-1.0 s					
	Vibration frequency: 40-140Hz								
Electrical discharge Machining	Pulse on time: 50-1000 μ s		Machining time: 15 s		Peak current: 10 -50 A		Gr. 5 Ti alloy (Ti-6Al-4V)	Copper electrode	[130]
	Gap voltage: 60 V				Kerosene				
Wire Electrical Discharge Machining	Pulse on time: 115 μ s			Pulse off time: 50 μ s		Ti-6Al-4V	Zinc coated brass electrode	[131]	
	Peak current: 12 A			Spark gap voltage: 40 V					
Electrical Discharge Machining	Open circuit voltage: 20-30 V				Peak current: 20-30 A		CP-Ti	Rapid prototyping (RP) manufactured tool, copper and graphite.	[132]
	Pulse duration: 100-300 μ s				Duty cycle: 65-85%				
	EDM-30 oil								
Ultrasonic machining of titanium/Dry and Water	Depth of cut: 2 mm	Power rating: 100-400 W	Frequency of vibration: 21 kHz	Static load: 1.63 kg	Amplitude of vibration: 25.3-25.8 μ m		CP-Ti (ASTM Gr. 1)	Sonic-Mill ultrasonic machine	[42]
	Slurry media: Water		Slurry flow rate: 36.4 \times 10 ³ mm ³ /min	Slurry temperature: 28°C (ambient room temperature)					
	Grit sizes: 220, 320, and 500		Tool geometry: straight cylindrical (with diameter 8 mm)	Thickness of workpiece: 10 mm					

Ultrasonic Machining of Titanium/Dry and Wet	Three temperature levels: 10°C, 27°C, 60°C	Three levels of slurry type: silicon carbide, boron carbide, alumina	Three levels of slurry concentration: 15%, 20% and 25%.	TITAN 15 (ASTM Gr. 2) TITAN 31 (ASTM Gr.5)	Various tools like diamond. Titanium carbide, high speed steel etc.	[90]
	Three levels of ultrasonic power: 30%, 60%, and 90% of 500 W.	Three levels of slurry grit size: 220, 320, and 500	Six levels of tool: stainless steel, high speed steel, diamond, titanium, carbide, and high carbon steel.			
Ultrasonic Machining/Dry	Pulse on time: 90,120 and 150 μs.	Pulse off time: 30 and 45 μs.		CP-Ti (ASTM Gr. 1)	Cemented Carbide and High Carbon Steel Tools	[21]
	Peak current: 6, 10 and 14 A	Electrode Material: Cu, Cu-Cr and Cu-W				
Ultrasonic Machining/Wet	Temperature levels: 10, 27 and 60°C	Ultrasonic Power Levels: 30, 60 and 90% of 500W.	Slurry type levels: silicon carbide, boron carbide, alumina	TITAN 15	Silicon Carbide	[90]
	Slurry Grit size: 220, 320, and 500.	Slurry Concentration: 15, 20 and 25%.	Tool Materials: Stainless Steel, High Speed Steel, Diamond, Titanium, Carbide, and High Carbon Steel.			