



Workshop handout

# Introduction to 3-Axis CNC machining

# HELLO!

**In this workshop you will learn how to use the Routermax 1325 CNC milling machine at MotionLab.Berlin.** This machine allows you to prototype 2D-3D parts through subtracting material by planing and milling parts of it. By the end of the session, you will have milled a series of parts from MDF that can be assembled.

This handout compiles the most relevant information about CNC milling, as well as some practical instructions on how to use the CNC mill at MotionLab.Berlin. We encourage you to always come back to this material in case you have any questions regarding the use of the technology and the machinery.

## YOUR LEARNING OUTCOME

During this workshop you will learn how to:

- Create a CNC-G-Code with Estlcam, and transfer it to the CNC machine
- Use the control software MACH 3
- Operate the Routermax 1325 CNC machine safely



# We introduce ourselves

What previous professional experience do you have?

What expectations do you have of this workshop?

Do any of you already have a concrete project?

Should the CNC milling machine be your "main tool" or be part of your manufacturing strategy?



# MACHINERY & EQUIPMENT



**Winter CNC  
Routermax - Basic 1325  
Deluxe**

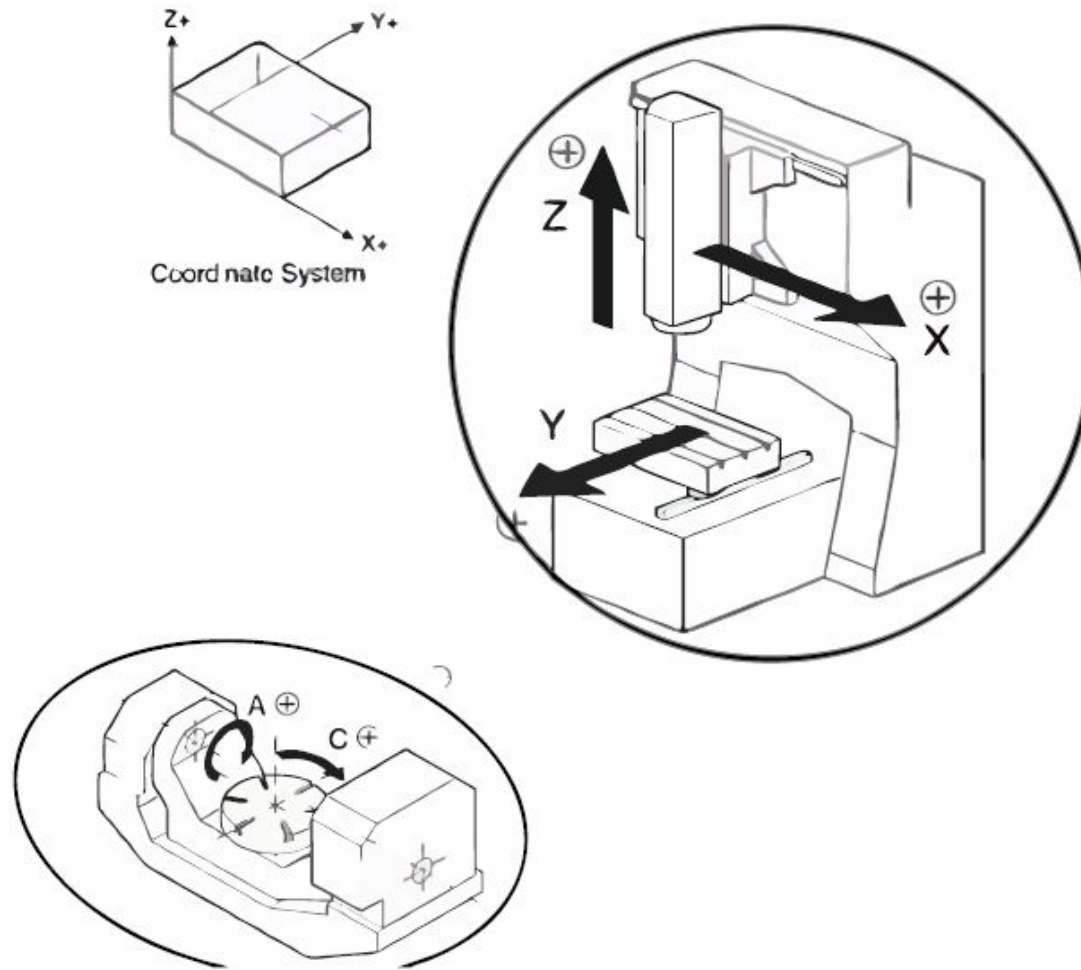
Workspace:  
2500 x 1250 mm



**Vacuum pump**

You can use the machines by booking them [HERE](#) 

# 3-axis CNC machine, 2,5 milling





# X-Box Controller / Key settings

Configuration

Triggers increase Jog speed when jogging with Thumbsticks

Left Shoulder: Jog Mode Inc/Cont

X Btn: ZeroX

Right Shoulder: Cycle Jog Step

Left stick - Side To Side Axis: Select X axis

☐ Reverse Direction

Left stick - Up and Down Axis: Select Y axis

☐ Reverse Direction

Custom Macro #1: 0

Custom Macro #2: 0

Custom OEM Code #1: 0

Custom OEM Code #2: 0

Back Btn: AutoTool Hight (Z-Axis)

Start Btn: Cycle Start

☐ Disable Diagonal Axis Movement

☐ Enable Triggers As Safety Switch

VendorID: 45E

ProductID: 2A1

Y Btn: ZeroY

B Btn: Reset

A Btn: ZeroZ

Right stick - Side To Side Axis: None


☐ Reverse Direction

Right stick - Up and Down Axis: Select Z axis

☐ Reverse Direction

Controller: Found

OK



# The journey is the reward.

## CAD Software

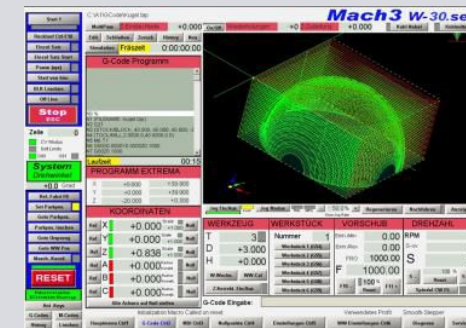
- Inventor
- Solid works
- Rhino
- Fusion360
- AutoCAD
- Etc.

## CAM postprocessing „Translator“

Frässtrategie festlegen  
Übergabe an den Postprozessor.

- Mach3 (Arc) mill
- Mach3 ATC (Arc) mill
  - Estl CAM
  - WinPc CNC
  - USB - CNC
  - Eding CNC
  - Linux - CNC
  - Many more...

## CNC control software MACH3, and/ or others



„Brain“



„Muscles“

# Gcode – a machine language

1. (Project square-100x100)
2. (Created by Estlcam version 8 build 8,507)
3. (Machining time about 00:00:20 hours)
4. (Required tools:)
5. (Fraeser 5mm)
6. G90
7. M03 S20000
8. G00 Z5.0000
9. (No. 1: Ausschnitt 1)
10. G00 X27.4935 Y-122.4535
11. G00 Z0.5000
12. G01 Z-1.0000 F900 S20000
13. G01 X27.4943 Y-27.4935 F1500
14. G01 X122.4543 Y-27.4943
15. G01 X122.4535 Y-122.4543
16. G01 X27.4935 Y-122.4535
17. G00 Z5.0000
18. G00 X0.0000 Y0.0000

Gcode	Explanation	Erklärung
G90	Use absolute coordinates	Benutze absolute Koordinaten
F900	Speed: 900	Vorschub: 900
S20000	Spindle RPM: 20000	Spindel U/min = 20.000
G00	Rapid Motion	Eilgang
G01	Cutting Motion	Arbeitsgang
Z5.0000	Move Z to 5 mm height	Fahre Z auf 5mm Höhe



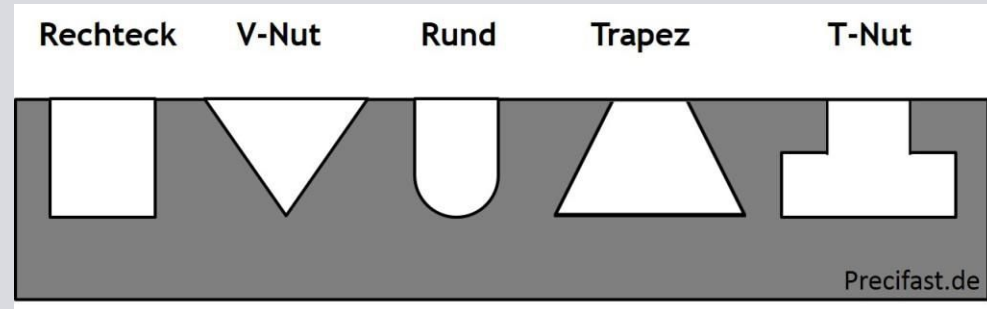
# Cutter (Router Bit) - Design - Geometry

## Type

- End Mill
- V-bit
- Ball Nose
- Trapeze cutter (dovetail)
- T-slot milling cutter

## Cutting geometry

- Up cut
- Down cut
- Combination up/down cut



Milling directions:  
Counter-face milling  
(outer contour)



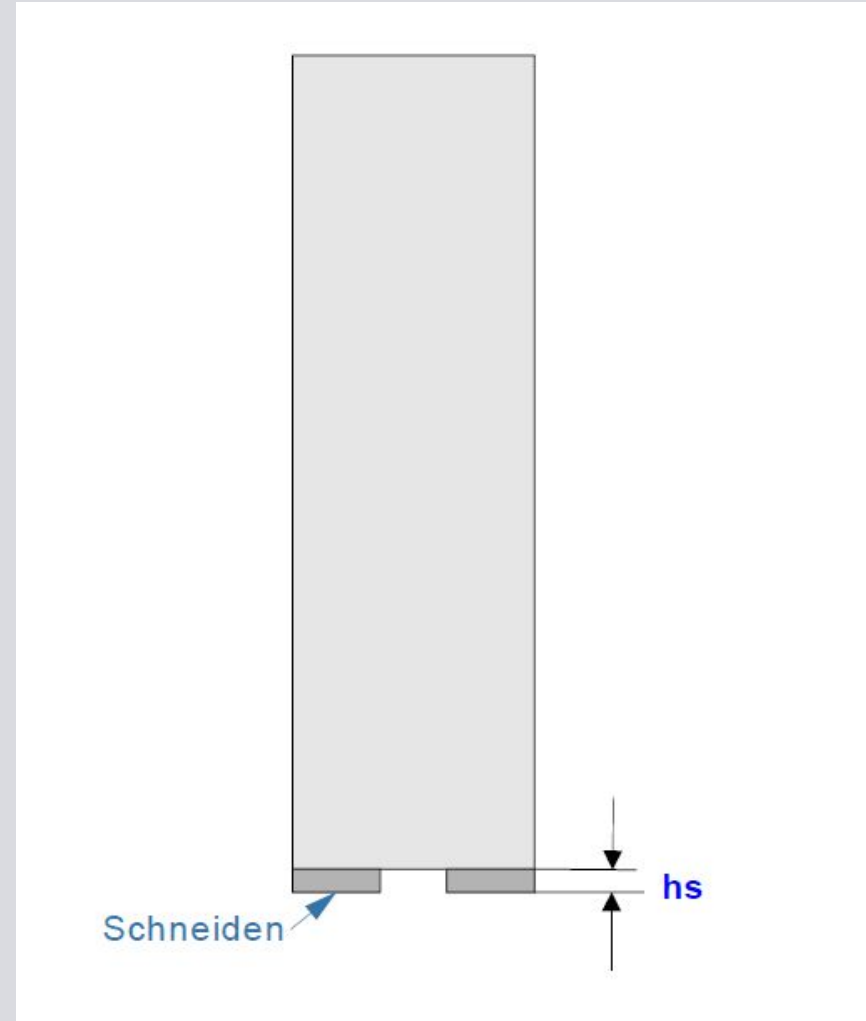
Synchronized milling  
(inner contour)



# "Plunge" of the milling cutter

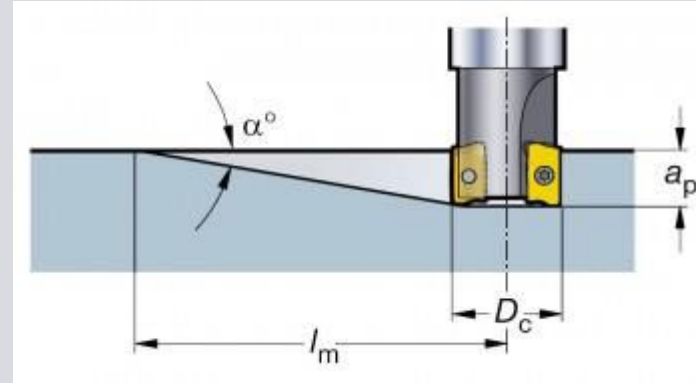
## plunge or "plunge in"

- only possible up to cutting edge height (hs)



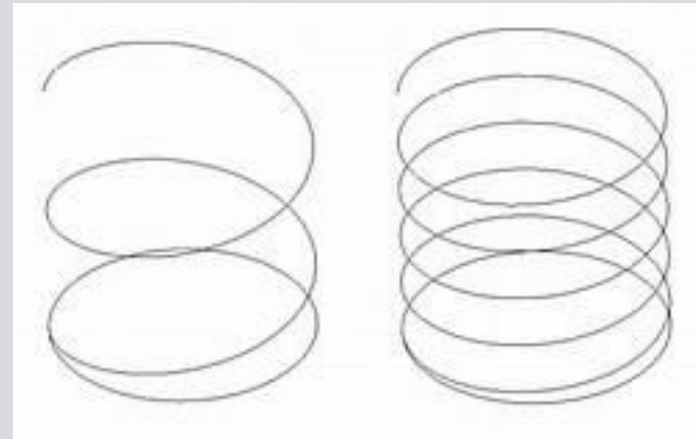
# "Plunge" of the milling cutter

## Ramp



## Helix

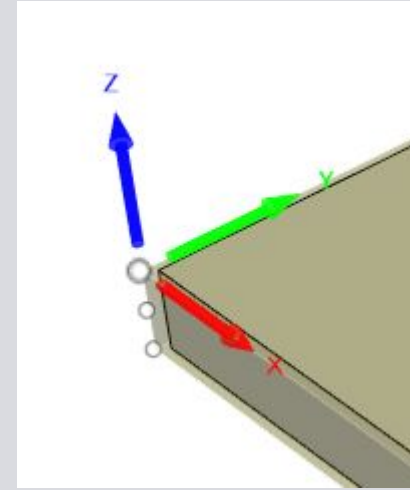
- Spiral-plunge



# The Z- zero point - alignment

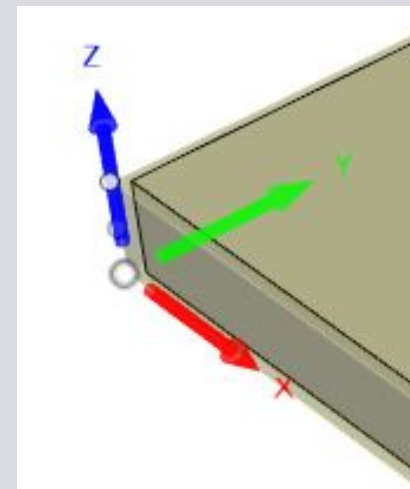
Z- Zero point on workpiece surface:

Depth of a "pocket", blind hole in relation to the workpiece surface

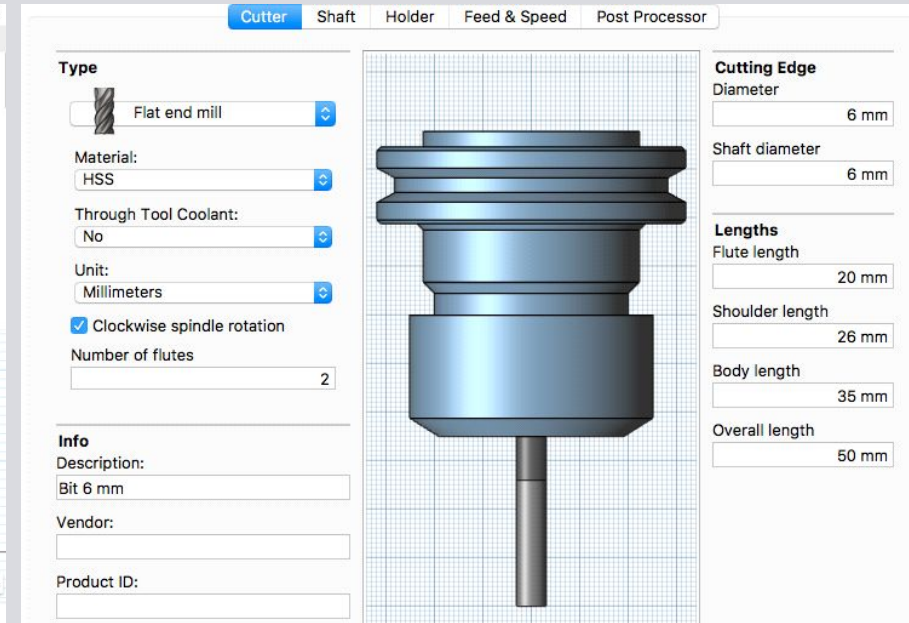
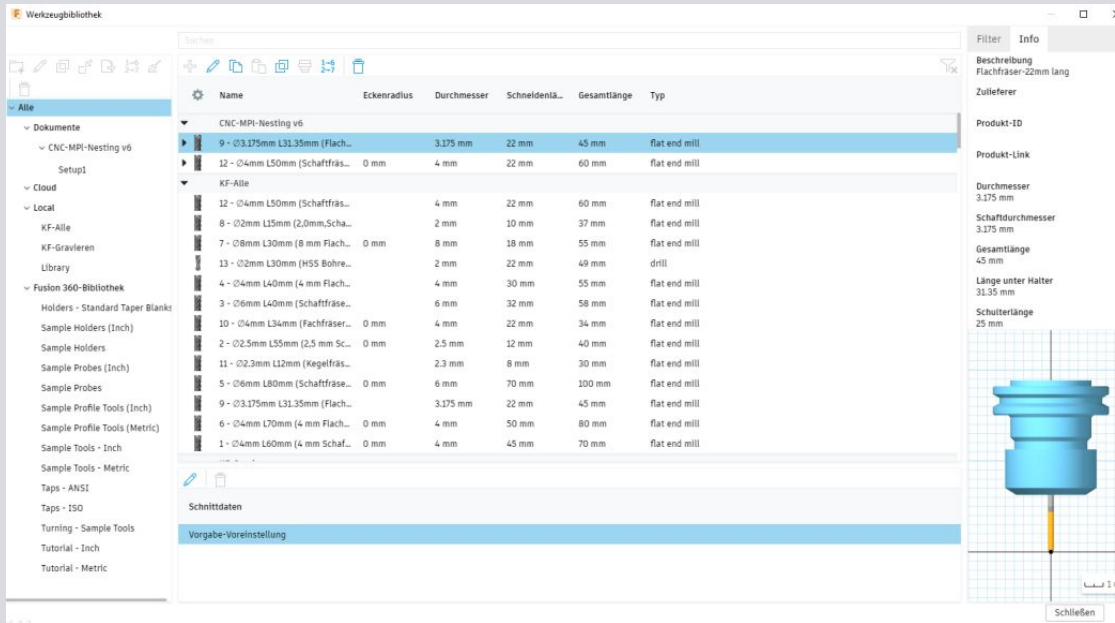


Z- zero point on the machine bed:

“Milling out” the contour of a geometry

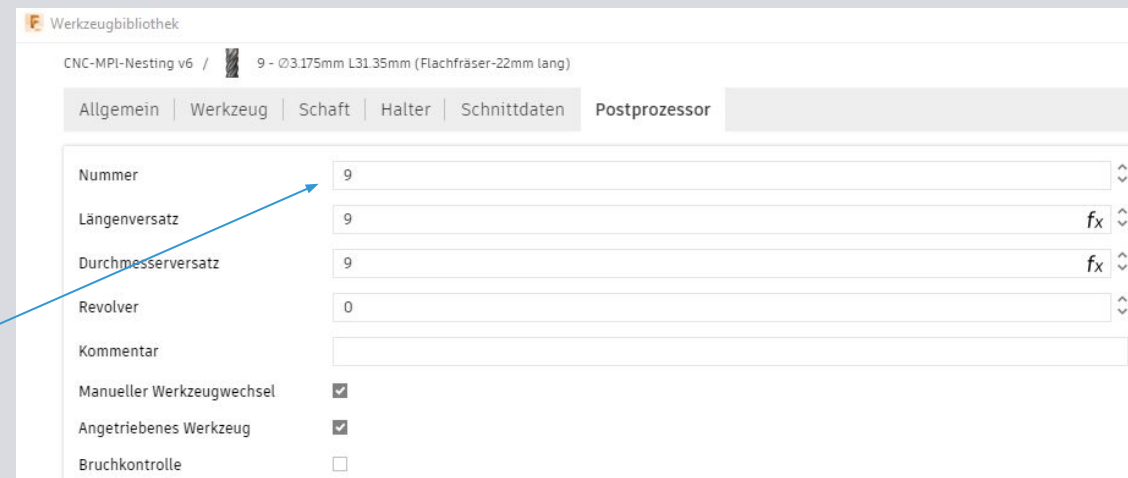


# Tool library Fusion360



## Tool change M6

Assign "unique" number





# ...a little arithmetic is necessary

Richtwerte Fräsparameter										
Materialien	Schnittgeschwindigkeit [m/min] Vc	Durchmesser Fräser								
		Ø 1 mm	Ø 2 mm	Ø 3 mm	Ø 4 mm	Ø 5 mm	Ø 6 mm	Ø 8 mm	Ø 10 mm	Ø 12 mm
		Zahnvorschub (fz) in mm/Zahn/ Umdrehung								
Alu- Druckguss	200	0,01	0,01	0,01	0,015	0,015	0,025	0,03	0,038	0,05
Knetlegierung, Aluminium	500	0,01	0,02	0,025	0,05	0,05	0,05	0,064	0,08	0,1
Weichkunststoff	600	0,025	0,03	0,035	0,045	0,065	0,09	0,1	0,2	0,3
Hartkunststoff	550	0,015	0,02	0,025	0,05	0,06	0,08	0,089	0,1	0,15
Holz hart	450	0,02	0,025	0,03	0,035	0,045	0,055	0,065	0,08	0,09
Holz	500	0,025	0,03	0,035	0,04	0,05	0,06	0,07	0,085	0,1
MDF	450	0,03	0,04	0,045	0,05	0,06	0,07	0,08	0,09	0,11
Messing, Kupfer, Bronze	365	0,015	0,02	0,025	0,025	0,03	0,05	0,056	0,065	0,08
Stahl	90	0,01	0,01	0,012	0,025	0,03	0,038	0,045	0,05	0,08

n - Speed of the milling cutter [1/min]

Vc - Cutting speed [m/min]

Vf - Feed speed [mm/min]

d - Diameter of the milling cutter [mm]

z - Number of teeth (number of cutting edges)

Fz - Tooth feed mm/ tooth/ revolution

$n = (Vc * 1000) / (\pi * d)$  [1/min]

$Vc = (n * \pi * d) / 1000$  [m/min]

$Vf = n * z * fz$  [mm/min]

Immersion depths

- Aluminum: 0,1- 0,5\*d
- Wood: 1- 1,5\*d
- Polyoxymethylene: 0,5- 1\*d
- Rigid foam 2- 5\*d

# The cutting data calculator

Schnittdatenrechner für Hobby Portalfräsmaschinen

**Materialauswahl** **Fräser Ø d** **Schneiden z**

Alu Knetlegierung (Blech) 3 0 mm 2

**Schnittdatenanpassung optional**

max. Drehzahl n (U/min) Vorschub / Zahn Fz (mm) Schnittges. Vc (m/min)

24000 0,02754 500

10% 100% 50% 100% 150% 50% 100% 150%

Drehzahl n optimal Vorschub Vf optimal Schnittges. Vc eff.

0 U/min 0 mm/min 0 m/min

**Ergebnisse**

Drehzahl (n) Vorschub Vf (X,Y) Vorschub (X,Y)

0 U/min (rpm) 0 mm/min 0 mm/sec

max. Zustell. (Nut) Eintauchen (Z) Eintauchen (Z)

0 mm 0 mm/min 0 mm/sec

**Berechnen** **Hilfe**

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Keine Gewähr für korrekte Schnittdaten

Free Download :

- <https://webseite.sorotec.de/service/downloads/>
- **Milling parameters**
- „Schnittdatenrechner zur Installation auf dem Pc“

# The dangers of feed speed

Cause	Consequence	How to fix
Feed rate too high	„Singing noise“, to fine chips	Reduce feed rate
Feed too large	Cutter rattles, vibrations, material melts	Reduce feed
Speed too low	Noise	Increase speed
Milling Cutter blunt	Unclean Results	Use sharp, high quality milling cutters
Cutting edge too short	Shaft grinding, smoke development, odor	Use end mills or mills with longer cutting edge
Cutting edge too long	Cutter bends, vibrations	Use shorter milling cutter with sufficient diameter
Cutting edge too hot	Smoke development, milling cutter turns black	Use shorter milling cutter with sufficient diameter
Resin deposition	Cutter turns black	Cleaning the milling cutter
Union nut not sufficiently tightened, collet not fitting	Cutter releases and drills into the workpiece	use exactly fitting collet chuck and tighten union nut with the wrench
Groove plugged with chips	Chips in the groove	Use milling cutter with large flute / suck out flute during milling, whirling
Cutter glued with melted chips	Grinding chips on the milling cutter	Use milling cutter with large flute, more feed, less infeed
Material gets into vibration	Noise emission	Tighten guides sufficiently, set connections, clamp properly, use vacuum table



# Workpiece clamping

We always use a "sacrificial plate"!

- Further clamping variants for the workpiece
- Vacuum
- Holding claws
- Screws (Spax)
- Individually designed holding elements

The sacrificial plate serves as a "protective layer" between the workpiece and the machine bed.

If minor inaccuracies occur, not the vacuum bed of the machine but only the sacrificial plate is damaged.



# MATERIALS

## Which materials can be milled and which not?

### DO

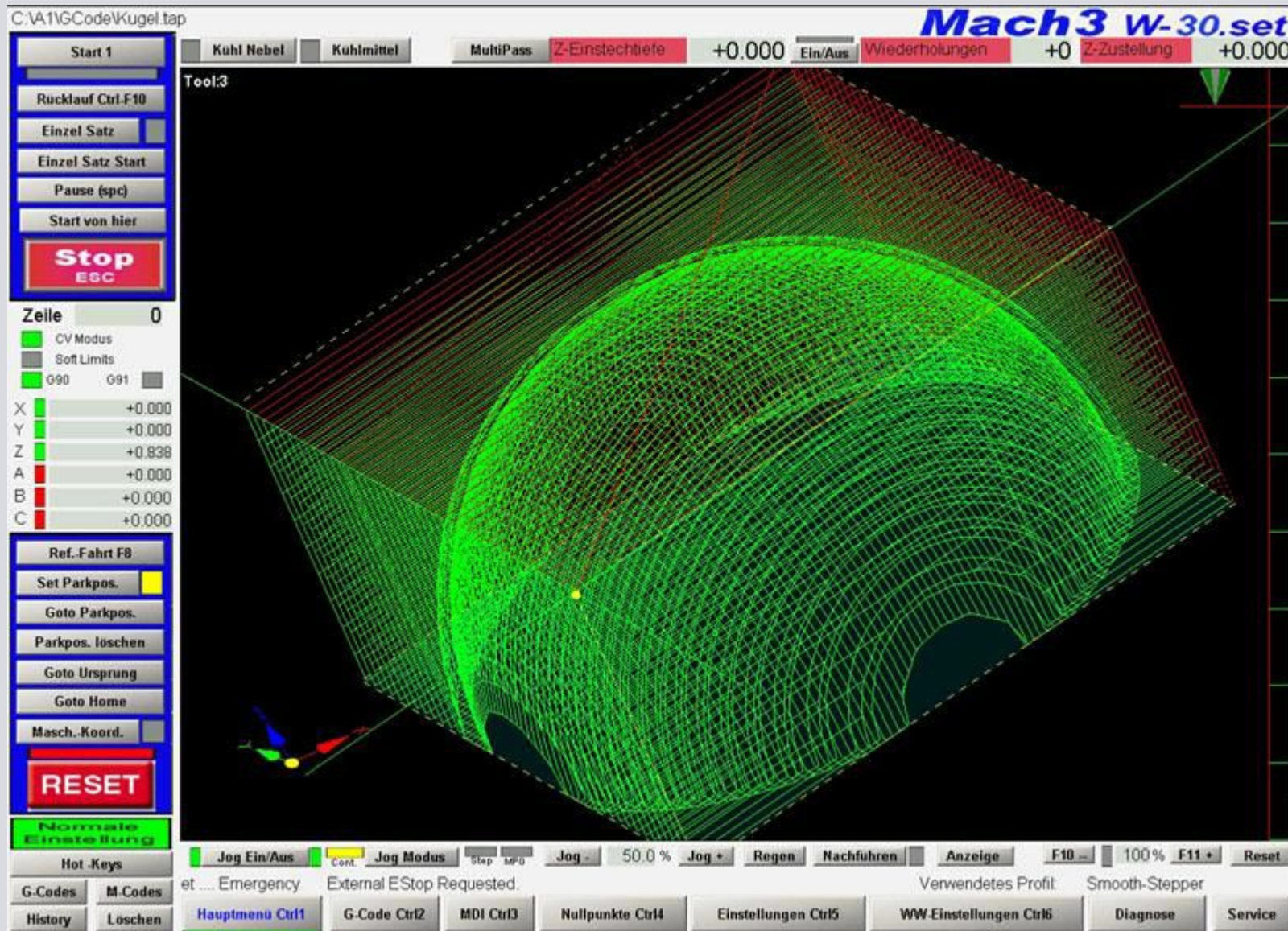
- NE metals (aluminium , brass, bronze, copper)
- Hard/ soft woods
- MDF (Attention: fine dust can be carcinogenic use suction)
- Plywood, multiplex
- Plastic (POM, acrylic)
- Rigid foam , polystyrene

### DO NOT

- Steel
- Stone



# Mach3 control software - start screen





# Mach3 control software - working screen

**Mach3 W-30.set**

C:\A1\GCode\Kugel.tap

MultiPass **Z-Einstechtiefe** +0.000 On/Off **Wiederholungen** +0 **Z-Zustellung** +0.000 **Kuhl Nebel** **Kuhlmittel**

Edit Schließen Zurück History Neu

Simulation **Fräszeit** 0:00:00:00

**G-Code Programm**

```

N0 %
N1 (FILENAME: Kugel.tap)
N2 G21
N3 (STOCK/BLOCK, 40.000, 40.000, 40.000, -E
N4 (TOOL/MILL, 2.0000, 0, 40.0000, 0.0)
N5 M6 T1
N6 G00X0.000Y0.000Z0.1000
N7 G00Z0.1000

```

Laufzeit 00:15

**PROGRAMM EXTREMA**

X	+0.000	+39.900
Y	+0.000	+39.900
Z	-20.000	+0.300

**KOORDINATEN**

Ref X	+0.000	Scale +1.000	Null
Ref Y	+0.000	Scale +1.000	Null
Ref Z	+0.838	Scale +1.000	Null
Ref A	+0.000	Radius Korrekt.	Null
Ref B	+0.000	Radius Korrekt.	Null
Ref C	+0.000	Radius Korrekt.	Null

Alle Achsen auf Null stellen

**WERKZEUG**

T	3
D	+3.000
H	+0.000

W.Wechs. WW-Cal Z.Korrekt. Ein/Aus

**WERKSTÜCK**

Nummer	1
Werkstück 1 (G54)	
Werkstück 2 (G55)	
Werkstück 3 (G56)	
Werkstück 4 (G57)	
Werkstück 5 (G58)	
Werkstück 6 (G59)	

**VORSCHUB**

Einh./Min	0.00
Einh./Rev	0.00
FRO	1000.00
F	1000.00
F10	100 %
F11	100 %

**DREHZAHL**

RPM	0
S-ov	0
S	0
S-	100 %
S+	100 %
Reset	
Spindel CW F5	

**G-Code Eingabe:**

Initialization Macro Called on reset.

Verwendetes Profil Smooth-Stepper

Hauptmenü Ctrl1 **G-Code Ctrl2** MDI Ctrl3 Nullpunkte Ctrl4 Einstellungen Ctrl5 WW-Einstellungen Ctrl6 Diagnose Service

**System Drehwinkel** +0.0 Grad

Ref.-Fahrt F8

Set Parkpos.

Goto Parkpos.

Parkpos. löschen

Goto Ursprung

Goto WW Pos

Masch.-Koord.

**RESET**

Normale Einstellung

Hot-Keys

G-Codes M-Codes

History Löschen

Stop ESC

CV Modus

Soft Limits

O90 O91

Start 1

Rücklauf Ctrl-F10

Einzel Satz

Einzel Satz Start

Pause (spc)

Start von hier

BLK Löschen

Off Line

# Work safety and behavior in WoodLab

## Industrial safety

- Hearing protection
- Safety goggles
- Face mask - Fine dust (MDF)
- Gloves - special case!!!
- head protection - longhaired "hoggers"
- Tight fitting clothing
- Sturdy shoes

## Clean up

- Remove our legacies (swarf) and empty the collection containers
- Return tools and materials to their original location
- Switch off power to machine (milling machine), shut down PC
- "All around" visual inspection
- Light off
- Locking the entrance door



# Checklist for working with the CNC

## Preparations:

- Book milling machine
- Boot up PC
- Switch on the switch cabinet (green control light)
- Mach3 software:
  - Press reset button
  - Axes X,Y,Z Move limit switch free
  - Homing of all axes : F8 key
  - Load Gcode menu item (File)
- Clamp milling cutter (Collet, union nut , insert into spindle)
- Position and clamp the sacrificial plate and raw material
- Working coordinates (X,Y,Z define zero points)
- Move "suction shoe" on/ into position
- Switch on the extraction system
- Start milling program (Gcode)

## Rules of conduct:

- Never leave the machine unattended during the milling process!
- Always keep milling paths free of chips!
- Keep checking the workpiece clamping regularly

## Postprocessing:

- Wait until the spindle "stops".
- Clamping the milling cutter
- Free movement of workpiece
- Clamping of workpiece and sacrificial plate
- Switch off switch cabinet
- Shut down pc
- Cleaning the machine
- Dispose of material residues
- Clean up workshop, sweep
- Empty chip container (suction system, vacuum cleaner)
- Visual inspection
- Lock the workshop





# ALMOST THERE!

NOW, PARTICIPATE FROM  
THE LIVE WORKSHOP AND START  
WORKING ON YOUR PROJECTS!

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DID YOU LIKE THE CONTENT OF THIS WORKSHOP  
AND YOU ARE STILL NOT A MEMBER?

Join our ecosystem and make your ideas come to life!

Reach out to our colleague [Matthew](#)

Or sign up for our [newsletter](#) to learn about the upcoming  
workshops and events.

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## Note:

This is a living document, which  
may experience changes as our  
labs evolve.

If any of the links don't work,  
please report it to

[info@motionlab.berlin](mailto:info@motionlab.berlin)