CNC milling

LBF/ZAB21 Software equipment in dental office

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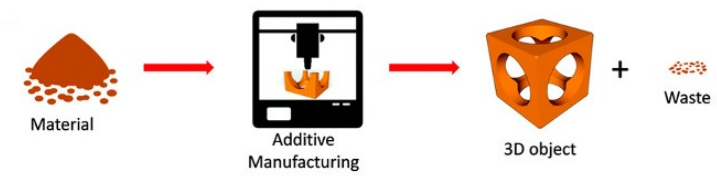
Additive vs. subtractive manufacturing

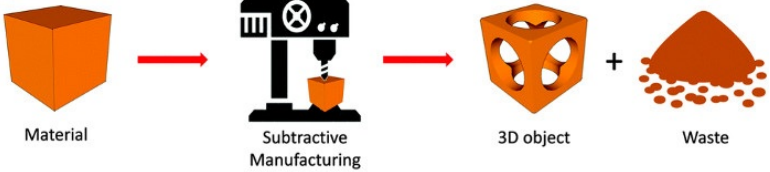
Additive process

- process that adds successive layers of material to create an object
- 3D print



Subtractive process

- as the name suggests, is the opposite
- removing sections of a material by machining or cutting it away
- milling machines



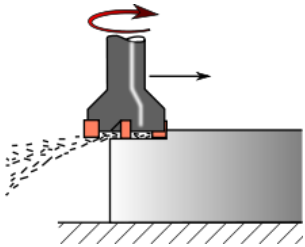
Milling

- process of machining using rotary cutters to remove material by advancing a cutter into a workpiece
- this may be done varying direction on one or several axes, cutter head speed, and pressure
- covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations
- can be done with a wide range of machine tools
- the original class of machine tools for milling was the milling machine (often called a mill)
- in the 1960s computer numerical control (CNC) was invented $\rightarrow$ milling machines evolved into machining centers
- **machining centers**: milling machines augmented by automatic tool changers, tool magazines or carousels, CNC capability, coolant systems, and enclosures
- generally classified as **vertical machining centers** (VMCs) or **horizontal machining centers** (HMCs)

Milling process

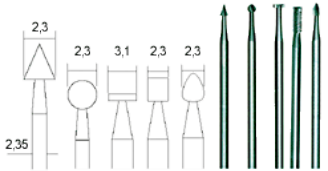
- uses a milling cutter to remove material from the surface of a workpiece
- **milling cutter** is a rotary cutting tool, often with multiple cutting points
- as opposed to drilling (the tool is advanced along its rotation axis), the cutter in milling is usually moved perpendicular to its axis so that cutting occurs on the circumference of the cutter
- cutting edges of the tool repeatedly cut into and exit from the material, shaving off chips (swarf) from the workpiece with each pass
- the milling process removes material by performing many separate, small cuts

- two major classes of milling process:
  - **face milling** — the cutting action occurs primarily at the end corners of the milling cutter, is used to cut flat surfaces (faces) into the workpiece, or to cut flat-bottomed cavities
  - **peripheral milling** — the cutting action occurs primarily along the circumference of the cutter, so that the cross section of the milled surface ends up receiving the shape of the cutter, is well suited to the cutting of deep slots, threads, and gear teeth



Milling cutters

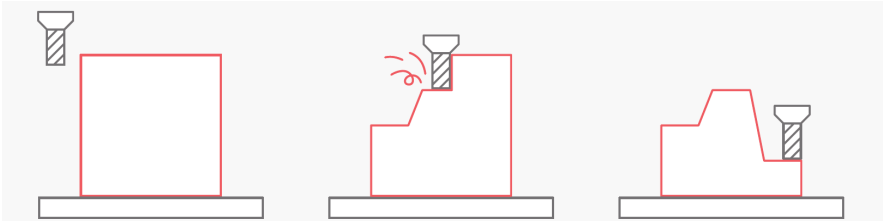
- many different types of cutting tools are used in the milling process
- milling cutters such as endmills may have cutting surfaces across their entire end surface, so that they can be drilled into the workpiece (plunging)
- milling cutters may also have extended cutting surfaces on their sides to allow for peripheral milling
- tools optimized for face milling tend to have only small cutters at their end corners
- cutting surfaces of a milling cutter are generally made of a hard and temperature-resistant material, so that they wear slowly



- wolfram vanadium milling bits
- for non-ferrous metals, plastic, plaster

Computer numerical control (CNC)

- automated control of machining tools by means of a computer
- CNC machine alters a blank piece of material to meet precise specifications by following programmed instructions and without a manual operator
- computer transform graphical computer-aided design (CAD) files, which are transformed into a sequential program of machine control instructions such as G-code
- instructions are then executed by milling machine
- object's mechanical dimensions are defined using CAD software, and then translated into manufacturing directives by computer-aided manufacturing (CAM) software
- resulting directives are transformed (by "post processor" software) into the specific commands necessary for a particular machine to produce the component, and then are loaded into the CNC machine



3D printing vs CNC

- Choice of materials:
  - CNC mills — huge variety of materials (metal, softwoods and hardwoods, thermoplastics, acrylic, modeling foams, machining wax)
  - 3D printers (desktop) — usually restricted to a few materials, typically thermoplastics (PLA, ABS, sometimes nylon) or resins
  - CNC mill can manufacture prototypes in the same material that will be used for the final product – so you can immediately start testing
- Precision:
  - CNC mills offers better precision
- Speed:
  - 3D printing jobs often take hours to complete, whereas CNC milling jobs with comparable size and complexity normally do not take more than an hour
- Noise:
  - CNC milling can get extremely noisy and also vibrates heavily
- Messiness:
  - CNC milling - subtractive process — lot of material spurting away, and that may be quite sharp

3D printing vs CNC

- Waste:
  - less waste in 3D printing as this technology only requires the material needed for building the workpiece
  - CNC milling you need a block of material that has at minimum the size of the workpiece – a lot of material has to be removed and often cannot be recycled
- Range of applications:
  - CNC milling is the better solution when manufacturing workpieces that need to be extremely robust and precise and/or heat-resistant
  - 3D printing can be used for bioprinting, for printing food, for building purposes, and it can be used in space
- Cost price:
  - 3D printing is cheaper

CNC vs. FDM

	CNC	**FDM** - personal	**FDM** - professional
Tolerance	$\pm 0.500mm$	$\pm 0.200mm$	$\pm 0.025 - 0.125mm$
Min. wall thick.	$0.8 - 1.0mm$	$0.8 - 1.0mm$	$0.75mm$
Max. size	$2000 \times 800 \times 1000mm$	$200 \times 200 \times 200mm$	$900 \times 600 \times 900mm$

Manufacturing process

3D print

- model creation
- choice of material, print setting (supports, size of layers, . . .)
- print (almost without human intervention)
- finishing - could be time consuming

CNC

- model creation
- choice of material, choice of tool, speed, cutting path, . . . (great impact on product quality)
- manual machine setting
- when finished, the product is ready for use - no finishing work is needed

Materials

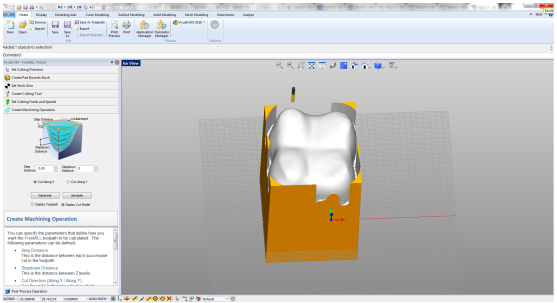
- metal alloys - aluminum, steel alloys, brass, copper
- thermoplastics - ABS, Nylon, Polycarbonate, PEEK
- softwoods and hardwoods
- modeling foams
- machining wax

Model creation

- create a 3D model in 3D graphics software (eg. CAD)
- converting to g. code (other than for 3D printing) - CAM (computer aided manufacturing) software

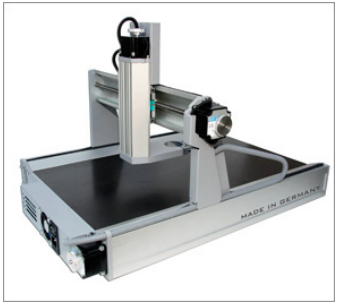
CAM software

- most CAM software is paid, free trial version
- **VisualCAD** - freeMILL (creating g.code a emulation)



Next3D CNC Router

- resolution: 0,00375 mm
- repetition accuracy: 0,03 mm / 300 mm
- clamping surface: 335 mm x 620 mm
- workspace: X-330mm Y-500mm Z-110mm
- maximal speed: 3000 mm/min



Control CNC mill

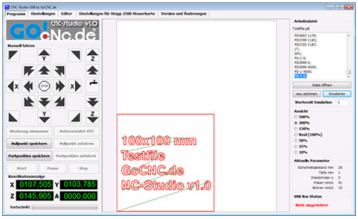
- Next3D CNC router contains **GoCNC Studio USB Box**
- CNC Studio USB Box connects a PC with USB port with a CNC machine with parallel port
- its own CPU, own software and memory in which the milling data are temporarily stored
- Easy Plug and Play hardware
- runs on all PCs, notebooks and netbooks with at least 1Ghz Leistunng and USB port
- USB 2.0 port, Windows 2000 and higher
- can not mill 3D models, only 2D, like drill boards, mill workpieces, rout front panels, engraving signs ...

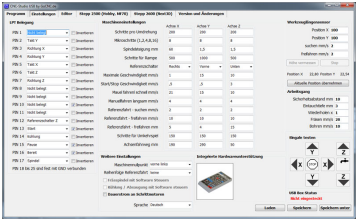
3D mill using Next3D

- for g-code integration, needs **GoCNC g-code processor 3D**
- Procesor G-Code connect Windows PC / Linux / Mac with CNC machine using parallel port
- it includes, in addition to USB and parallel ports, the Arduino microcomputer with GRBL firmware

GoCNC Studio USB

- Several parts:
  - Program = is used to operate your machine
  - Settings = changing the parameters of your machine or the job process
  - Editor = allows you to configure your CNC program directly (HPGL format)
- **Program** - Manual drive (moving the axes, reference points setting - zero point, park position, ...)
- Working area of your machine = The size and proportions of the working area (parameters entered in the settings), displaying job graphically, emulation
- Current parameters



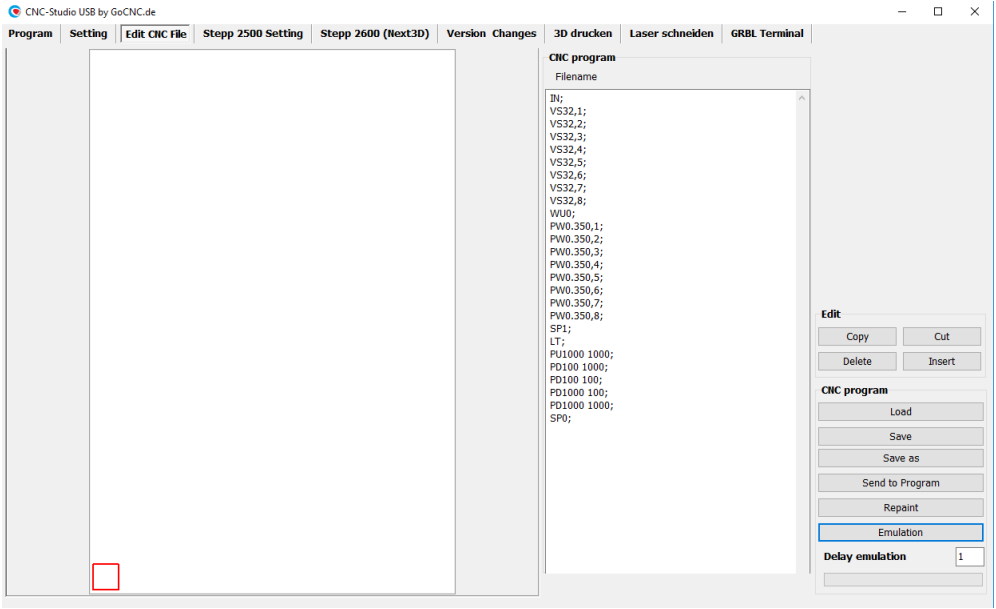


HPGL language

- vector graphic formats = many of them store information about 2D drawing or a 3D model in text form
- Hewlett-Packard Graphics Language = originally developed for plotters
- purely text format
- at the beginning — initialization (each plotter has its own)
- a sequence of commands that are separated by ;
- **Commands**

Command	Parameters	Description
IN		initialize
SP	n	select pen
LT	number, length	line type
PU	x,y	pen up - pen up and move to coordinates
PD	x,y	pen down - pen down and move to coordinates

HPGL language = example



Creating HPGL images graphically

- Some graphic editors support the format .ptl (they convert the image to HPGL instructions)
- CorelDraw
- AutoCAD
- AutoSketh
- Eatle
- HCAM
- CADdy
- Note! The middle of the tool (cutter) will always trace the line exactly when milling
- you must include the diameter of the tool in your drawings and calculate the drawn dimensions correctly during the drawing stage
- if you draw a circle with a 10 mm diameter and use a 2 mm thick cutter to mill, the inner circle will have a diameter of 9 mm and the outer circle a diameter of 11 mm

Task

Create a simple image in plt format, that is, using the lines specified by the coordinates.

.plt file can be converted to another file type (for example png):
`https://convertio.co/`

```
IN;
VS32,1;
VS32,2;
VS32,3;
VS32,4;
VS32,5;
VS32,6;
VS32,7;
VS32,8;
WU0;
PW0.350,1;
PW0.350,2;
PW0.350,3;
PW0.350,4;
PW0.350,5;
PW0.350,6;
PW0.350,7;
PW0.350,8;
SP1;
LT;

YOUR PROGRAM


SP0;
```