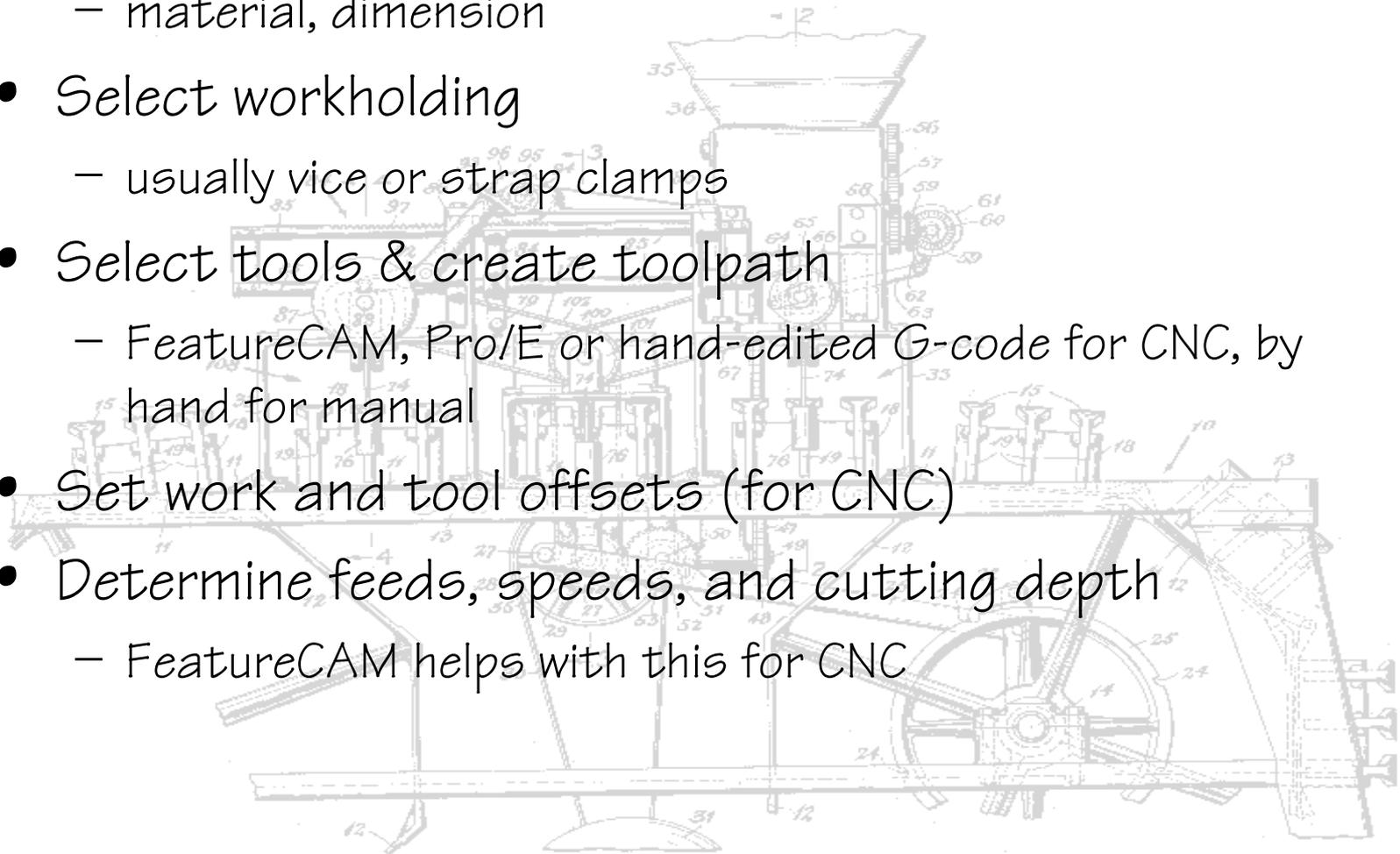# Doing Vertical Milling

- Select stock
  - material, dimension
- Select workholding
  - usually vice or strap clamps
- Select tools & create toolpath
  - FeatureCAM, Pro/E or hand-edited G-code for CNC, by hand for manual
- Set work and tool offsets (for CNC)
- Determine feeds, speeds, and cutting depth
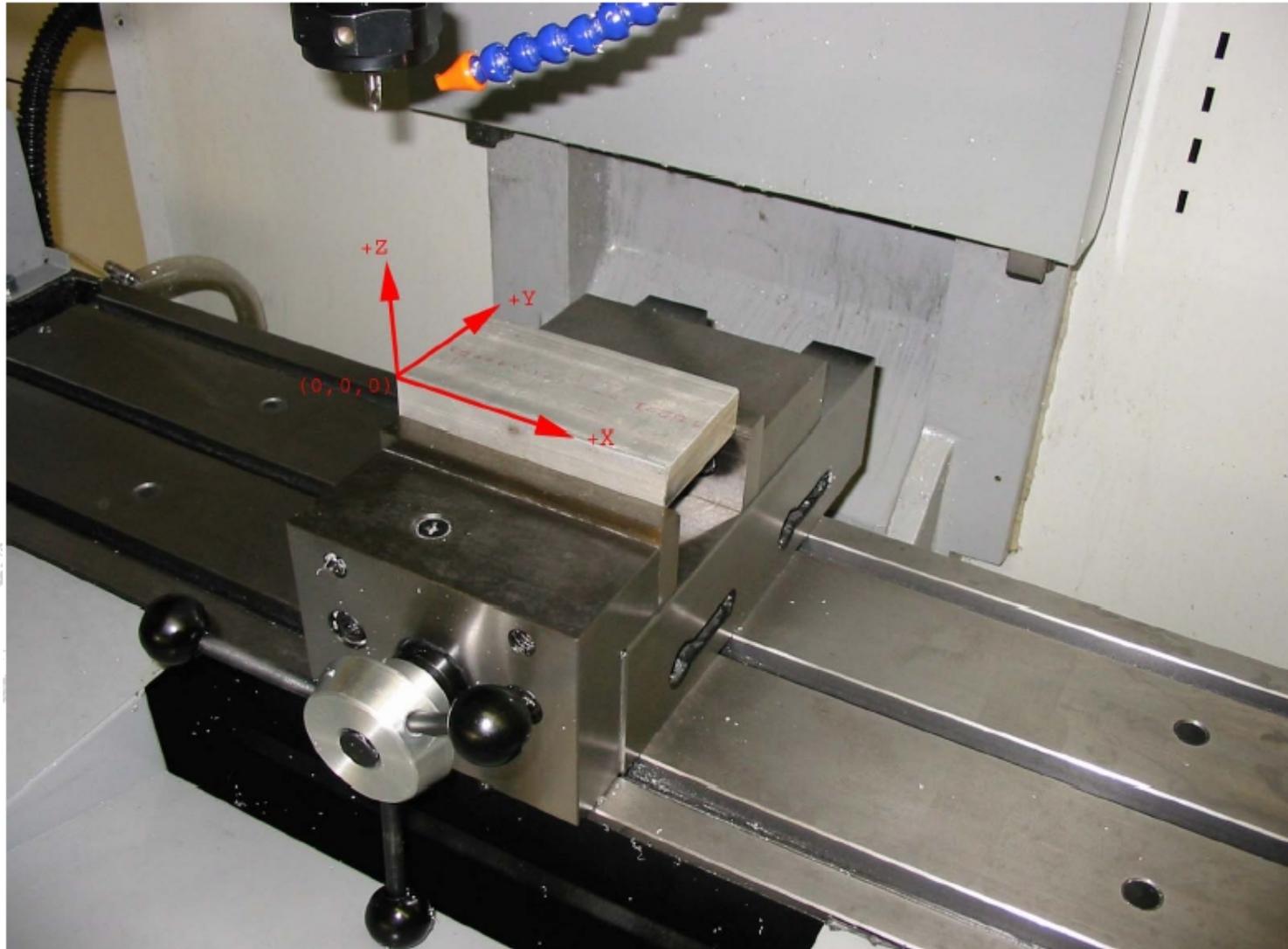 - FeatureCAM helps with this for CNC

Vertical Milling
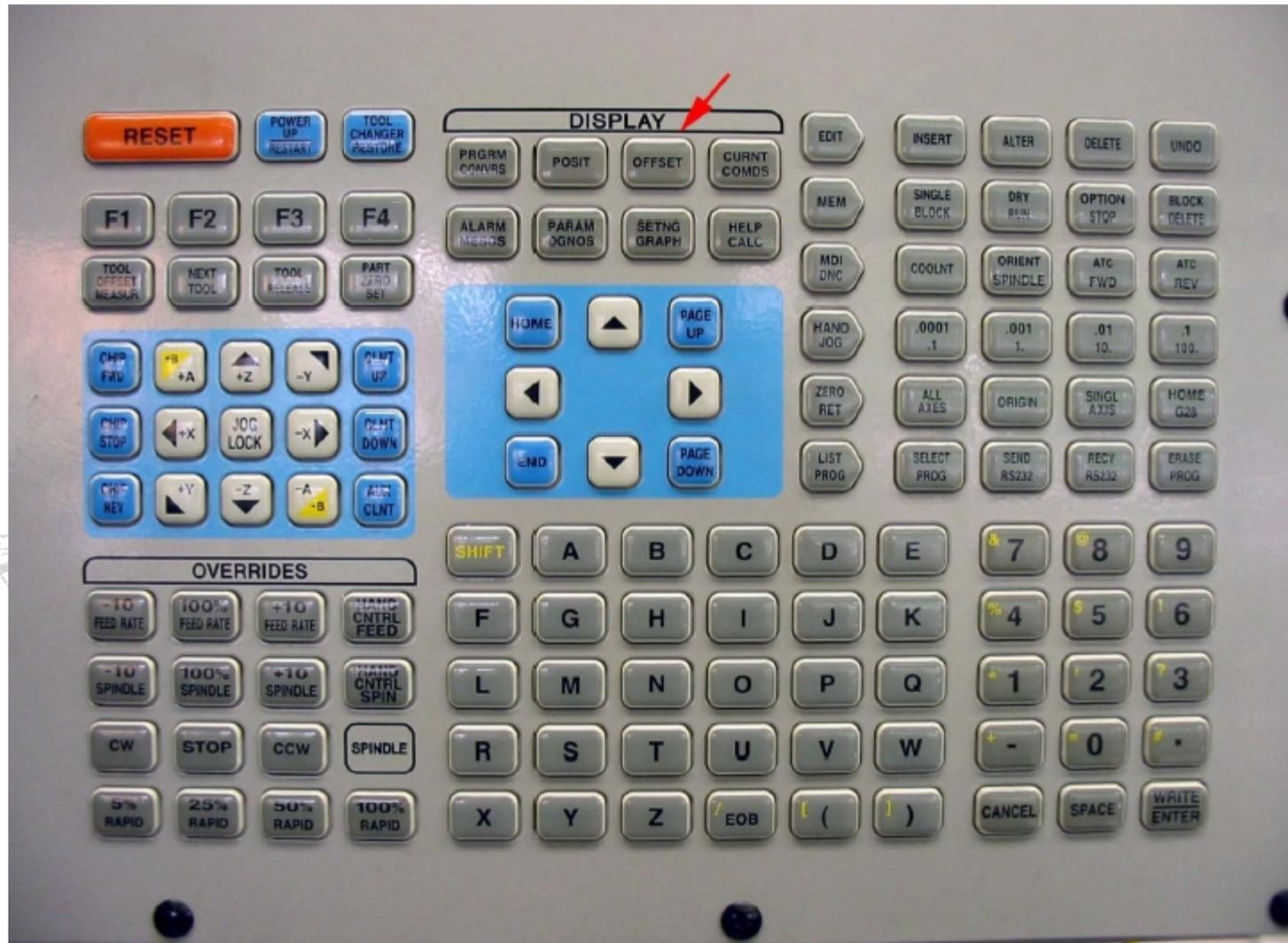
Coordinate System

Work Offsets

- Work Offsets
  - G54-G59
  - G54 X & Y aligned with vice jaw left front
 - Set G54 Z to height of top of work (type number, press F1)

Offsets

Setting Work Offset

WORK ZERO OFFSET

G CODE	X	Y	Z	
G 52	0.	0.	0.	
G 54	-18.4071	-8.1975	6.4513	
G 55	-10.8700	-8.5000	0.	
G 56	-22.6680	-6.8000	0.	
G 57	-16.3900	-2.6200	6.0000	
G 58	-12.4185	-8.0782	5.0240	
G 59	-18.4071	-8.0782	5.2285	
G154 P1	0.	0.	0.	(G110)
G154 P2	0.	0.	0.	(G111)
G154 P3	0.	0.	0.	(G112)
G154 P4	0.	0.	0.	(G113)
G154 P5	0.	0.	0.	(G114)
G154 P6	0.	0.	0.	(G115)
G154 P7	0.	0.	0.	(G116)
G154 P8	0.	0.	0.	(G117)
G154 P9	0.	0.	0	(G118)
G154 P10	0.	0.	0.	(G119)
G154 P11	0.	0.	0.	(G120)
G154 P12	0.	0.	0.	(G121)
G154 P13	0.	0.	0.	(G122)
G154 P14	0.	0.	0.	(G123)
G154 P15	0.	0.	0.	(G124)
G154 P16	0.	0.	0.	(G125)
G154 P17	0.	0.	0.	(G126)

Z POSITION : -5.0343   WRITE ADD/F1 SET/OFSET TOGGLE

RAPID 50%

JOGGING Y AXIS HANDLE .0001
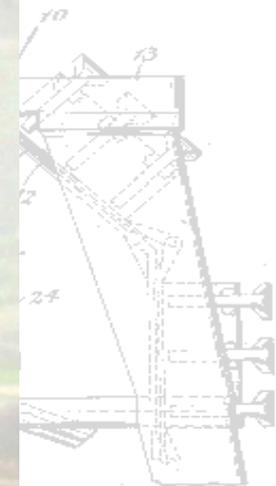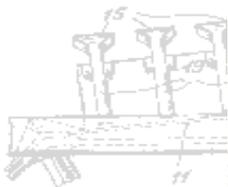
Tool Offsets

- Select tool #
- Jog until touch
- Press "Tool Offset Measure"
- Subtract 2.000" (-2.0 Enter)

TOOL	POSITION GEOMETRY	WEAR	GEOMETRY	WEAR	FLUTES
1	-16.1442	0.	0.1250	0.	2
2	-16.7966	0.	0.1250	0.	2
3	-16.7883	0.	0.1250	0.	2
4	-12.2747	0.	0.1000	0.	2
5	-13.9795	0.	0.3750	0.	4
6	-16.2011	0.	0.2500	0.	2
7	-14.4871	0.	0.3125	0.	2
8	-14.4289	0.	0.1250	0.	2
9	-16.9389	0.	0.0625	0.	2
10	-17.0816	0.	0.0625	0.	2
11	0.	0.	0.	0.	2
12	0.	0.	0.	0.	2
13	0.	0.	0.	0.	2
14	0.	0.	0.	0.	2
15	0.	0.	0.	0.	2
16	0.	0.	0.	0.	2
17	0.	0.	0.	0.	2
18	0.	0.	0.	0.	2
19	0.	0.	0.	0.	2
20	0.	0.	0.	0.	2

Z POSITION : -14.1442   WRITE ADD/F1 SET/OFSET TOGGLE

2.0000"
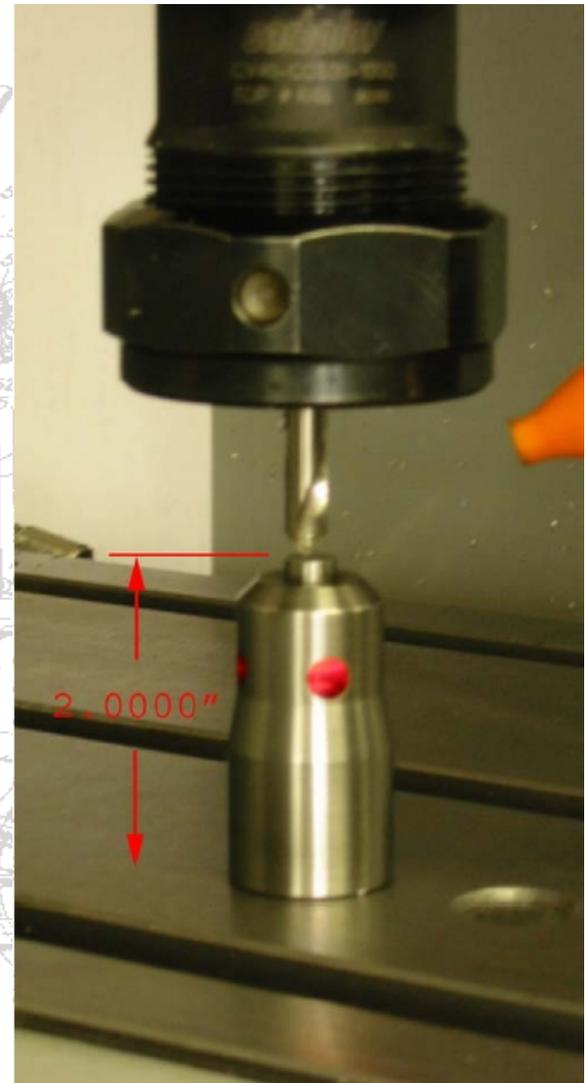
Process

- Rigidity:
  - use shortest tool and tool holder
    - deflection of tool or work causes form error
  - keep workpiece firmly clamped and supported
  - avoid speed/feed/depth combos that chatter
- Heat:
  - use carbide tools when heat is a problem
  - keep chips cleared (liquid or air coolant)
    - hard chips get harder
    - soft chips stick to tool
  - don't go too fast OR too slow
- Chip load:
  - keep volume removed constant!
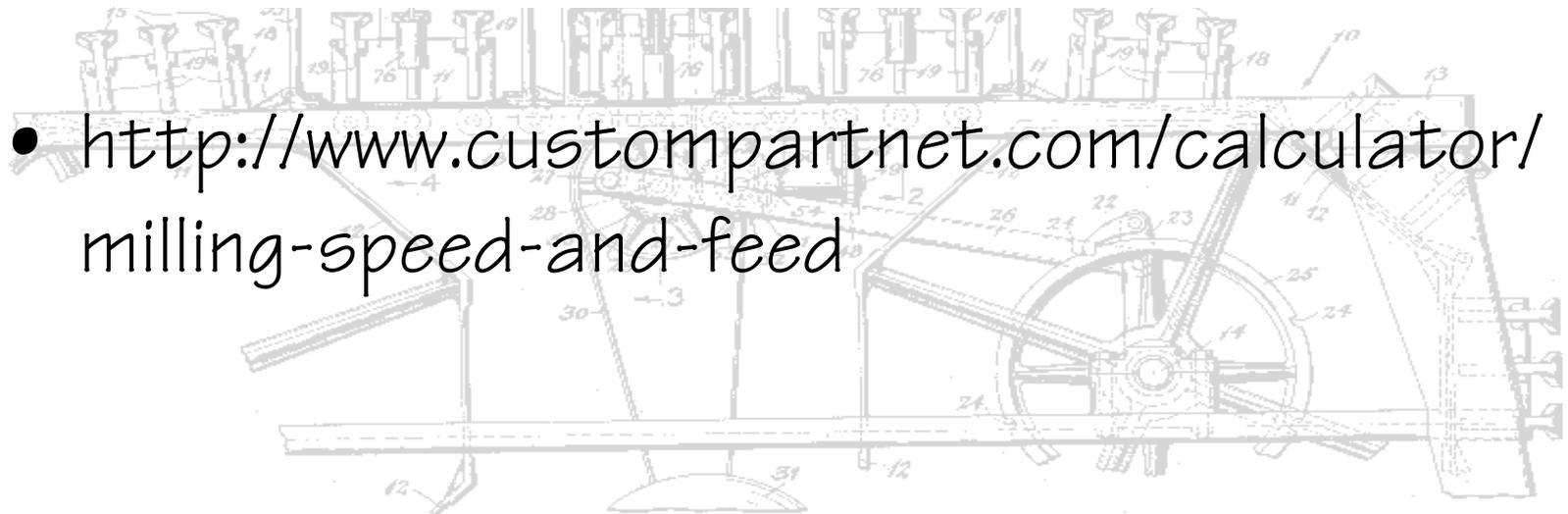 - especially watch tool entry, exit, corners
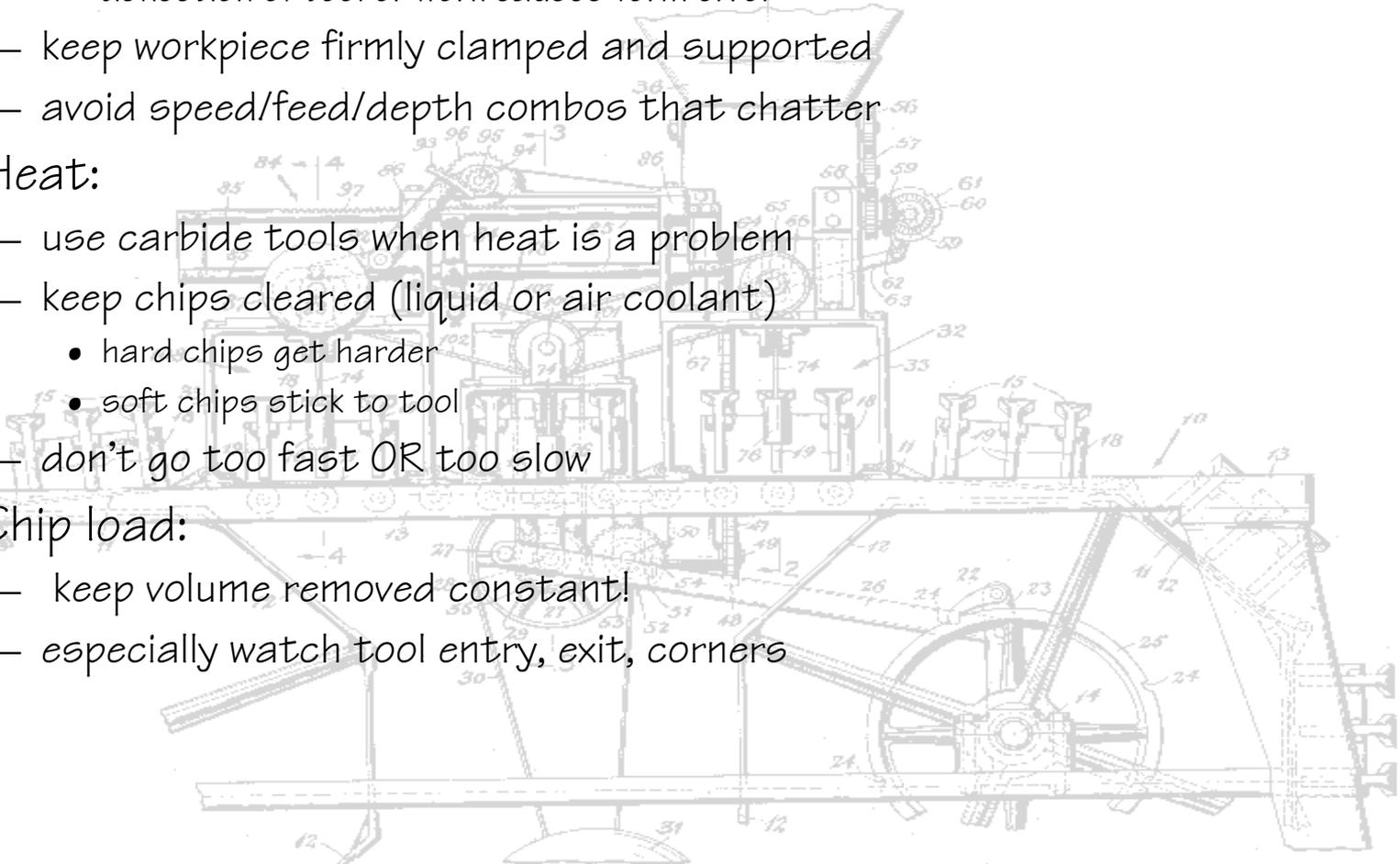
Setting Feeds & Speeds

Aluminum (6061, 2024, 7075)				
SFM	Chipload Per Tooth			
2, 3, & 4 Flute	up to .125 dia.	.125-.250 dia.	.250-.500 dia.	.500-1.0 dia.
300-500	.0008-.0020	0015-.0040	0020-.0060	0030-.0090

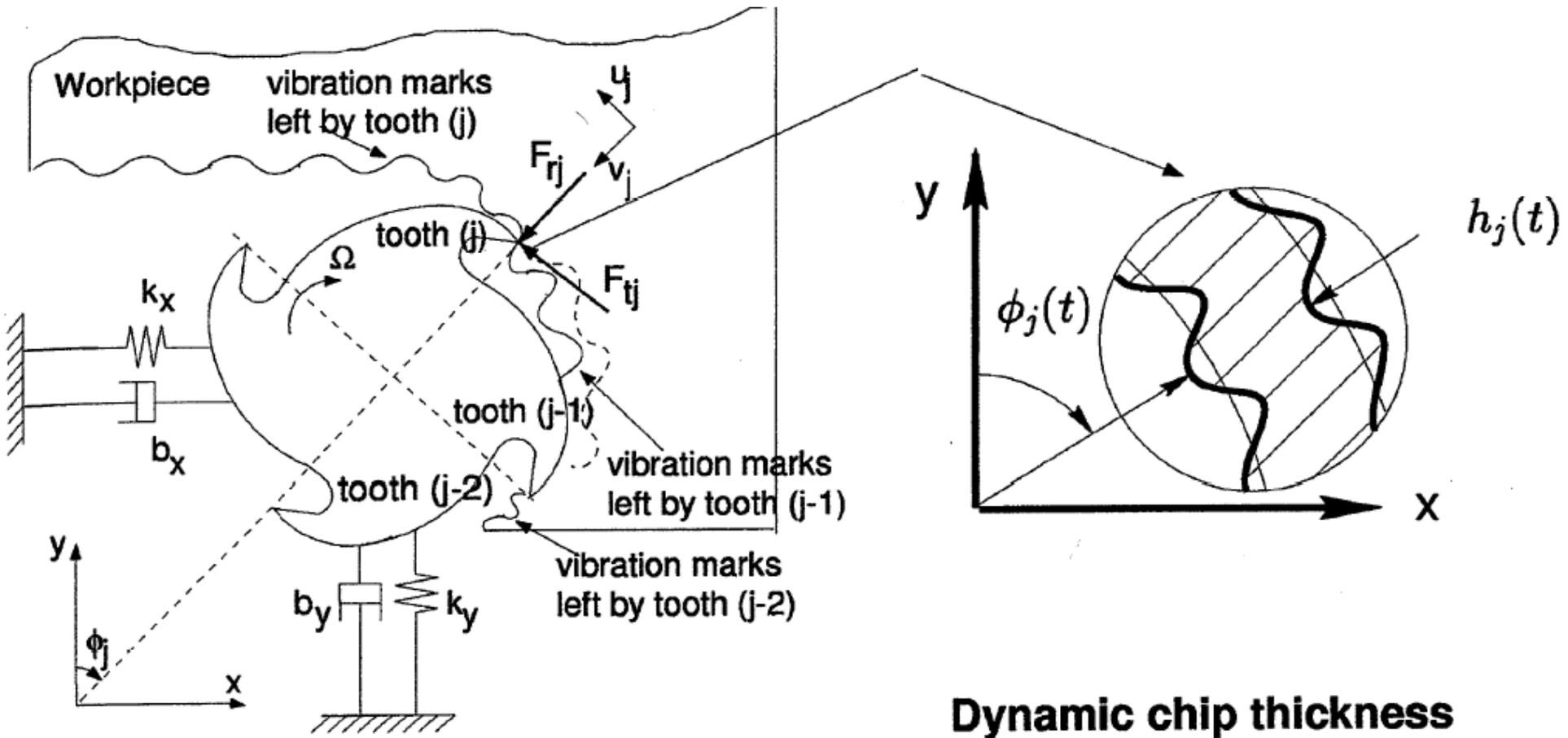| Tool Steels <30 RC (4140, 4340, A2, D2, O1, S7, P2,H13)				
SFM	Chipload Per Tooth			
2, 3, & 4 Flute	up to .125 dia.	.125-.250 dia.	.250-.500 dia.	.500-1.0 dia.
150-225	.0005-.0010	0008-.0020	0010-.0030	0020-.0040

Carbon Steels <35 RC (A36, 1000's, 1100's, 1300's)				
SFM	Chipload Per Tooth			
2, 3, & 4 Flute	up to .125 dia.	.125-.250 dia.	.250-.500 dia.	.500-1.0 dia.
175-250	.0006-.0015	0010-.0025	0015-.0040	0020-.0050

- http://www.custompartnet.com/calculator/milling-speed-and-feed

Vibration (chatter)

Dynamic chip thickness

Vibration

$h_{st}(t)$ $v_j(t)$ $v_j(t\text{-}T)$
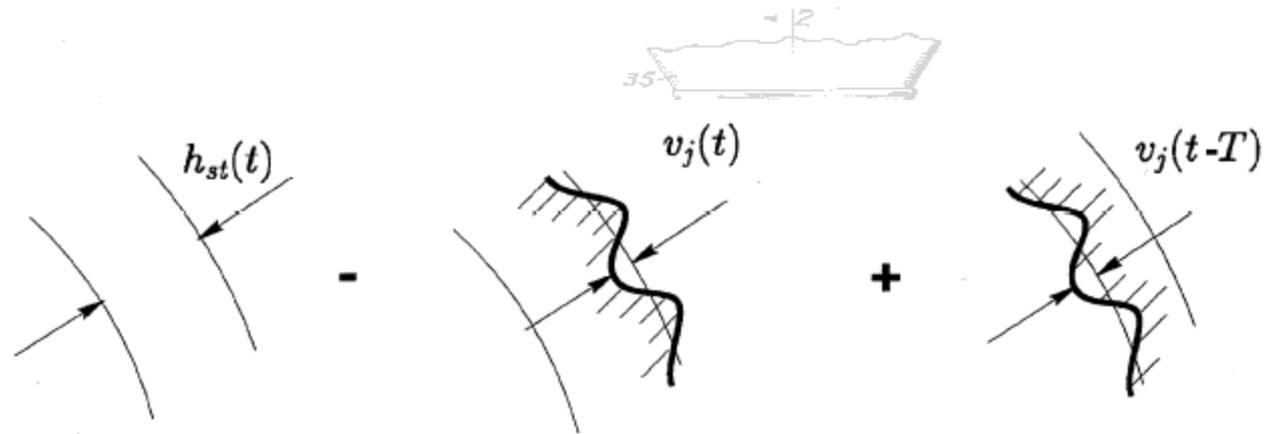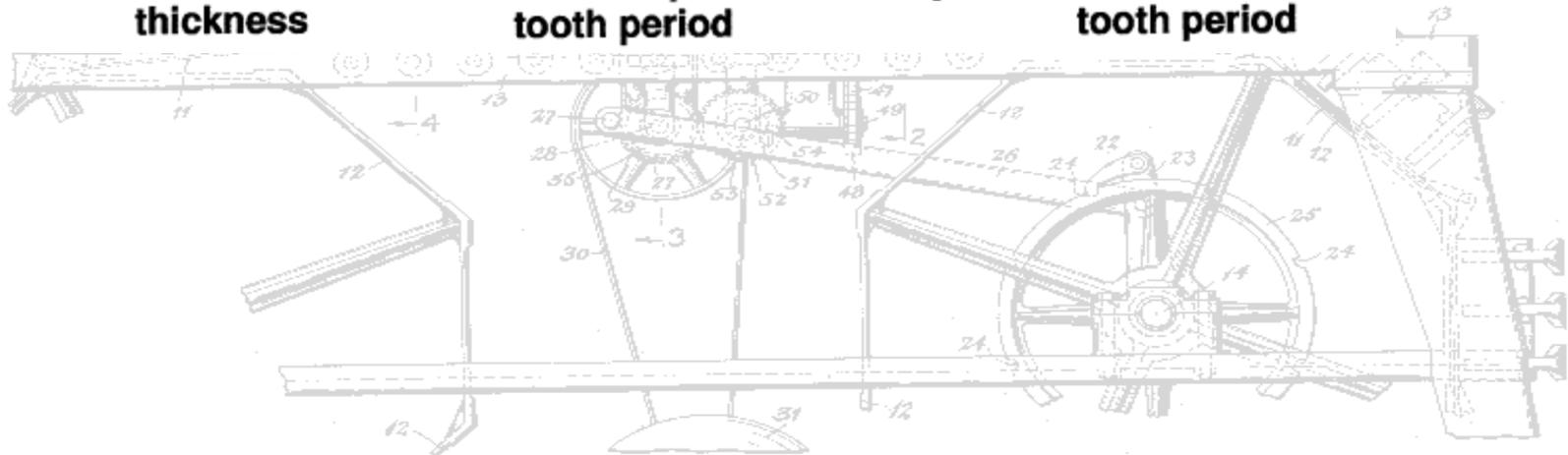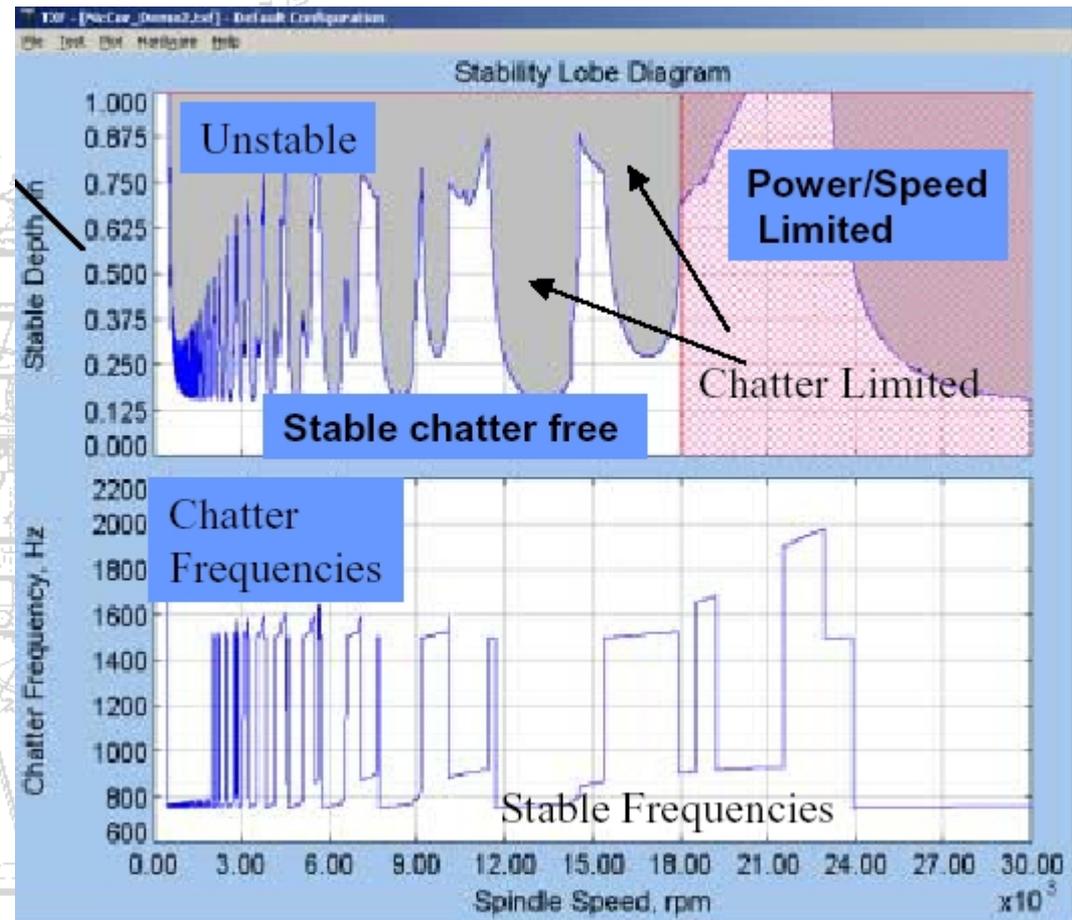
Static chip thickness − **Vibration at present tooth period** + **Vibration at previous tooth period**

Vibration

- For Max Material Removal Rate:
  - Choose highest spindle RPM
  - Tune tool length to stay in a stable lobe at top spindle RPM

Vibration

Stability Lobes for Bull Nose Cutter and Al7075

(9500 rpm)
(4.7 mm)

(14000 rpm)
(4.7 mm)

Spindle speed [rev/min]

Experimental Resultant Force
Tool Rotation Angle [deg]

Simulated Resultant Force
Tool Rotation Angle [deg]

Surface Roughness
$R_{max} = 12\ \mu m$
Z [mm] (axial direction)
X [mm] (feed direction)

FFT for Resultant Force
Chatter Frequency (1448 Hz)
Frequency [Hz]

Experimental Resultant Force
Tool Rotation Angle [deg]

Simulated Resultant Force
Tool Rotation Angle [deg]

Surface Roughness
$R_{max} = 2\ \mu m$
Z [mm] (axial direction)
X [mm] (feed direction)

FFT for Resultant Force
Tooth Passing Frequency (467 Hz)
Frequency [Hz]