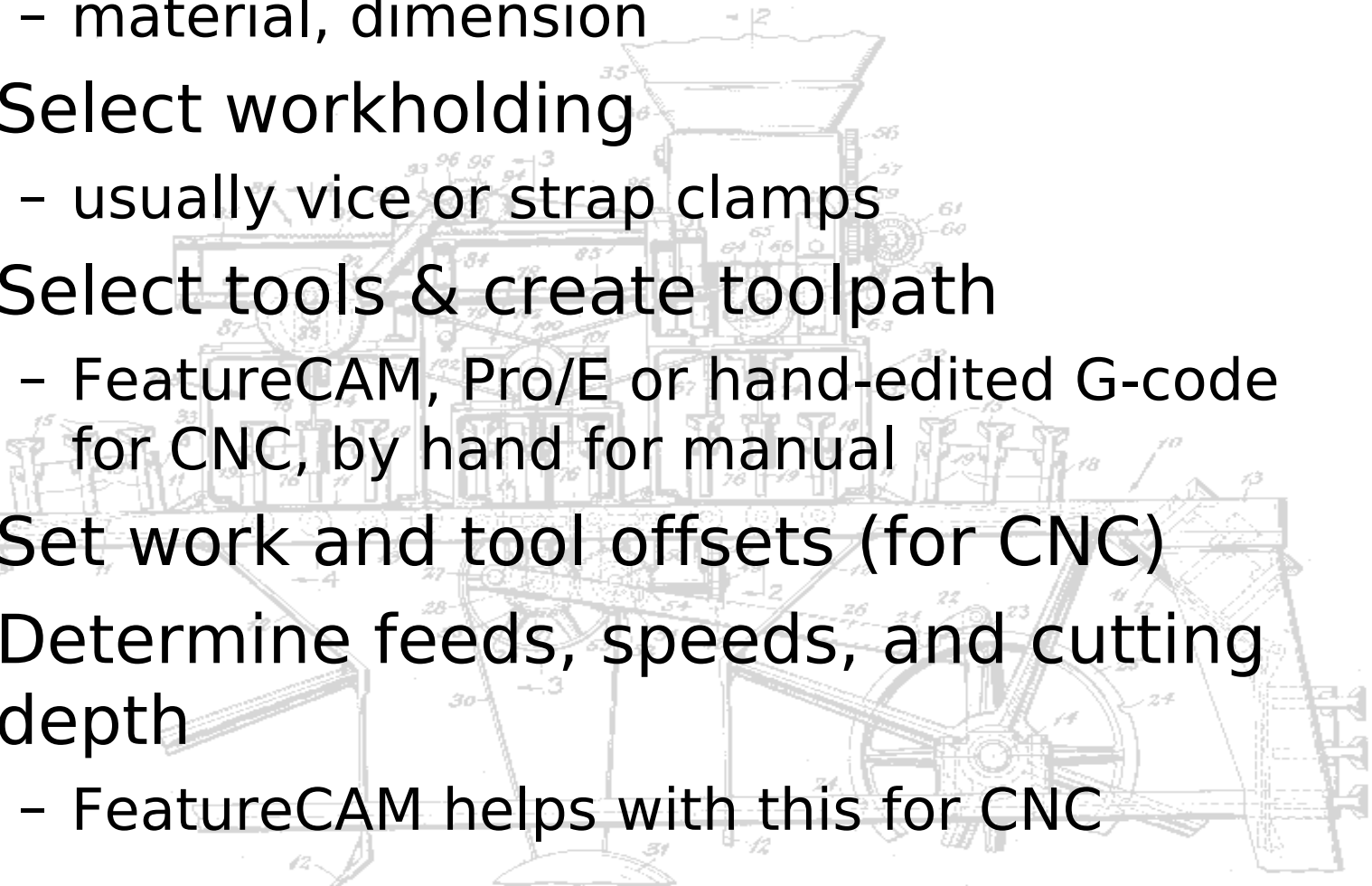


Doing Vertical Milling

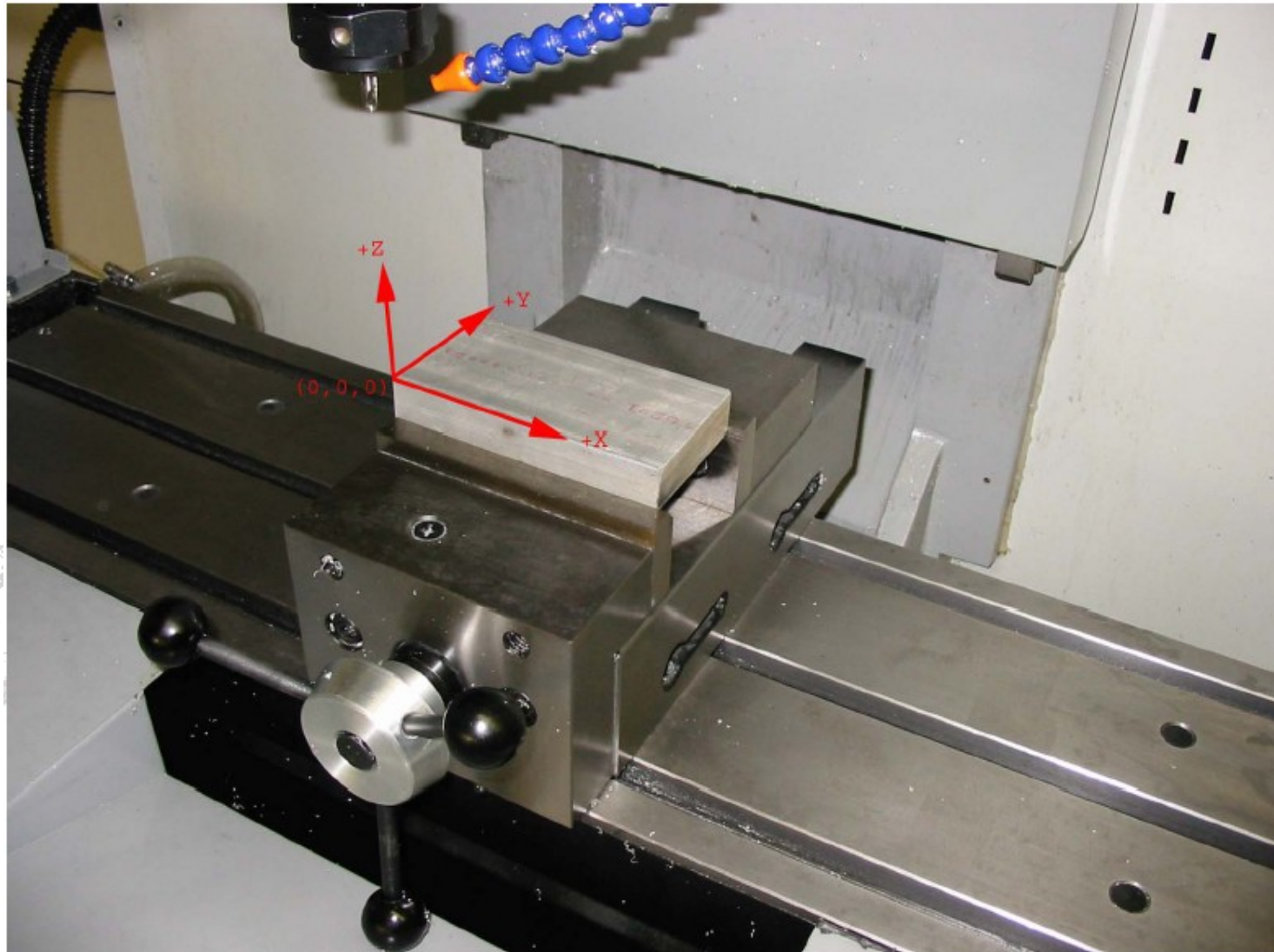
- Select stock
 - material, dimension
- Select workholding
 - usually vice or strap clamps
- Select tools & create toolpath
 - FeatureCAM, Pro/E or hand-edited G-code for CNC, by hand for manual
- Set work and tool offsets (for CNC)
- Determine feeds, speeds, and cutting depth
 - FeatureCAM helps with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



Vertical Milling



Coordinate System

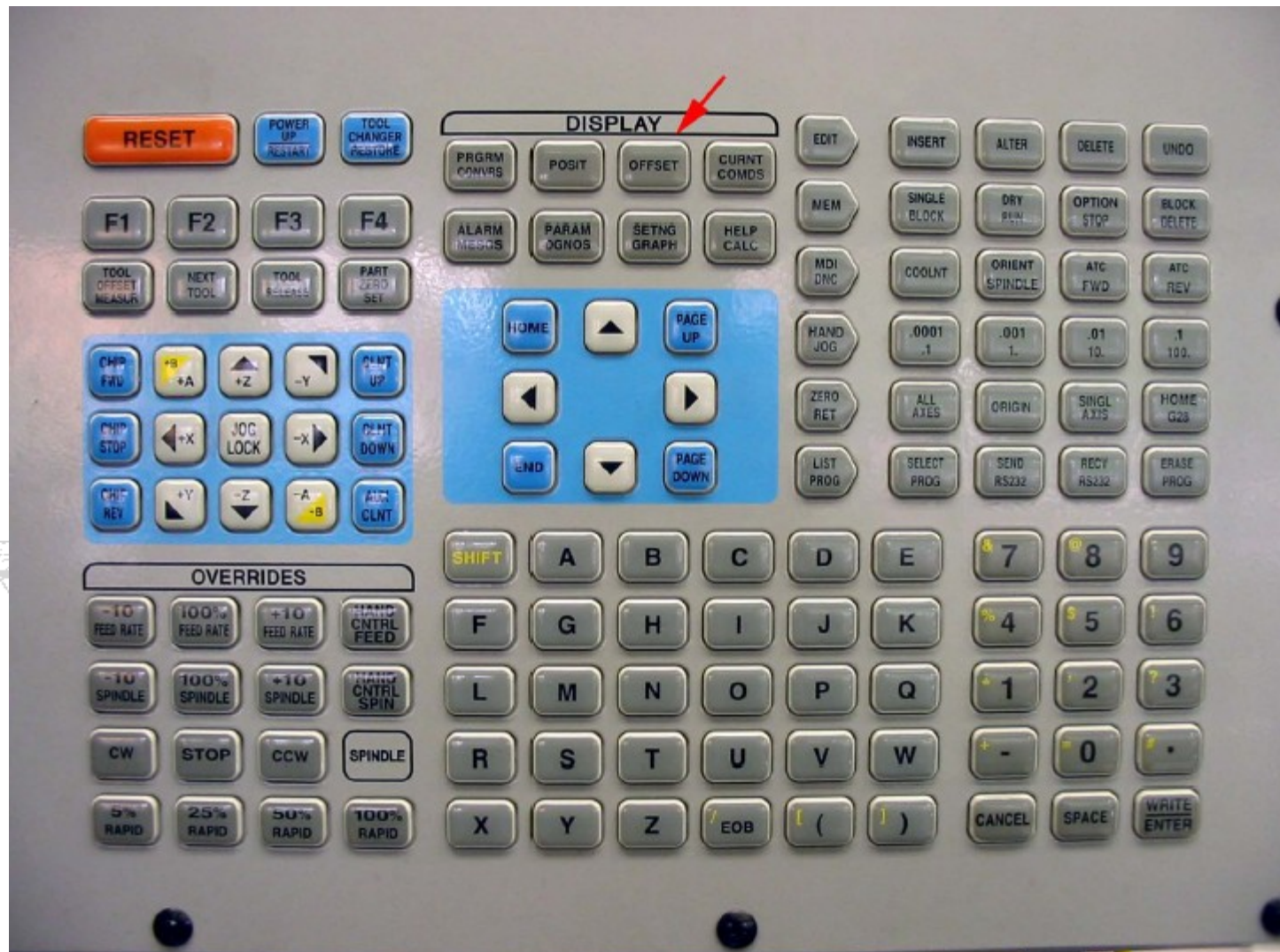


Work Offsets

- 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	-18.4871	-8.1975	6.4515	
G 55	-18.8788	-8.5888	0.	
G 56	-22.6688	-6.8888	0.	
G 57	-16.3988	-2.6288	6.8888	
G 58	-12.4185	-8.8782	5.8248	
G 59	-18.4871	-8.8782	5.2285	
G154 P1	0.	0.	0.	(G118)
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 : -5.8343 WRITE ADD/F1 SET/OFFSET TOGGLE

RAPID 58X
JOGGING Y AXIS HANDLE .8881

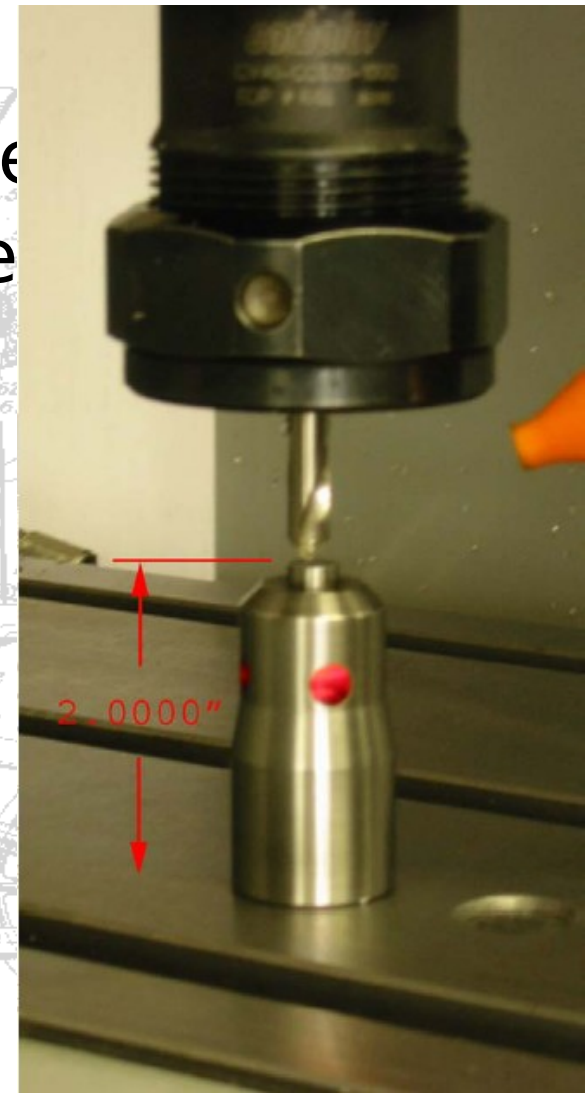
5.8675

Tool Offsets

- Select tool #
- Jog until touch
- Press “Tool Offset Measure
- Subtract 2.000” (-2.0 Ente

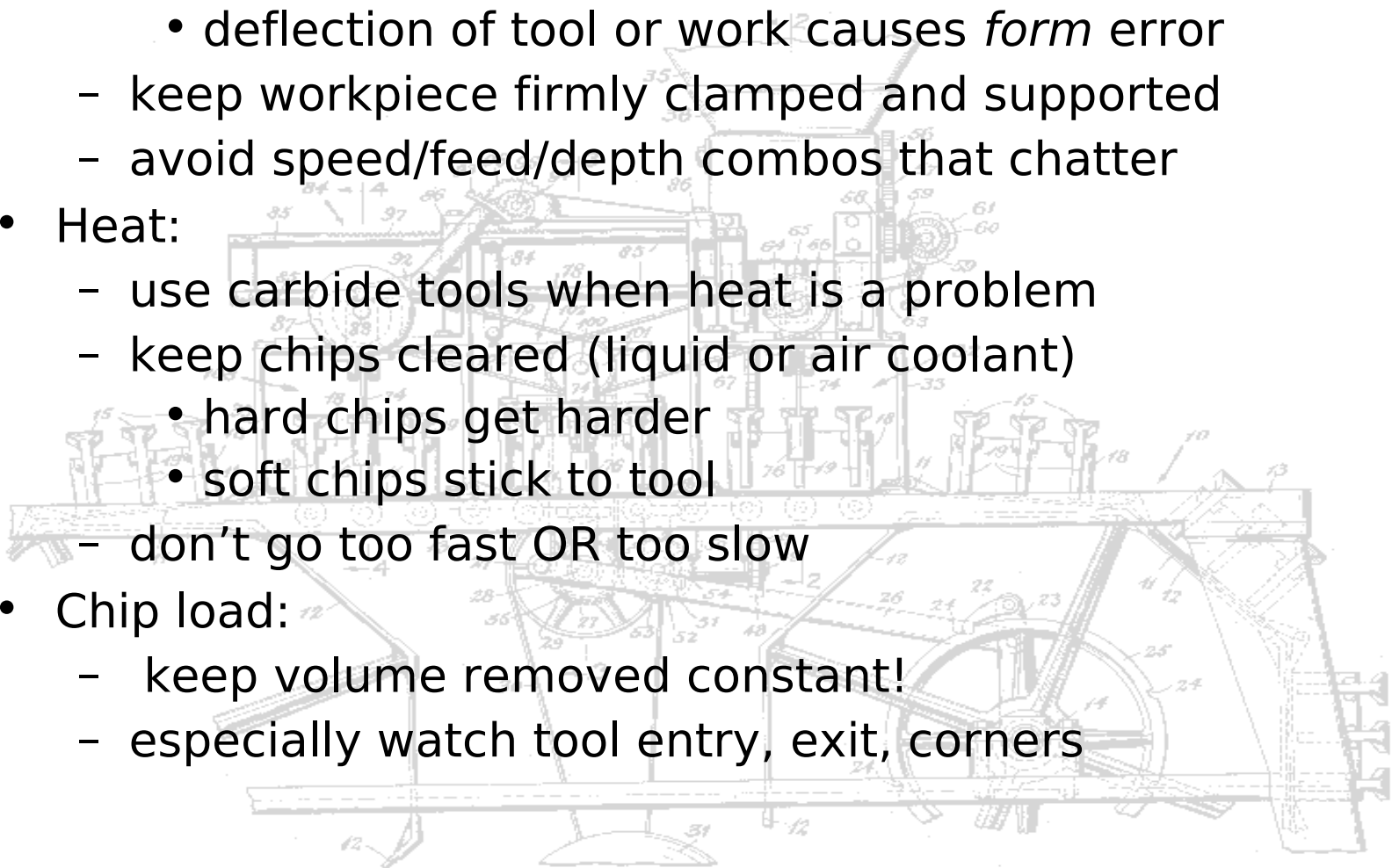
TOOL	POSITION	GEOMETRY	WEAR	GEOMETRY	WEAR	FLUTES
1		-16.1442	0.	0.1250	0.	2
2		-16.7966	0.	0.1250	0.	2
3		-16.7883	0.	0.1250	0.	2
4		-12.2747	0.	0.1000	0.	2
5		-13.9795	0.	0.3750	0.	4
6		-16.2011	0.	0.2500	0.	2
7		-14.4871	0.	0.3125	0.	2
8		-14.4289	0.	0.1250	0.	2
9		-16.9389	0.	0.0625	0.	2
10		-17.0816	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/OFFSET TOGGLE



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



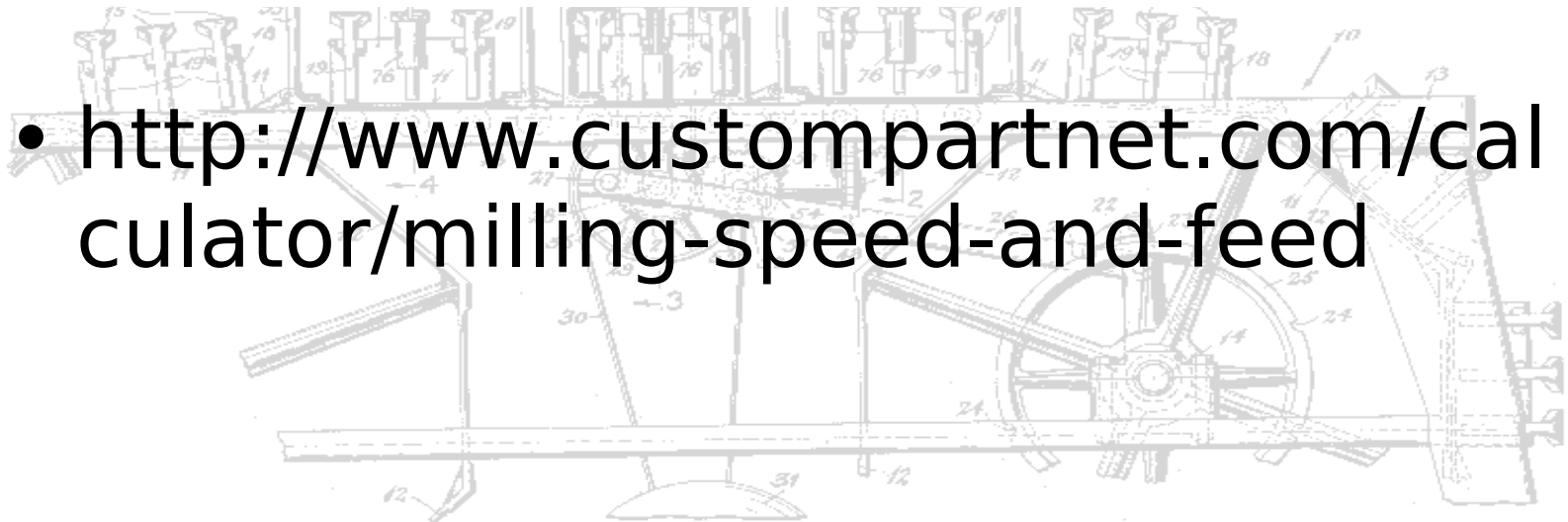
Setting Feeds & Speeds

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

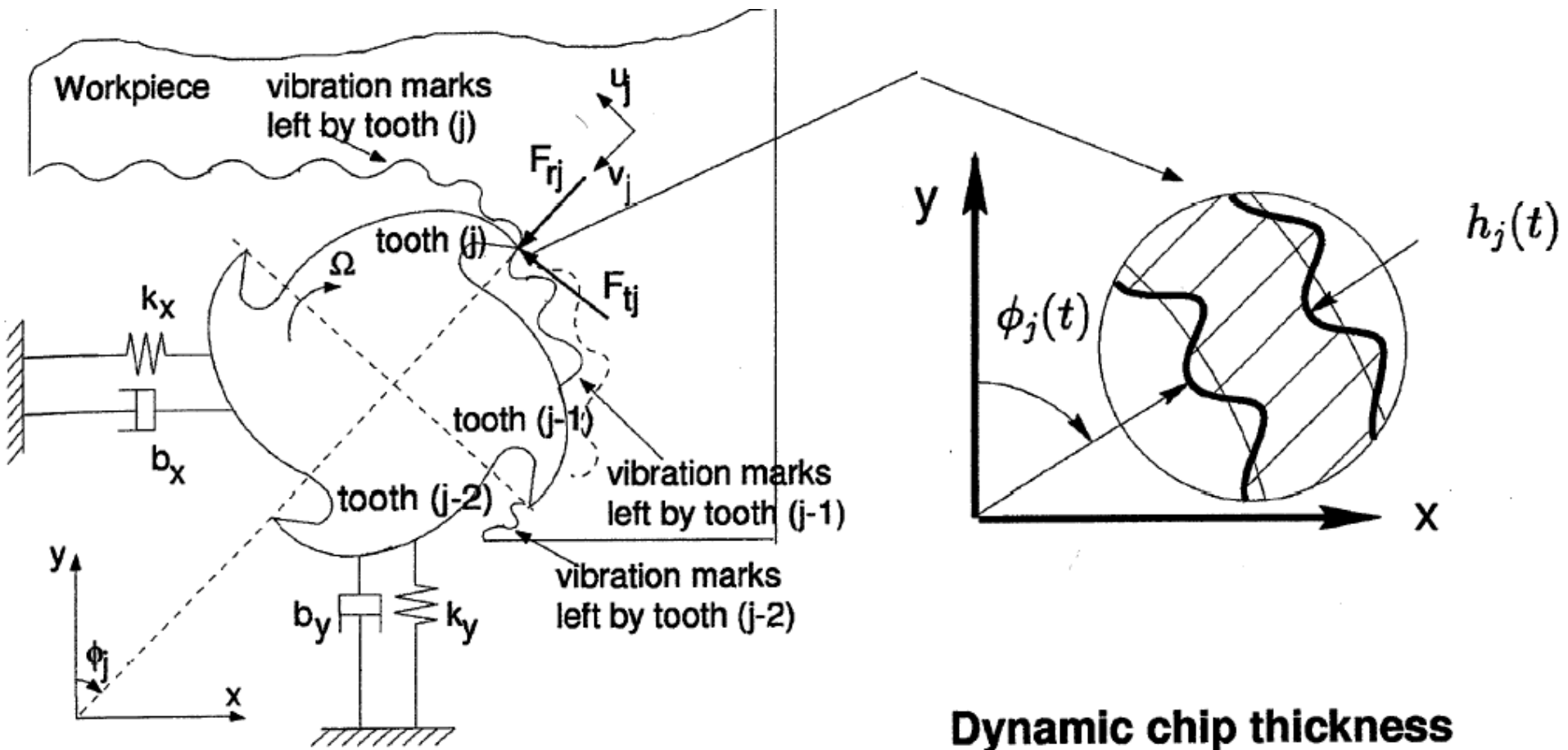
<u>Tool Steels <30 RC (4140, 4340, A2, D2, O1, S7, P2,H13)</u>				
SFM	Chipload Per Tooth			
<u>2, 3, & 4 Flute</u>	<u>up to .125 dia.</u>	<u>.125-.250 dia.</u>	<u>.250-.500 dia.</u>	<u>.500-1.0 dia.</u>
150-225	.0005-.0010	0008-.0020	0010-.0030	0020-.0040

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

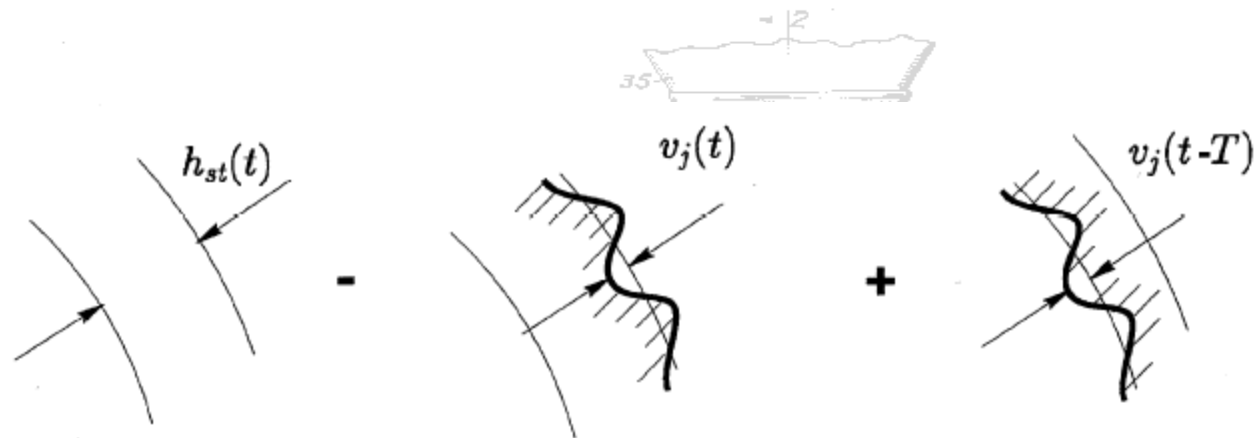
- <http://www.custompartnet.com/calculator/milling-speed-and-feed>



Vibration (chatter)



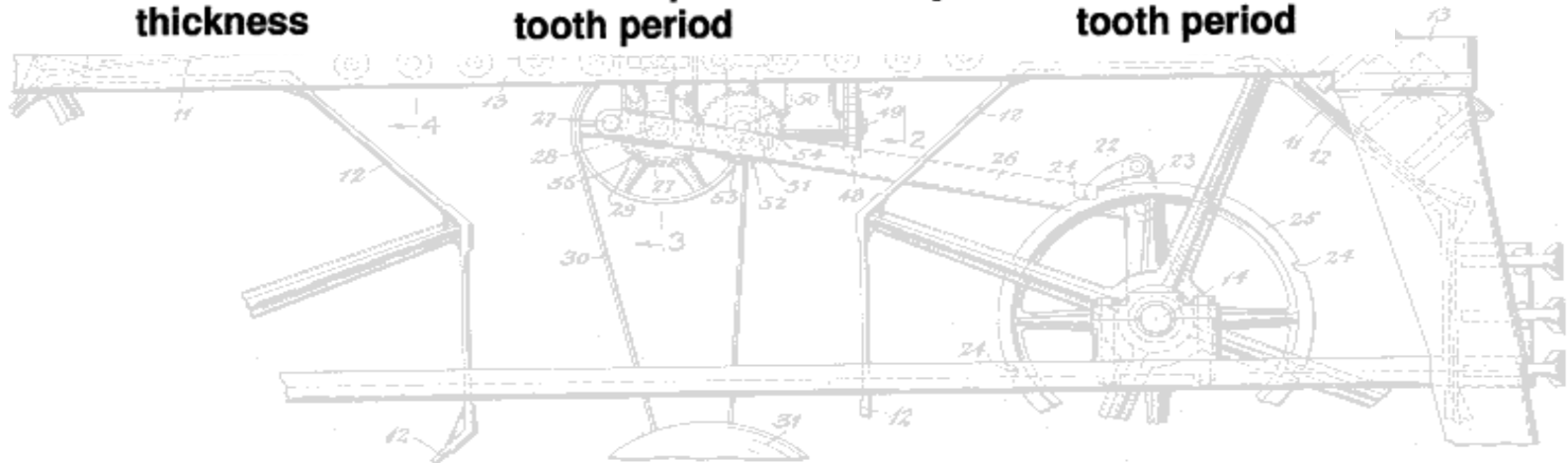
Vibration



Static chip
thickness

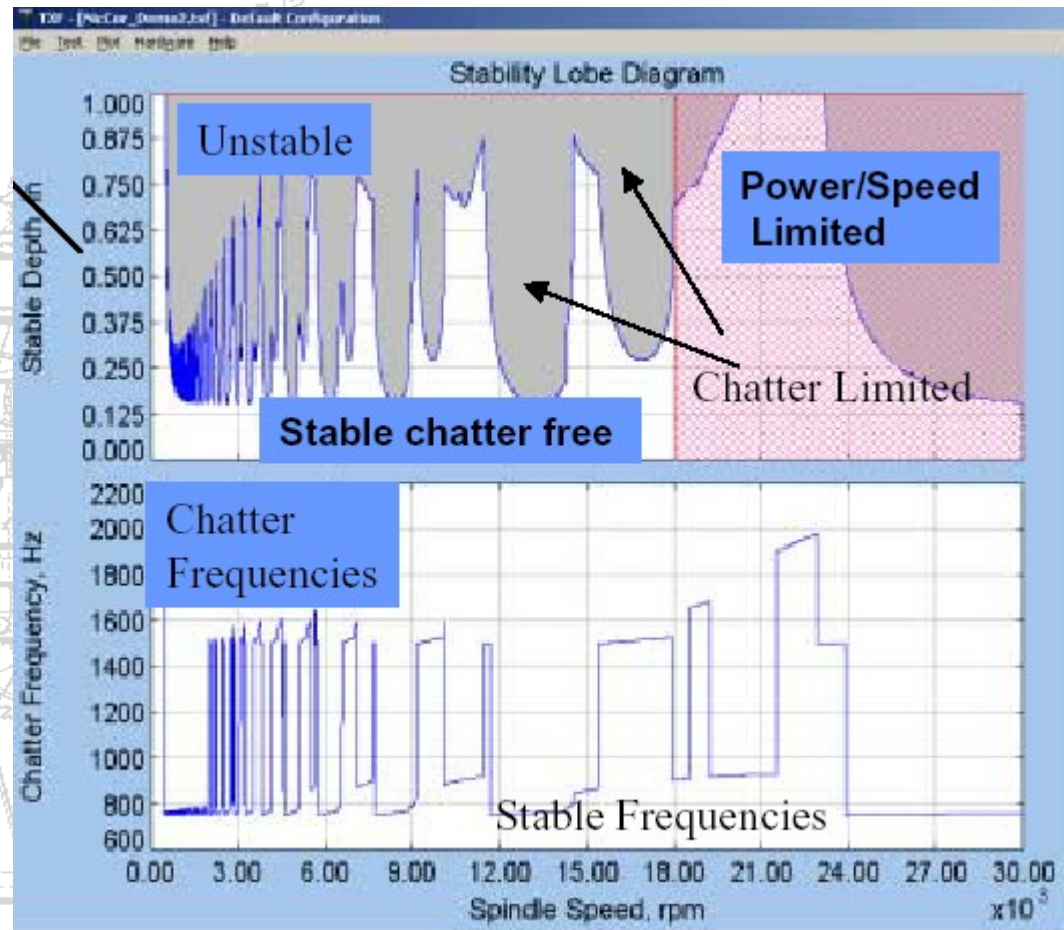
- Vibration at present
tooth period

+ Vibration at previous
tooth period



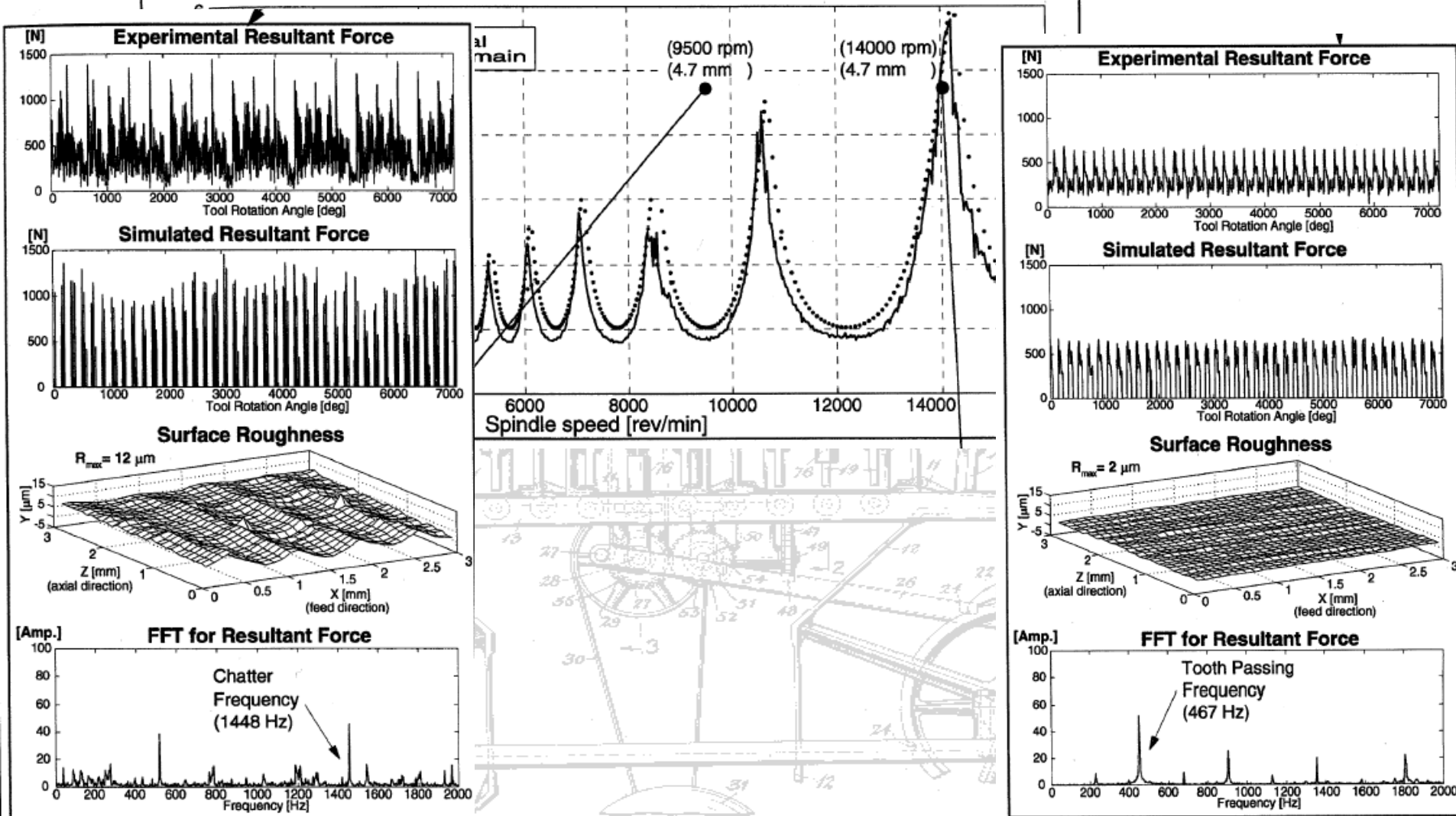
Vibration

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



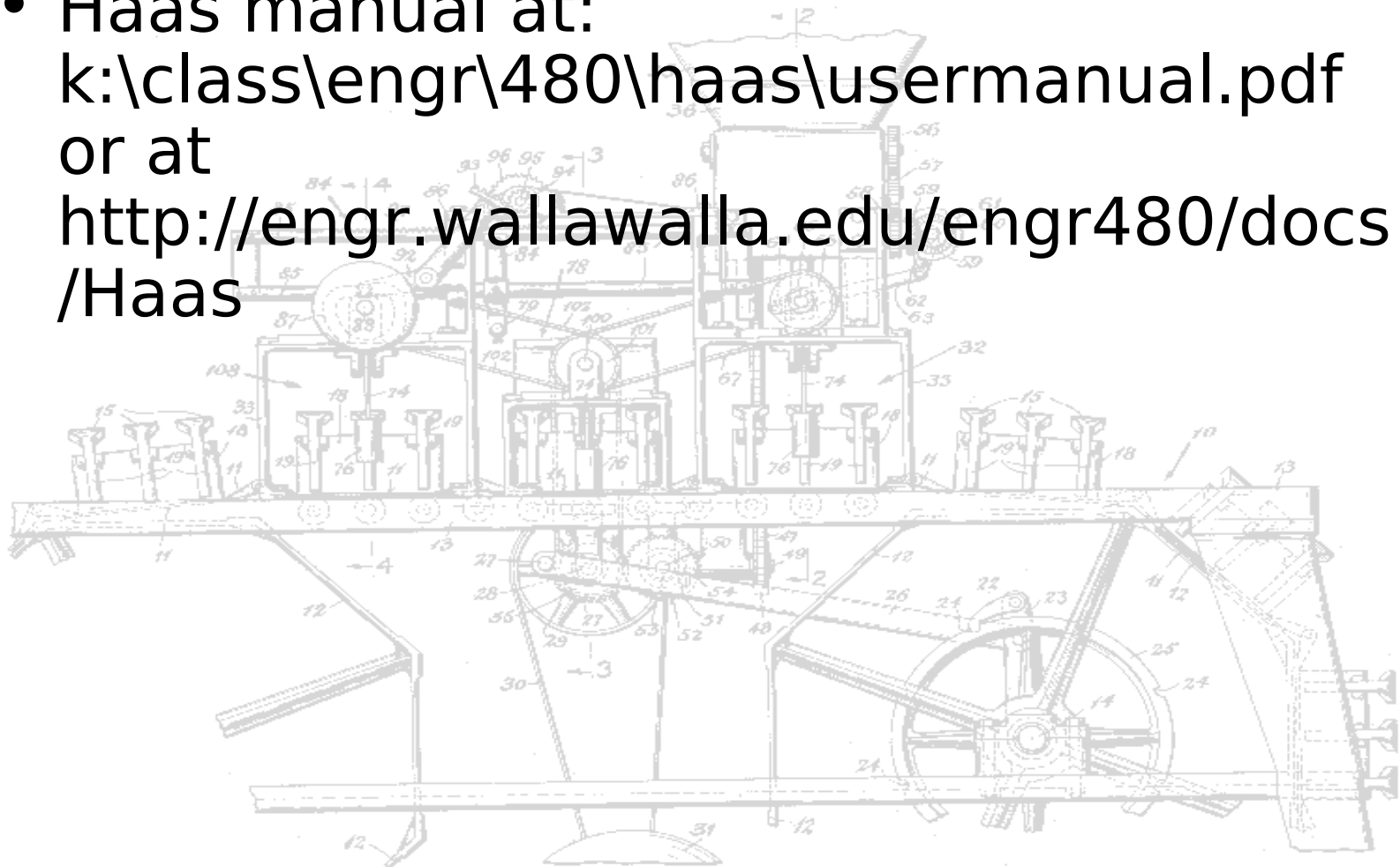
Vibration

Stability Lobes for Bull Nose Cutter and Al7075

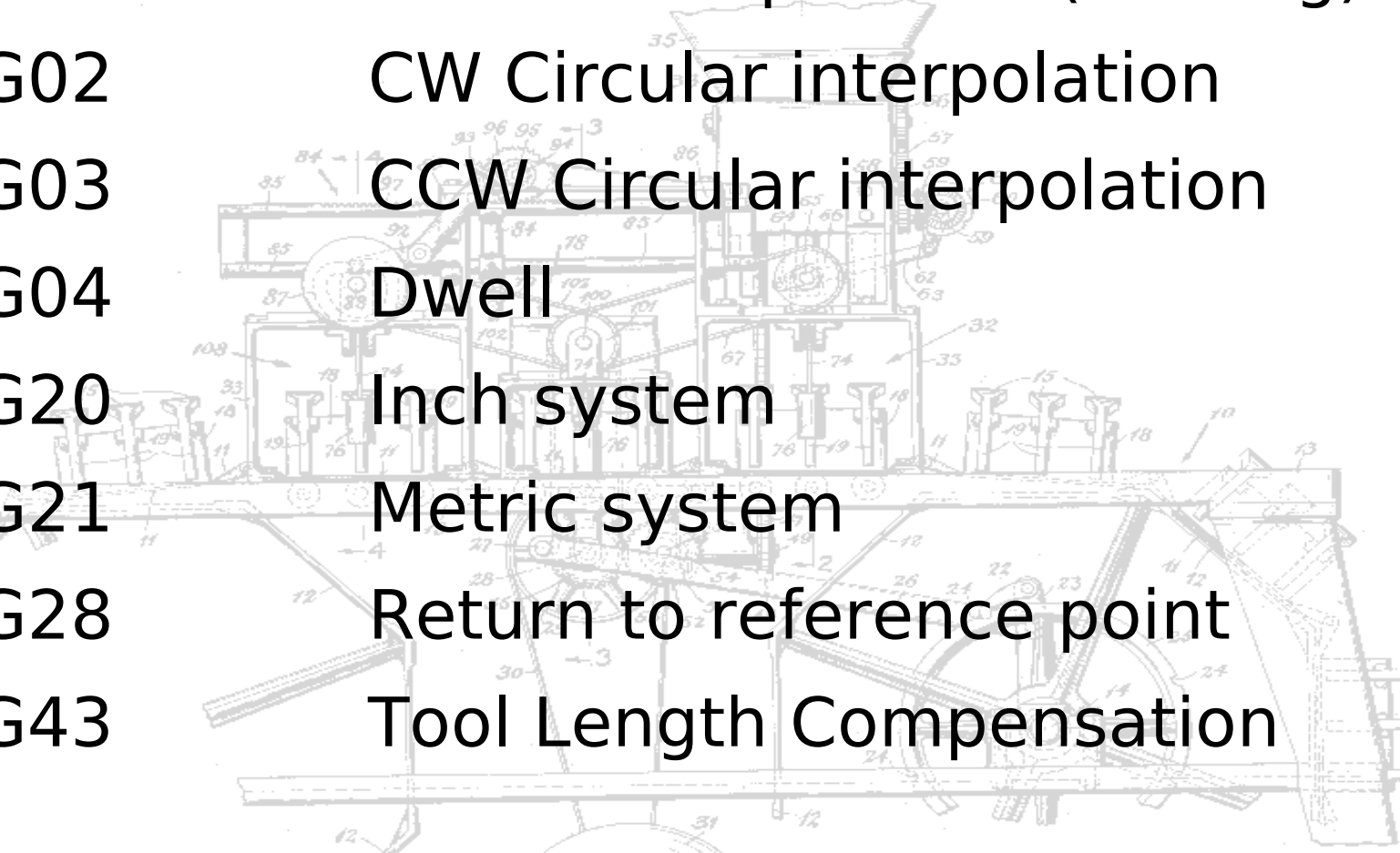


CNC Programming for Mill

- Example CNC program – drills four holes
- Haas manual at:
k:\class\enr\480\haas\usermanual.pdf
or at
<http://enr.wallawalla.edu/enr480/docs/Haas>



G-Codes for Milling



A detailed technical drawing of a milling machine, showing various components and their assembly. The drawing includes numerous numbered callouts (e.g., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200) pointing to specific parts of the machine, such as the table, saddle, knee, and spindle. The drawing is a cross-sectional view, showing the internal components and their arrangement.

G00	Rapid positioning
G01	Linear interpolation (feeding)
G02	CW Circular interpolation
G03	CCW Circular interpolation
G04	Dwell
G20	Inch system
G21	Metric system
G28	Return to reference point
G43	Tool Length Compensation

G-Codes for Milling

G54-G59 Select work coord system

G65 Macro call

G70 Bolt circle cycle

G81 Drill canned cycle

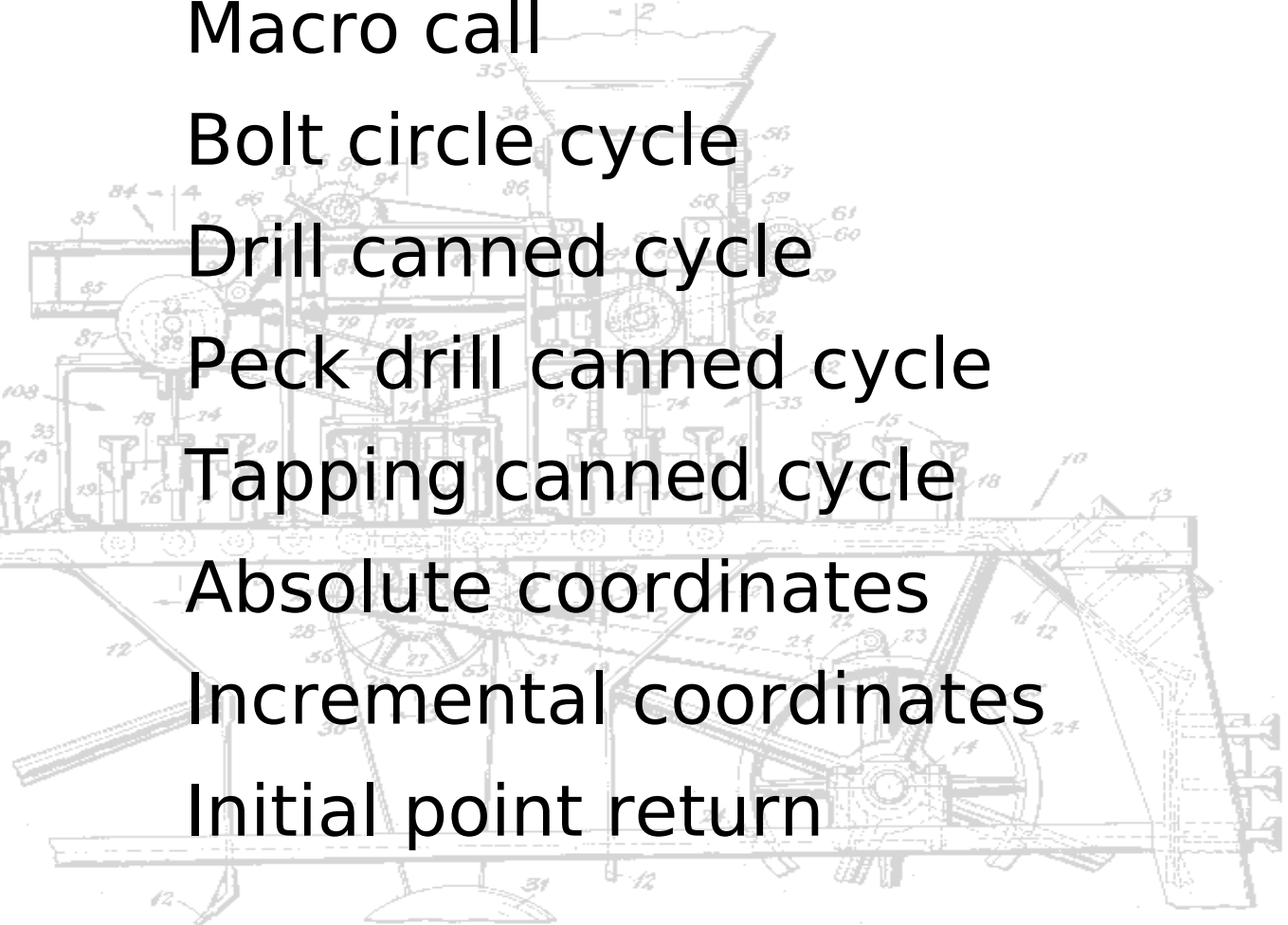
G83 Peck drill canned cycle

G84 Tapping canned cycle

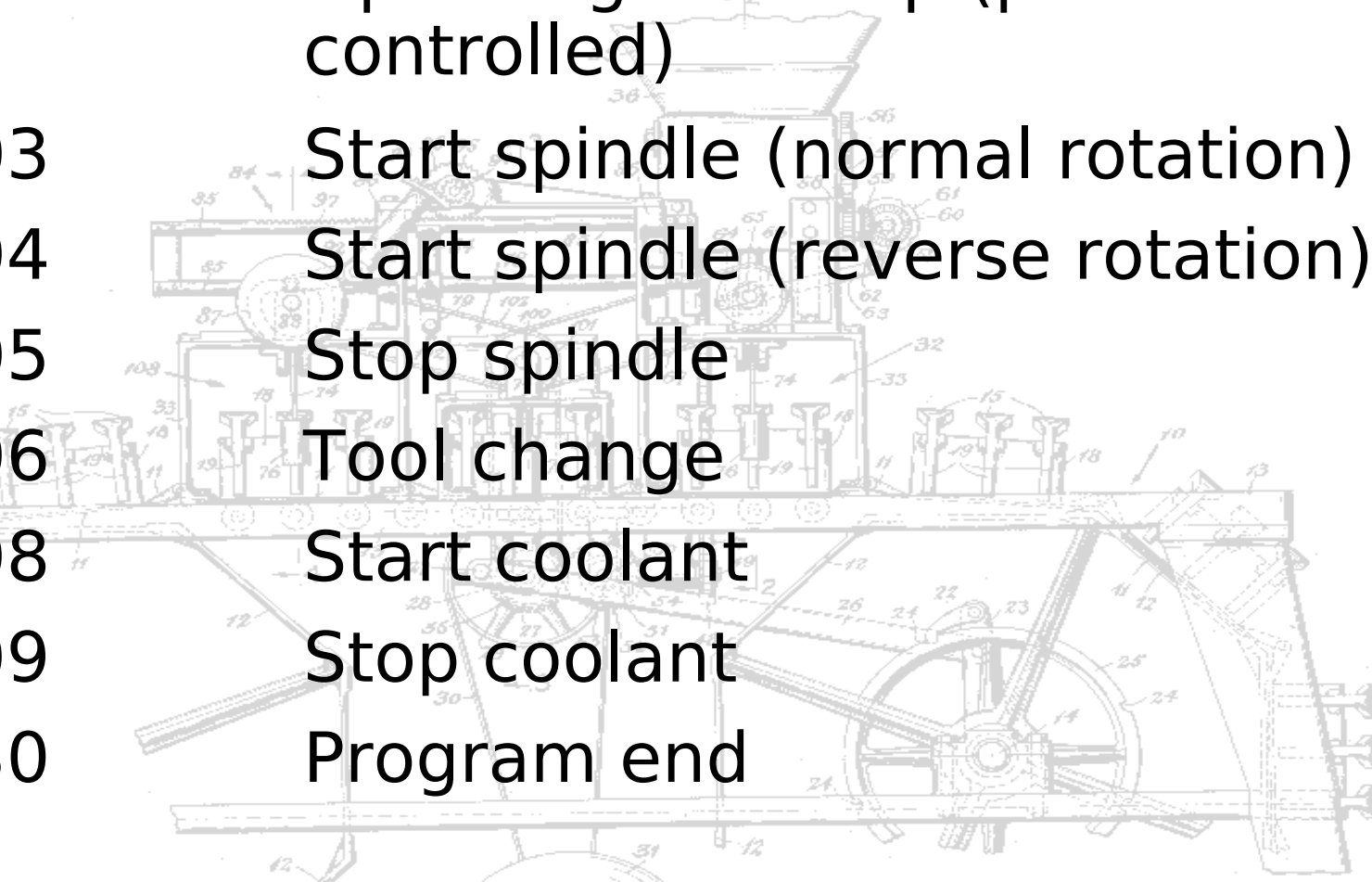
G90 Absolute coordinates

G91 Incremental coordinates

G98 Initial point return



M-Codes for Milling



A detailed technical drawing of a milling machine, showing various components such as the spindle, table, and feed mechanisms, with numerous numbered callouts (e.g., 1, 2, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100) indicating specific parts.

M00	Program Stop
M01	Opt. Program Stop (panel controlled)
M03	Start spindle (normal rotation)
M04	Start spindle (reverse rotation)
M05	Stop spindle
M06	Tool change
M08	Start coolant
M09	Stop coolant
M30	Program end

Example Program

% (DRILL 1/4IN HOLES)

O01001

(DRILL EXAMPLE - 2013-04-05)

(OP1- TOP SIDE)

(STOCK- 2IN X 2IN X 1/4IN)

(G54 ZERO- LEFT FRONT TOP)

G54

G00 G40 G90 G17 G20

(SPOT DRILL HOLES)

T7 M6

G43 H7

S2000 M3

M8

G0 X0.50 Y0.50 Z0.1

G81 Z-0.1 R0.1 F10.; (CANNED

T9 M6

G43 H9

S2000 M3

M8

G0 X0.50 Y0.50 Z0.1

G83 Z-0.35 Q0.1 R0.1

F10.0

X0.50 Y1.00

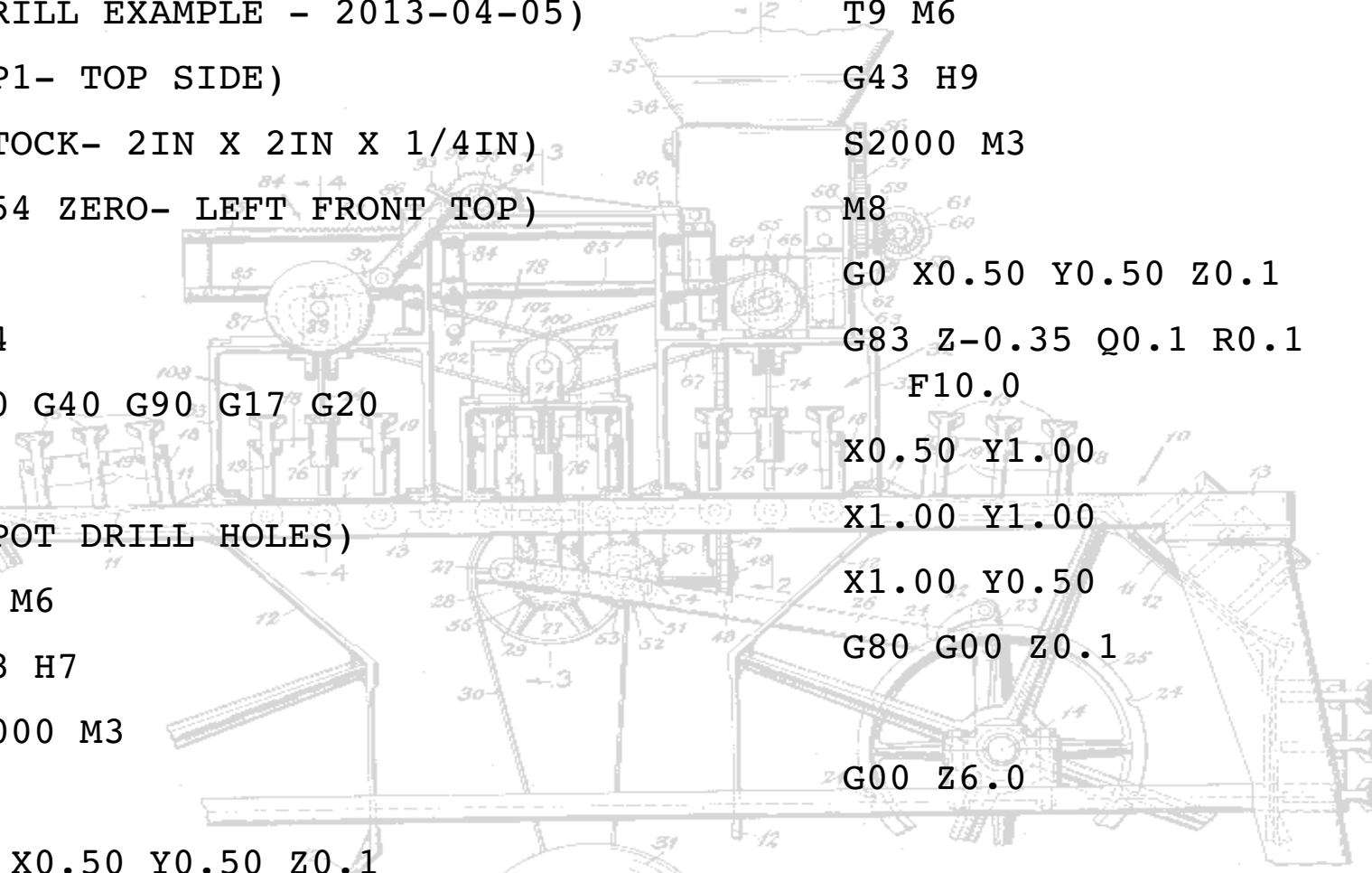
X1.00 Y1.00

X1.00 Y0.50

G80 G00 Z0.1

G00 Z6.0

M9

A technical drawing of a mechanical assembly, likely a machine tool or a complex bracket, is shown in the background. The drawing is a top-down view of a rectangular base with various internal structures, including what appears to be a central rotating mechanism or a complex linkage system. Numerous parts are labeled with numbers, such as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200. The drawing is a detailed line drawing showing the geometry and assembly of the parts.

Loading CNC Program

- Copy to K:\class\enegr\cnc as haascode.txt
- Press List Prog
- Type program number (O01234)
- Press RECV RS232



```
PROGRAM (LIST PROG) 000555 000000
000001 (p:\Pend\seq0001.ncl.1)
000002 (p:\Pend\step2.ncl.5)
000101 (p:\Senior Project\Prototype3\sa)
000102 (p:\Senior Project\Prototype3\sa)
000111 (p:\Senior Project\Prototype3\h2)
000112 (p:\Senior Project\Prototype3\h2)
000113 (p:\Senior Project\Prototype3\h2)
000200 (p:\Senior Project\Prototype3\ho)
000300 (p:\Senior Project\Prototype3\ho)
000314 (p:\Senior Project\Prototype3\h2)
000400 (p:\Senior Project\Prototype3\h2)
000500 (p:\Senior Project\Prototype3\ca)
000555
001027 (p:\Senior Project\Prototype3\h2)
001103 (p:\Pend\step3.ncl.7)
001117 (p:\cnc.ncl.2)
001238 (G83 Peck Drill, 2-Hole)
001557 (p:\cal.ncl.1)
002346 (C:\Documents and Settings\David)
004324 (C:\Documents and Settings\David)
005656 (p:\manu_lab\pcd2.ncl.2)
005768 (p:\manu_lab\platecdrill.ncl.2)
006968 (p:\Senior Project\Prototype3\sa)
006969 (p:\Senior Project\Prototype3\sa)
30 PROGRAMS 69% FREE (706812 BYTES)
ALL TO SEND, RECV, ERASE F1 TO DUP PROG
F2 DISK WR, F3 DISK RD, F4 DIR RD
RAPID 50%
```