Milling Machine Fundamentals

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Overview

- Safety
- Shop Etiquette
- Basic Terminology
- Before Machining
- Indicating
- Calculating Feeds and Speeds
- Machining
- Maintenance

Safety

- Respect the machines
- Common Sense
  - Wear safety glasses
  - Avoid loose clothing
  - Restrain long hair
  - Never wear gloves
  - Never wear shorts or sandals
  - Stay alert

Shop Etiquette

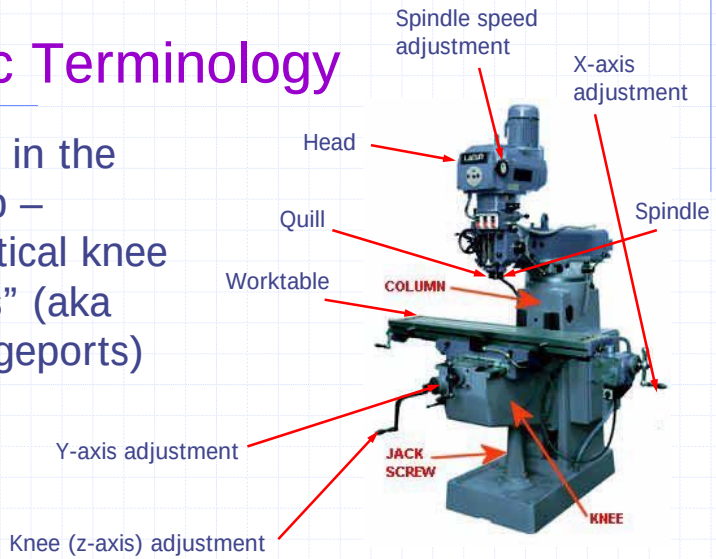
- Vehicle Projects Machine Shop
  - Clean up / Vacuum
  - Oil machinery
  - Leave notes when necessary
  - Report broken tools

Shop Etiquette

- COE Shop
  - ALWAYS leave machines cleaner!
  - Ask for help, if needed
  - Come prepared
    - Tooling list
    - Plan of action
    - Dimensioned drawings
  - Check out CNC machines in advance

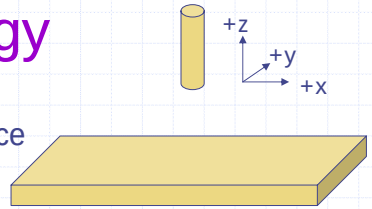
Basic Terminology

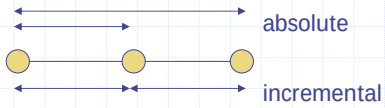
- Mills in the shop – "vertical knee mills" (aka Bridgeports)



Basic Terminology

- Coordinates
  - With respect to workpiece





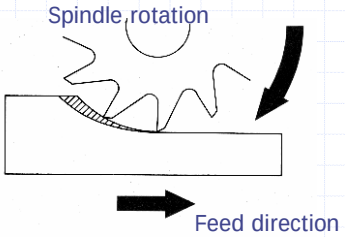
- Digital Readout (DRO)
  - Displays coordinates
  - Absolute or incremental, standard or metric

Basic Terminology

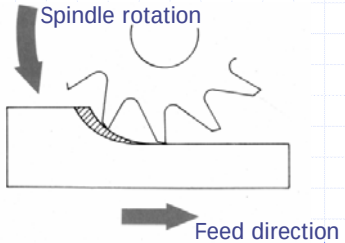
- Feeds and Speeds (F/S)
  - Spindle Speed (speed) [rpm]: Speed (rpm) that tool rotates
  - Feed Rate (feed) [in/tooth or in/rev]: Amount of lateral movement occurs during each rotation of the tool
  - Surface Speed [sfpm – surface feet per minute]: How fast edge of tool moves with respect to workpiece

Basic Terminology

- Cutting
  - Conventional (up) milling
    - For roughing cuts, or if workpiece cannot be positioned securely
    - On CNC mill, “tool right”

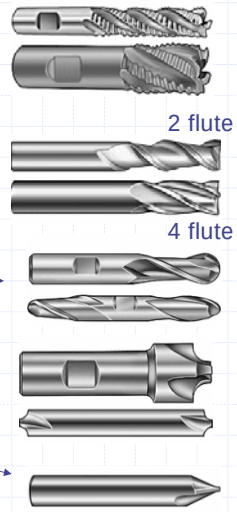


  - Climb (down) milling
    - For finishing cuts
    - On CNC mill, “tool left”



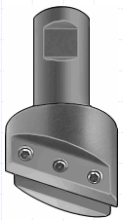
Basic Terminology

- Tooling
  - End mills
    - Rouging End Mill (aka Rougher)
    - Finishing End Mill (aka Finisher)
    - Ball End Mill
      - For internal radii
    - Corner Rounding End Mill
      - For external radii
    - Chamfer Mill
    - And, many, many more



Basic Terminology

- Tooling
  - Fly cutter



Basic Terminology

- Tooling
  - Center Drill

    - Keeps holes accurately positioned
  - Twist Drill

  - Reamer

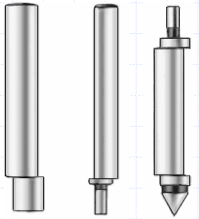
    - Usually pre-drill to 1/64th under
  - Adjustable Boring Bar

Basic Terminology

- Tooling
  - Collets
    - End mill goes into collet, and then into spindle
  - Jacobs Chuck
    - Mainly for drill bits
    - Usually not as accurate as a collet
  - Mill wrench

Basic Terminology

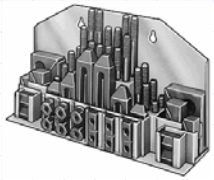
- Indicating
  - Dial indicator
  - Test indicator
  - Edge finder

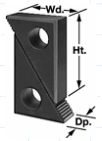


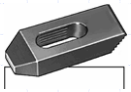
Pointed edge finder – for locating a hole

Basic Terminology

- Fixturing
  - Vise
  - Clamping Kit
    - T-slot nuts
    - Flange nuts
    - Coupling nuts
    - Step blocks
    - Step clamps
  - Parallel Bars

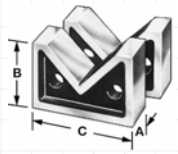


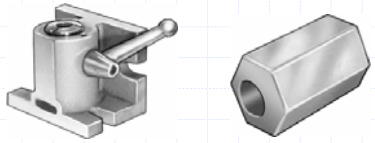


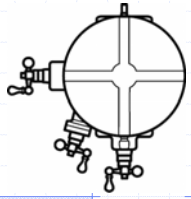


Basic Terminology

- Fixturing
  - V-blocks
  - Collet blocks
  - Rotary table

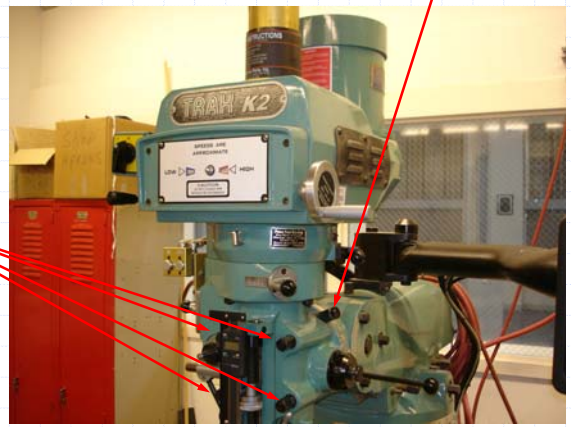






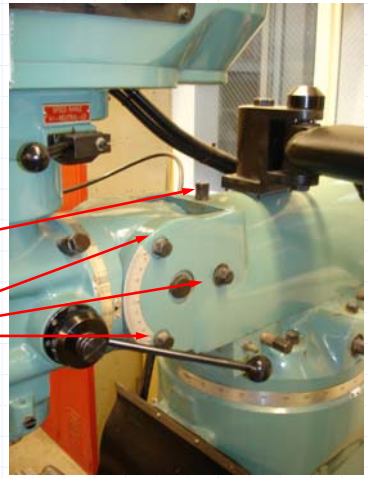
Before Machining

- Tramming the head
  - X-axis



Before Machining

- Tramming the head
  - Y-axis



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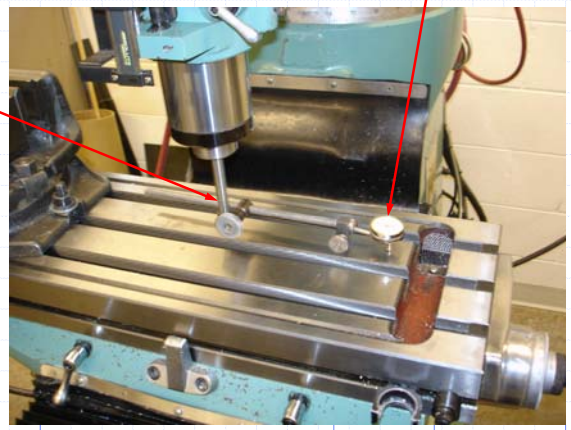

Before Machining

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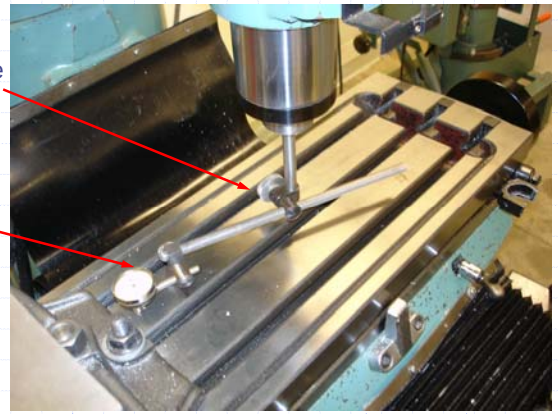


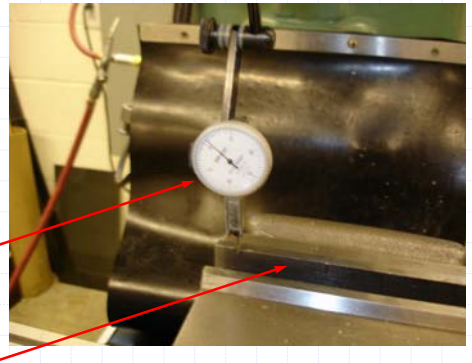
Before Machining

- Tramming the head

1. Preload dial indicator against table by raising knee
2. Check height on either end of circle defined by fixture (put mill in neutral)
3. Loosen locking screws (not completely)
4. Make adjustment (beware of backlash and split the difference)

Before Machining

- Squaring the vise
  - Similar to tramming the head
  - Try to avoid overcorrection: approach the goal slowly



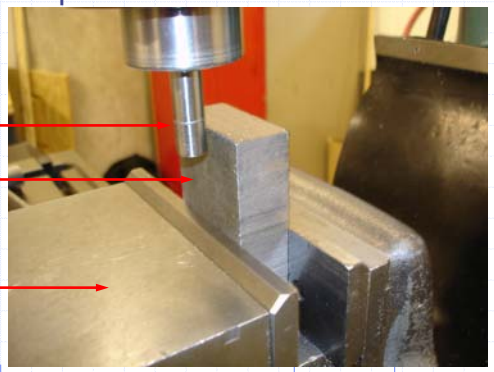
Before Machining

- Squaring the vise

1. Start at one end and zero indicator
2. Move to other end, read indicator
3. Loosen vise clamping nuts slightly
4. Tap with mill wrench (split the difference)
5. Tighten vise clamping nuts and repeat procedure

Indicating

- Using an edge finder
  - Useful for locating a straight edge
  - Remember to compensate for tool radius



Indicating

- Using an edge finder

Indicating

- Using an edge finder

1. Insert edge finder/collet into spindle
2. Turn on mill (avoid high speeds – stick with 1600 or below)
3. Approach edge of part
4. When edge finder is visibly concentric, you have found the edge
5. If edge finder makes noise and comes off center, you've gone too far
6. Remember – You must compensate for the tool radius when setting the DRO!

Indicating

- Using a dial (test) indicator
  - Useful for finding the axis of a cylindrical surface

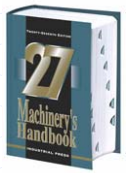
Indicating

- Using a dial (test) indicator

1. Move stock so that axis is almost directly under the spindle
2. Ensure that indicator never loses contact with stock or bottoms out (this involves adjusting the indicator screws)
3. Put mill in neutral and rotate spindle around part
4. Move x and y axes so that indicator has consistent reading around part

Calculating Feeds and Speeds

- Machinery's Handbook
  - Can use formulas from here to calculate proper spindle speed
- Chart
  - Use this if you don't feel like doing any math
- Calculate feed (for CNCs) using formulas from Machinery's Handbook
- Proper F/S makes a big difference!



Calculating Feeds and Speeds

Sp. Sfpm	40	50	60	70	80	90	100	120	140	160	180	200	225	250	275	300	325
Dia. in.	Revolutions per minute																
1/4	611	764	917	1070	1222	1376	1528	1834	2139	2445	2750	3056	3438	3820	4202	4202	4966
5/16	489	611	733	856	978	1100	1222	1466	1711	1955	2200	2444	2750	3056	3362	3362	3973
3/8	408	509	611	713	815	916	1018	1222	1425	1629	1832	2036	2292	2546	2801	2801	3310
7/16	349	437	524	611	699	786	874	1049	1224	1398	1573	1748	1964	2182	2401	2401	2837
1/2	306	382	459	535	611	688	764	917	1070	1222	1375	1528	1719	1910	2101	2101	2483
9/16	272	340	407	475	543	611	679	813	951	1086	1222	1358	1528	1698	1868	1868	2207
5/8	245	306	367	428	489	552	612	736	857	979	1102	1224	1375	1528	1681	1681	1987
11/16	222	273	333	389	444	500	555	666	770	888	999	1101	1250	1389	1528	1528	1806
3/4	203	254	306	357	408	458	508	610	711	813	914	1016	1146	1273	1401	1401	1655
13/16	190	237	284	332	379	427	474	569	664	758	853	948	1058	1175	1293	1293	1528
7/8	175	219	262	306	349	392	438	526	613	701	788	876	982	1091	1200	1200	1419
15/16	163	204	244	285	326	366	407	488	570	651	733	814	917	1019	1120	1120	1324
1	153	191	229	267	306	344	382	458	535	611	688	764	859	955	1050	1050	1241
1 1/16	144	180	215	251	287	323	359	431	503	575	646	718	809	899	988	988	1168
1 1/8	136	170	204	238	272	306	340	408	476	544	612	680	764	849	933	933	1103
1 3/16	129	161	193	225	258	290	322	386	451	515	580	644	724	804	884	884	1045
1 1/4	123	153	183	214	245	274	306	367	428	490	551	612	687	764	840	840	993
1 5/16	116	146	175	204	233	262	291	349	407	466	524	582	654	727	800	800	946
1 3/8	111	139	167	195	222	250	278	334	389	445	500	556	625	694	764	764	903
1 7/16	106	133	159	186	212	239	265	318	371	424	477	530	598	664	730	730	863
1 1/2	102	127	153	178	204	230	254	305	356	406	457	508	573	636	700	700	827
1 9/16	97.6	122	146	171	195	220	244	293	342	390	439	488	550	611	672	672	794
1 5/8	93.9	117	141	165	188	212	234	281	328	374	421	468	528	587	646	646	764
1 11/16	90.4	113	136	158	181	203	226	271	316	362	407	452	509	566	622	622	735
1 3/4	87.3	109	131	153	175	196	218	262	305	349	392	436	474	527	579	579	685
1 7/8	81.5	102	122	143	163	184	204	244	286	326	367	408	443	493	542	542	640
2	76.4	95.5	115	134	153	172	191	229	267	306	344	382	429	477	525	525	620
2 1/8	72	90	108	126	144	162	180	216	252	288	324	360	404	449	494	494	584
2 1/4	68	85.5	102	119	136	153	170	204	238	272	306	340	382	424	468	468	551
2 3/8	64.4	80.5	96.6	113	129	145	161	193	225	258	290	322	362	402	442	442	522
2 1/2	61.2	76.3	91.7	107	122	138	153	184	213	245	275	306	343	382	420	420	496
2 5/8	58	72.5	87	102	116	131	145	174	203	232	261	290	327	363	400	400	472
2 3/4	55.6	69.5	83.4	97.2	111	125	139	167	195	222	250	278	312	347	381	381	451
2 7/8	52.8	66	79.2	92.4	106	119	132	158	185	211	238	264	299	332	365	365	431

Steel (tough)	Mild steel	Cast iron (medium)	Bronzes	Brass (soft)	Aluminum
15 - 18	30-38	18-24	24-45	45-60	75-105
50 - 60	100-125	60-80	80-150	150-200	250-350

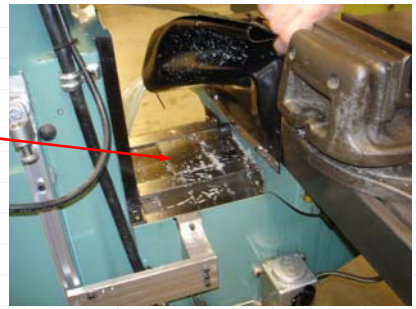
Machining

- Always lock axes for straight cuts (unless on a CNC)
- Make sure nothing is tangled in cutter
- Always know locations of stop and E-stop buttons

Maintenance

- Clean up
  - Vacuum and sweep chips
  - Limit use of air hose

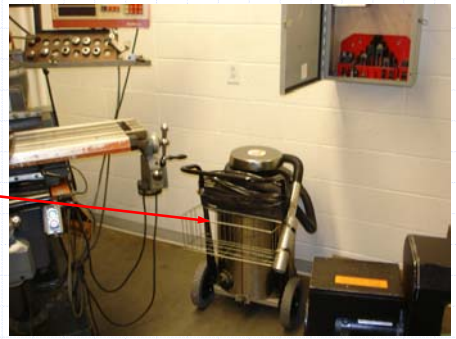
Always wipe up this area (behind the worktable)



Maintenance

- Clean up

Vacuum (aka R2D2)



Maintenance

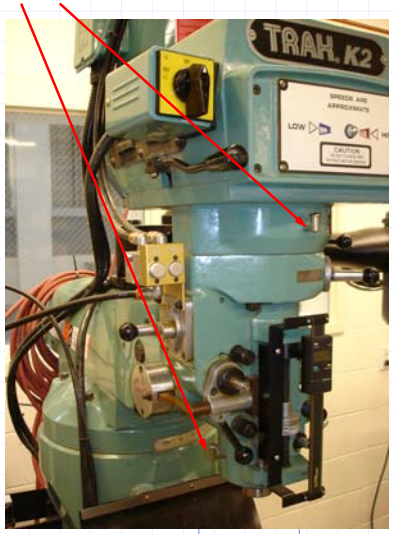
- Oil machines
  - Ways: 1-2 pumps on the way oiler
  - Spindle bearings: Fill after each use
    - Note: COE shop staff does this weekly, but it's your responsibility in the vehicle projects shop
    - DO NOT use way oil for the spindle bearings!
  - Worktable and vise: wipe down with oil after each use
  - Parts: Apply fogging oil or WD-40 to prevent corrosion

Maintenance

- Oil machines

Oil ways here (pump)

Oil spindle bearings here



Maintenance

- Oil machines

Way oil

Rag

Questions

Conclusion

- Now, make some parts and learn to use the CNC mills in the COE shop
  - Ask someone who knows, or check out the user manual
- Never be afraid to ask for help
- Experience is the best way to learn