

# Machine Shop Overview

Prof. Steven S. Saliterman

Introductory Medical Device Prototyping

Department of Biomedical Engineering, University of Minnesota

<http://saliterman.umn.edu/>

# Safety

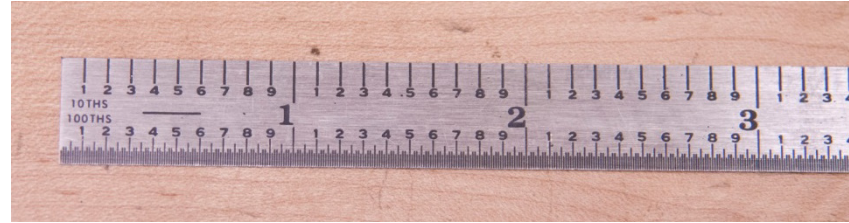


- Always wear OSHA approved eye and ear protection.
- Familiarize yourself with the shop first aid kit, location of telephone, and emergency phone numbers.

# Topics

- ▶ Remember safety first!
- ▶ “Machinist Tool Chest”
- ▶ Power Tools
- ▶ Workpiece Layout
- ▶ Mill
- ▶ Lathe
- ▶ Lubricants / Coolants
- ▶ Cleanup

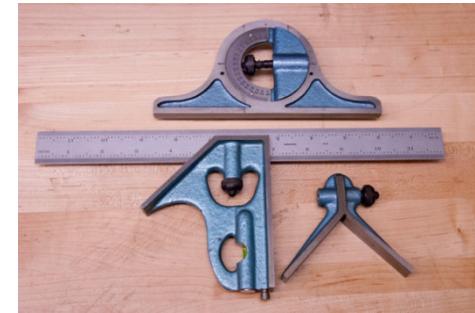
# Machinist Tool Chest



Ruler – tenths and hundredths

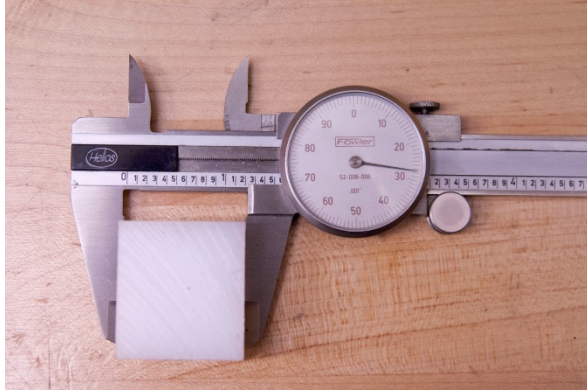


Machinist square

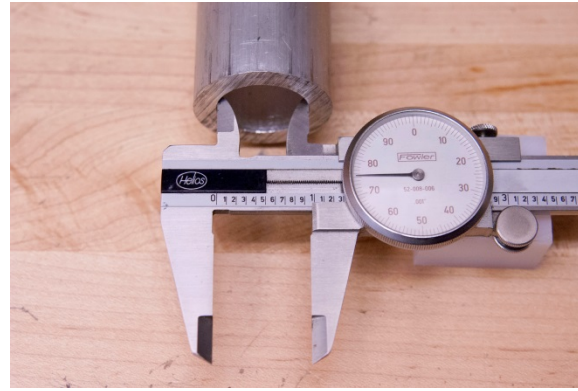


Combination square

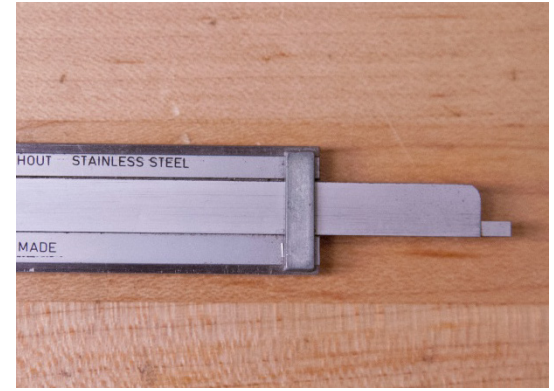
# Calipers...



Outside measurement to .001"



Inside measurement



Depth measurement



Digital caliper

# Power Tools



Vertical Band Saw



Floor Drill Press



Bench Drill Press

# *Belt/Disk Sander...*



Belt Sander

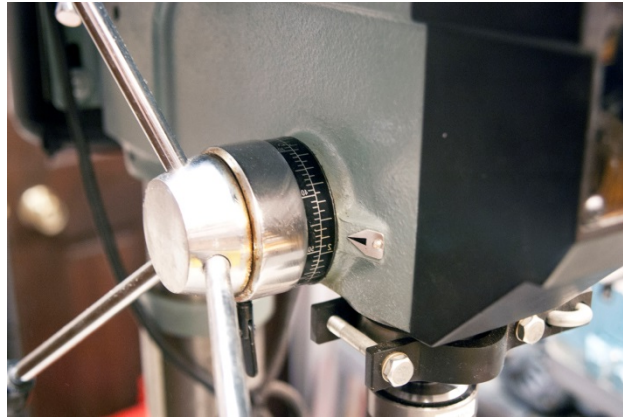


Disk Sander

# *Drill Press Features...*



Drill, spindle & chuck.



Hand feed and depth adjustment.



Upper table height adjustment on column.



# Drill Bits...



English fractional, letter and number set.



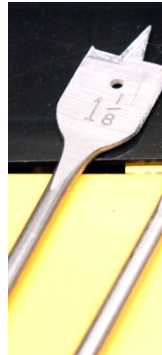
Reduced shank or "Deming" drill set.



Step Drills for Larger Holes

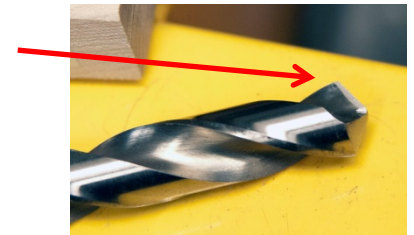


Spotting/center drills.



Spade bit for wood.

Note lip ground flat.



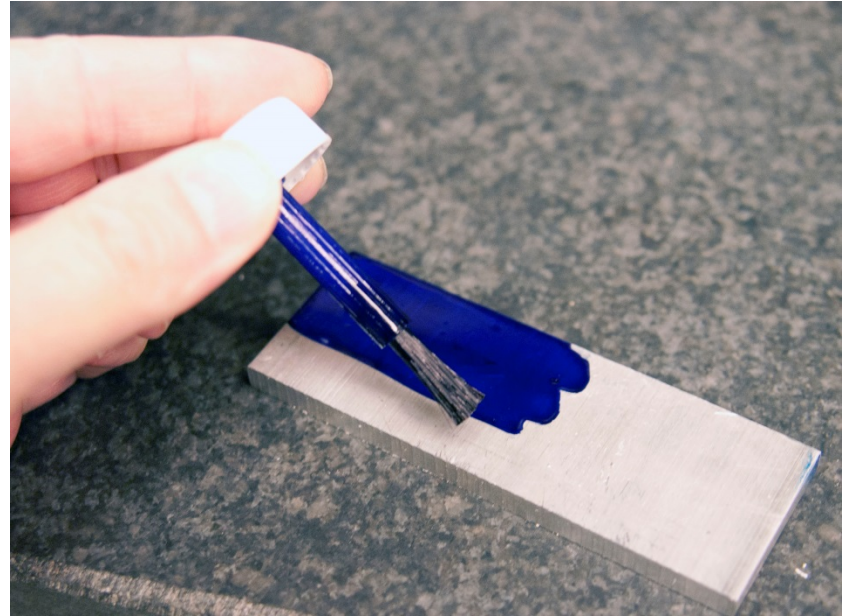
Drill bits for Plexiglas and polycarbonate.

# *Drill Vise, and Clamp...*



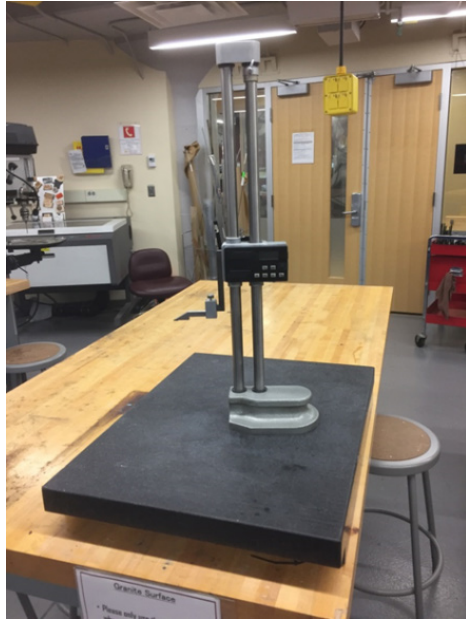
Hold vise firmly, or secure vise with clamp for larger drill bits (generally if  $> \frac{1}{4}$ " diam.) to prevent vise from moving.

# Workpiece Layout



Apply Dykem or equivalent over area holes are to be drilled. Polymers are tricky, as the Dykem may be hard to remove. Pre-test.

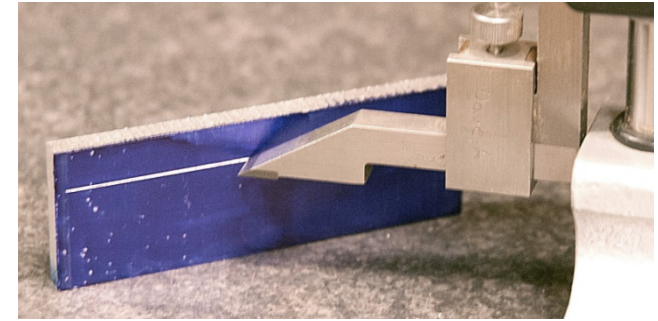
# Using a Height Gage...



Height Gage & Granite Surface

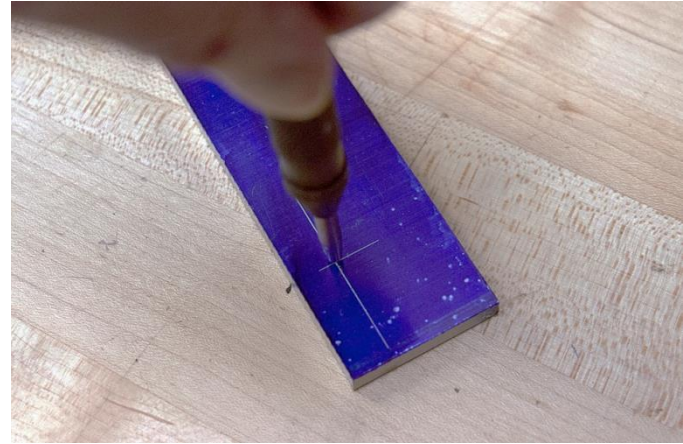


Be sure to zero gage by leveling on the granite surface before dialing desired height.



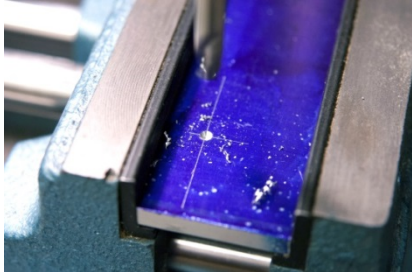
Hold your workpiece down, and move the height gage to scribe the line.

# *Spring-Loaded Center-Punch...*

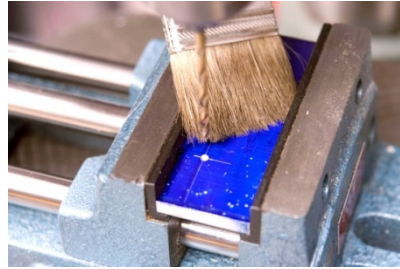


Locate the center visually, align punch and push straight down.

# *Center and Hole Drilling...*



Make a small hole made with the spotting drill bit.



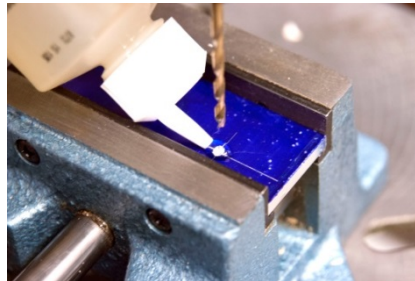
Clear away chips with a brush.



Select the #29 drill for an 8-32 tap (per the chart).



Replace spotting drill with #29 drill bit. Remove the key!

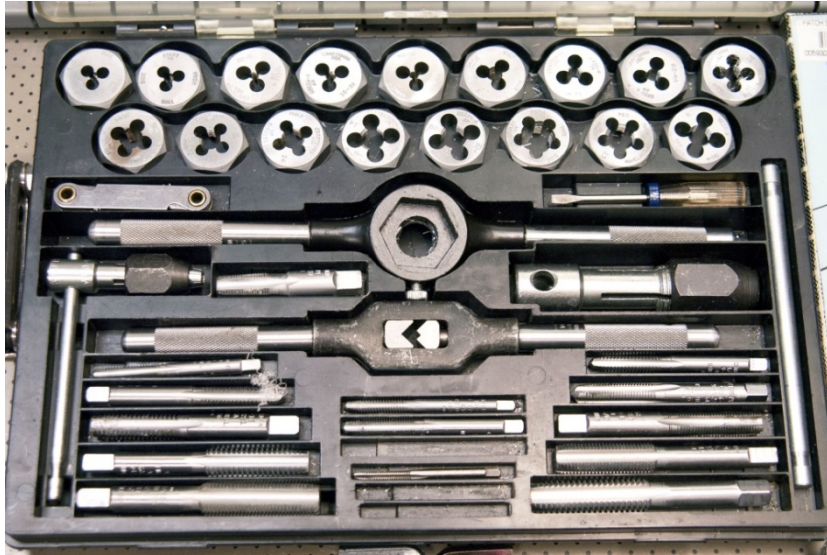


Place a drop of lubricant over the starter hole.



Drill - take short pecks - lifting drill every so often to release chips.

# Tap & Die Set...



- Taps, dies, thread gage, screwdriver, tap holders and die holders. English & metric sets.
- Pick your bolt thread first, select the drill size, drill and tap.

## TAP DRILLS

American Std. and Unified Form Threads Tap Drill Size is approximately 75% Thread						METRIC THREADS					
THREAD NOMINAL SIZE	Pitch Series	DRILL		THREAD NOMINAL SIZE	Pitch Series	DRILL		French and International Standard (D.I.N.)			
		SIZE	DECIMAL			SIZE	DECIMAL	TAP SIZE	STD.	DRILL STD. D.C.	
0-80	NF	3/64	.047	3/16-12	NC-UNC	3/64	.484	2.5-45	French	3/64	.0781
1-64	NC	53	.060	18	NF-UNF	3/64	.516	2.6-45	D.I.N.	#45	.082
72	NF	53	.060	5/16-11	NC-UNC	1/32	.531	3-50	D.I.N.	#39	.0995
2-56	NC	50	.070	18	NF-UNF	3/64	.578	.60	French	3/2	.0937
64	NF	50	.070	3/8-10	NC-UNC	1/32	.656	.75	Optional	#43	.089
3-48	NC	47	.079	16	NF-UNF	1/16	.688	3.5-60	French & D.I.N.	#33	.113
56	NF	45	.082	3/8-9	NC-UNC	1/16	.766	4-70	D.I.N.	#30	.1285
4-40	NC-UNC	43	.089	14	NF-UNF	1/16	.813	-.75	French	1/4	.125
48	NF	42	.094	1 - 8	NC-UNC	3/8	.875	4.5-75	French & D.I.N.	#26	.147
5-40	NC	38	.102	12	NF-UNF	5/64	.922	5-75	Optional	#19	.166
44	NF	37	.104	1 1/2- 7	NC-UNC	4/64	.984	.80	D.I.N.	#19	.166
6-32	NC-UNC	36	.107	12	NF-UNF	1/32	1.047	.90	French	#20	.161
40	NF	33	.113	1 1/2- 7	NC-UNC	1/16	1.109	1.00	Optional	5/2	.156
8-32	NC-UNC	29	.136	12	NF-UNF	1/16	1.172	5.5-75	Optional	3/4	.1875
36	NF	29	.136	1 3/4- 6	NC-UNC	1/32	1.219	.90	French & D.I.N.	#14	.182
10-24	NC-UNC	25	.150	12	NF-UNF	1/16	1.297	6-1.00	French & D.I.N.	#9	.196
32	NF-UNF	21	.159	1 1/2- 6	NC-UNC	1/16	1.344	1.25	Optional	3/4	.1875
12-24	NC	16	.177	2	4 1/2	NC-UNC	1 3/32	7-1.00	French & D.I.N.	1 1/4	.234
28	NF	14	.182	1 3/4- 5	NC-UNC	1/16	1.563	1.25	Optional	#1	.228
1/4-20	NC-UNC	7	.201	2 1/2- 4 1/2	NC-UNC	2/16	2.031	8-1.00	French	1	.277
28	NF-UNF	3	.213	2 1/2- 4	NC-UNC	2/16	2.250	1.25	D.I.N.	1 1/4	.265
3/8-18	NC-UNC	F	.257	2 3/4- 4	NC-UNC	2 1/16	2.500	9-1.00	French	3/4	.3125
24	NF-UNF	I	.272	3- 4	NC-UNC	2 3/16	2.750	1.25	D.I.N.	3/4	.3125
3/8-16	NC-UNC	Q	.313	3 1/4- 4	NC-UNC	3	3.000	10-1.00	Optional	3/4	.359
24	NF-UNF	Q	.332	3 1/2- 4	NC-UNC	3 1/16	3.250	1.25	Optional	1 1/2	.3437
7/16-14	NC-UNC	U	.368	4 - 4	NC-UNC	3 3/16	3.500	1.50	French & D.I.N.	R	.339
20	NF-UNF	2 1/4	.391					11-1.50	D.I.N.	3/4	.375
1/2-13	NC-UNC	2 3/4	.422					12-1.25	Optional	3/4	.4375
20	NF-UNF	2 3/4	.453					1.50	French	1 1/2	.406
								1.75	D.I.N.	1 1/2	.406
								13-1.50	Optional	2 1/4	.453
								1.75	Optional	2 1/4	.453
								2.00	Optional	3/16	.4375
								14-1.25	Optional	3/16	.5156
								1.75	Optional	1/2	.500
								2.00	French & D.I.N.	1 1/2	.4687
								15-1.75	Optional	1 1/2	.531
								2.00	Optional	3/4	.5156
								16-2.00	French & D.I.N.	3/4	.5468
								17-2.00	Optional	1 1/2	.5937
								18-1.50	Optional	2 1/2	.656

DECIMAL EQUIVALENTS OF LETTER SIZE DRILLS					
Letter	Inches	Letter	Inches	Letter	Inches
A	0.234	J	0.277	S	0.348
B	0.238	K	0.281	T	0.358
C	0.242	L	0.290	U	0.368
D	0.246	M	0.295	V	0.377
E	0.250	N	0.302	W	0.386
F	0.257	O	0.316	X	0.397
G	0.261	P	0.323	Y	0.404
H	0.266	Q	0.332	Z	0.413
I	0.272	R	0.339		

Sold by SEARS, ROEBUCK AND CO., Chicago, IL 60684 U.S.A.

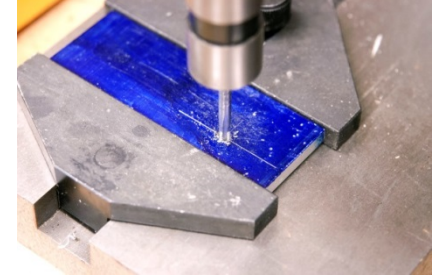
# *Tapping an 8-32 Hole...*



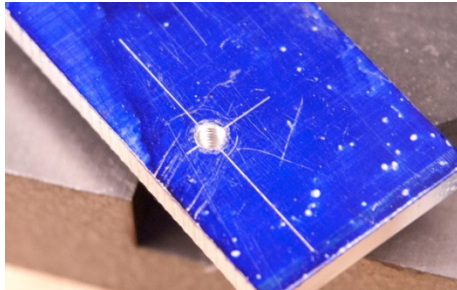
Select the 8-32 tap.



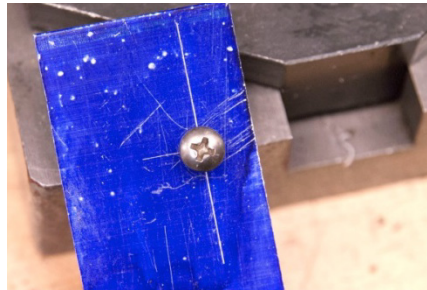
Place and tighten into #8 adaptor,  
or a hand tap holder.



Rotate one turn CW/quarter turn  
CCW until well through the work.



Lift gently while rotating CCW  
to remove tap.



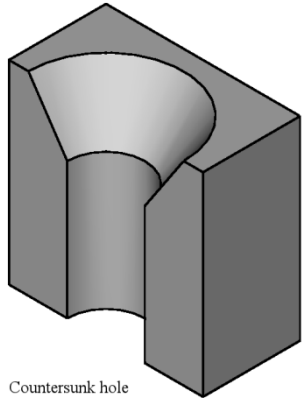
Test by screwing in an 8-32 bolt.



Clean with Dykem Cleaner.  
Wear a glove!



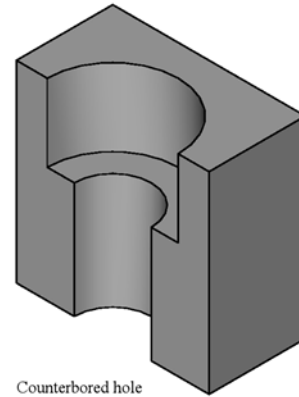
# *Countersinking & Counterboring...*



Countersunk hole



Countersink



Counterbored hole



Counterbore

# Milling

- ▶ Mill features.
- ▶ Collets
- ▶ Aligning the vise.
- ▶ Securing the work piece.
- ▶ Using an edge-finder.
- ▶ Facing a surface.
- ▶ Edge-rounding



# End Mills...



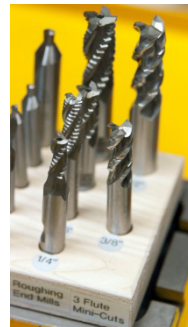
Fractional End Mills – 2 Flute Center Cutting and 4 Flute



Ball-Nose (Round) End Mills



45° Chamfer



Roughing

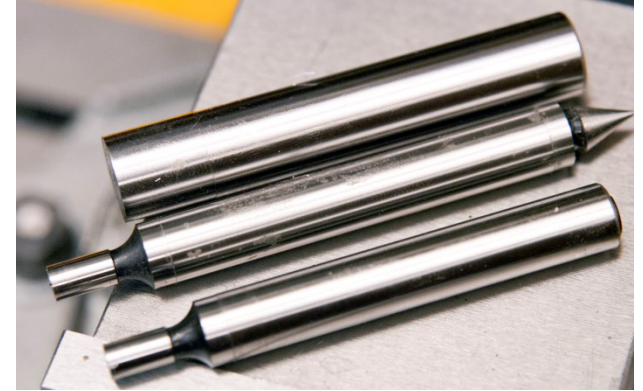


Finishing



Corner Rounding (Radius) & Taper

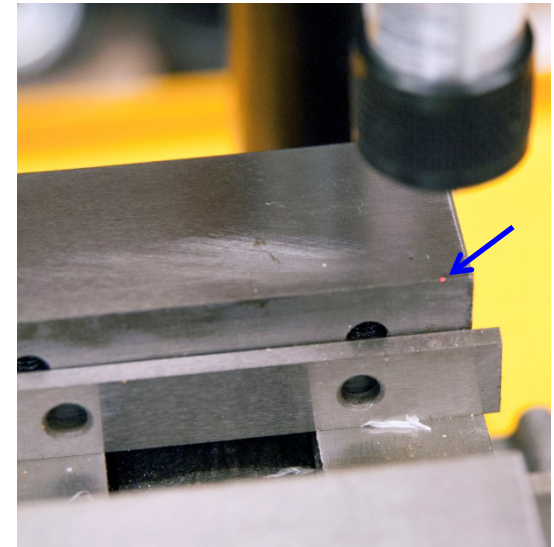
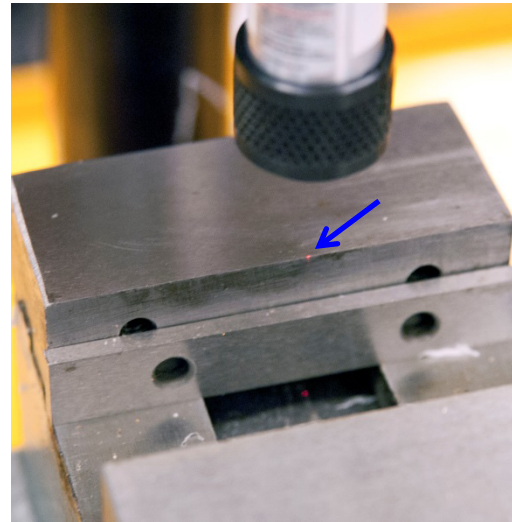
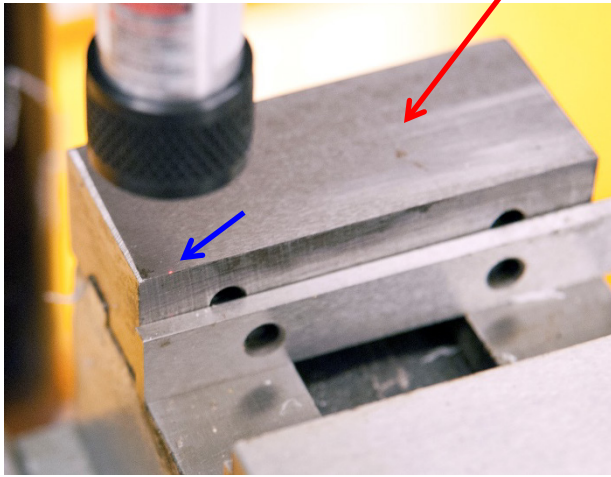
# Edge Finding/Zeroing...



Top – Laser center and edge finder.  
Right – Different spring-loaded edge-finders.

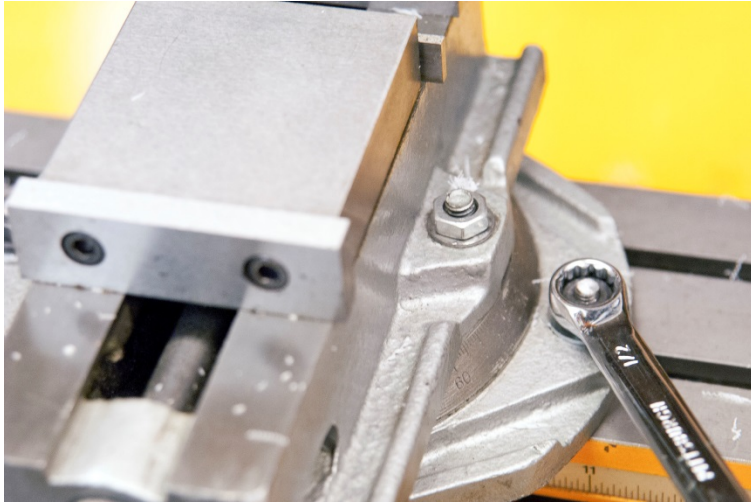
# *Align Back of Vice – the Fixed Jaw – First ...*

Fixed jaw.



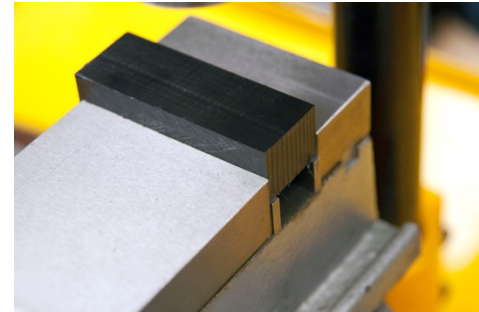
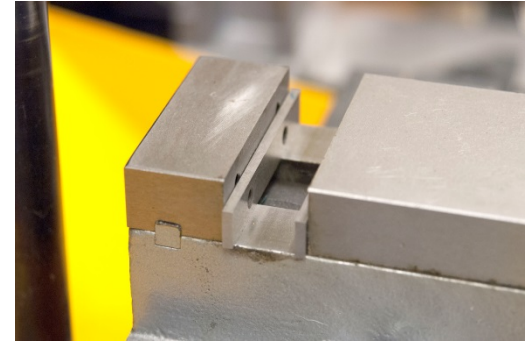
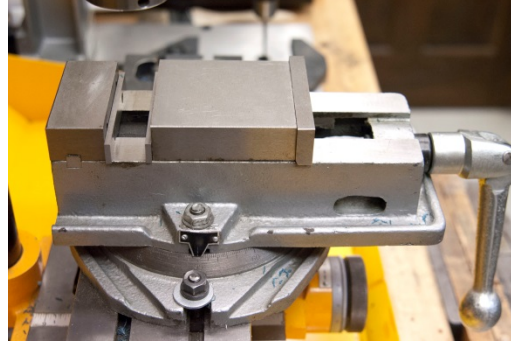
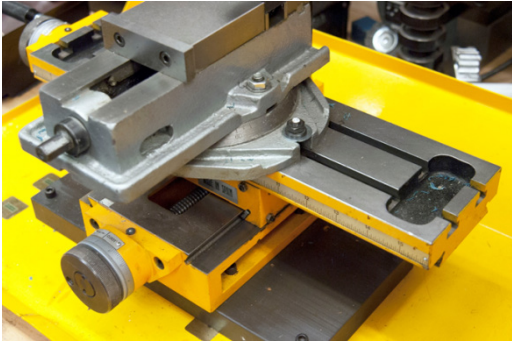
Laser is shown above, but spring-loaded edge-finder works fine too.

# *Move Vise with Gentle Tap...*



If vise needs alignment, loosen only one of two nuts holding the vise to the table, not the rotation nut!

# *Securing Work Piece...*



T-Slot table, rotatable vise and parallel plates

# *Securing Work...*



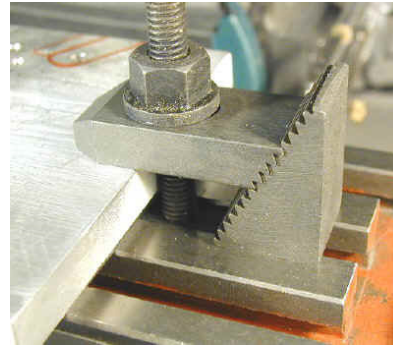
Tap lightly while tightening vise to ensure work is flat against parallel plates.



# *Clamp Sets...*



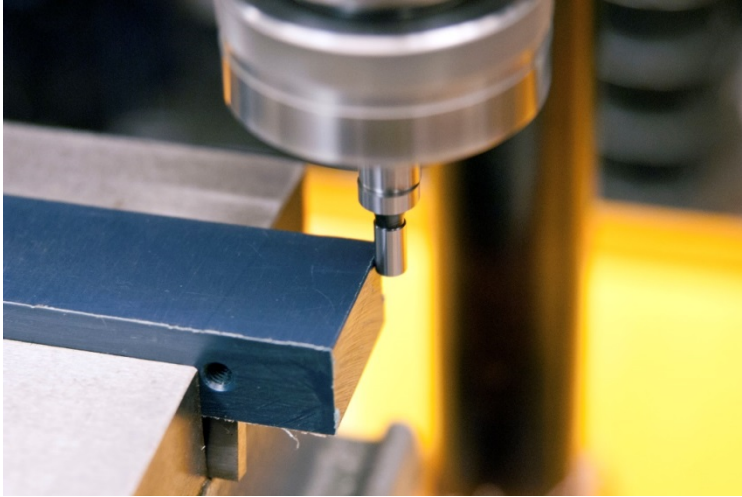
Image courtesy of Jet.



Images courtesy of Frank J. Hoose, Jr.

T-nuts, washer-nuts, threaded stems, step blocks and flanges can hold down vises, work piece and other objects to the table.

# Using an Edge Finder...



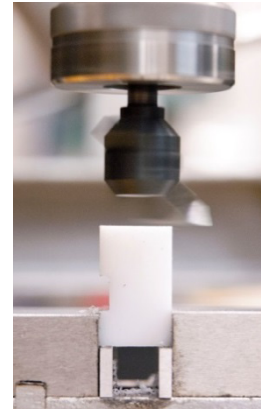
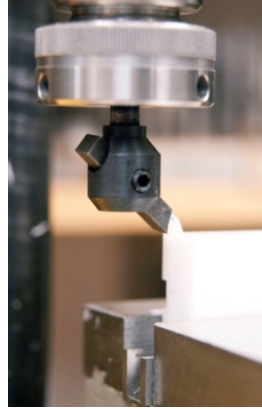
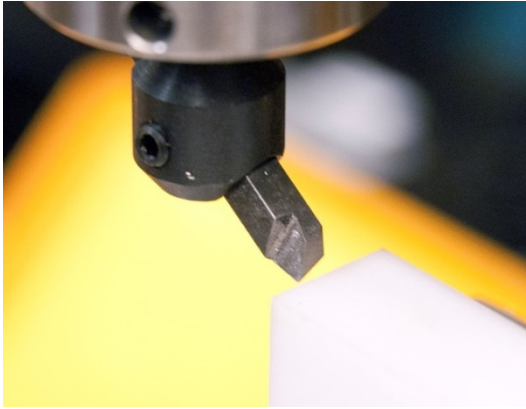
- Using an edge-finder to zero each work axis.
- Induce wobble, then move slowly against work piece until wobble stops.
- Remember to subtract radius of edge finder when zeroing DRO.

# *Handle Micrometers for X and Y Axis...*



- The handle micrometers are used when no Digital Readout (DRO) is present.
- The inner dial rotates separately from the outer handle table adjust.
- While holding the outer handle firmly, rotate inner dial to zero.

# *Facing the Work Piece...*



- The first surface you face becomes your reference for further facing or other operations. HSS fly-cutter tool shown above (there are other styles).
- Take off .03" or less at a time to prevent jamming the work. Visually double check your clearances from all angles before starting.

# *Clearing Chips...*



Never use your hands to clear chips.



Adjust Z axis no more than about .03" to .05" with each pass (material and machine dependent).

# *Milling a Round Edge...*



First align with lower inside edge of cutter – being sure the end mill rotates freely.



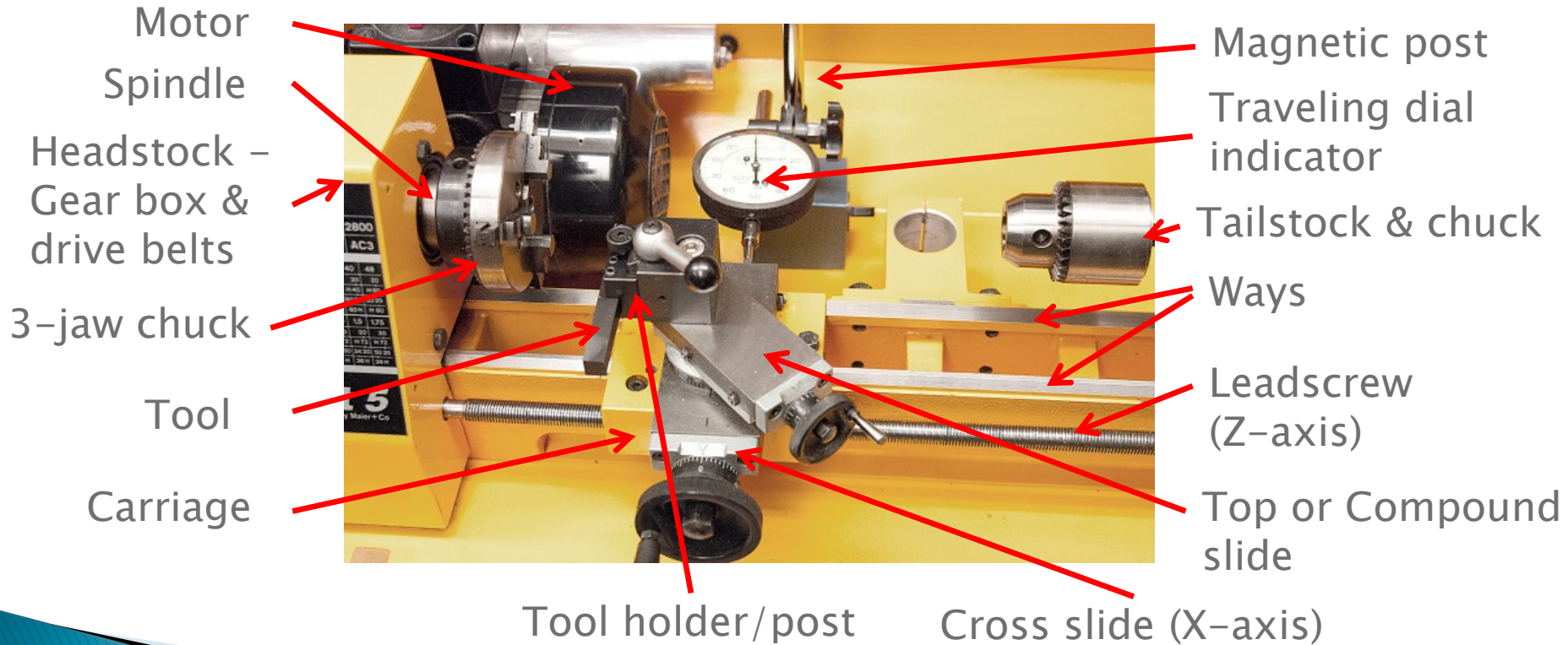
Cut by adjusting the Z axis slightly with each Y axis pass. The X axis stays fixed. (Reverse if cutting along the X axis.)

# Lathe Operations

- ▶ Facing
- ▶ Center Drilling
- ▶ Turning to a diameter
- ▶ Turning to a left or right shoulder
- ▶ Drilling
- ▶ Knurling
- ▶ Parting
- ▶ Chamfering



# More Lathe Components...

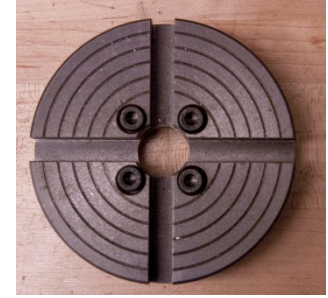
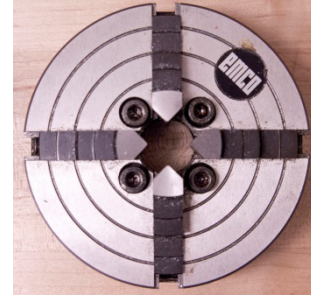




# Chucks...



3-Jaw chuck for round and hex stock.

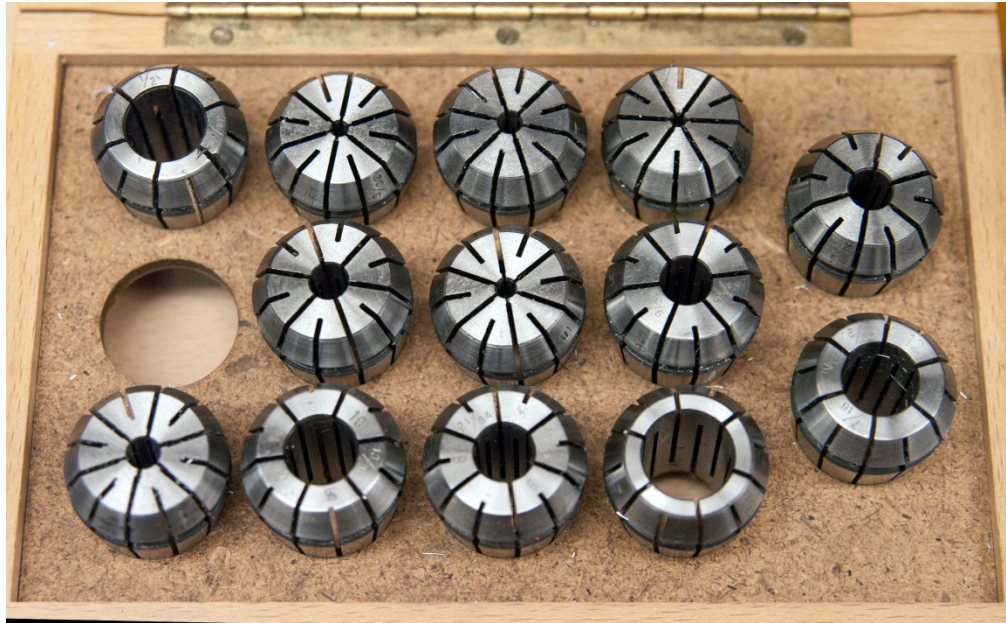


4-Jaw and face plate chucks.



Collet holder.

# *Fractional Spring Collet Set...*



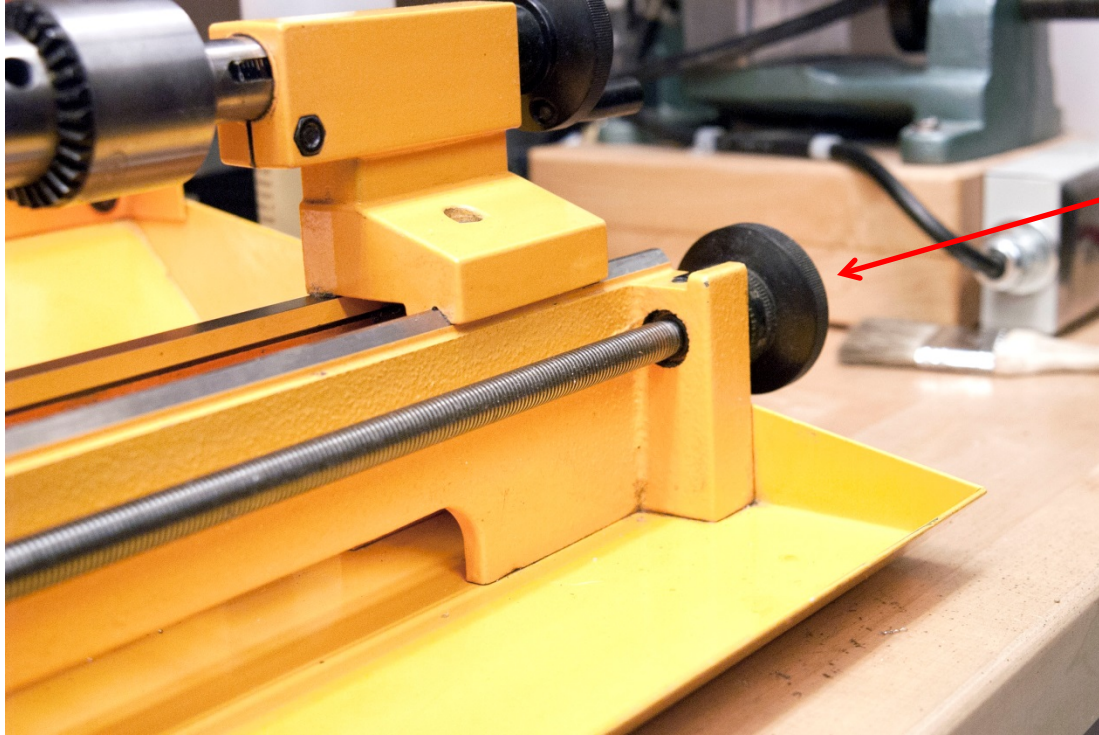
Each collet accepts a small range of stock diameters.

# *Chuck Key...*



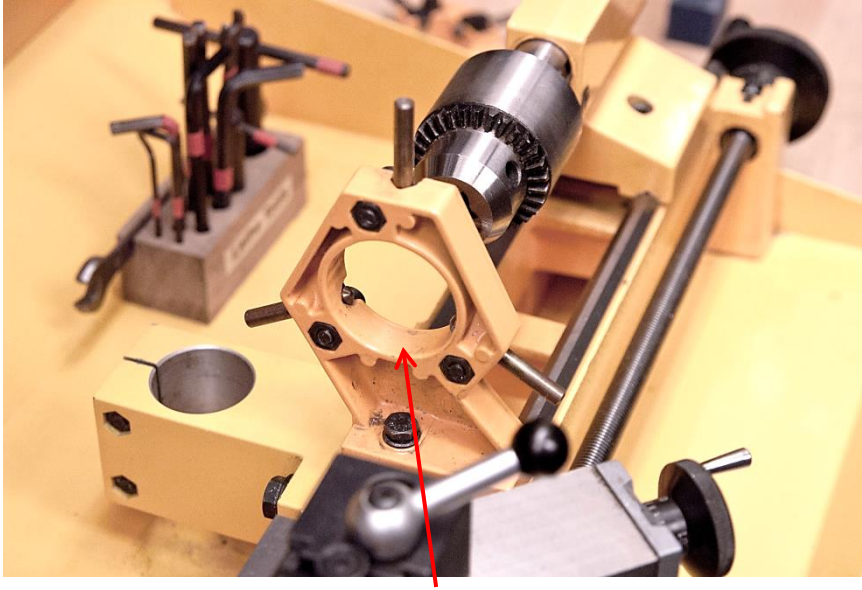
Tighten work piece in chuck and remove key immediately!

# *Z-Axis/Lead Screw Handle...*

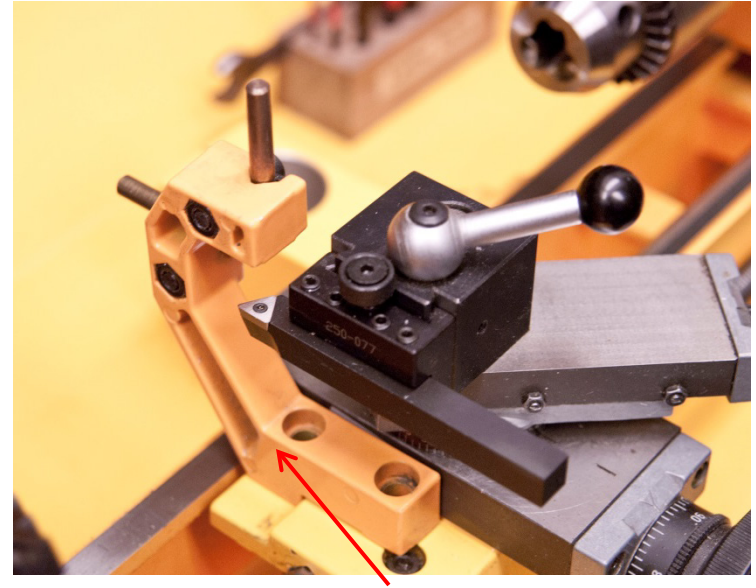


Turn to move carriage.

# *Steady and Traveling Rest...*

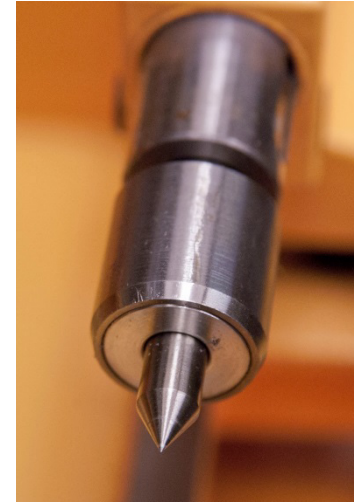
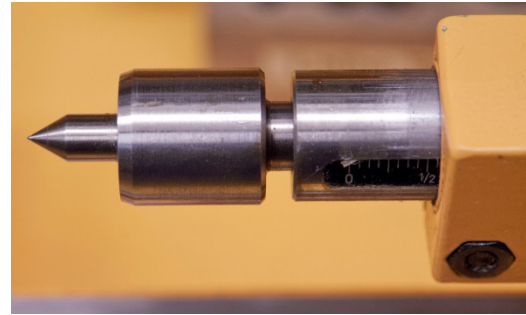
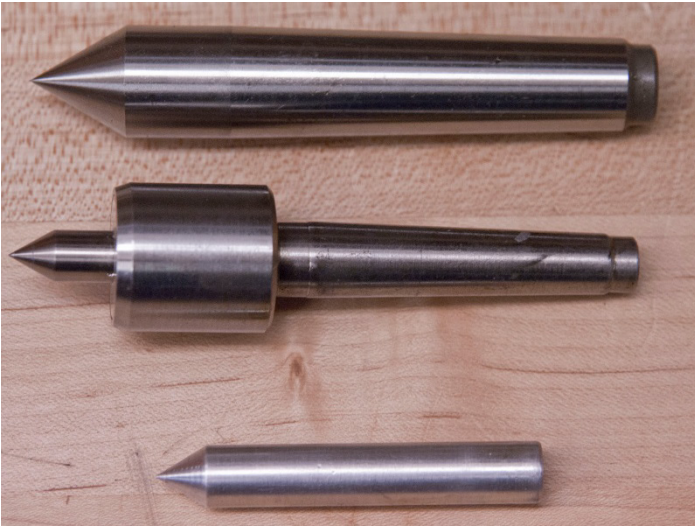


Steady rests attaches to ways.



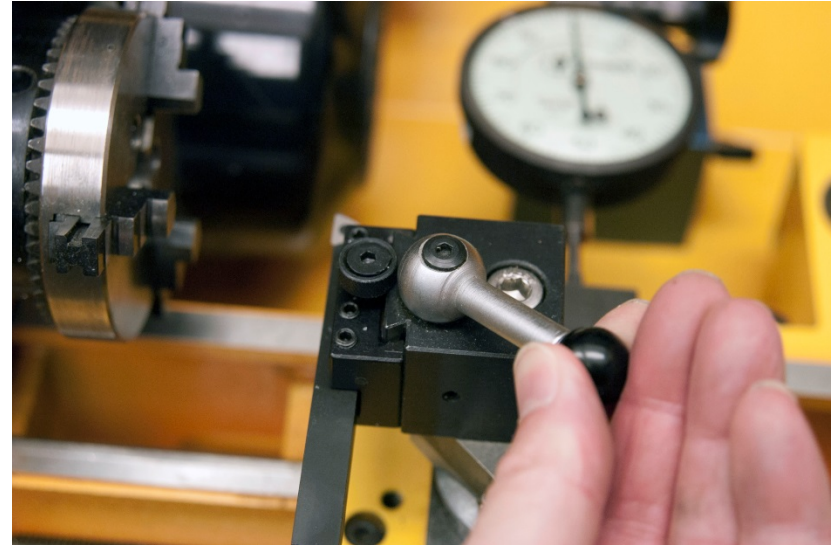
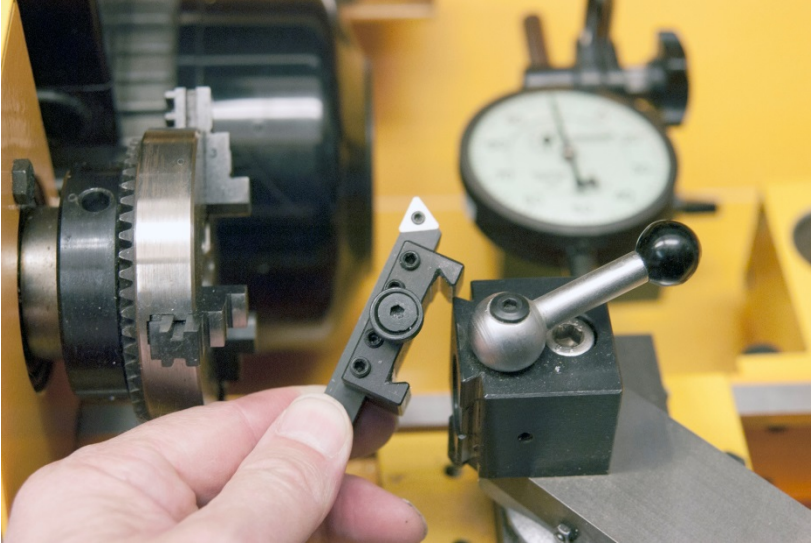
Traveling rest moves with carriage.

# *Tailstock Centers...*



- Use when affixing work at the chuck and tailstock.
- Shown are different taper center points, and rotating or “live” center.
- It is best to spot drill in the center face of the work so that the center is firmly making contact.

# *Tool Holder...*



Quick change tool post.

# *Tool, Tool Post, Cross and Top Slides...*

Quick change tool  
post

Tool holder

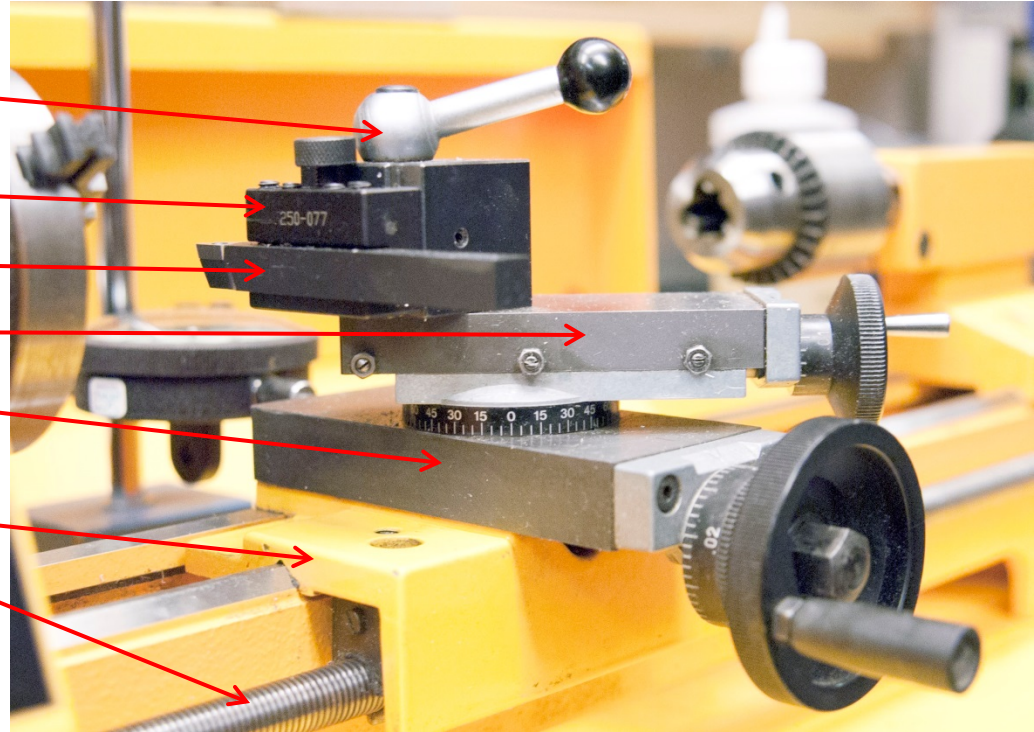
Tool

Top slide

Cross slide (X axis)

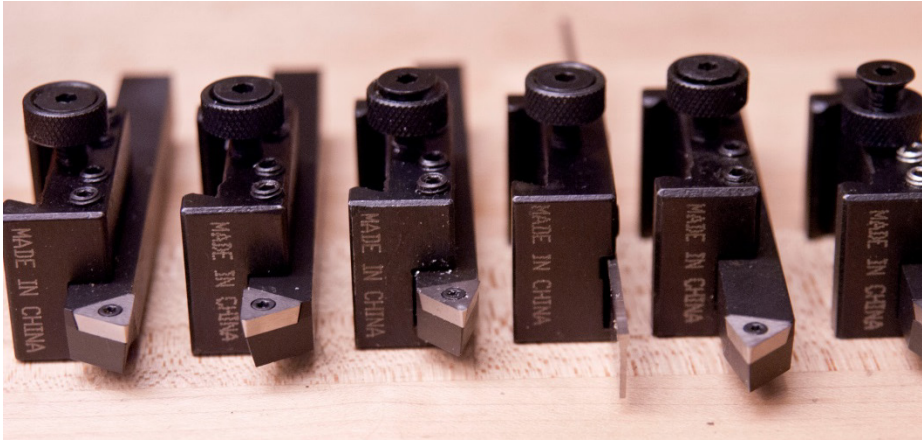
Carriage

Lead screw (Z axis)

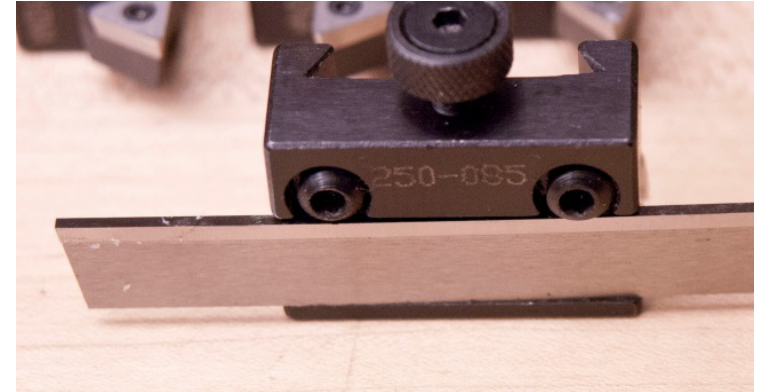




# *Tools, Tool Holders & HSS Inserts*



Tools with HSS (high speed tool) inserts and tool holders.



Parting tool and tool holder.

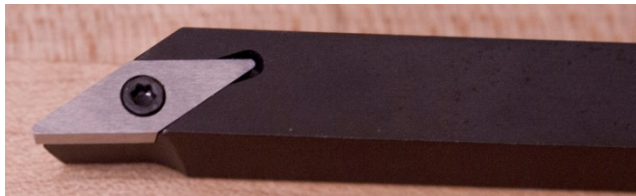


Ground HSS tools.

# *Boring, Profiling and Threading Tools...*



Boring tool.



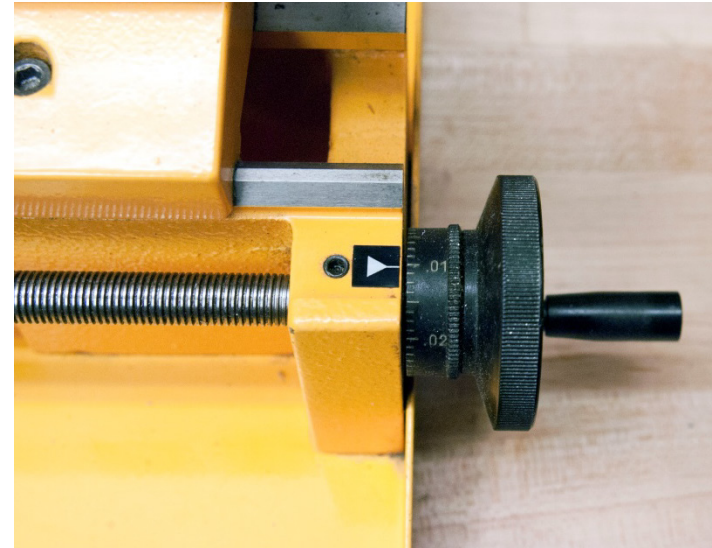
Profiling tool.



Internal & external  
threading tool.

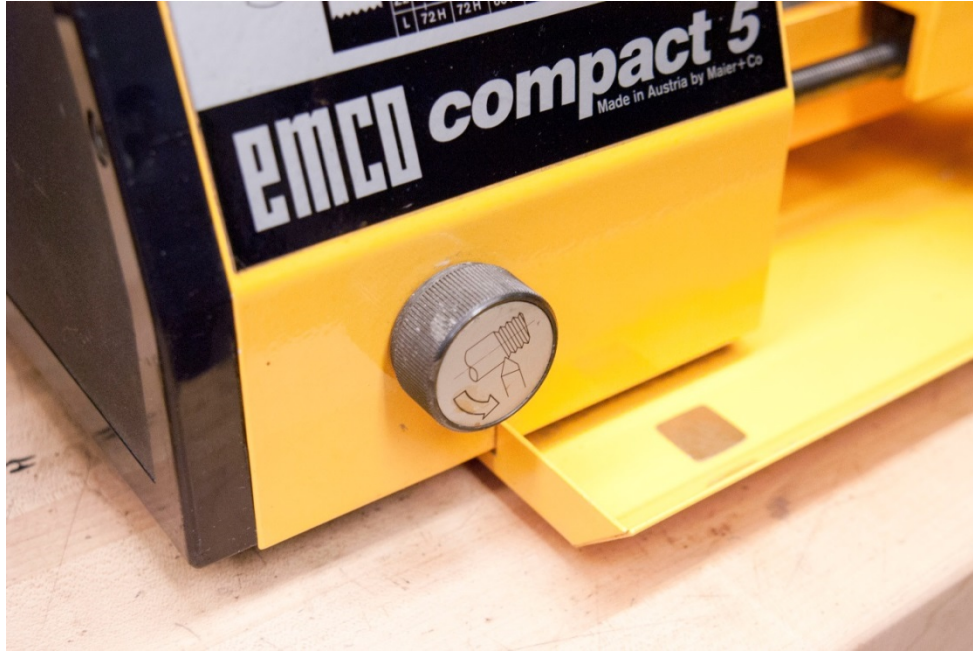
These tools have HSS inserts. Carbide inserts are also available.

# *Handle Micrometers...*



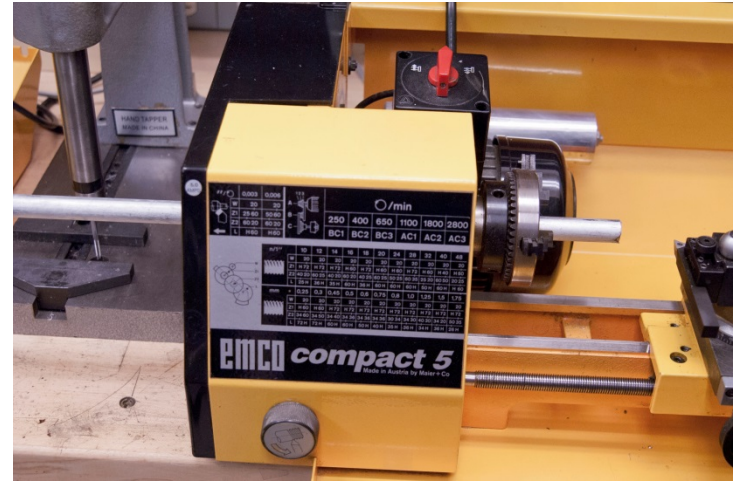
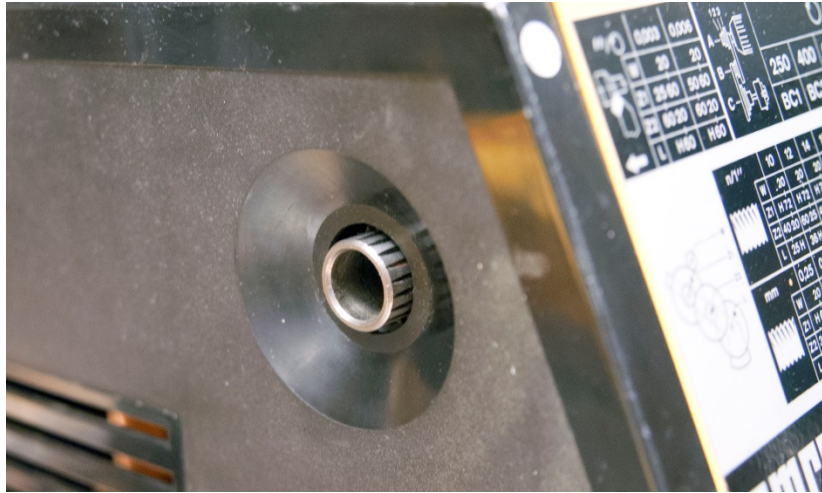
The cross slide micrometer is marked in “diameters” (2 x the actual movement).

# *Power Feed Engage for Threading...*



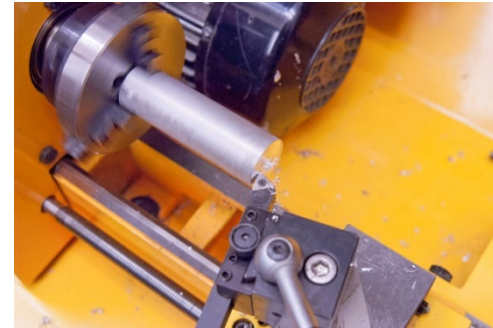
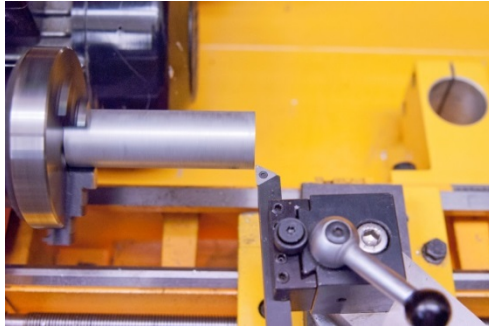
- This moves the carriage to the left by power feed.
- Excellent for finish turning or making threads.

# *Spindle Bore...*



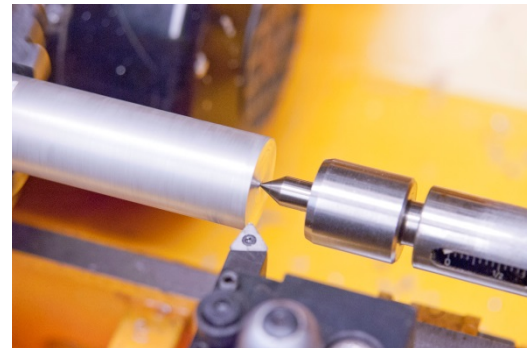
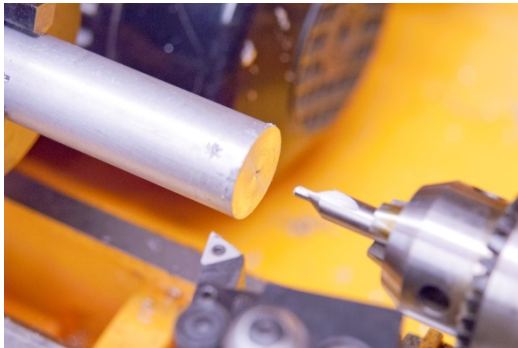
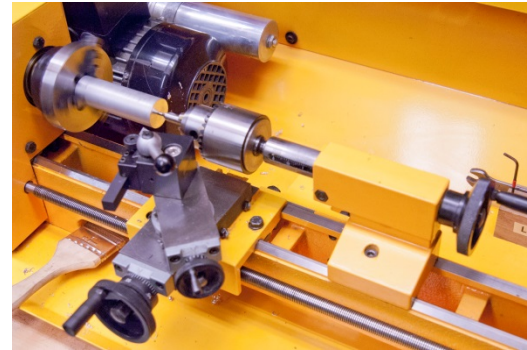
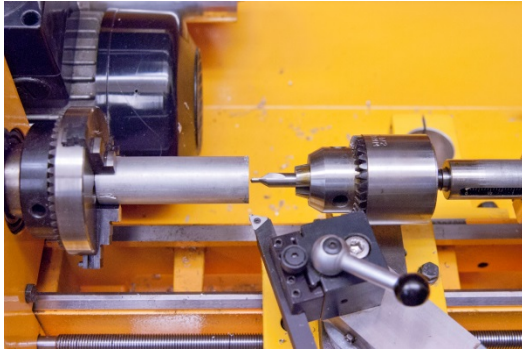
Stock extends through spindle. Typically use with collet and long stock.

# *Facing Operation...*



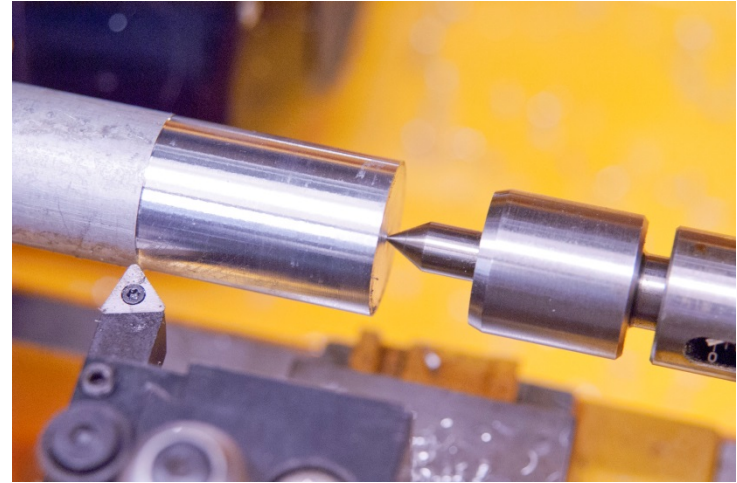
Angle of tool holder is set to allow tool tip only to cut across the face of the work. Work is unsupported here – better to temporarily use a fixed steady rest. Once faced, center drill and use a live center.

# *Center Drilling Operation...*



Make sure carriage is out of the way. Place spotting drill (center drill) in the tailstock chuck and turn the tailstock handle to advance drill into work. Replace chuck with a live center, and align with center hole.

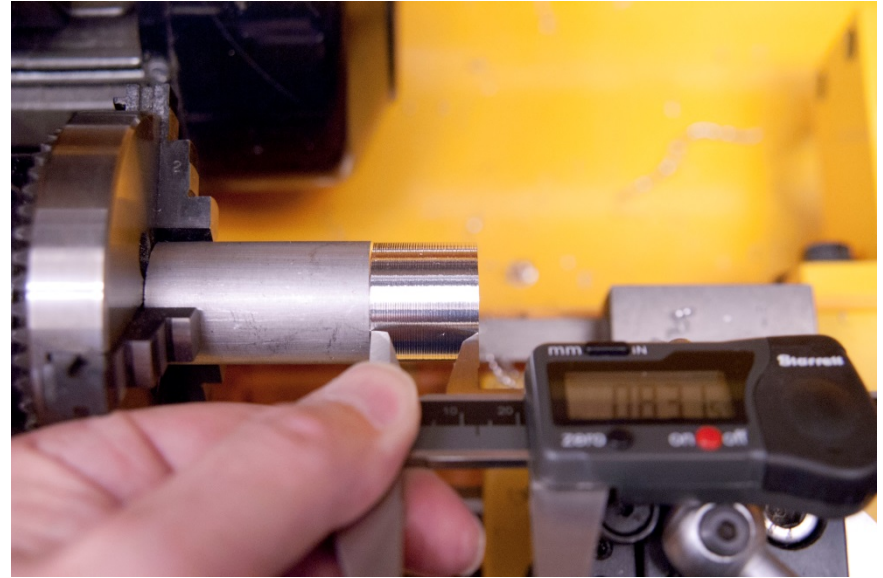
# *Turning to a Diameter...*



Using a left hand tool, take off small amounts at a time and make multiple passes.

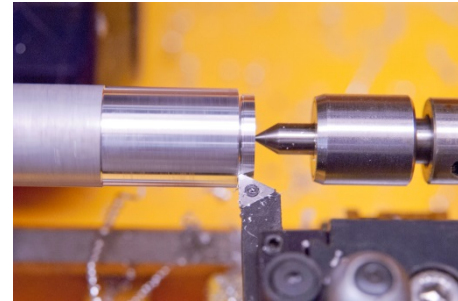
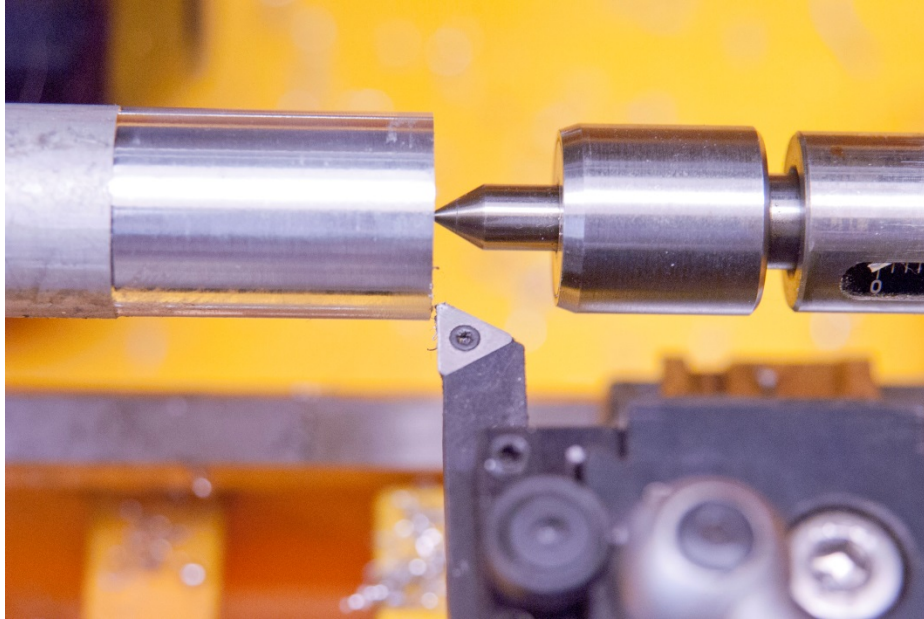


# *Checking Progress with a Caliper...*



Always turn lathe OFF when using the caliper or a micrometer!

# *Turning to a Left Shoulder...*



Notice the left hand tool with perpendicular insert.

# *Drilling Operation...*

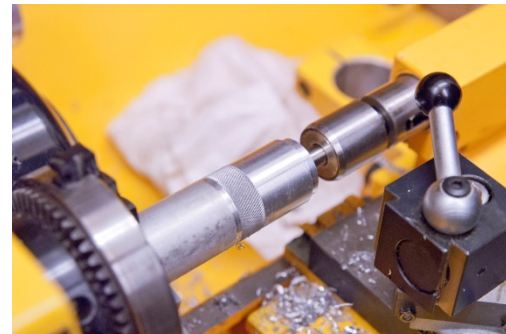
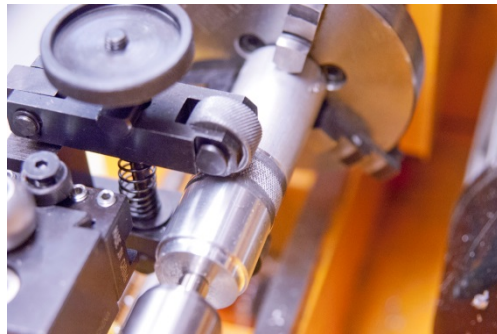
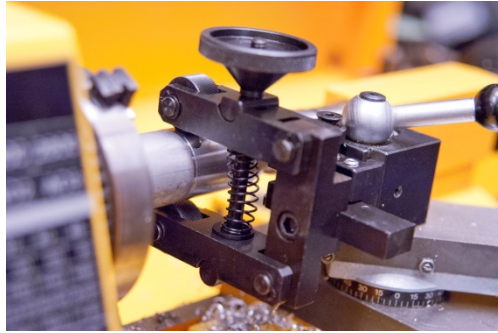


Drill bit is stationary while work turns.



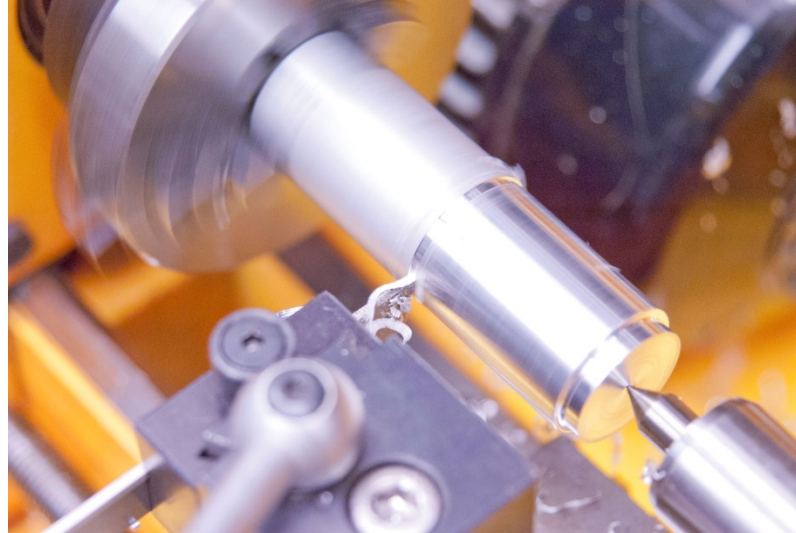
First center drill if not already done. Rotate tailstock handle to advance drill into rotating part. Peck drill (in and out) to clear chips).

# *Knurling Operation...*



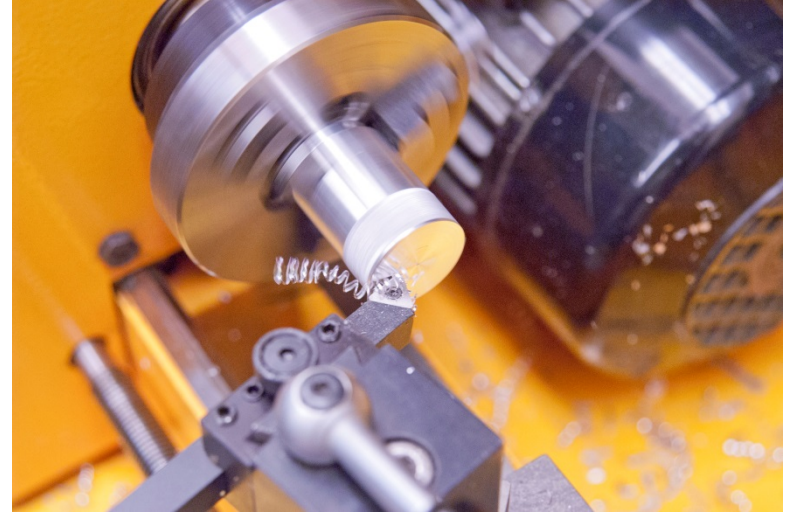
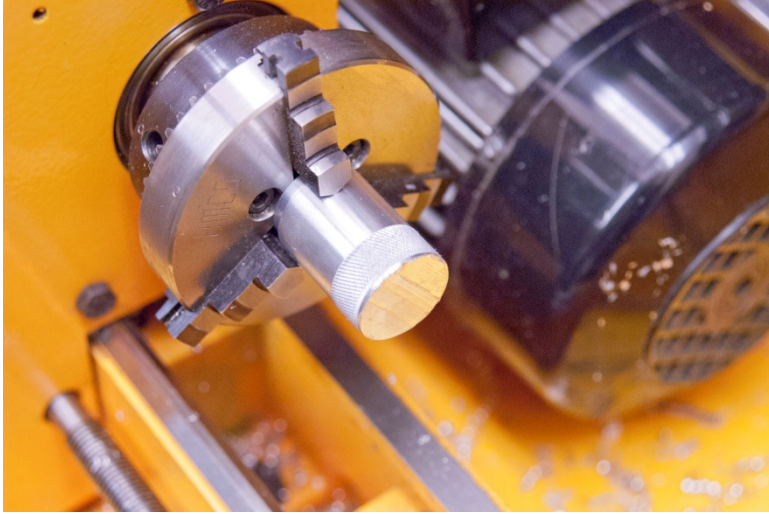
Ideally support work with live center on tailstock.

# *Parting Operation...*



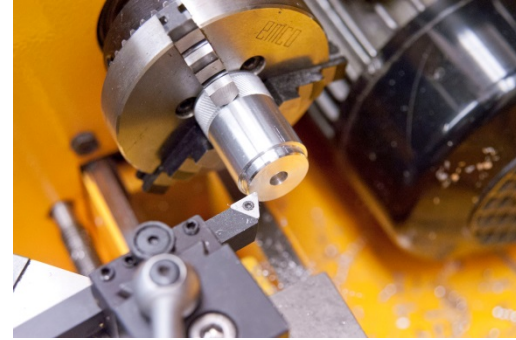
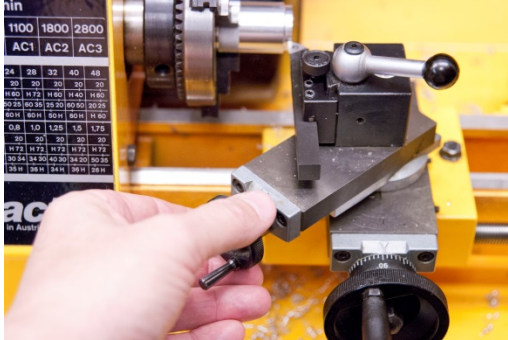
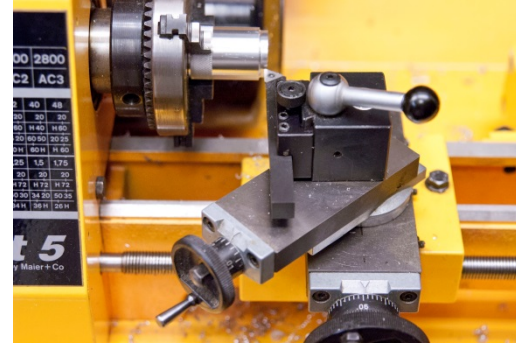
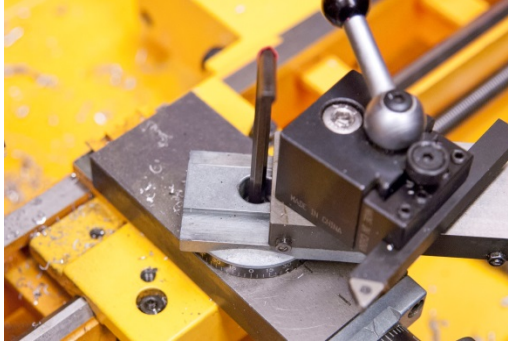
- Check that the tool is aligned and secure in the holder and tool post.
- Check your clearances and distance to center of work.
- Lubricant is essential for metals.
- Part is being pushed sideways and could jam in a small lathe. Consider a small groove, then taking the part out and using the band saw.

# *Facing the Other End...*



Notice slight angle of the tool holder and left hand tool.

# Chamfering Operation...



Top (compound) slide is rotated to the left to 45°, and the tool holder realigned. Slowly rotate top slide handle, machining across edge of work. Advance by slowly turning the cross slide handle.

# *Finished Part...*





# Lubricants / Coolants



Most polymer materials will not need lubricant or coolant. Heavy-duty aluminum, brass and all steel machining should be lubricated/cooled. Wipe clean tools and oil as indicated.

# Cleanup



- ▶ “Brush and sweep” is preferable when you are done.
- ▶ Careful “puffs” of air can be useful, but do not make chips fly carelessly into equipment and onto others.
- ▶ Solvent/oily rags should be disposed in an air tight receptacle to prevent spontaneous combustion.
- ▶ Return flammables to their storage locker.

# Summary

- ▶ Remember safety first!
- ▶ “Machinist Tool Chest”
- ▶ Power Tools
- ▶ Workpiece Layout
- ▶ Mill
- ▶ Lathe
- ▶ Lubricants / Coolants
- ▶ Cleanup