Build a Drill Press Vise

Introduction
This activity plan will develop the student’s machining and metalworking skills as they fabricate a multi-piece steel vise. The project will encompass basic lathe operations, layout procedures, drill press operations, slot milling and face milling, and oil or chemical blackening finish painting or powder-coat finishing process. The student will also perform GMAW welding.

Lesson Objectives
The student will be able to:

• Use a machine lathe to face off, centre drill, cut threads, knurl, turn to diameter, and file in a scrolling 3-jaw chuck, and do facing, boring, and reaming in an independent 4-jaw chuck
• Lay out hole locations for drilling
• Use a drill press with a drill press vise to pilot drill, bore, and ream to a given nominal size
• Cut stock steel using a band saw
• Use a milling machine to face mill, slot mill, and perform combined use of indexing head and end milling
• Complete oil or chemical blackening, painting, or powder coating finish processes
• V-groove, tack weld, and fillet weld the frame components using the GMAW process

Assumptions
The student will already know:

• Hand tool safety
• Measurement
• Basic layout techniques
• Names and usages of layout and hand tools
• Basic GMAW technique
**Terminology**

**End mill**: a type of cutting tool different from a drill bit in that it can generally cut in all directions. An end mill creates a flat surface on the sides along the same axis as the spindle.

**Face off**: a process performed on a lathe in which irregularities on the face of an object are removed so that the face is at a 90-degree angle (right angle) to the object’s sides.

**Face mill**: a cutting tool with blades along the bottom or sides, used to shape the face of an object.

**Knurl**: a process where a pattern of straight, crossed, or angled lines is cut or rolled into a metal surface, resulting in a series of small ridges or beads that aid in gripping.

**Live centre**: a part of a lathe that holds and revolves with the work piece. Usually refers to the headstock centre.

**Reamer**: a rotary cutting tool used to enlarge a previously cut hole to a high precision.

**Swarf**: metal debris left as a result of a machining operation.

**Tailstock**: the movable part of a lathe that supports the dead centre.

**V-groove**: a type of butt joint in which the edges of two pieces of metal are both cut at an angle and form a V-shaped groove when they are placed together.

**Estimated Time**

25 hours

**Recommended Number of Students**

20, based on the *BC Technology Educators’ Best Practices Guide*

**Facilities**

Metal shop as per the *BC Technology Educators’ Best Practices Guide*

**Tools and Equipment**

- Drill bits: bell end centre drills with $\frac{5}{16}$" body, $\frac{1}{4}$" tip
- HSS twist drills: $\frac{3}{16}$", $\frac{15/32}{\text{and} \frac{7/32}{\text{and} \frac{21/32}{\text{and} \frac{39/64}{\text{"}}}$
- $\frac{1}{4}$" transfer punch
- Taps: $\frac{1}{4}$-28NF plug tap, $\frac{3}{4}$"-6 Acme tandem tap or $\frac{3}{4}$"-10NC plug tap
- Layout tools, including height gauge, centre punch, scribe, dividers, layout dye, layout hammer
- Hacksaw, bench vise, flat file, mill file, de-burring tool, cold chisel
- Drill press
• Chucking reamers: ½", 1"
• Machine lathe, knurling head, LH tool holder/bit, 3- and 4-jaw chucks, ⅜" square tool bit
• Acme threading gauge
• Belt machine with 60 g and 120 g belts
• Vertical milling machine with tooling: 2"+facing mill, ¾"+ end mill, indexing head
• T-slot clamping kit for milling machine
• Bench grinder, wire wheel
• Chemical blackening kit or oxy-fuel torch and used motor oil
• Paint or powder-coating equipment

**Materials**

*Note:* All parts can be pre-cut except the bronze bushing and jaw spacer plate.

**Frame**
- 2 – 1.5 × 1.5 × ¼ × 9" angle iron (rails)
- 3 – 1.5 × 1.5 × ¼ × 4.5" angle iron
- 1 – 1 × 1 × 2" solid (jaw block)
- 1 – 1.25 × 1.25 × 2" solid (nut block)
- 1 – 1.5 × ¼ × 2.5" flat bar (jaw retainer)
- 1 – 1.5 × ¼ × 1.6" approx. (jaw spacer)
- Spindle: 1 – ¾ × 13" round
- Bronze nut: 1 – 1¼ × 2" cast silicon bronze
- Jaws: 2 – 1½ × ⅜ × 4⅝" flat bar – MS or aluminum

**Fasteners**
- 1 – ¾₆ × ¾" RH plain rivet
- ¾₁₈ × 1" split roll pin
- 2 – ¼"-28 × 1" socket head bolts with ¼" lock washers
- 4 – ¼"-28 × ⅜" button head sockets
Teacher-led Activity

Demonstrate the following steps to fabricate a multi-piece steel vise. Students will then each make their own vise.

Bronze ¾-6 Acme nut

1. Face off end. Turn bronze to 1.000 × 1.5 long, leave \( \frac{3}{16} \) " × 1.2" diameter shoulder at top end, part off.

2. Reverse nut in lathe chuck, centre drill, pilot drill at \( \frac{3}{4} " \), bore through at \( \frac{39}{64} " \).

3. Set lathe feed to 6 TPI, remove tool post, set rpm to about 50, align tandem Acme ¾-6 tap with live centre in tailstock, turn 3 revolutions by hand, keeping tap in contact with live centre while running through. Posi-drive with tap bar or wrench.
Completed bronze nut with chamfered edges

**Spindle**

1. 0.750 HRMS × 13"
   
   Faced and centre drilled both ends

2. One end turned to 0.500 D × ¾ long
3. Turn spindle to 0.740+/–0.002 diameter × 6.5¾ long. Beginning from the shoulder, cut relief groove 0.070" deep × 0.150" wide.

4. Cutting Acme ¾-6 × 6.5" long

Set lathe to about 150 rpm, gear box to 6 TPI, compound slide at 14.5 degrees.

First cut at 0.025" deep on compound engage threading dial at appropriate increment for a 6 TPI thread as per lathe make and model. Use Sulflo or equivalent heavy duty cutting fluid.

5. Subsequent cuts are made at these depths:
   - 2nd: 0.012"
   - 3rd–5th: 0.008"
   - 6th–11th: 0.005"
   - 12th and subsequent cuts: 0.002", until 0.095" is registered on the compound slide dial.

Test fit bronze nut only after filing, then cleaning spindle of all burrs and swarf. Final cut: Do not advance compound but rather recut, file, clean, and check fit with bronze nut. Do not remove from chuck until a final fit is established.

6. File threads to de-burr flats and edges. Fit Acme nut to threads.
7. Mill $\frac{3}{4} \times 0.245$ deep in two stages $\frac{3}{8}''$ from end of threaded section. Use indexing head with tailstock for 180-degree rotation. Band-saw off handle section at handle end of flats.

8. Coarse knurl 3'' of handle end, groove at termination of knurl, chamfer end.

9. Set handle on mill bed T-slot using a clamp. Insert and tighten a $\frac{1}{4}''$ carbide end mill into the collet chuck. Mark edge $\frac{3}{8}''$ from end with rotating $\frac{1}{4}''$ EM to form a shallow “football” mark. Zero the cross slide (y-axis dial) and raise and centre bit (0.500'' y-axis motion), lock y-axis in place.
10. Make ¾” long × ⅛” depth cuts: set auto stop, and feed at 3–4 IPM. Flood-cool the end mill.

Make successive ⅛” passes until end mill is through the diameter of the handle.

11. Centre-punch the spindle handle on the “football” mark. Align in vise V-jaw ensuring that tongue is level, then slid handle over spindle and clamp tightly.
12. Drill through $\frac{3}{16}''$, counter-bore $\frac{3}{8}''$ diameter × $\frac{1}{4}''$ depth on one side and counter sink on other.

13. Round off ends of spindle and handle to semi-circular. Test fit with a $\frac{3}{16}'' \times \frac{3}{4}''$ round head rivet so that 90-degree motion right and left is possible.

14. Fasten together with $\frac{3}{16}'' \times \frac{3}{4}''$ plain rivet: Slide through counter-bore side first, peen into countersunk area, then blend to radius using a mill file.
**Vise Frame**

1. Use band saw to cut 1.5 × 1.5 × 0.0250 angle iron to 2@9", 3@4.5" lengths.

2. V-groove the corners for welding and belt-sand sliding surfaces.

   - V-grind two jaws on bench grinder; belt one jaw smooth on one outer face.

3. V-groove ends of side rails for welding; belt on top surface only.
4. Clamp rails to mill bed using a clamp kit. Mill all longitudinal edges of rails at 650 rpm using 3" carbide facing mill, –1.5 mm cut. Power feed at about 8–10 IPM or 200 mm/min.

5. Spindle blocks: cut one of each piece on the band saw: 1 × 1 × 2", 1¼ × 1¼ × 2".

6. Face off on 4-jaw chucks.

7. Mark centre lines around each block using digital height gauge (measure height and divide by two).
8. Grind off one edge of both blocks to allow blocks to sit tightly against the angle iron. Chamfer ends of blocks using a flat file.

9. Clamp and weld blocks to 4.5" angle iron, centred with:
   • 1¼" square to V-ground piece (spindle nut boss)
   • 1" square to sanded smooth piece (sliding jaw)

10. Set the welding unit for ⅜" thick stock corresponding to wire diameter and constitution of the shielding gas. Fillet weld ends of blocks only to angle iron.

11. Mark height line 0.750" from bottom of angle iron on face of both blocks (V-groove side down for spindle boss and sanded side down for sliding jaw).
12. Centre-punch along centre line at intersections and at 0.270 offset from centre line for the sliding jaw retaining pin.

13. Drilling the sliding jaw:
   
   1. Pilot drill all holes $\frac{3}{16}$" @ 1500 rpm, through.
   
   2. Drill jaw offset hole first 0.270" from C-line (sanded side down). Drill centre spindle hole at $\frac{15}{32}$" @ 800 rpm, ream to $\frac{1}{2}$" @ 400 rpm. **Note:** Jaw must be level in the drill press vise to ensure the hole is perpendicular to the jaw’s smooth-ground side.

14. Lay out and centre-punch holes for jaw plates 0.625" from bottom and ends of the fixed and sliding jaws.
15. Drill both jaws ¼" through for jaw plates.

16. Drill retaining pin hole in spindle nut holder. Offset by about 0.540" from centre line and drill through using a 3⁄16" bit. This hole is from opposite the V-grooved side of the piece.

17. Align large block in a 4-jaw chuck at centre-punch mark using live centre. Centre drill, pilot drill through at 3⁄16", drill out at 33⁄32" at about 300 rpm, ream to 1" at about 150 rpm. Note the position of ground V-grooves.
18. Spindle nut holder completed
   Note that the weld V-grooved edge is down!

19. Frame assembly:
   Ensure nut boss and fixed jaw are square and flush to the rails, then firmly hold in place with locking pliers. Tack weld at three locations of lap joint to one rail only.

20. Construct sliding jaw spacer and retainer from ¼” × 1.5 stock. Spacer to have parallel ground edges, about 1.6” long. Use spacer to position second rail, then clamp and tack weld rail in place.
21. Grind spacer V-groove, position sliding jaw using spindle and nut, then tack weld spacer in position.

22. Remove sliding jaw from frame. Fill weld the V-groove and grind weld flush with edges.

23. Retainer to be about 2.5" long. Temporarily tack weld to spacer. Cover spindle when welding.

24. Drill retaining pin holes ($\frac{3}{16}$") through the entire assembly from top of sliding jaw while having the spindle tightly in place. Drill two holes $\frac{7}{32}$" × 1.5 deep for retaining plate bolts. These are located $\frac{3}{4}$" from the front edge of the sliding jaw and $\frac{3}{8}$" toward the centre from the inner edges of the sliding frame rails.
25. Remove retaining plate using a cold chisel and hammer. Drill out all holes in plate to ¼", tap two 7/32" holes only, ¼-28NF × ¾" deep in the sliding jaw.

26. Remove spindle assembly and turn retaining groove at 0.500" end with forming tool only removing entire felt-penned drill mark.
27. Jaw plates: \( \frac{3}{8}'' \times \frac{1}{8}'' \) longer than vise width, two pieces. Place \( \frac{1}{8} \times \frac{3}{4} \times 4'' \) spacer under plates, position, and then tighten in place. Use a \( \frac{3}{4}'' \) transfer punch to mark hole placement.

28. Drill plates \( \frac{7}{32}'' \) and tap \( \frac{1}{4}-28 \) NF through.

29. Option: V-groove fixed jaw plate on milling machine: \( \frac{3}{4}'' \) end mill at 45 degrees, 4.0 mm deep.

30. Pulse weld frame; MIG set at 21.5 V and 425 wire feed or manufacturer’s specification for \( \frac{3}{4}'' \) material. Alternate side to side filling in the V-grooves and fillets.
31. Drill $\frac{25}{64}''$ holes $\frac{5}{6}''$ in from edge and end, four corners. Countersink to de-burr holes top and bottom.

32. Face mill sides, ends, and top of jaw plates to square off frame.

33. Mill the ends or grind and file flat.
**Finishing**


2. Bead blast all frame components clean.

3. Mask off contact areas on the sliding jaw and rails.
4. Paint or powder coat frame. If powder-coating, remember to remove tape while hot!

5. Handle may be painted or powder-coated rather than blackened. Do not paint or powder-coat past the handle.
Assembly

1. Secure jaw plates to both fixed and sliding jaws using ¼NF × ¾" round socket head bolts.

2. Secure sliding jaw to frame with retaining plate using ¼NF × 1" socket head bolts with lock washers.

3. Thread spindle through nut and into sliding jaw. Insert 3⁄16" roll pin using a drift punch and hammer. Split side of roll pin should face away from the rotating end of the spindle.

4. Insert 3⁄16" roll pin through bushing block using a drift punch and hammer.

5. Apply a small amount of light lubricant on all moving parts.
Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

Spindle and nut:  threads fit and finish
                 end fit and motion
Handle:          knurl and chamfer
                 joint articulation, finish, fit
Frame:           squareness, finish preparation, applied finish
Sliding jaw:     fit, finish preparation, applied finish
Jaw plates:      alignment, finish preparation
Assembly:       vise smoothly functioning as a unit
Finish:         even, smooth