Complete Machining Guide: From Raw Stock to Finished Part

Introduction

This guide will walk you through the complete process of machining the rectangular part with holes and threads shown in the engineering drawing. As a beginner, you'll learn not just what to do, but why and how to do it with precision. Remember that attention to detail and cleanliness are essential for successful machining.

Materials and Equipment

- 2-inch hexagonal steel stock
- Bridgeport manual mill (2 available)
- Manual lathe
- Various cutting tools (face mill, drills, reamers, taps)
- Measurement tools (calipers, micrometers, dial indicators)
- Deburring tools
- Cutting oil for tapping operations
- Kool Mist or similar coolant for cutting operations
- Safety equipment (safety glasses, gloves, etc.)

Safety First

Before beginning any machining operation: 1. Always wear safety glasses - put them on before entering the shop area 2. Remove all jewelry including watches, rings, necklaces, and bracelets 3. Roll up long sleeves past your elbows 4. Tie back long hair securely so it cannot fall forward 5. Wear closed-toe shoes with non-slip soles 6. Know the location of emergency stops on all machines 7. Familiarize yourself with the location of the first aid kit and fire extinguisher 8. Never leave machines running unattended 9. Keep the work area clean and organized at all times 10. No food or drinks in the shop area

Now, let's begin the machining process with extremely detailed instructions for every step.

Setup 1: Material Preparation and Squaring

Step 1: Material Inspection and Preparation

1. Locate the 2-inch hexagonal steel stock in the material storage area.
2. Visually inspect the entire length of the stock for any defects, deep scratches, or damage.
3. Place the stock on a clean surface and use a shop rag to wipe it down completely, removing any dirt, oil, or debris.
4. Take a 6-inch caliper and measure the stock across the flats (the distance between two parallel sides of the hexagon).
5. Verify that the measurement is approximately 2 inches (it may be slightly larger).
6. Measure the length of your stock to ensure you have enough material for the final dimensions (3.200±.010 × .875±.005 × 1.600±.005).
7. You'll need at least 4 inches of stock to allow for proper workholding and cutting.
8. Use a permanent marker to mark where you'll cut if the stock is longer than needed.
9. Clean the stock again with a shop rag, paying special attention to removing any marker residue from areas that will be machined.

Step 2: Setting Up the Bridgeport Mill

1. Approach the Bridgeport mill and visually inspect it for cleanliness and any obvious issues.
2. Check that the table, vise, and surrounding areas are free of chips and debris.
3. If chips are present, use a brush (never your hands) to clear them away.
4. Wipe down the table and vise with a clean shop rag.
5. Check that the spindle and quill move freely by hand (with the machine OFF).
6. Locate the face mill cutter appropriate for steel (typically a 2-3 inch diameter carbide insert face mill).
7. Inspect each cutting insert on the face mill for chips, cracks, or dullness.
8. If any inserts are damaged, notify your instructor for replacement.
9. If the face mill is not already installed:
10. Ensure the machine is OFF and unplugged
11. Clean the spindle taper with a taper wiper
12. Clean the face mill holder taper
13. Insert the face mill holder into the spindle
14. Secure it according to the specific holder type (R8, ISO, etc.)
15. Once the face mill is installed, rotate it by hand to ensure it spins freely without wobble.
16. Plug in the machine if it was unplugged.

17. Turn on the main power to the mill by locating the main power switch (usually on the left side or back of the machine) and switching it to the ON position.
18. Wait for any digital readouts to initialize.
19. Do NOT start the spindle yet.
20. **CRITICAL: Set the Bridgeport to LOW GEAR before starting the spindle:**
    - Locate the gear selection lever (typically on the head of the machine)
    - Ensure the spindle is completely stopped
    - Move the lever to the LOW position (or REVERSE position on some models)
    - If the lever is difficult to move, rotate the spindle slightly by hand to help engage the gears
    - Verify the gear selection is properly engaged
    - This low gear setting is ESSENTIAL for proper cutting in steel and to prevent tool wear

Step 3: Mounting the Stock in the Mill Vise

1. Locate the mill vise on the table (or install it if not present).
2. Use a brush and shop rag to thoroughly clean the vise jaws, removing any chips or debris.
3. Open the vise wide enough to accommodate your workpiece plus parallels.
4. Select a set of parallels that are:
5. Clean and free of nicks
6. Tall enough to raise the workpiece above the vise jaws
7. Wide enough to support the workpiece properly
8. Clean the parallels with a shop rag to remove any oil or debris.
9. Place the parallels in the vise, ensuring they are:
10. Parallel to each other
11. The same height
12. Positioned to support the workpiece adequately
13. Position the hex stock on the parallels with:
14. One flat side facing down on the parallels
15. Enough material extending from the vise to allow for machining (about 1 inch)
16. Not so much extension that it will cause vibration (not more than 2 inches)
17. Gently close the vise until it just contacts the workpiece.
18. Take a soft hammer (brass, plastic, or dead-blow) and gently tap the top of the workpiece directly over each parallel.
19. This ensures the workpiece is seated firmly and flat on the parallels.
20. While maintaining downward pressure on the workpiece, tighten the vise handle.
21. Tighten until the workpiece is secure but not distorted - typically a firm quarter-turn after initial resistance.

22. Check that the workpiece doesn't rock or move when you apply moderate pressure by hand.

Step 4: Setting Up for Face Milling

1. With the machine still OFF, use the handwheels to position the table so the workpiece is roughly centered under where the face mill will be.
2. For the X-axis (left-right movement):
3. Locate the X-axis handwheel (typically on the front of the table)
4. Turn it clockwise to move the table to the left
5. Turn it counterclockwise to move the table to the right
6. For the Y-axis (front-back movement):
7. Locate the Y-axis handwheel (typically on the front right of the table)
8. Turn it clockwise to move the table toward you
9. Turn it counterclockwise to move the table away from you
10. Position the table so the workpiece is approximately centered under the spindle.
11. Now, you need to lower the quill to position the face mill close to the workpiece:
12. Locate the quill handle (the large handle on the right side of the head)
13. Grasp it firmly with your right hand
14. Release the quill lock if engaged (usually a lever on the left side of the head)
15. Slowly pull down on the handle to lower the quill
16. Lower until the face mill is approximately 1 inch above the workpiece
17. Now, you must pull the quill down tight and lock it:
18. Continue pulling down on the quill handle until the face mill is about 1/2 inch above the workpiece
19. Pull down firmly to ensure the quill is fully extended
20. While maintaining downward pressure, engage the quill lock (Z-axis lock) by pushing the lock lever
21. Ensure the lock is fully engaged - the quill should not move up or down
22. Now, zero the knee handwheel:
23. Locate the knee handwheel (the large wheel at the front bottom of the machine)
24. Rotate the dial portion (not the whole handwheel) until the zero mark aligns with the reference mark
25. Make a mental note of the handle position
26. You're now ready to establish your witness cut position.
27. Set up the Kool Mist system:
28. Ensure the Kool Mist reservoir is filled with the proper coolant mixture
29. Position the nozzle to direct coolant at the cutting area
30. Adjust the flow rate to provide adequate cooling without excessive spray

Step 5: Making the Witness Cut

1. Before starting the spindle, set the appropriate speed for face milling steel:
2. **CRITICAL: Verify the machine is in LOW GEAR**
3. Locate the speed control (either levers or a variable speed dial)
4. Set to approximately 200 RPM for a carbide face mill in steel
5. This low speed is essential for steel to prevent tool wear and ensure a good finish
6. Ensure the power feed is disengaged:
7. Locate the power feed engagement lever
8. Ensure it is in the disengaged position
9. Now, start the spindle:
10. **DOUBLE-CHECK that the machine is in LOW GEAR before starting**
11. Locate the spindle start button (typically a green button on the control panel)
12. Press it firmly to start the spindle
13. Verify the spindle is rotating in the correct direction (typically clockwise when viewed from above)
14. Listen to the sound - it should be smooth and not laboring
15. Turn on the Kool Mist system:
16. Activate the coolant flow
17. Ensure it's directed at the cutting area
18. Now, you'll make your witness cut:
19. Slowly turn the knee handwheel clockwise to raise the table
20. Turn very slowly, watching carefully as the workpiece approaches the spinning cutter
21. Continue until the cutter just barely touches the highest point of the workpiece
22. You'll know contact is made when you see a small bright spot appear on the workpiece
23. This might only remove a small bright spot on the surface
24. Once you've established this witness cut:
25. Stop the spindle by pressing the stop button (typically red)
26. Turn off the Kool Mist system
27. Observe the bright spot to confirm contact was made
28. If no contact was made, restart the spindle (in LOW GEAR), turn on Kool Mist, and continue raising the table very slightly

Step 6: Face Milling the First Surface

1. With the witness cut established and the spindle stopped:
2. Note the position on the knee handwheel dial
3. Turn the knee handwheel clockwise to raise the table by approximately 0.010-0.020" (1-2 small marks on the dial)

4. This will be your first real cutting depth
5. Restart the spindle:
6. **CRITICAL: Verify the machine is still in LOW GEAR (200 RPM)**
7. Press the start button
8. Verify proper rotation
9. Turn on the Kool Mist system:
10. Ensure coolant is flowing properly
11. Direct it at the cutting area
12. You have two options for moving the table:
13. Manual feed: You'll turn the handwheel yourself
14. Power feed: The machine will move the table automatically
15. For manual feed:
16. Grasp the X-axis handwheel firmly
17. When turning the crank clockwise (moving the table to the left), hold the left brake with your left hand
18. When turning counterclockwise (moving the table to the right), hold the right brake with your left hand
19. Begin turning the handwheel at a steady pace to move the workpiece under the cutter
20. For power feed:
21. Ensure the table is positioned so the cutter is at one end of the workpiece
22. Set the power feed rate to a slow setting (typically 3-5 inches per minute for steel)
23. Engage the power feed by pulling out the engagement lever
24. Stand ready to disengage it when the cut is complete
25. As the cutter moves across the workpiece:
26. Watch for consistent chip formation
27. Listen for consistent cutting sounds
28. Ensure Kool Mist continues to cool the cutting area
29. Be ready to stop if anything sounds or looks wrong
30. After the cutter has traversed the entire workpiece:
31. If using power feed, disengage it
32. Stop the spindle by pressing the stop button
33. Turn off the Kool Mist system
34. Wait for the spindle to come to a complete stop
35. Examine the cut surface:
36. With the machine OFF, carefully feel the surface with your hand
37. Look for a consistent finish across the entire surface
38. If the surface is not completely machined (some low spots remain):
    - Restart the spindle (**in LOW GEAR at 200 RPM**)
    - Turn on Kool Mist

    - Make another pass at the same height
    - Stop and check again
39. Once the entire surface is machined to a consistent finish:
    - Stop the spindle
    - Turn off Kool Mist
    - Lower the table slightly by turning the knee handwheel counterclockwise
    - Move the table to position the workpiece for the next pass if needed

Step 7: Squaring All Six Sides of the Workpiece

First Side (Bottom Face)

1. With the machine OFF, position the face mill above the workpiece.
2. Pull the quill down until the face mill is close to the workpiece surface.
3. Pull the quill down tight and engage the quill lock (Z-axis lock) to secure it in position.
4. Zero the knee handwheel by rotating it until the dial reads zero. Make a mental note of the handle position.
5. **CRITICAL: Verify the machine is in LOW GEAR before starting the spindle.**
6. Turn on the spindle at 200 RPM for face milling steel.
7. Turn on the Kool Mist system and direct it at the cutting area.
8. Slowly lift the knee handle up (turning clockwise) until the cutter just barely touches the highest point of the workpiece for your witness cut.
9. Once you've established this witness cut, lift the knee handle to raise the table by approximately 0.010-0.020" for your first real cut.
10. Engage the X-axis power feed by pulling out the engagement lever.
11. After completing the first pass, turn OFF the machine, then check the surface with your hand for smoothness.
12. Turn off the Kool Mist system.
13. Take additional passes as needed until the entire bottom surface is machined flat.
14. For each additional pass:
    - **Always verify LOW GEAR (200 RPM) before starting the spindle**
    - Always use Kool Mist during cutting

Marking and Flipping for Second Side (Top Face)

1. Turn off the machine and measure the machined surface.
2. Release the quill lock before removing the workpiece.
3. Remove the workpiece from the vise and clean it thoroughly.
4. **Important:** Mark the freshly machined surface with a paint pen. This is your reference surface.
5. Clean the vise jaws thoroughly with a shop rag.

6. Place clean parallels in the vise.
7. Position the workpiece with the **UNMARKED** (raw) side facing up and the marked (machined) side sitting on the parallels.
8. Ensure the workpiece is rotated exactly 180 degrees from its previous position to maintain parallelism between the first and second faces.
9. Gently close the vise until it contacts the workpiece.
10. Tap the workpiece down with a soft hammer to ensure it's seated firmly on the parallels.
11. Tighten the vise securely.

Machining the Second Side (Top Face)

1. Pull the quill down tight and engage the Z-axis lock.
2. Zero the knee handwheel by rotating it until the dial reads zero.
3. **CRITICAL: Verify the machine is in LOW GEAR (200 RPM) before starting the spindle.**
4. Start the spindle.
5. Turn on the Kool Mist system and direct it at the cutting area.
6. Make a witness cut by slowly lifting the knee handle up until the cutter just touches the highest point.
7. Lift the knee handle to raise the table by 0.010-0.020" for your first real cut.
8. Complete the face milling of the second side using the same technique as the first side.
9. Turn off the spindle and Kool Mist system when finished.
10. After machining, you now have two parallel surfaces (top and bottom).

Third Side (Back Face)

1. Release the quill lock and remove the workpiece from the vise.
2. Clean the workpiece and vise thoroughly.
3. Reposition the workpiece in the vise with the marked (first machined) surface against the BACK jaw of the vise. This ensures squareness to your first reference surface.
4. The raw stock side should be sitting loosely on the parallels - do not force it down tight as this could distort your workpiece.
5. Tighten the vise securely but not excessively.
6. Pull the quill down tight and engage the Z-axis lock.
7. Zero both the X and Y handwheels by rotating until the dials read zero.
8. **CRITICAL: Verify the machine is in LOW GEAR (200 RPM) before starting the spindle.**
9. Start the spindle.
10. Turn on the Kool Mist system and direct it at the cutting area.

11. Make a witness cut and then proceed with face milling the third side.
12. Turn off the spindle and Kool Mist system when finished.
13. You now have three squared surfaces (bottom, top, and back).

Fourth Side (Front Face)

1. Release the quill lock and remove the workpiece.
2. Rotate the workpiece 180 degrees to position the newly machined third side against the back jaw.
3. **Important difference:** Now that you're sitting on a freshly machined surface, ensure the workpiece is tight against the parallels. This is different from the previous setup where it was sitting loosely.
4. Tighten the vise securely.
5. Pull the quill down tight and engage the Z-axis lock.
6. Zero the handwheels again.
7. **CRITICAL: Verify the machine is in LOW GEAR (200 RPM) before starting the spindle.**
8. Start the spindle.
9. Turn on the Kool Mist system and direct it at the cutting area.
10. Machine the fourth side using the same technique.
11. Turn off the spindle and Kool Mist system when finished.
12. You now have four squared surfaces (bottom, top, back, and front).

Fifth Side (Right Face) - Side Milling

1. Release the quill lock and remove the workpiece.
2. For side milling, you'll need to reposition the workpiece in the vise with one of your machined surfaces (typically the bottom) sitting on a single parallel.
3. Position the workpiece so the unmachined right side is exposed for cutting.
4. The back machined surface should be against the back jaw of the vise.
5. Tighten the vise securely.
6. For side milling, you'll use the Y-axis handwheel more than in previous operations:
7. Pull the quill down tight and engage the Z-axis lock
8. Zero both X and Y handwheels
9. Position the cutter to the side of the workpiece
10. **CRITICAL: Verify the machine is in LOW GEAR (200 RPM) before starting the spindle**
11. Start the spindle
12. Turn on the Kool Mist system and direct it at the cutting area
13. Make a witness cut by slowly moving the Y-axis handwheel
14. For subsequent cuts, move the X-axis handwheel to position the cutter deeper
15. Machine the right face, taking multiple passes if necessary.

16. Turn off the spindle and Kool Mist system when finished.
17. You now have five squared surfaces.

Sixth Side (Left Face)

1. Release the quill lock and remove the workpiece.
2. Rotate the workpiece 180 degrees to position the newly machined right side against the back jaw.
3. Ensure the bottom machined surface is sitting firmly on the parallel.
4. Tighten the vise securely.
5. Pull the quill down tight and engage the Z-axis lock.
6. Zero both X and Y handwheels.
7. **CRITICAL: Verify the machine is in LOW GEAR (200 RPM) before starting the spindle.**
8. Start the spindle.
9. Turn on the Kool Mist system and direct it at the cutting area.
10. Machine the left face using the same side milling technique.
11. Turn off the spindle and Kool Mist system when finished.
12. After this operation, measure the overall width to ensure you're approaching the final dimension (3.200±.010).

Final Sizing to Dimension

1. After all six sides are squared, you'll likely need to make final precision cuts to bring the workpiece to the exact required dimensions (3.200±.010 × .875±.005 × 1.600±.005).
2. For these final passes:
3. Always pull the quill down tight and engage the Z-axis lock
4. Zero the appropriate handwheel before each cut
5. **CRITICAL: Always verify LOW GEAR (200 RPM) before starting the spindle**
6. Always use Kool Mist during cutting
7. Take very light cuts (0.005" or less)
8. Measure after each cut
9. For the X dimension (3.200±.010):
10. Position the workpiece with the left or right face to be machined
11. Zero the X-axis handwheel
12. Make light cuts until dimension is achieved
13. For the Y dimension (.875±.005):
14. Position the workpiece with the front or back face to be machined
15. Zero the Y-axis handwheel
16. Make light cuts until dimension is achieved
17. For the Z dimension (1.600±.005):

18. Position the workpiece with the top or bottom face to be machined
19. Zero the Z-axis handwheel
20. Make light cuts until dimension is achieved

Setting the Dials on the Bridgeport

Throughout this process, proper dial setting is critical:

1. **Knee Handwheel (Z-axis):**
2. Each full rotation typically equals 0.100"
3. The dial is marked in 0.001" increments
4. Always turn clockwise to raise the table for cutting

5. Zero this dial before making witness cuts

6. **X-axis Handwheel:**

7. Each full rotation typically equals 0.200"
8. The dial is marked in 0.001" increments
9. Turn clockwise to move the table to the left
10. When turning clockwise, hold the left brake

11. When turning counterclockwise, hold the right brake

12. **Y-axis Handwheel:**

13. Each full rotation typically equals 0.200"
14. The dial is marked in 0.001" increments
15. Turn clockwise to move the table toward you

16. Turn counterclockwise to move the table away from you

17. **Backlash Compensation:**

18. Always approach your final position from the same direction
19. If you overshoot, back up at least 0.050" and then approach again
20. This eliminates the effect of backlash in the lead screws

Remember: After each machining operation, deburr the edges with a file and clean chips away frequently with a brush, never with your hands. Cleanliness and attention to detail are essential throughout the entire squaring process.

Setup 2: Layout and Center Drilling

Step 1: Layout Preparation

1. After squaring all six sides of the workpiece, remove it from the vise.
2. Use a shop rag to thoroughly clean all surfaces, removing any oil, coolant, or chips.
3. Place the workpiece on a clean surface with the top face (the face that will receive the holes) facing up.
4. Locate the layout dye or layout fluid (typically blue or red).
5. Shake the layout dye container vigorously for at least 30 seconds to mix the contents.
6. Apply a thin, even coat of layout dye to the entire top surface:
7. Hold the container 6-8 inches away from the workpiece
8. Spray or brush in a smooth, even pattern
9. Cover the entire surface with a thin coat
10. Avoid applying too much, which can run or drip
11. Allow the layout dye to dry completely:
12. This typically takes 2-3 minutes
13. Do not touch or disturb the surface while drying
14. The surface should appear uniformly colored with no wet spots
15. While waiting, gather your measurement and marking tools:
16. Height gauge or surface gauge
17. Scriber
18. Precision ruler or scale
19. Center punch
20. Small hammer

Step 2: Securing the Workpiece for Layout and Drilling

1. Clean the mill vise thoroughly with a shop rag.
2. Place clean parallels in the vise, ensuring they are:
3. The same height
4. Parallel to each other
5. Positioned to support the workpiece adequately
6. Position the workpiece in the vise with:
7. The layout dye-coated surface (top face) facing up
8. The bottom face sitting firmly on the parallels
9. One of the squared sides (preferably the back face) against the fixed jaw
10. Gently close the vise until it contacts the workpiece.
11. Tap the workpiece down with a soft hammer to ensure it's seated firmly on the parallels.

12. Tighten the vise securely, but not excessively.
13. Use a precision square to verify the workpiece is perpendicular to the table:
14. Place the square against the front face of the workpiece
15. Check that it sits flush against both the workpiece and the table
16. If adjustment is needed, slightly loosen the vise and adjust
17. Once properly aligned, tighten the vise securely.

Step 3: Finding Edges and Establishing Reference Points

1. With the workpiece secured, you need to find the precise edges to establish your X and Y zero positions.
2. For this operation, you'll use an edge finder:
3. Locate an edge finder tool (typically a two-piece tool with a cylindrical body)
4. Clean it thoroughly with a shop rag
5. Insert it into the spindle chuck
6. Tighten the chuck securely
7. Set the spindle speed for edge finding:
8. **CRITICAL: Verify the machine is in LOW GEAR**
9. Set to approximately 250 RPM (lower than typical because we're working with steel)
10. **Double-check that the machine is in LOW GEAR before starting**
11. Start the spindle
12. Finding the X-axis edge (left side):
13. Position the edge finder approximately 1/4" to the right of the left edge of the workpiece
14. Slowly move the table to the right (turning the X handwheel counterclockwise)
15. Continue until the edge finder's tip just "breaks" or "jumps"
16. This happens when the edge finder contacts the workpiece edge
17. Stop the table movement immediately
18. Setting X-axis zero:
19. Note the position on the X-axis dial
20. The edge finder has a known diameter (typically 0.200")
21. Turn the X handwheel counterclockwise (moving right) by exactly half the edge finder diameter (typically 0.100")
22. This positions the spindle centerline exactly at the workpiece edge
23. Zero the X-axis dial by rotating just the dial (not the handwheel) until zero aligns with the reference mark
24. Finding the Y-axis edge (bottom side):
25. Position the edge finder approximately 1/4" above the bottom edge of the workpiece
26. Slowly move the table away from you (turning the Y handwheel counterclockwise)

27. Continue until the edge finder's tip just "breaks" or "jumps"
28. Stop the table movement immediately
29. Setting Y-axis zero:
30. Note the position on the Y-axis dial
31. Turn the Y handwheel counterclockwise (moving away) by exactly half the edge finder diameter (typically 0.100")
32. This positions the spindle centerline exactly at the workpiece edge
33. Zero the Y-axis dial by rotating just the dial (not the handwheel) until zero aligns with the reference mark
34. You have now established the bottom-left corner of the workpiece as your X=0, Y=0 reference point.
35. Stop the spindle and remove the edge finder.

Step 4: Positioning for the First Hole

1. According to the drawing, the first hole (Ø.2195±.0005) is located at:
2. X = 0.500" from the left edge
3. Y = 0.500" from the bottom edge
4. To position for this hole:
5. Turn the X-axis handwheel clockwise to move the table left by exactly 0.500"
6. Watch the dial carefully as you turn
7. Each full rotation equals 0.200", so you'll need 2 full rotations plus 0.100" more
8. When turning, hold the left brake with your left hand
9. Stop exactly at 0.500" on the dial
10. Now move in the Y direction:
11. Turn the Y-axis handwheel clockwise to move the table toward you by exactly 0.500"
12. Watch the dial carefully as you turn
13. Each full rotation equals 0.200", so you'll need 2 full rotations plus 0.100" more
14. Stop exactly at 0.500" on the dial
15. The spindle is now positioned directly above where the center of the first hole should be.

Step 5: Center Drilling the First Hole

1. Install a center drill in the chuck:
2. Select a #2 or #3 center drill
3. Clean the shank thoroughly
4. Insert it into the chuck
5. Tighten the chuck securely
6. Check that the center drill runs true by rotating it by hand

7. Set the appropriate spindle speed:
8. **CRITICAL: Verify the machine is in LOW GEAR**
9. For a center drill in steel, set to approximately 250 RPM
10. **Double-check that the machine is in LOW GEAR before starting**
11. Start the spindle
12. Turn on the Kool Mist system and direct it at the drilling area.
13. Prepare for center drilling:
14. Pull the quill down until the center drill is approximately 1/2" above the workpiece
15. Zero the quill depth stop or make a mental note of the current position
16. Begin center drilling:
17. Grasp the quill feed handle firmly
18. Slowly lower the quill, applying light pressure
19. As the center drill contacts the workpiece, maintain steady, light pressure
20. Continue until the conical portion of the center drill is fully engaged (typically 1/8" to 3/16" deep)
21. Do not drill deeper than the conical portion of the center drill
22. Retract the center drill:
23. Release pressure on the quill feed handle
24. Allow the quill to return to its upper position
25. If it doesn't return automatically, gently pull it up
26. Stop the spindle and turn off the Kool Mist system.
27. Check the center-drilled hole:
28. It should be centered and symmetrical
29. The conical portion should be fully formed
30. There should be no burrs or rough edges

Step 6: Positioning and Center Drilling the Second Hole

1. According to the drawing, the second hole is located at:
2. X = 2.200" from the left edge
3. Y = 0.500" from the bottom edge
4. To position for this hole:
5. Note your current X position (0.500")
6. You need to move to X = 2.200", which is 1.700" to the right from your current position
7. Turn the X-axis handwheel counterclockwise to move the table right
8. When turning counterclockwise, hold the right brake with your left hand
9. Move exactly 1.700" (8 full rotations plus 0.100")
10. Stop exactly at 2.200" on the dial
11. The Y position remains the same (0.500"), so no Y-axis movement is needed.
12. Center drill this hole using the same technique as the first hole:

13. **CRITICAL: Verify the machine is in LOW GEAR (250 RPM) before starting**
14. Start the spindle
15. Turn on the Kool Mist system
16. Lower the quill slowly
17. Center drill to the same depth as the first hole
18. Retract the quill
19. Stop the spindle and turn off Kool Mist
20. Check the result

Step 7: Positioning and Center Drilling the M20×1.5 Threaded Hole

1. According to the drawing, the M20×1.5 threaded hole is located at:
2. X = 1.350" from the left edge
3. Y = 0.800" from the bottom edge
4. To position for this hole:
5. Note your current X position (2.200")
6. You need to move to X = 1.350", which is 0.850" to the left from your current position
7. Turn the X-axis handwheel clockwise to move the table left
8. When turning clockwise, hold the left brake with your left hand
9. Move exactly 0.850" (4 full rotations plus 0.050")
10. Stop exactly at 1.350" on the dial
11. Now adjust the Y position:
12. Note your current Y position (0.500")
13. You need to move to Y = 0.800", which is 0.300" away from you from your current position
14. Turn the Y-axis handwheel counterclockwise to move the table away from you
15. Move exactly 0.300" (1 full rotation plus 0.100")
16. Stop exactly at 0.800" on the dial
17. Center drill this hole using the same technique as the previous holes:
18. **CRITICAL: Verify the machine is in LOW GEAR (250 RPM) before starting**
19. Start the spindle
20. Turn on the Kool Mist system
21. Lower the quill slowly
22. Center drill to the same depth as the previous holes
23. Retract the quill
24. Stop the spindle and turn off Kool Mist
25. Check the result

Step 8: Final Check of Center-Drilled Holes

1. Stop the spindle completely.
2. Raise the quill to its highest position and lock it.
3. Move the table to provide clear access to the workpiece.
4. Visually inspect all three center-drilled holes:
5. They should be clean and symmetrical
6. The conical portion should be fully formed in each
7. There should be no burrs or rough edges
8. If any holes appear problematic, address the issues before proceeding.
9. Clean the workpiece with a brush to remove any chips.
10. Do not remove the workpiece from the vise yet, as you'll proceed to drilling operations next.

Setup 3: Precision Hole Operations

Step 1: Preparing for Precision Drilling

1. With the workpiece still secured in the vise and all three holes center-drilled, you're ready to begin precision drilling.
2. First, gather the necessary tools and equipment:
3. Drill bits of appropriate sizes
4. Precision reamer for the Ø.2195±.0005 hole
5. Cutting fluid or coolant
6. Depth gauge or caliper for measuring
7. Chip brush
8. Ensure your work area is clean and organized:
9. Clear away any chips or debris
10. Arrange tools in order of use
11. Have cutting fluid within easy reach
12. Check that the workpiece is still securely held in the vise:
13. Apply moderate pressure to test for any movement
14. If any movement is detected, re-tighten the vise

Step 2: Drilling the First Precision Hole

1. Position the table to the location of the first hole (X = 0.500", Y = 0.500"):
2. Use the X and Y handwheels to move precisely to these coordinates
3. Remember to use the appropriate brake when turning each handwheel
4. Verify the position by checking the dial readings
5. Select a drill bit for the Ø.2195±.0005 hole:

6. Choose a drill bit slightly smaller than the final size (typically 7/32" or 0.218")
7. This allows for the reaming operation to achieve the final precise dimension
8. Clean the drill bit shank thoroughly
9. Install the drill bit in the chuck:
10. Insert the drill bit fully into the chuck
11. Tighten the chuck securely using the chuck key
12. Remove the chuck key immediately after tightening
13. Never leave the chuck key in the chuck
14. Set the appropriate spindle speed:
15. **CRITICAL: Verify the machine is in LOW GEAR**
16. For a 7/32" drill bit in steel, set to approximately 150 RPM
17. This slower speed is essential for drilling steel accurately
18. **Double-check that the machine is in LOW GEAR before starting**
19. Start the spindle
20. Turn on the Kool Mist system and direct it at the drilling area.
21. Begin drilling using the peck drilling technique:
22. Pull the quill down tight and engage the quill lock
23. Grasp the quill feed handle firmly
24. Lower the drill bit until it enters the center-drilled hole
25. Apply steady, moderate pressure to begin cutting
26. Drill to a depth of approximately 1-2 drill diameters (about 1/4")
27. Retract the drill bit completely to clear chips
28. Apply more Kool Mist
29. Lower the drill bit again and continue drilling
30. Repeat this peck drilling process until you've drilled completely through the workpiece
31. Once the drill breaks through:
32. Continue for one more short peck to ensure complete breakthrough
33. Retract the drill bit completely
34. Stop the spindle
35. Turn off the Kool Mist system
36. Clean the hole and surrounding area:
37. Use a brush to clear away chips
38. Apply compressed air if available (wear safety glasses)
39. Inspect the hole for quality and position

Step 3: Reaming the First Precision Hole

1. With the first hole drilled, you'll now ream it to the final precise dimension (Ø.2195±.0005).
2. Remove the drill bit from the chuck:

3. Loosen the chuck using the chuck key
4. Remove the drill bit and set it aside safely
5. Remove the chuck key from the chuck
6. Select the precision reamer:
7. Locate the Ø.2195" precision reamer
8. Inspect it for any damage or wear
9. Clean the shank thoroughly
10. Install the reamer in the chuck:
11. Insert the reamer fully into the chuck
12. Tighten the chuck securely using the chuck key
13. Remove the chuck key immediately after tightening
14. Set a slower spindle speed for reaming:
15. **CRITICAL: Verify the machine is in LOW GEAR**
16. For reaming steel, set to approximately 100 RPM
17. This very slow speed is essential for achieving precision in steel
18. **Double-check that the machine is in LOW GEAR before starting**
19. Start the spindle
20. Apply cutting fluid generously:
21. Use a small brush or squeeze bottle
22. Ensure the hole is well-lubricated
23. This is critical for achieving the required precision
24. Begin the reaming operation:
25. Pull the quill down tight and engage the quill lock
26. Grasp the quill feed handle firmly
27. Lower the reamer until it contacts the hole entrance
28. Apply very light, consistent pressure
29. Allow the reamer to start cutting on its own
30. Maintain steady, even pressure throughout the entire operation
31. Do not force the reamer or apply excessive pressure
32. Continue until the reamer passes completely through the workpiece
33. Important reaming technique:
34. Keep the feed rate slow and consistent
35. Never reverse the reamer while it's in the hole
36. If the hole goes through the workpiece, continue through and out the other side
37. If the hole doesn't go through, retract the reamer carefully without reversing
38. After reaming:
39. Retract the reamer completely
40. Stop the spindle
41. Remove the reamer from the chuck

42. Clean and inspect the reamed hole:
    - Use a brush to clear away chips
    - Apply compressed air if available
    - Visually inspect the hole for finish quality
    - If possible, check the hole size with a pin gauge or precision micrometer

Step 4: Drilling the Second Hole

1. Position the table to the location of the second hole (X = 2.200", Y = 0.500"):
2. Use the X and Y handwheels to move precisely to these coordinates
3. Remember to use the appropriate brake when turning each handwheel
4. Verify the position by checking the dial readings
5. Select the appropriate drill bit for this hole:
6. Based on the drawing, determine the required size
7. Clean the drill bit shank thoroughly
8. Install the drill bit in the chuck:
9. Insert the drill bit fully into the chuck
10. Tighten the chuck securely using the chuck key
11. Remove the chuck key immediately after tightening
12. Set the appropriate spindle speed:
13. **CRITICAL: Verify the machine is in LOW GEAR**
14. For drilling steel, set to approximately 150 RPM for larger bits or 250 RPM for smaller bits
15. **Double-check that the machine is in LOW GEAR before starting**
16. Start the spindle
17. Turn on the Kool Mist system and direct it at the drilling area.
18. Drill the hole using the same peck drilling technique described earlier:
19. Lower the drill bit until it enters the center-drilled hole
20. Apply steady, moderate pressure
21. Use the peck drilling method to clear chips
22. Continue until you've drilled completely through the workpiece
23. Once complete:
24. Retract the drill bit completely
25. Stop the spindle
26. Turn off the Kool Mist system
27. Clean the hole and surrounding area

Step 5: Drilling for the M20×1.5 Threaded Hole

1. Position the table to the location of the threaded hole (X = 1.350", Y = 0.800"):
2. Use the X and Y handwheels to move precisely to these coordinates

3. Verify the position by checking the dial readings
4. Select the appropriate drill bit for an M20×1.5 tap:
5. For metric threads, the drill size is typically the major diameter minus the pitch
6. For M20×1.5, use an 18.5mm or 47/64" drill bit
7. Clean the drill bit shank thoroughly
8. Install the drill bit in the chuck:
9. Insert the drill bit fully into the chuck
10. Tighten the chuck securely using the chuck key
11. Remove the chuck key immediately
12. Set the appropriate spindle speed:
13. **CRITICAL: Verify the machine is in LOW GEAR**
14. For a larger drill bit in steel, set to approximately 150 RPM
15. **Double-check that the machine is in LOW GEAR before starting**
16. Start the spindle
17. Turn on the Kool Mist system and direct it at the drilling area.
18. Begin drilling:
19. Lower the drill bit until it enters the center-drilled hole
20. Apply steady, moderate pressure
21. Use the peck drilling method, retracting frequently to clear chips
22. Apply additional Kool Mist with each peck
23. Continue until you reach the required depth (not through the workpiece)
24. Once the required depth is reached:
25. Retract the drill bit completely
26. Stop the spindle
27. Turn off the Kool Mist system
28. Clean the hole and surrounding area thoroughly
29. Measure the hole depth to ensure it meets requirements

Step 6: Tapping the M20×1.5 Threaded Hole

1. With the hole drilled to the correct size and depth, you're ready to tap the M20×1.5 threads.
2. Remove the drill bit from the chuck:
3. Loosen the chuck using the chuck key
4. Remove the drill bit and set it aside safely
5. Remove the chuck key from the chuck
6. For tapping, you'll need:
7. M20×1.5 tap
8. Tap handle or wrench
9. Cutting oil (not Kool Mist)
10. Tap guide (if available)

11. If using a tap guide:
12. Install the tap guide in the chuck
13. Tighten the chuck securely
14. Insert the M20×1.5 tap into the guide
15. Do NOT run the spindle with the tap guide installed
16. If not using a tap guide:
17. You'll need to align the tap manually
18. Use the center-drilled hole and previous drilling to help with alignment
19. Prepare for tapping:
20. Position the tap directly over the drilled hole
21. Apply cutting oil generously to the tap and hole
22. **IMPORTANT: Use cutting oil, not Kool Mist, for tapping operations**
23. The cutting oil is essential for proper thread formation and tap lubrication
24. Begin tapping:
25. Apply light downward pressure to start the tap
26. Turn the tap clockwise slowly and carefully by hand
27. Ensure the tap starts straight and true in the hole
28. Once the tap has started cutting threads (1-2 turns), release downward pressure
29. Continue turning clockwise for one full turn
30. Then turn counterclockwise a quarter turn to break the chip
31. Apply more cutting oil
32. Continue this forward-backward pattern until you reach the required depth
33. Removing the tap:
34. Once the required depth is reached, turn the tap counterclockwise
35. Continue turning until the tap is completely removed from the hole
36. Be careful not to apply side pressure that could break the tap
37. Clean and inspect the threads:
38. Use a brush to clear away chips
39. Apply compressed air if available
40. Visually inspect the threads for quality and completeness

Step 7: Final Inspection of All Holes

1. With all drilling and tapping operations complete, perform a final inspection:
2. Visually inspect each hole for quality, position, and finish
3. Check the reamed hole with a pin gauge if available
4. Check the threaded hole with a thread gauge or by testing with a mating fastener
5. Clean the workpiece thoroughly:
6. Use a brush to remove all chips and debris
7. Apply compressed air if available
8. Wipe with a clean shop rag

9. If all holes meet specifications, you can proceed to the final operations.
10. If any issues are found, consult with your instructor before proceeding.

Setup 4: Final Operations and Inspection

Step 1: Deburring Operations

1. Remove the workpiece from the vise:
2. Loosen the vise carefully
3. Remove the workpiece and set it on a clean surface
4. Remove and clean the parallels
5. Inspect all edges and holes for burrs:
6. Look for raised edges around drilled or reamed holes
7. Check all machined edges for sharpness or burrs
8. Pay special attention to the exit side of drilled holes
9. Gather deburring tools:
10. Deburring tool or countersink
11. Fine file
12. Sandpaper (320 grit or finer)
13. Clean shop rag
14. Deburr the edges of the workpiece:
15. Hold the workpiece securely
16. Use a fine file to lightly break all sharp edges
17. Make only 1-2 passes - the goal is to remove the sharpness, not create a visible chamfer
18. Work systematically around all edges
19. Deburr the drilled and reamed holes:
20. For the precision reamed hole (Ø.2195±.0005):
    - Use extreme caution to avoid damaging the precision surface
    - Use only a hand-held deburring tool
    - Make a single light pass around the entrance and exit of the hole
    - Do not insert the deburring tool deep into the hole
21. For the second drilled hole:
    - Use a deburring tool or countersink
    - Lightly deburr both the entrance and exit of the hole
22. For the threaded hole (M20×1.5):
    - Use a deburring tool to lightly break the edge at the entrance
    - Be careful not to damage the first thread
    - Do not deburr the bottom of the hole
23. Clean the workpiece after deburring:

24. Use a brush to remove any filings or debris
25. Wipe with a clean shop rag
26. Inspect again to ensure all burrs have been removed

Step 2: Final Dimensional Inspection

1. Gather precision measuring tools:
2. Micrometers (0-1", 1-2", 2-3", 3-4")
3. Calipers
4. Pin gauges or precision bore gauges
5. Thread gauges
6. Surface plate and height gauge (if available)
7. Measure the overall dimensions:
8. Length (3.200±.010):
    - Use a 3-4" micrometer
    - Measure at multiple points along the workpiece
    - Record the measurements
    - Verify they fall within the tolerance range (3.190-3.210")
9. Width (.875±.005):
    - Use a 0-1" micrometer
    - Measure at multiple points along the workpiece
    - Record the measurements
    - Verify they fall within the tolerance range (.870-.880")
10. Height (1.600±.005):
    - Use a 1-2" micrometer
    - Measure at multiple points along the workpiece
    - Record the measurements
    - Verify they fall within the tolerance range (1.595-1.605")
11. Measure the precision reamed hole (Ø.2195±.0005):
12. Use pin gauges or a precision bore gauge
13. Check at both the entrance and middle of the hole
14. Verify the diameter falls within the tolerance range (0.2190-0.2200")
15. Check the second hole:
16. Use a caliper or pin gauges
17. Verify the diameter meets the drawing requirements
18. Check the threaded hole (M20×1.5):
19. Use a thread gauge if available
20. Alternatively, test with a known good M20×1.5 fastener
21. The fastener should thread in smoothly without binding or excessive play
22. Check hole positions:
23. If a surface plate and height gauge are available, verify the hole positions

24. Otherwise, measure the distances between holes with calipers
25. Compare to the drawing dimensions
26. Record all measurements for reference.

Step 3: Surface Finish Inspection

1. Inspect all machined surfaces for finish quality:
2. Look for tool marks, gouges, or scratches
3. Check for consistent finish across each surface
4. Ensure there are no deep scratches or flaws
5. Inspect the precision reamed hole:
6. Look for a smooth, consistent finish
7. Check for any scoring or tool marks
8. Ensure the hole is straight and true
9. Inspect the threaded hole:
10. Check for clean, well-formed threads
11. Look for any torn or damaged threads
12. Ensure the threads run true and straight
13. If any surface finish issues are found:
14. Determine if they affect the functionality of the part
15. Consult with your instructor if necessary

Step 4: Final Cleaning and Preparation

1. Thoroughly clean the completed workpiece:
2. Use a clean shop rag to remove any oil or fingerprints
3. Use compressed air to blow out any chips from holes
4. Ensure all surfaces are clean and free of debris
5. Apply a light coat of protective oil:
6. Use a clean rag with a small amount of machine oil
7. Apply a very thin coat to all surfaces to prevent rust
8. Be careful not to apply too much oil
9. Prepare for storage or delivery:
10. If the part will not be used immediately, wrap it in clean paper
11. Place it in a protective container or bag
12. Label the container with part information if required

Step 5: Documentation and Process Review

1. Gather all measurement records and notes.
2. Compare the final part to the original drawing:

3. Verify all dimensions are within tolerance
4. Confirm all features are present and correct
5. Ensure the part meets all requirements
6. Document any challenges or issues encountered during the machining process.
7. Note any process improvements for future similar parts.
8. Present the completed part to your instructor for final approval.

Conclusion

You have now completed the machining process for this part. Throughout this process, you've learned how to: - Properly set up a workpiece in a mill vise - Face mill surfaces to create square and parallel sides - Locate and drill precision holes - Ream holes to tight tolerances - Tap threads in steel - Verify dimensions and ensure quality

Remember that attention to detail, cleanliness, and patience are the keys to successful machining. Each step builds on the previous one, and mistakes are difficult to correct once made. Take your time, measure twice, and cut once.

The skills you've practiced in creating this part form the foundation of all machining operations. As you continue to develop these skills, you'll be able to create increasingly complex and precise parts.