GRT Shop Safety Training: Mill Curriculum (22-23)

Trainer notes:

- *Materials must be prepared at the stations before each lesson; OK to retrieve tools during the lesson to show where they are located. Be sure to put away materials + tools after lessons.*
- *Every day starts with a safety inspection of everyone's attire to make sure we are shop safe. The first day is led by the trainer, on subsequent days ask trainees to check each other.*
- *Introduce yourself and learn your groups' names. These will be your teammates for the whole year, so start off on a good foot.*

Session 1 (45 minutes)

General Safety + Expectations (2)

- Wear safe attire for shop work (safety glasses, hair tied in a bun, sleeves above elbows, closed-toe shoes, covered back/shoulders/midriff, pants below knees, no dangling clothing/jewelry)
- Work with a shop buddy at all times
- Keep limbs away from power tools + sharp edges
- Don't use broken or dull equipment; Immediately report injuries and broken tools to safety captain & mentors
- Proper workholding: Secure stock (vise, clamp, etc.) before cutting
- Turn off machines and clean parts, tools, and workspace after each use
- Lightly oil metal to be cut; only oil the tool when tapping (Q1)
- Always clean, deburr, and measure a part before giving it to QC/anyone else (Q2)
- Don't be afraid to ask questions :)

Intro to Mill (5)

- 2022-23 GRT mill lead is Aiden Man
- Milling: the process of removing metal or plastic using a spinning tool (called an endmill) to cut into the part held by the vise, attached to the table that moves
- Used to square stock and make accurate holes, slots, and shapes with tight tolerance

Show example mill parts, then box beam, sheet metal, air compressor in the metal cat closet

- Mill operations are typically used to machine box beam and sheet metal (Q3)

Parts of the Mill (names + functions) (15)

Make sure to gesture towards + touch each part as you name it, and use quick demos

Show+define XYZ directions with movement of the table using the handwheels

- Power Switch: Turns the machine on or off, has forward or reverse options
- Spindle Brake: Stops the spindle rotation, use after machine is turned off
- Spindle: Holds and spins the tool
- Quill: Holds the spindle, moves up+down
- Quill Feed Handle: Raises and lowers the quill+spindle+tool
- Quill Feed Lock: Locks the quill in place
- Quill Stop: Moves up and down with the quill, limited by the micrometer nut
- Micrometer Nut: Limits quill movement (holds a set locked position) and allows repeated holes at the same depth
    - Ticks indicate 0.001" in depth, rotate clockwise to lower, rotate counterclockwise to raise, center button detaches it from the threaded rod (allows faster relocation)
- Speed Change Handwheel (Rocky exclusive): Adjusts machine's RPM, change only when the motor is on
- Pneumatic Power Drawbar: Tightens/loosens the collet holding the tool in the spindle
- DRO (digital readout): Shows displaced distance (x and y) relative to a user-defined zero
- X-axis Handwheel: Moves the table in the x direction
    - When you change direction when moving the mill table, the gap between the gears causes the DRO to incorrectly register the shift; to avoid this, always move the table until you feel the gears mesh/shift, then turn back to intended location
- Y-axis Handwheel: Moves the table in the y direction
- Z-axis Handwheel: Moves the table in the z direction; better to use the quill for z axis motion whenever possible (Quill maintenance costs significantly less)
- X-axis Lock: Locks the table in the x direction
- Y-axis Lock: Locks the table in the y direction
- Vise: Clamps stock in place to the table
- Vise Handle: Tightens/loosens the jaws of the vise, removed or flipped when machining (prevents part from being loosened) or not in use (prevents others from bumping into it)

Tools used with the Mill (names, functions + locations) (15)

Show where each tool is kept

- Collet: Holds tool shafts of specific diameter, more secure than a chuck
    - Tools that go directly into a collet: end mills, edge finders, tap guides, drill chucks, Silver and Deming or standard drill bits (Q4)
- End Mill: Cuts material; cutting edge on the sides, not at the end like a drill bit (Q5)
- Edge Finder: Used to locate the edges of a part, used with the DRO to map other operations (Q6)
- Parallels: Raise the part to protect the vise, hold it parallel to the table, positions the part in a range where the spindle has the least vibration (extended quill = more vibration)
    - Always retrieve a pair of identical parallels
- Hardstops: Holds stock at a set x position on the vise
    - Vise hard stop for shorter stock, table hard stop for longer stock

Show how to set up both types of hard stops

- Drill Bit: Drills holes
- Types of Drill Bits:
    - Regular: Same diameter throughout, usually smaller and held in drill chuck or collet
    - Silver and Deming: Cutting edges/flutes have a larger diameter than the shank, any bit drilling ≥½ is inserted directly into the collet, NOT THE DRILL CHUCK

Reminder of how to measure drill bits, measure the flutes

- Tap: Cuts threads into holes
    - Always clamp onto the right angle section of the tap, not circular

Take a drill bit+tap back to the mills to show how they fit in the drill chuck and tap handle

- Drill Chuck: Holds drill bits (shaft diameter NEVER LARGER THAN ½")
- Center Drill: Creates divot, marks where holes will be drilled, prevents walking/slipping while drilling, held in the drill chuck
- Tap Handle: Holds the tap, allows user to manually turn the tap
- Tap Guide: Pushes the tap handle and tap into the part, keeps the tool centered and vertical

Extra time goes to questions

Should have answered 1-6

Session 2 (45 minutes)

Prepare spindle speed at 1400 rpm, no need to change speeds with these operations

Prepare box beam + corresponding drawing sheet (length depends on group #)

Turning on/off the machine (1)

- Turn power switch to "forward", not "reverse"
    - "Forward" goes clockwise, correct direction for all tools
    - "Reverse" goes counterclockwise, used to make slow speed clockwise
- Turn power switch to "off" then press the spindle brake

Inserting tools into the spindle (Demo) (5)

- Check the meter on the side of the mill reads 80 psi
- Quill all the way up and locked
- Clean/wipe off the collet and tool (including the slits in the collet)
- Feel the inside of the spindle for the alignment pin
- Position the collet to align the collet alignment slot with the spindle alignment pin
- Carefully push the collet up while holding the tool in place
- Keep fingers under the collet and away from the slits (or use the hand guide)
- Always tighten the collet with a tool in it; tightening without a tool will deform the collet
- Keep the tool flutes out of the collet; tightening onto flutes will damage collet and tool
- Announce "loud noise"
- Engage the power drawbar with 2-3 short, hard presses of the "in" button until you hear the "pitch drop"
- Long presses can result in the collet coming loose, damaged collet threads, and possibly the machine breaking

Removing Tools (Demo + Practice) (5)

Remove in 2 steps: first remove and replace only the tool, then remove the collet

- Quill all the way up and locked
- Place hand under the tool and collet
- Announce "loud noise"
- Disengage the power drawbar with 2-3 short, hard presses of the "out" button
- Catch/remove the tool (only)
- When using the same collet for another operation, insert the new tool and press "in"
    - Most tools we use are held by the ½" collet
- To remove/change the collet, press "out" again and catch/remove the collet

Work Holding (5)

- Wipe the vise, parallels, and parts with a clean rag to remove chips and oil (Q7)
- We assume that the clean vise is flat and the walls are perpendicular
- Use parallels to raise the part (Q7)
    - Especially used when drilling thru holes - we don't want to drill into the vise
- Snug the vise jaws - make sure the part is clamped tightly
- For thin box beam/sheet metal, clamping too tightly will deform the stock
- Apply pressure downward to check the part is against/parallel to the bottom surface

Adjustable Parallels (1)

- Used when stock is long/hanging off the edge of the vise - support the stock
- When performing operations far from the vise the part will vibrate, making the operation inaccurate
- Easier than setting up another vise
- Parallel to the table, heavy enough to maintain placement
- Use a rag to fill spaces when moving up a notch cannot

Facing (Demo) (10)

- Accurate measurements require that we square/face the stock
    - Smooth, perpendicular to table/vise, origin for measurements
- We assume extruded sides (box beam, rectangular stock) are squared
- Have trainees retrieve materials and set up: ½" collet, ½" end mill
- Clamp the part with the edge off the right side of the vise and oil along the cut
- Power on; advance the table until the part barely contacts the side of the tool; move the table/part backwards then forwards using the y-axis handwheel; zero on the x axis (X_0)
- Max pass is 50 thousandths of an inch (0.050") - more will damage the tool (Q8)
- Lined marks indicate faced edges; make passes until the entire surface is faced
- Climb vs Conventional milling (Q9)
    - Climb milling goes with the tool rotation, used for shallow finishing passes, tends to snag on stock
    - Conventional milling goes against the rotation, use for most passes, safer

Facing to specific lengths (Demo +Practice) (10)

- Face one end, rotate the part, then face on the opposite end to square it
- Wipe faced edges + inside of the caliper jaws, and re zero the caliper before measuring
- Use calipers to measure the length while the part is clamped and calculate the cut required to get to the desired length - may require multiple passes
- Measure with the caliper jaws over both the top and bottom layers (for box beam)
- Face, then measure with calipers after each pass
- As you get closer to the desired length, measure more frequently and make smaller passes (Q10)
- Always undercut - we can always subtract material, but we cannot add material

Clean up (5)

- Clean parts, tools, and vise using a clean rag
- Vacuum the table (on top, behind, under the table, inside the slots using the attachment)
- Put tools away (Q11)

Should have answered 7-11

Session 3 (45 minutes)

Prepare box beam from session 2, duplicate box beam, and drawing sheet (depends on group #)

Edge Finding (Demo + Practice) (15)

- Required for accurate drilling and slotting; only used with a properly faced piece
- Have trainees retrieve tools and set up: ½" collet, ½" edge finder
- Offset the magnetic head, power on
- Advance the table until the part barely contacts the edge finder
- Advance the table slowly until the magnetic head becomes aligned, then slightly offset
- Set the X zero (press "X_0" on the DRO)
- Back the table away from the edge finder, offset the magnetic head and repeat the process until zeroes are <0.003" apart
- After finding the right edge, raise the edge finder above the stock and advance the table until the DRO reads x = - 0.25 (represented by the radius of the edge finder) and reset the zero (so now the center of the spindle is aligned with the edge of the part) (Q12)
- Have one trainee zero on the X axis, then have one zero on the Y axis (help them think it through)

Duplicate Parts (w/ hard stop) (Demo + Practice) (15)

Use edge finder for duplicating previous part

Explain how we normally use the hard stop from the start, zero after final pass, face to zero

- Face one of the ends
- Attach the hard stop to the vise, press the faced end against the hard stop, and clamp
- Face the other side down to the specified length
- After the final pass set the X zero (press "X_0" on the DRO)
- Clamp next part in the vise, face one end
- Press the faced end against the hard stop, clamp, and face the other end to the zero
- Remember, max increments of 0.050" (Any more will damage the endmill)

Clean Up (5)

- Clean parts and tools using a clean rag
- Vacuum the table (on top, behind, under the table, inside the slots using the attachment)
- Put everything away

Should have answered up to 12

Session 4 (45 minutes)

Prepare sheet metal stock for 2" x 2" (1 per group) and the sheet metal drawing sheet

Squaring Sheet Metal (Demo+Practice) (40)

- Have trainees retrieve materials and set up: ½" collet, ½" end mill, parallels
- Start with sheet metal oriented vertically
- Oil along the top edge
- Lower the quill so the end mill slightly overlaps the top edge, lock the quill, then face
- Push the micrometer nut up to the quill stop after the first pass (setting an initial zero)
- Rotate the micrometer nut (clockwise) to lower, max 0.020" (20 ticks)
- Make sure the tool is not above the part
- Lower the quill until the quill stop contacts the micrometer nut
- Lock the quill, turn on the mill, then face
- Repeat until edge is completely faced (circular marks indicate faced edges)
- Wipe the top edge, then flip the piece upside down to face the opposite edge
- Rotate the piece so the faced edges are clamped in the vise and face the remaining edges

Have trainees each do vertical facing on a different edge, then face to drawing sheet specifications

Use hard stop for normal facing

Clean Up (5)

- Clean parts, tools, and vise using a clean rag
- Vacuum the table (on top, behind, under the table, inside the slots using the attachment)
- Put tools away

Session 5 (45 minutes)

Use the same part from Session 4

Speeds (5)

- We do almost all milling with aluminum so most operations can run at the same speed (1400 rpm); drilling and plastics may require different speeds
- Leave Bullwinkle at 1400 rpm for facing and edge-finding; use Rocky when other speeds are necessary
- Facing: 1400 rpm
- Edge Finding: 1000 rpm
- Center Drilling: 1200 rpm
- Drilling: Consult chart (if you hear squeaking, slow the spindle speed) (Q13)

Speed Change (Rocky) (5)

Both groups go to Rocky

- Turn on spindle
- Rotate speed change hand wheel
- Note to change speeds only when the spindle is rotating (Q14)

Drilling (Demo) (10)

- Have trainees retrieve tools and set up: ½" collet, drill chuck, center drill, size #21 drill bit, parallels, edge finder (Q15, center drill, drill chuck, drill)
- Larger holes/bits require pilot hole (>¼") and slower speeds for more torque (Q16)
- Zero, offset, and move to the specified location
- Center drill (no need for oil)
- Oil the cut
- Emphasize that the drill bit must be at the center of the chuck with all jaws in contact
- Turn on the machine and lower the drill bit into the part
- Explain pecking, drilling and then bringing the bit back out to break off large chips, prevents the flutes from getting filled up (Q18)

Tapping (Demo + Practice) (10)

- Have trainees retrieve tools and set up: 10-32 tap, tap handle, tap guide (Q19)
- Mention for mill training, we are showing how to tap through holes
- More efficient to tap the hole immediately after drilling - the spindle is already positioned
- Never turn on the spindle for tapping!
- Show the chart next to the drill bit table, show tap sizes and corresponding hole size
- Show how the jaws in the tap guide from a square, that clamps around the end of the tap
- Oil the part and the tap
- Make sure the tap guide is lowered on the tap handle, only showing a bit of the spring
- Lock the quill, and adjust/lower the quill when the guide becomes disengaged
- ½ turn clockwise, ¼ turn counterclockwise (Q20)
- Keep going until you feel no more resistance
- Stop if there is too much resistance
- Keep the guide on the handle, but raise as the tap is twisted (counterclockwise) out

Trainees take turns rotating the tap

Drilling + Tapping Practice (20)

Follow the drawing sheet and alternate between trainees, each do drilling+tapping process

If out of time, only alternate drilling

Clean Up (5)

- Clean parts, tools, and vise using a clean rag
- Vacuum the table (on top, behind, under the table, inside the slots using the attachment)
- Put tools away

Should have answered all questions

Session 6

Continue previous lessons

<u>Slotting only if you have extra time</u>

Slotting (Demo+Practice) (40)

Prepare 2" box beam + drawing sheet

Have trainees face to 2", edge find, offset, and follow the drawing sheet

- Materials: Edge finder, ½" end mill, ¼" end mill, ½" collet, ⅜" collet, 15/64" drill bit, center drill, drill chuck
- When slotting, drill holes 1 size smaller than the end mill diameter
    - Allows the endmill to cut all surfaces, consistent cut
- Speed: 1400 rpm
- Drill two hole, one at each end of the slot
- Oil along the path of the slot
- Lock the axis (for straight slots)
- Double check the direction of the table movement
- Turn on the machine, then lower the tool into the hole
- Make sure the cutting edge covers the depth of the layer, then lock the quill
- Move slowly as you approach the specified end location
- Watch the DRO to know where to stop
- Slow down even more as you get closer to the specified end location
- Raise the quill while the tool is spinning
- Once the tool is out, turn the machine off

Have trainees practice following the drawing sheet

Extra time goes to questions

Clean Up (5)

- Clean parts, tools, and vise using a clean rag
- Vacuum the table (on top, behind, under the table, inside the slots using the attachment)
- Put tools away