Mandrel Bending 101 – The Basics

Heavy Duty – American Made
Rotary Draw Tube Benders
Mandrel Bending 101 – The Basics

Presented to:

Agenda:

Day 1 – Afternoon in Classroom (4 to 5hrs)
1) Introduction
2) Safety
3) Principles of Rotary Draw Mandrel Bending
4) All about Tooling & Machines
5) Set-up practices

Day 2 – Meet in Classroom (1/2hr) and Shop (3.5hrs)
1) Set-up & Tear down bending machines, troubleshoot problems, identify improvements & create action plan

Day 2 – Afternoon (4hrs)
1) Finish up set-up in Shop if needed
2) Review of Classroom theory as applied to shop work
3) New Ideas for quick change setups
4) Wrap up

Presenter: Kent Horn

Date:
USA Made Benders

Rebuilds & Service

Excellent Results

Horn Metric Series
“High Capability & Value”

Replacement Parts

www.hornmachinetools.com  Tel: 559-431-4131

California – Texas – Minnesota - Indiana
Safety Precautions:
1) Most common severe injury is from clamp die
2) Second most common injury is from Swing Arm & Tube
3) Other areas, pressure die, carriage & mandrel
4) Strains & injury during set-up
5) Two operators – Must have interlock system

Always:
1) Operate machine with systems and guards in place
2) Follow Company safety policies
3) Use the right tool for the job
4) Be aware of machine condition
5) Be aware of others in the area

Never:
1) Disable a safety device or violate safety procedures
2) Compromise safety for production efficiency
3) Reach into machine operation zone while cycling
4) SET THE MACHINE UP WITH MOTOR “ON”

ANSI B11.15 Safety for Tube and Pipe Bending Machines

End user is ultimately responsible for safety of operations
Safety Video

Watch safety video on YouTube at:

Click here for Safety Video

Go to the Horn Machine Tools YouTube Channel

The video is under the safety playlist
Safety Mat Operation:
1) Safety Mats must be secured to floor
2) Safety Mats must be connected to a safety rated relay
3) Safety Relay must stop all machine motions when activated
4) Do not place cardboard on top of mats to hinder operation
5) Do not move the mats to allow closer access

Safety Zone:
1) Must block access to tooling pinch points
2) Must not allow access to area between swing arm and PD Arm
3) Used in combination with other point of operation machine guarding

Safety zone around bender with safety mats secured to floor
Safety Floor Scanner

Safety Scanner Operation:
1) Safety scanner must be secured to floor or machine, cannot move
2) Safety scanner must be connected to a safety rated relay
3) Safety Relay must stop all machine motions when activated
4) Can be programmed for a specific zone shape to accommodate area
5) Do re-program the zone area to allow closer access

Safety Zone:
1) Must block access to tooling pinch points
2) Must not allow access to area between swing arm and PD Arm
3) Used in combination with other point of operation machine guarding

Safety zone around bender with safety scanner secured to machine
Safety Point of Operation Guarding

Safety point of operation guarding Carriage

Safety Point of Operation Guarding and signage:
1) Safety guards to cover pinch points and areas not covered by mats
2) Safety warning labels to alert operators to potential hazards
3) Moveable guards and access covers must have electrical interlocks
4) Pinch Points, carriage, collet, mandrel, tube support, retractable wiper multi-stack shifting, pressure die, clamp slide, centerline radius motors
5) Consider safety cage around bender or on machine guarding

Safety point of operation guarding mandrel base
Safety Warning Labels

Must be affixed to machine and warn operators of potential hazards
Mandrel Bending 101
“The Basics”

- **Machine**
  Bender Type and Condition

- **Tooling**
  Design and Condition of tools

- **Set-up**
  Proper Set-up and Adjustment

- **Material**
  Material Type and Quality

- **Lubrication**
  Proper Type and Amount
Tooling Locations

Picture of HMT 5.0 Bender
Bending Machine Terminology

- Mandrel
- Extractor
- Pressure Die Holder
- Clamp Die Holder
- Overhead Tie Bars
- Y Axis Boost Motor
- Mandrel Rod
- Mandrel Extractor
- PD Arm
- Y Axis Distance DBB
- B Axis Rotate POB
- C Axis Bend Arm DOB
- Die Boss
- Wiper Die Holder
- Tube Support

Picture of HMT 5.0 Bender
Principles:
Rotary Draw Mandrel Bending

Description:
“Tube forming process where the tube is drawn over a mandrel and formed around a radius die while supported on all surfaces ID and OD at the tangent point”
Principles:
Rotary Draw Mandrel Bending

“Main Concept”

• A balance of pressure must be achieved, so material can be put into a “plastic” state and allow material to “flow” into the desired shape without undesired deformation.

Representative plastic strain distribution after bending
Principles:
Rotary Draw Mandrel Bending

“Two Laws”

1) The tube must be supported on all surfaces, ID and OD at tangent during bending.

2) Tube must “Flow” over the mandrel.
Principles: Rotary Draw Mandrel Bending

1) The tube must be supported on all surfaces, ID and OD at tangent during bending.

During bending, the tube is drawn over the mandrel while being supported on all sides. This process induces high enough pressure to yield the material.

If there is any unsupported area of the tube, the material will flow into that area and cause a defect (bulge – wrinkle, etc).
Principles: Rotary Draw Mandrel Bending

2) Tube must “Flow” over the mandrel under the lowest pressure possible.

1- Wiper die adjusted so pressure of tube compressing is spread out
   • Too much rake angle and more pressure die force is needed
     More Pressure die force will increase drag and cause clamp to slip.
   • Not enough rake angle and tube will drag upon entering
2 – Adjust mandrel: Far enough forward to eliminate wrinkles and stretch outside of tube correctly. But not so far forward it will cause excessive drag and break tube
3- Adjust the pressure die: Lightest force possible.
4 – Adjust Pressure die assist: To push outside of tube over mandrel

Anything that causes drag or resistance in the bend process will hinder the flow of material over the mandrel.
Principles:
Tube Forming Process Results

1) Inside wall of tube thickens
2) Outside wall of tube thins
3) The tube goes into a oval shape in the bend area
4) The tube elongates
5) The tube springs back after bending when clamp opens
Principles:
Tube Forming Process Results
Wall Thinning and Ovality

Wall Thinning
The outside radius wall thins as it is drawn over the mandrel

Ovality
The tube is collapsed to an oval condition

Normal Wall Thinning = 8-30%
Normal Ovality = 5-20%
Principles:
Tube Forming Process Results

- Tube Thickens on Inside radius
- Tube Thins on Outside radius
Principles:
Tube Forming Process Results
Elongation

- Tube Thickens on inside radius and grows in length.
- Tube Thins on outside radius and pulls back.
- Effect of draw bending over a mandrel is elongation of the tube.
Principles:
Wrap up of bending principles

Rule #1
Tube must be contained on all sides at point of tangent

Rule #2
Tube must flow over the mandrel with minimum pressure

Almost every problem with bending will go back to one or both of these rules
## Principles: Material Properties

### Carbon Steel Aluminized

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<th>Yield</th>
<th>Tensile</th>
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<tr>
<td></td>
<td>33 ksi</td>
<td>49 ksi</td>
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### Stainless Steel 304

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<td>35 ksi</td>
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Typically between 8% - 12% Nickel content

### Stainless Steel 409

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<tr>
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<td>39 ksi</td>
<td>68 ksi</td>
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Typically less than 5% Nickel content

**Notes:**

Ksi: 1,000 pounds per sq/in force (33,000 lbs/sq in)
Yield: Amount of force needed to form material
Tensile: Amount of force needed to break material (pull apart)
Elongation: Stretch-ability factor, higher the number the better

**Nickel Content in Stainless material:**

5% or less, difficult to form on tight radius
8% to 12%, deep draw material very formable on tight radius
12% to 15%, ultra deep draw material, extremely good forming properties on tight radius at very thin wall
Tooling – Bend Die Types

- Spool Die
- Multi-Stack Dies
- Flange Style
- One Piece
- Partial Platform
Tooling – Bend Die Basics

Bend die with square block insert

Keyway
Fit: .003” to .005”

Centerline Radius
This is the distance from the center of the radius to the center of the tube

Thru Hole
Clearance to die boss
Stud should be .031”
For ease of install

Centering pocket
Fit: .003” to .005”
Die must be concentric when rotated

Centerline Height
3” machine = 2” CLH
6” machine = 3.75” CLH

Best for difficult applications

Interlock for Clamp and PD

Bend die with concentric bore insert

Non-Interlock Bend die

Most economical

One piece bend die with no insert
Tooling – Bend Die Inserts

Typical spool type bend die with flat back type insert, standard design, economical to make

- Insert should be securely mounted to bend die
- No mismatch to bend die groove, or marking will occur
- No misalignment to bend die or clamping problems will occur
- When clamping surface deteriorates, replace insert if slipping
- Insert can become fish-mouthed and slip

Premium type concentric bore insert, best for difficult applications, advanced design, expensive to make
Tooling – Bend Die Mounting

1) Die boss should be clean, flat & level
2) Key should be straight, square & fit die .003” to .005”
3) Centering ring should be concentric & fit die .002” to .003”
4) Die boss stud should be perpendicular to die boss, not bent. Should be tightly screwed into bend head
5) Die boss nut should be tightly secured so bend die does not tilt
6) Groove should be in good condition or poor bend quality will result, along with accelerated wear of the wiper die

Properly mounted bend die should be stable and not tilt or deflect when clamp or pressure die closes
Clamp die locks the tube into the bend die and prevents the tube from slipping during forming.

If tube slips, then bend defects such as marking and wrinkling will occur.

**Before adding more force to reduce slippage, always check set-up for excessive drag first.**
Strive for optimum clamp length and grip surface combination. The more aggressive the grip surface, the shorter the clamp length can be. Typical clamp length is 2 times the OD of tube.

Clamp Die shown interlocked with Bend Die.

Adjust the height of clamp die To match bend die carefully or Damage to surface will occur

Alignment of tube groove in all directions

Gap top and bottom Should be equal .025” - .050” typical

Set-up Notes:
• Alignment of clamp die and bend die tube grooves.
• Squareness of clamp die to bend die, top to bottom, side to side.
• Must have a gap between the dies, not bottomed out.
• Correct force applied to hold the tube from slipping.
• No excessive force applied that will cause bend die tilt or clamped thru mandrel

Only use enough clamp force to hold the tube in the bend die and Keep it from slipping
The HMT All Electric direct acting Clamp Die uses an inline roller screw to create a specific amount of force on the tube at all times.

The all electric direct clamp die automatically finds the correct position. It’s ideal for repeating set-ups without the use of adjusting a jam bolt, force can be programmed or set in the control then repeated with every set up.

The HMT All Electric Clamp die is guided by 4 linear rails and 8 linear bearings. This system provides an extremely rigid clamping system and is the best system available.
Holds clamp die in position locks tube into bend die.

Mounting with T-Slot or half round post to keep clamp die aligned square with bend die.

Holder has lock down bolts and some type of back up bar or method to keep holder from backing up.

*The tube can not slip in the bend die grip*
Tooling – Drop Away Clamp
Principle of operation

Picture of clamp toggle linkage
* Clamp toggle linkage creates a mechanical advantage and produces much more force than hydraulic cylinder alone.
* Cylinder must extend far enough to take linkage over center and “lock” in place.
* If not locked in place over center then possible that hydraulic cylinder will lose pressure during the bend cycle and back off causing clamp slippage

Clamp Open

Clamp Closed

Use a straight edge to make sure toggle links are over center.

Avg amount is 1/16” to 1/8”
Tooling – Drop Away Clamp Setup and Adjustment

With Bend Die Mounted & tube in place
1) Back up clamp holder to clearance position
2) Install clamp Die
3) Start machine and close clamp
4) Position holder to contact tube & adjust height
5) Tighten jack screw to obtain correct clamping pressure
6) Tighten bolts on clamp holder

Picture of jack screw
• Jack screw backs up the clamp holder and keeps holder from sliding back and loosing position.

• Subjective set up: It is possible to use a quarter turn method to determine how much pressure is being applied to clamp. Example: Tighten up jack screw to closed die position, then go ¼ turn, try bend, if slippage then tighten another ¼ turn.

Positive set-up: Use a torque wrench!
Direct acting Clamp Die uses a hydraulic cylinder to create a specific amount of force on the tube at all times.

The direct clamp die is ideal for repeating set-ups without the use of adjusting a jam bolt, pressure can be programmed or set in control.

NOTE: The cylinder MUST NOT be positioned so it will bottom out during the bend. There should be 1/8” to ¼” of travel left on cylinder when clamp is closed.
**Pressure Die:**
- Holds tube in bend die groove
- Supports the tube on the outside of the radius
- Helps push the outside of the tube over the mandrel – PDA (Pressure Die Assist)

Pressure die min length = MAL + 2xD

Max arc length + 2 times tube OD (may use less... 1.5)

MAL Formula : CLR x 2 x 3.14 / 360 = in/per degree , then
In/per degree x max bend angle = MAL
Example 2” OD x 4” CLR
4 x 2 x 3.14/360 = .0697” In/per degree x 90 = 6.279” MAL

6.279” + 4” = 10.279” or 10” long pressure die
Tooling – Pressure Die Setup

Adjust height of pressure die for proper Alignment with bend die. Use caution or Damage to die surface will occur

Keyway fit .003”

If marking is present on bend die interlock Then pressure die is bottoming out

Gap top and bottom Should be equal Typical .025”

• Create a balance of pressure between the wiper die and pressure die
• Setup PD so minimum pressure is used to form tube, this will reduce drag and clamp slip.
• If pressure die groove is worn, then slip will occur.
• Slippage on PD reduces the “sticktion” or ability of the PD to push the outside of the tube over mandrel
The HMT all electric pressure die arrangement uses a specific amount of force from a roller screw directly where it’s needed to keep the tube captured into the bend die groove. The force is set through the control and is repeated on every setup.

One of the features of a direct acting pressure die is that it allows the roller to “float” a constant pressure on the tube during bending. This allows for minor non-concentric movement of the bend die to be absorbed. As well, when the tube goes into a slightly oval shape during bending the pressure die can move in a small amount and still maintain a constant force.

1) Gearbox and roller screw inline with center of tool stack
2) Linear guiding rails on bottom of pressure die
3) Top linear guiding rail, a unique HMT feature for ultimate rigidity
Tooling – Pressure Die Holder

Pressure die holder aligns and positions the pressure die so tube is supported under pressure and allows the pressure die to move forward during the bend.

Direct acting pressure die uses a hydraulic cylinder to create a specific amount of force on the tube at all times. As tube starts to form and ovality occurs, the pressure die must be able to move in and keep the same amount of pressure on the tube.

The pressure die is mounted on the follower bar with hanger brackets and is held in place by a drive key. The pressure die should be level to the bend die and height adjust so tube groove is aligned.
Tooling – Direct Acting Pressure Die

A direct acting pressure die arrangement uses a specific amount of force from a hydraulic cylinder to keep the captured into the Bend die groove. The force is set by a pressure control valve from The hydraulic system. It is either set manually or programmed through the control.

One of the features of a direct acting pressure die is that the Hydraulic cylinder “floats” a constant pressure on the tube During bending. This allows for minor non-concentric movement Of the die to be absorbed.

As well, when the tube goes into a slightly oval shape during The pressure die can move in slightly and still maintain a constant force.
Tooling – Set-up
Direct Acting Pressure Die

When setting up a direct acting pressure die, always insure that there is at least 1/8” to ¼” of travel left at the end of stroke on the hydraulic cylinder.

This will allow the pressure die to move forward slightly and compensate for ovality.

- Never bottom out the pressure die cylinder
- Adjust the force to minimum pressure needed to make the bend
A toggle acting pressure die acts much the same as a toggle acting clamp die. It uses hydraulic force to drive a mechanical linkage over center and locks in place. The pressure die force is adjusted by the jack screw on the end of the slide.

End view of PD arm

Jack screw adjusts pressure

View of toggle links

Toggle links must be slightly over center by 1/16” – 1/8” in order to lock in place.

Close the PD slide, then use a straight edge to check toggles for correct over-center position. Adjust cylinder clevis if needed.
The HMT ALL Electric pressure die assist automatically matches the PDA speed to the bend die rotation as it moves forward.

The speed is set through the control. It allows the operator to match speed at 100%, or advance forward slightly to 102% or 105%, thereby pushing the tube forward during the bend. As well if needed the PDA speed can be retarded to 98% or 95% to stretch the tube.

HMT ALL Electric PDA – Automatic setup and following

The HMT ALL Electric PDA can mount two pressure dies at one time. This can be used for two different sizes or different lengths. This design is also required to roll form and draw bend on the same part.

The design incorporates automatic up/down movement of the PD so that both true multi-radius and multi-stack bending can be accomplished. Note: machines with one common PDA Follower bar cannot do this.
Pressure die travel speed must match bend die, or slightly pushing forward.

To determine speed, mark the tube at the back of the pressure die. Then make a bend and check relationship.

Two common ways to control pressure die assist:

**Speed**
Turn pressure up and use flow control to match speed of bend die

**Pressure**
Open up flow control and use pressure setting to push on tube Without exceeding position.

**Third possibility:** Automatic servo following by control system
Tooling – Mandrels
Tooling – ALL Electric Mandrel System

Rotating mandrel rod bearing system

Driven by electric servo motor and gearbox which provide precise positioning.

Linear rails guide the mandrel rod and prevent damage to the system.

The HMT All Electric mandrel system allows the operator to set the position of the mandrel from the control. Then this position can be repeated on every setup.
Tooling – Mandrels

**Plug type mandrel,** for easy bending applications

**Hard chrome steel mandrel** for bending carbon steel or non-ferrous materials.

**Aluminum Bronze mandrel** for bending stainless and other alloy materials.

*Note: single ball mandrel, with normal pitch.*

*Note: 4 ball mandrel, with close pitch.*

**Mandrel:**
* Supports tube on the ID to keep it from collapsing.
* Forms tube to correct radius on outside of radius.
1) Retainer bolt
2) Shank
3) Ball stack
4) Mandrel Link
5) Ball Link
6) Retainer Clip
7) Spring & ball
8) Ball Stack Assembly
Note on Mandrel Ball Stack assembly:
It is common for the ball diameter to be smaller than the shank, this gives the balls additional clearance and keeps from breaking links.

For tight radius bending, the balls may be sized differently. They may get smaller as they progress from shank, so the end ball is smaller OD than the first ball. Measure balls before assembly to make sure they are correct for the shank being used.
Mandrel Working Points:
• The work should is adjusted approximately at Tangent
• All of the forming work is done on shoulder
• Shank supports tube behind tangent to prevent collapse
• Balls keep tube collapsing after bending
• Balls add drag into the forming process, use few as possible to achieve a quality bend

Mandrel Sizing:
General rule of thumb is mandrel clearance should be 25% of tube wall thickness. This applies to a 1-1/2 or 2 x D bend. For tighter radius bends, clearance will be less.

Example: .065” wall material on 2 x D bend

.065 x .25 = .016” overall clearance
Mandrel:

*In proper position, should stretch outside of tube to correct radius which helps to control springback and ovality.*

If too far back, results will be:
- More ovality, bend will have flat or collapsed appearance.
- Wrinkles, not supporting tube correctly on inside
- Higher springback, outside radius not formed correctly

If too far forward, results will be:
- Excessive wall thinning on outside radius
- Tube breakage
- Mandrel hump at end of bend (Use early withdrawal)
- Excessive wear on mandrel shoulder
- Shuttering or chatter during bend (poor lubrication can also cause this)

Note: Mandrel must be locked into position so that tube rotations can’t cause the mandrel or rod to turn and loose position. For tubes that fight tightly on mandrel, use rotating mandrel rod.
Tooling – Mandrel Setup

Picture of mandrel adjusted ahead of tangent

Mandrel forward, low pressure:

*Position mandrel shoulder forward of tangent which will stretch outside of tube to correct radius with lowest amount of pressure die force.*

Challenges:

• Must have a control system capable of early mandrel extract.

• Some hydraulic machines have a difficult time extracting mandrel early while bend arm is moving fast

• Some hydraulic systems will react differently when fluid is cold or hot. This will vary the early withdrawal extract position as machine heats up

• Tube breakage

• In consistent mandrel hump at end of bend

• Excessive wear on mandrel shoulder
The HMT multi-stack wiper design allows for independent adjustment in each direction.

This wiper die system can be used as a cartridge type system. Whereby multiple wiper holders can be used to permanently set up the wipers, then the entire holder can be changed out as a unit.
Tooling – Wiper Dies

Inserted Wiper tip and holder

Various square back Wipers

Aluminum Bronze wiper for bending stainless and other alloy materials

Hard chrome steel wiper for bending carbon steel or non-ferrous materials.

**Wiper die:**

*Supports tube on the inside of radius, behind tangent*

*Works in conjunction with pressure die to apply balanced pressure on the OD of tube entering the bend die.*

Hardest die to set and align
Tooling – Wiper Die Types

Insert type wiper die tips

- Replacement cost is lower
- Replacement time is quicker
- Initial investment higher (Holders)
- Allows close tangent positioning by CNC bender collet
- May not be suitable for some difficult applications

Square back type wiper

- May be re-sharpened (30% of new cost)
- Works well for difficult set-ups
- Easier to set up… more surface area
- Longer tangent positioning length by CNC bender collet
- No special holder required, fits all benders.
Tooling – Wiper Die Set-up Seating

Wiper die must be able to absorb force and transfer it to bend die. The wiper die must be properly positioned and seated so the force can be transferred without damaging wiper die or causing it to deflect and loose containment.

Note: Too much lubrication on face of wiper will cause wrinkles.

Clamp and pressure die, apply force to out side of tube
That force is transferred onto the face of the wiper
Then from backside of wiper to bend die
Tooling – Wiper Die Set-up Seating

Approximately 25-30 degree of the back side of the wiper must be seated on bend die. Shown above with tool makers die wiped off by bend die.

At least .75 to 1 x tube OD seated on the front side of wiper

Example:
2” OD tube = 1.5” to 2.0” seated
In the picture below, a new wiper die is shown on the left. On the right a wiper die that has been installed and then just a few bends made. You can see that during the first few bends, the tip gets broken off. This is because most wipers are made with the tip too thin. In the last few slides, we talked about seating a wiper properly in order to absorb to PD force. Problem is once the wiper is seated properly, it then its far enough forward to have the tip broken off.

Prevent the tip of the wiper from breaking off prematurely by trimming and fitting the wiper to the bend die.

In order to prevent the wiper tip from being broken off, some wipers can be trimmed slightly and shaped. This will allow full contact seating of the wiper but also keep the tip back far enough to prevent it from being damaged prematurely. Call HMT to find out more.

This wiper has been trimmed by one of our expert techs. Notice how the tip blends into the bend die.

After several bends, little or no damage has occurred.
Tooling – Wiper Die Set-up

Tip position to tangent

Tip too far forward will break off sections and cause premature wear.

Ideal position for wiper tip is directly behind tangent.

Bending forces should be on bend die, not wiper tip

Wiper tip should be feathered in to support tube directly behind tangent.

**Note:** Wiper must be locked into position so that bending force or Pressure Die force does not move the wiper out of position
Tip too far back reduces seating area. Possibility of bending wiper and causing concave area behind tangent.

Note: Wiper must be locked into position so that bending force or Pressure Die force does not move the wiper out of position.
Tooling – Wiper Die Set-up
Tip position to tangent

Tip in correct location

Note: Wiper must be locked into position so that bending force or Pressure Die force does not move the wiper out of position
The wiper needs to sit at a slight angle to the pressure die. As radius of bend decreases, so will wiper angle.

If wiper position is too flat, or negative angle, then tube will drag upon entering wiper die.

Negative rake will also cause a gap and containment will be lost allowing wrinkle to form.
How To Position Wiper die

Slide wiper forward until seated and tip is slightly behind tangent.

Rotate wiper die back 1/10th to ¼ degree back to obtain rake angle.
Tooling – Wiper Die Set-up
How To Repeat Wiper Die Position

Use caliper to record position of wiper die once set-up is correct.

Use straight edge and wire gauge to check Rake Angle.

Note: Too much lubrication on face of wiper will cause wrinkles.
Collets

Flange style
Bolt in collet pads

Collet pads bolt
Into the face of
the master collet

3-5 minute
Change out
time

HMT Quick Change
Snap in collet pads

Several types, most use a
mechanical feature to
retain collet pads

5 sec
Change
out time

Note: Collet should be adjusted tight enough to keep tube from Rotating in collet and loosing orientation. But not so tight that it is reducing the end of tube making it difficult to remove off mandrel

Some machines have mechanical adjustment, some have pressure valve adjustment
Y axis carriage booster functional description:
Mandrel bending tight radius tubes with a short clamp length is greatly improved by applying force to the back of the tube as it enters the back of the bend die.
This does several things:
1) Keeps material flowing over the mandrel and reduces drag in the draw process.
2) Because drag is reduced there is less requirement for clamp area, so clamp lengths can be shorter.
3) Reduces wall thinning and ovality of the tube.
4) Reduces the effect of marking with short clamp grips that are serrated.
Pressure die assist can only add a minimal amount for force to the bend before slipping forward, with Y axis boost, the tube is shouldered into the collet. The amount of force can be applied up to the column strength of the tube or up to the maximum of rating of machine

Difficult Application Set-ups:
Boost at high force for first 30 to 45 degrees, then start backing off boost force as tube becomes wrapped around the die.

Note: Too much carriage boost will cause wrinkles.
The HMT design uses dual helical gear racks to drive the carriage. This system provides fast positioning that is both accurate and powerful.

The system is designed with the gear rack incased within the frame and orientated facing down. This protects the gear rack from debris and also keeps the gear rack out of the way from operators.

The dual gear rack, is positioned on both sides of the carriage to distribute force evenly. The racks are also positioned as close to the linear bearing as possible to reduce any unnecessary load on the bearings or rack.

The racks are made from alloy steel and heat treated for long life.

This design is superior to any single rack design. Ball screws used in this application are slow and if crashed hard will not survive, leaving a very expensive repair bill to recover from with potentially long lead time.
Carriage Boost

Effects of carriage boost adjustments on clamp grip marks

Note: Too much carriage boost will cause wrinkles.
Carriage Boost

Tube with 8% carriage boost, note depression at front of clamp.

Note: Too much carriage boost will cause wrinkles.
Carriage Boost

Tube with 10% carriage boost, depression at front of clamp reduced

Note: Too much carriage boost will cause wrinkles.
Note: Too much carriage boost will cause wrinkles.
Mandrel & Wiper Selection

1) Determine the Wall Factor “WF”

2) Determine the “D” of Bend

3) Consult Chart to determine proper die set-up. (next page)
## Mandrel & Wiper Selection

Determine the wall factor and “D” of bend on previous page

Then select the appropriate mandrel/wiper configuration from the chart below.

These are recommendations based on average conditions.

### Wall Factor

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<th>1.5</th>
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### “D” of Bend

- **P** = Plug Mandrel
- **M1** = 1 ball
- **M2** = 2 ball
- **T** = Thin wall
- **UT** = Ultra Thin wall
- **W** = Wiper

Purple shaded area = Standard mandrel,
Yellow shades area = Thin Wall Mandrel
Blue shaded area = Ultra Thin Wall Mandrel
# Mandrel Bending Lube

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<tr>
<th>Brand</th>
<th>Type</th>
<th>Used For</th>
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<tr>
<td><strong>Tower Oil</strong></td>
<td>Oil</td>
<td>Water soluble oil used for Steel, Aluminum, &amp; non ferrous. Part # 4100</td>
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<tr>
<td>(312) 927-6161</td>
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<td></td>
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<tr>
<td><strong>Irmco</strong></td>
<td>Gel</td>
<td>Water soluble Gel type paste, used for steel, Aluminum, &amp; non Ferrous. Part # 460-80A</td>
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<tr>
<td>(847) 864-0255</td>
<td></td>
<td>IRMCO Extreme for S/S</td>
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<tr>
<td><strong>Houghton International</strong></td>
<td>Heavy Oil</td>
<td>Non Water Soluble oil used for Stainless Steel.</td>
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<tr>
<td>(610) 395-8440</td>
<td></td>
<td>Part# How-to-Draw 3105</td>
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Tool Changes

Remove Tooling: Machine Position

- Swing arm at 100+ degrees (verify max angle)
- Clamp full open
- Pressure Die full open
- Pressure die assist full extend
- Mandrel full extract
- Turn Off Machine

Remove and install tooling but do not adjust, pre position only

1) Remove Clamp, move clamp holder back to clearance position
2) Install new clamp
3) Remove Pressure Die, then install new Pressure Die
4) Remove Wiper
5) Remove Overhead tie bar (if equipped)
6) Remove Bend Die, Clean die boss, then install new Bend Die
7) Tighten nut on bend die to proper torque
8) Install Overhead Tie, tighten tie rod to compensate for tilt
9) Install new wiper and pre-position
10) Remove mandrel, install new mandrel
11) Remove collets, install new collets
Tool Changes

Adjust Tooling: Machine Position

• Pressure die assist full retract
• Swing arm at 0 degrees
• Clamp full open
• Pressure Die full open
• Mandrel full extract
• Turn machine OFF

Picture of machine at tooling adjust position
Tool Changes

Adjust Tooling: Procedure

1) Position Wiper tip just behind tangent with proper rake & tighten
2) Put a set-up tube on the mandrel to protect it
3) Adjust the centerline radius to match the new bend die
4) Insert tube into collet and check pressure, adjust as required
5) Start machine, bring mandrel full forward, check & adjust position
6) Jog clamp close slowly, position clamp holder to contact tube
7) Check height alignment of clamp die, adjust if needed
8) Tighten jack screw to adjust clamp pressure
9) Close pressure die slowly, verify height adjustment
10) Adjust position of pressure die, set hydraulic pressure
11) Check position of wiper rake
12) Open Clamp and PD, check and verify position of wiper tip
13) Adjust wiper final position as needed
14) Double check all tooling hardware is secure
15) Make sure mandrel is lubed and wiper if required
16) Open and close Clamp and pressure dies several times, check
    Check position of all tooling, making sure position is maintained
17) Install a first part tube

Ready to test bend:

Clean oil or debris off tooling
Start out with a shallow bend, 45 degrees or less at slow speed
Make sure clamp is not slipping,
Make sure PDA is in time with bend die rotation, adjust as needed
If wrinkles are present, check and adjust wiper & mandrel first before
adding more pressure to pressure die.

Make one adjustment at a time and check results
Tube Bending Defects and Corrections

TUBE BREAKAGE:
1. Material does not have the proper ductility and elongation properties.
2. Tube slippage in the clamp die. Adjust pressure on the clamp die. Use different grip surface on the clamp and grip section of bend die.
3. Too much pressure on the pressure die causing excess drag. Reduce pressure on pressure die.
4. Material is wrinkling and becoming locked between the mandrel balls. Use as thin wall style mandrel.
5. Clamp die pressing on mandrel balls. Reduce pressure on clamp die.
6. Not enough lubrication is being applied, or the wrong type of lubricator is being used.
7. Mandrel is advanced too far forward past tangent. Move mandrel back.

WRINKLES:
As the tube bends, the inside wall is compressed and tends to buckle causing wrinkles. Wrinkles are prevented by confining the tube so that they cannot start.
The following factors are possible sources of wrinkling.
1. Tube slippage in clamp die. Add pressure to clamp die or use different grip in clamp die and the grip area of bend die.
2. Mandrel is not far enough forward. Advance mandrel past tangent.
3. Wiper die not far enough forward. See Appendix A.
4. Wiper die is worn or not fitting properly. Make sure the centerline radius matches the centerline radius of the bend die.
5. Too much clearance between mandrel and tube. Try larger size mandrel.
6. Not enough pressure on pressure die. Add pressure to pressure die.
7. Excessive lubrication being used.
8. Mandrel fits too loosely; wrong mandrel size, or oversize tube.

BEND FLATTENS:
1. Tube slippage in clamp.
2. Too low a pressure die force.
3. Mandrel too loose, or requires more balls.
4. Mandrel not forward far enough.
5. Increase boost force.

MARKING CLAMP & PRESSURE DIE.
1. Foreign material in die or on tube.
2. Scars on dies.
3. Excessive die pressure.
4. Pinching of tubing along top and bottom.
1. Oversize tube.
2. Bad vertical alignment.
5. Burnish marks on outside of bend. Excessive clamp force pinches tube against mandrel balls.

INACCURATE BENDS:
1. Bend speed too high.
2. Variable mandrel drag due to galling.
3. Tube slightly slips in clamp die.
4. Tube temper or other characteristics vary along tube length.

BUMP AT END OF BEND.
1. Mandrel too far forward. Need early withdrawal
Tube Bending Defects and Corrections

- Tube Bending Should be Performed on a Rotating Die
- V-Notch Dies Require Special Care
- Mandrel Size Can Be Adjusted for Different Types of Bends
- Tube Bending Machine Speeds Can Be Optimized for Different Materials
- Common Tube Bending Mistakes and Their Solutions

Horn Machine Tools, Inc.
Summary

The successful mandrel bending operation:

• Correct machine for the application
• Correct tooling for the application, in good condition
• Correct material and lubrication

• Training program for operators
  - Periodic updated training

• Good preventative maintenance
  - Periodic review of machines and tooling
  - Action plan to address issues

Hot tips for the operator:

• Stay in contact with the OEM’s of machine and tooling
• Use online resources, many available
• Contact FMA, good source of training

• Keep the machine and tooling in good working order
• Make good set-ups a priority
• Make one adjustment at a time
• Don’t use excessive pressure to cure problems

• Explore new technologies and techniques