Tooling Tips
For
Metal Stamping Professionals

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MACOR Education and Training
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Preface

The Metal Stamping Industry has been in existence for well over 100 years. In this time, many new innovations have taken place. For the most part, these innovations came in the form of machine technologies that help us perform faster and with more accuracy. The fully motorized press, CNC machining, Wire EDM, LED readouts, and CAD are a few worth mentioning. The principles and formulas we use in designing and building dies is not an exact science. For instance, for any given part there may be up to 10 or more design and build approaches. There are many variable inputs into the metal stamping process that ultimately affect the outcome. These variables can be the raw material itself. It can be the design approach, which may lend itself to inconsistent performance. Variables can be introduced at the build stage, as well as in the production of the actual parts. The tips contained in this booklet have been compiled over many years and from different personal experiences and problems. Many of these tips have come about in an effort to control process variables.
Tooling Tip 1

Tool Failures
If your tools are cracking and breaking prematurely, you may need to look at how they are made. Machining punch and die forms across the grain of steel, instead of parallel to the grain, as shown below, will add significant strength to the tool.

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The undercut is easily accomplished utilizing the wire EDM process to cut the punch, stripper and die components.

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**Tooling Tip 3**

**Manufacturing Cost Reduction through innovation, training & teamwork**

**Force calculations**

- For the first scenario:
  - **Formula:** $F = L \times (\text{Total Length of All Cuts}) \times X \times Y$
  - **Equation:** $F \times T$ (in tons)
  - **Explanation:** $F = \text{force to strip}, L = \text{total length of cut}, X = \text{metal thickness}, T = \text{metal thickness}$

- For the second scenario:
  - **Formula:** $F = L \times T \times T$
  - **Equation:** $F = \text{force to strip}$
  - **Explanation:** $L = \text{length of strip}, T = \text{metal thickness}$

- For the third scenario:
  - **Formula:** $F = C \times X \times Y$
  - **Equation:** $F = \text{force to draw cup}$
  - **Explanation:** $C = \text{outside diameter or perimeter}, X = \text{metal thickness}, Y = \text{yield strength}$

- For the fourth scenario:
  - **Formula:** $F = L \times T \times 1.8$
  - **Equation:** $F = \text{stripping force}$
  - **Explanation:** $L = \text{total length of cut}, T = \text{metal thickness}$

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**Tooling Tip 4**

**DESIGNING FOR PART FEATURES**

**EXTRUSIONS**

- **APPROX. 0.03-0.08 STRAIGHT**
- **B DIA - 0.01**
- **POLISH AND TREAT SURFACE**
- **B DIA PIERCED HOLE**

1 DEG TAPER PER SIDE

**A DIA**

70 PERCENT T

**H**

**D**

**G DIA**

THE MAXIMUM HEIGHT (H) OF AN EXTRUSION IS USUALLY 2-4 TIMES T. ALWAYS TAPER THE BUSHING APPROX 1 DEG TO FACILITATE EJECTION. GENERALLY IRON WALLS OF EXTRUSIONS TO 70% METAL THICKNESS IF POSSIBLE EXTRUDE IN THE OPPOSITE DIRECTION OF PIERCING. BACK TAPER THE EXTRUSION PUNCH .001-.002 PER SIDE. IF POSSIBLE SHAVE HOLE (B DIA - 0.01) OR Coin BURR SIDE OF STRIP BEFORE EXTRUDING.

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When making right angle bends, the inside radius should equal 1T as a minimum. This is necessary to prevent cracking, even with bend relief applied.

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Parts Cracking at Bend

The inside radius should be equal to 1T minimum, larger if possible, to minimize any chance of cracking.

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Right Angle Bends

**MINIMUM MATERIAL FOR 90 DEGREE BENDS**

![Diagram showing minimum material for 90 degree bends]

**NOT ENOUGH MATERIAL TO MAKE BEND**

**MINIMUM INSIDE HEIGHT OF FORM**

$H = 2.5T + R$

When making right angle bends, there must be enough material to allow for success. The above formula is a good general guideline in calculating minimum flange height.

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The above picture depicts 2 different methods of countersinking. The method on the left is preferred because it produces a cleaner part with no slug to contend with.

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Tooling Tip 9

MANufacturing COst Reduction through innovation, training & teamwork

Dimples or protrusions

Chipping occurs

Example A

Conventional method

Example B

Alternative method

\[
\begin{align*}
T &= \text{stock thickness} \\
X &= \text{extrusion hole in die} \\
Y &= 75\% \text{ of } T \\
A &= X + 25\% \\
B &= 60\% \text{ of } X \\
D &= 85\% \text{ of } Y \\
R &= 0.50 \text{ of } A
\end{align*}
\]

The values and percentages are a guideline for fabrication and not an absolute. An angle may be used in place of a radius provided that the angle is not too steep as to produce a direct outward force.

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**Tooling Tip 10**

RIB ENDPOINT SHOULD PASS INSIDE RADIUS

DOWEL USED TO FORM GUSSET

MATERIAL MAY PULL IN ON BOTH SIDES


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Tooling Tip 11

**SHAVING AND BURNISHING 3 STATION**

- **PIERCe PUNCH**
- **SHAVE PUNCH**
- **BURNISH PUNCH**

**DIMENSIONS**

- **A** = B MINUS 10% T PER SIDE
- **B** = NOMINAL SHAVE DIMENSION
- **C** = B DIAMETER PLUS .0001 PER SIDE
- **D** = B DIAMETER PLUS .0002/.0004 PER SIDE
- **E** = D DIAMETER PLUS .001 TOTAL

**CONCAVE SHAPE**

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Tooling Tip 12

Shaving and Burnishing Single Station

- Shave Diameter Plus .0002-.0004 Per Side
- Finish Shave Diameter
- Burnish Diameter Plus .0005 Per Side
- Stone and Polish Leading Edge
- Concave Shape

This illustration is an example of a single station shave and burnish operation. The dimensional relationships are the same as set forth on the previous page. Remember, die cut holes one inch and smaller tend to close and blanks under one inch tend to swell. This should be taken into consideration when determining final sizes.

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Designing the lance feature with a taper, facilitates ejection from the die resulting in a better performing tool.
Tooling Tip 14

**FORMING RIGHT ANGLE BENDS**

**THEORETICAL TRUE RADIUS**

**ACTUAL RADIUS = 1.3 X**

**DIE BLOCK RESIDES INSIDE FORM**

**FRONT VIEW HEEL BLOCK AND PUNCH NOT SHOWN**

This illustration shows one method of achieving an accurate bend that also minimizes springback by setting or coinining the top of the metal with the punch. The punch must be machined with the actual part radius plus .003-.005 to ensure metal contact. It is also recommended to machine the lower die block narrower than the part so the burr does not interfere with the form.

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Formation of Right Angle Bends

1 - 5 DEG TAPER RELIEF ON PUNCH

PUNCH PART

APPROX. 10% T

SET RADIUS ON DIE

PRESSURE PAD

DIE

THIS OPERATION INVOLVES A CHANNEL PART FORMED DOWN INTO A DIE. THE DIE BLOCKS ARE MACHINED WITH THE SET RADIUS AND THE PUNCH IS MACHINED WITH A RECESS OF 10 PERCENT METAL THICKNESS. THE PUNCH RECESS PRODUCES A SLIGHT CONCAVE PART WHICH CAUSES THE METAL TO SPRING BACK TOWARDS 90 DEGREES. THE PUNCH CAN ALSO BE RELIEVED TO ALLOW LEGS TO FORM INWARD.

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Tooling Tip 16

Forming Right Angle Bends

PUNCH MACHINED AT 45 DEG.
THEORETICAL TRUE RADIUS
ACTUAL RADIUS = 1.3 X

STRIPPER AND DIE MACHINED AT MATCHING ANGLES

THE ABOVE METHOD IS A TYPICAL CONFIGURATION EXCEPT THAT THE DIE AND STRIPPER ARE MACHINE ON SLIGHT ANGLES TO ENSURE CONSISTENCY AND DEAL WITH SPRINGBACK. THIS METHOD CAN BE USED IN MOST FORMING CONFIGURATIONS.

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Tooling Tip 17

FORMING WITH A RUBBER TUBE

FORMED PART

RUBBER ROD

AFTER FORM

RUBBER ROD

BEFORE FORM

PRESSURE PAD

CENTER ROD

SECTION A-A
FORM PUNCH NOT SHOWN

THE ABOVE ILLUSTRATION UTILIZES A RUBBER ROD FOR FORMING. THE ROD IS ALLOWED TO COLLAPSE AND APPLY CONSTANT FORMING PRESSURE TO THE METAL FLANGE. THE
ADVANTAGES ARE OVERBEND CAPABILITY AND IS EXCELLENT FOR PAINTED STOCK. IT WILL
NOT MARK THE PARTS. IT IS DESIGNED FOR LIMITED PRODUCTION.

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Dealing with Spring Back

The above formed semi-circle part is done in a single station utilizing small grooves machined through the die. When metal to metal contact is made the corners of the grooves produce small stress points in the metal. These stress points eliminate or minimize spring back. This can be extremely critical if the parts are to be heat treated. The disadvantage is the parts may be slightly marked.

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Dealing with Spring Back

THE ABOVE EXAMPLE IS AN ALTERNATIVE APPROACH TO FORMING. IN THE FIRST STATION, THE PART IS FORMED OUT OF TOLERANCE ON PURPOSE. IN THE SECOND STATION, AN ORDINARY BRASS MACHINE SCREW IS DESIGNED INTO THE STRIPPER TO RESTRIKE THE PART AND FLEX THE PART INTO TOLERANCE IN THE DOWN STROKE OF THE PRESS. THE SCREW IS DESIGNED TO BE ADJUSTABLE AT THE PRESS OPERATION BY THE OPERATOR.
Tooling Tip 20

MAufacturing COst Reduction through innovation, training & teamwork

Accurate Bends in Thick Metals

**COINED LINE**  
-.3 T MAX  
**T**

**BEND LINE**

**USING A COINED LINE IN THE STOCK IN THE EXACT LOCATION OF THE BEND, PRODUCES AN ACCURATE AND LEVEL FLANGE. IT ALSO REQUIRES LESS FORCE TO MAKE THE BEND WITHOUT SACRIFICING STRENGTH. THE PART WILL, HOWEVER, HAVE A SHARP CORNER.**

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Manufacturing Cost Reduction through innovation, training & teamwork

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Tooling Tip 22

**DRAW RADIUS**

\[
R = 0.8 \sqrt{(D-d)T}
\]

- **D** = Blank Diameter in Inches
- **T** = Metal Thickness
- **H** = Overall Height of Cup
- **R** = Die Radius
- **d** = Outside Dia of Draw

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 Tooling Tip 23

Manufacturing Cost Reduction through innovation, training & teamwork

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Designing Punches

The most friction is produced during the stripping operation. Some metals actually shrink around the punch. To reduce this friction area to a minimum, a slight reverse taper is recommended. This also allows the lubricant to attach to the punch. This is illustrated to the left. The angle is exaggerated for the illustration. Machining a back taper on contoured punches may be cumbersome. Below illustrates a scored punch after just several sharpens. That is a typical result and the punch is ruined by loss of hardness.

Punch head breakage is common in heavy metal stamping operations. This can be caused by various conditions such as alignment of the press and die. Machining a 45 degree angle as shown can prevent head breakage.

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Eliminating Shock

MAufacturing COst Reduction through innovation, training & teamwork

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Tooling Tip 26

Pilots

At the left, is an example of a spring loaded pilot mounted integrally with the stripper plate. This assembly is excellent for stamping thinner materials because the exposure of the straight portion of the pilot can be held to close tolerance. This should only be used with a guided stripper.

The example of the conical shape pilot shown at the left is a special application for stamping thicker materials. The conical shaped tip engages the raw material 360 degrees around the hole. It must be spring loaded to prevent miss hits. The body of the pilot can be much larger than the hole. This application is also excellent for single operation dies and the pilots can be mounted in the lower die. This facilitates operator loading and unloading of because the part holes never have to match the pilot.

The illustration at the left shows the correct timing relationship between the lower face of the stripper plate and the amount of exposure of straight on the pilot. This relationship depends on the material thickness and is very critical. If the straight is too long it will tend to pull the stock up away from the die during operation. If the straight is set too short, it will not properly locate the strip. The pilots must enter the stock before any other activity on it takes place.

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Design for Quick Change

THE ILLUSTRATION FAR LEFT DEPICTS A REMOVABLE PUNCH BY MEANS OF THE RETAINER KEY. THE PUNCH IS HELD IN POSITION BY THE MATCHING ANGLE ON IT AND THE RETAINER KEY. TO REMOVE THE PUNCH, SIMPLY LOOSEN THE RETAINER KEY AND SLIDE IT TO THE RIGHT. THE ADJUSTMENT SLOT SHOULD BE LONG ENOUGH TO ALLOW FOR FULL RETRACTION WITHOUT HAVING TO REMOVE THE SCREW. THIS IS AN EXCELLENT METHOD WHEN USING STICK TYPE PUNCHES.

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Utilizing Wire EDM

THE ABOVE DESIGN UTILIZES THE WIRE EDM PROCESS TO FACILITATE MACHINING THE PUNCH RETAINER AND ALLOWING ACCESSIBILITY TO THE PUNCH. A SLOT IS PRECISION MACHINED FOR THE PUNCH ALONG WITH A RUN OUT SLOT .010 WIDE. A BRASS SHIM IS INSERTED IN THE SLOT TO PREVENT OVER TORQUE AND BREAKING THE RETAINER. TO REMOVE THE PUNCH, SIMPLY UNIGHTEN THE CLAMP SCREW AND PULL THE PUNCH OUT. THIS SYSTEM ALSO ALLOW FOR THE PUNCH TO BE INVERTED TO CREATE A NEW CUTTING EDGE. THIS TECHNIQUE CAN SIMPLIFY THE MAINTENANCE AND OR REPLACEMENT OF PUNCHES. IT IS IMPORTANT TO NOTE THE LOCATION OF DOWEL HOLES. THEY MUST BE IN AN AREA NOT AFFECTED BY THE CLAMP SCREW.

THIS IS AN EXCELLENT METHOD OF SECURING THIN OR FRAGILE PUNCHES. THE CONFIGURATION POSSIBILITIES OF THIS STYLE RETAINER IS ALMOST ENDLESS. THE PUNCHES CANNOT BE PULLED OUT AS LONG AS THE STRIPPING FORCE IS NOT EXCESSIVE.

All hardened wire EDM blocks should be stress relieved after burning.

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Utilizing Wire EDM

**The Wire EDM Process Requires a Start Hole to Insert the Wire Through.**

Normally, many designers and programmers place the start hole in the theoretical center of the hole to be machined. That can add up to huge amounts of wasted machine time as opposed to placing the start hole near the perimeter of the finished size as shown above.

All hardened wire EDM blocks should be stress relieved after burning.

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Utilizing Wire EDM

All hardened wire EDM blocks should be stress relieved after burning.

FINISHED SIZE OF HOLE
PUNCH RETAINER OR DIE BLOCK PLAN VIEW
WIRE EDM START HOLE

THE ILLUSTRATION ABOVE EMPLOYS A START HOLE CLOSE TO THE FINISHED SIZE. USING THIS METHOD ELIMINATES THE SLUG COMPLETELY. THE WIRE EDM MACHINES OUT ALL THE MATERIAL. THESE START HOLES HAVE TO BE MACHINED REGARDLESS. THIS METHOD MAY ALSO DECREASE MACHINING TIME. SEVERAL CUTS MAY BE REQUIRED TO ACHIEVE THE FINISHED SIZE.

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Tooling Tip 31

Manufacturing Cost Reduction through innovation, training & teamwork

Slug Retention

STOCK CROWDERS

Plan View of Die Block

The exhibit above illustrates an edge trim operation whereby stock crowders are used to lock the slug in place in the die. The vertex of the crowders indents or creases the stock edge slightly (approximately .015). This action locks the slug. The crowders are made adjustable. This approach comes from the multi slide industry where the dies are run horizontally. The advantage of this approach is that it works well. The disadvantage is the additional machining required to install the components.

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Slug Retention

**Die Block and Punch**

The die block and punch to the left use clearance to keep the slug in the die. The clearance has been reduced to 5 percent at 4 places on the die. This reduction in clearance produces a greater shear length thereby, more surface to adhere to the die walls. This example is for heavy or thicker materials. The advantages are that it works and that it is free. It is part of the EDM program and can also be reversed to the punch. It is also an excellent method to retain blanks in the strip using blank and carry applications.

Illustration at the left also uses clearance to retain the slugs. In this case, the clearance is increased at 4 points to produce a slight burr on the slug. This burr grabs or hugs the die walls. The advantage is that it works and it is free. It also is part of the EDM program.
Tooling Tip 33

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eduction through innovation, training & teamwork

Slug Retention

ANOTHER RELATIVELY NEW METHOD OF SLUG RETENTION IS SHOWN AT THE LEFT. THESE BUSHINGS OR DIE BUTTONS ARE AVAILABLE COMMERCIALLY AT A SLIGHTLY HIGHER COST THAN STANDARD BUSHINGS. THEY EMPLOY A BURR PRODUCING GROOVE SIMILAR TO THE ONE ABOVE. THE ADVANTAGE IS THAT THEY WORK AND ARE GUARANTEED BY THE SUPPLIER.

THE MOST IMPORTANT ADVANTAGE TO THESE NON CONVENTIONAL METHODS IS THAT ALL THE SLUG RETENTION IS NOW IN THE DIE. THIS MEANS THE MAINTENANCE IS JUST FLAT GRINDING. THE HOURS SAVED IN MAINTENANCE CAN BE TREMENDOUS. THE COST OF PUNCHES IS REDUCED DRAMATICALLY.

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The exhibit above demonstrates how to set the pilot release on the feed. The nose of the pilot should be visible below the stock line. This is an indication that the radial portion of the pilot is in the stock. The stock should also be able to move slightly from left to right. When using bridge type strippers or in certain applications where the stock is not visible, the set up of the pilot release is accomplished by feel. The stock should be able to move slightly from left to right.
Tooling Tip 35

Die Set Up Techniques

**STOCK LIFTERS**

**STOCK IN UP POSITION**

**DIE HEIGHT**

**FEED ROLLERS**

**STOCK IN DOWN POSITION**

**CORRECT FEEDLINE**


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THE LINE UP OR PARALLELISM OF THE FEED UNIT TO THE CENTERLINE OF THE DIE IS EXTREMELY CRITICAL WITH PROGRESSIONS 1.00 INCH AND HIGHER. TAPER OR ANGLE IS MEASURED AT THE RATE OF .017 PER 1 INCH PER 1 DEGREE. IF THE FEED UNIT WAS 1 DEGREE OUT OF ALIGNMENT WITH THE DIE, THIS WOULD MEAN A .170 INCH ERROR IN A 10 INCH PROGRESSION. THE PILOTS WOULD BE UNABLE TO CORRECT THIS AMOUNT. IF THE FEED UNIT WAS 1/2 DEGREE OUT OF ALIGNMENT, THIS WOULD MEAN A .085 ERROR. THE PILOTS WOULD STILL BE UNABLE TO CORRECT THIS MISALIGNMENT, AND SO ON. THE AMOUNT OF ERROR A PILOT SHOULD BE RESPONSIBLE FOR IS .015 ON AVERAGE THICKNESS STOCK. FOR THIN STOCK, .005-.010 WOULD BE AN ACCEPTABLE RANGE.
Fasteners

If the total tolerance of the shoulder screw exceeds 1/3 metal thickness, it must be re-machined to +/- .002. This applies to spring loaded stripper plates and other dynamic components that utilize 2 or more bolts.

The above screw sizes are general guidelines for construction. For extreme side thrust it is recommended to exceed that thrust by at least 6 times. The minimum engagement of screws should be a minimum of 1.5 times diameter.

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Dealing with Camber

THE ABOVE STRIP ILLUSTRATES A PIERCED NOTCH TO RELIEVE THE STRESS CREATED BY THE FIRST NOTCHING PUNCH. THE PIERCED NOTCH WILL ELIMINATE CAMBER AND KEEP THE STRIP RELATIVELY STRAIGHT. THE PIERCED NOTCH SHOULD BE IN A SCRAP AREA OF THE STRIP AND SHOULD BE USED FOR MATERIALS .025 AND THICKER.
Dealing with Camber

Designing in 2 chisel punches at the beginning of a progressive die is an excellent method of eliminating camber. This works well with progressions or pitch up to 1 inch.

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THE STRIP ABOVE SHOWS A 2-OFF DIE. THIS IS ALSO CALLED A MULTIPLE PART DIE. THIS TYPE OF DIE IS AN EXCELLENT WAY TO INCREASE PRODUCTION RATES, SAVE ON RAW MATERIAL, NEUTRALIZE ANY SIDE THUST AND ELIMINATE CAMBER AT THE SAME TIME. THE IMPORTANT FACTORS GOVERNING MULTIPLE DIES ARE:
A. THE PART GEOMETRY LENDS ITSELF TO THIS TYPE.
B. SIDE THRUST IS AN ISSUE.

IT IS ADVISABLE TO PERFORM THE SAME OPERATIONS IN THE SAME STATION.

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Dual Safety Probe

The commercially available mechanical miss feed detector can also be used as a double thickness indicator. Machining a step in the detector, as shown, allows the stripper plate to activate the switch upon detecting double thickness caused by a slug or part lying on the die surface.

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Grinding Precision Small Radii

TO MACHINE A PRECISION SMALL RADIUS ONTO A RIGHT ANGLE BLOCK, USE THE FORMULA ABOVE. THE STEEL IS PLACED IN A V BLOCK SO THAT THE VERTEX IS POINTED UP. THE "A" DIMENSION IS HOW MUCH STOCK WILL BE REMOVED. THE BLOCK IS ROTATED 22.5 DEGREES AND THE SAME IS DONE FOR THE "B" DIMENSION. SIMPLY STONE THE REMAINING CORNERS SMOOTH FOR A PERFECT RADIUS.
Die Set Up and Run Technique

THE PUNCH TO THE LEFT IS AN EXCELLENT METHOD TO SET UP DIES WHEN STAMPING WIDE OR THICK STOCK. THE TIP OF THE PUNCH IS ENGRAVED WITH AN OUTER RAISED CIRCLE AND INNER LETTERS "NG". THE OUTER CIRCLE IS SLIGHTLY HIGHER THAN THE LETTERS. IF THE OPERATOR SEES A CIRCLE MARK MADE IN THE STOCK, THE DIE IS SET PROPERLY. IF THE CIRCLE AND THE LETTERS "NG" APPEAR, THE DIE IS SET TOO DEEP. THIS IS ALSO EXCELLENT FOR RUNNING STOCK WITH EXCESSIVE VARIATIONS IN METAL THICKNESS.

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It is a good practice to stress relieve all hardened steels after wire EDM machining, especially blocks that have large cut outs. The recommended time and temperature is 350 degrees F for approximately 1 hour per inch of thickness.

It is a good practice to also stress relieve dies and punches the same way, especially after extensive production runs, stamping thick materials. This will help prevent tool cracks and failures.

It is a good practice to “float” round draw punches in their retainers. This allows for self centering and compensates for any press or die mis alignment.

To drill a small hole straight through several inches of length, using conventional machines, rotate the block with every “peck” of the drill. This is easily done by hand and will help keep the hole straight.

In draw applications and forming thin metal boxes, it is advantageous to provide air release holes through the punches. This will facilitate stripping and prevent deformation or oil canning. If the diameter of the air release hole is smaller than metal thickness it will not mark the part.

Whenever possible, always draw polish die rings. This will increase productivity and reduce chances of galling.

All nitrogen cylinders should be precision machined before installation in the tool. The bases of the cylinders are not necessarily square with the piston rod. This will cause premature leaking and eventual failure.

When sharpening dies, it is a good practice to grind “into” the cutting edge as opposed to away from it. This will help maintain the original hardness and prevent loss of Rc.

Avoid using press fits in tools, especially hardened components into hardened retainers. This will prevent eventual failure and it will facilitate tool assembly and disassembly.
Eliminate Possible Tool Failure

When fabricating new tools, avoid sharp corners. Sharp corners and counter bored holes produce stress points that fail over time. This is especially important when stamping heavier metals and applying increased forces. Leave generous corner radii prior to heat treatment.

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The timing between the pilot and the bearing surface of the stripper is extremely critical. The pilot must register the material before any other contact is made.
Stripper Wear

Bearing surfaces on strippers should be checked occasionally for excessive wear. They should be reground to remove all depressions and marks.

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To help reduce galling, fabricate each sliding member from a different alloy. Make one component from A2 and the other from D2.

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If at all possible, avoid using counter bored holes for screws. The sharp corners produce stress points during the heat treatment process. The alternative is to use a larger counter bore with radial corners.
Tool Failure

This is an example of punch head breakage caused by lack of counter sunk hole in the retainer. All punches are manufactured with an inside corner radius. Clearance for that radius must be provided for.