High Productivity Tapping
Cullen Morrison – Business Development Manager, Threading
KOMET
Experts In High Performance Threading

- KOMET JEL is a leading manufacturer of ultra premium threading tools used primarily in production and difficult applications world wide
  - Solid carbide and HSSE-PM cutting taps
  - Solid carbide and HSSE-PM roll taps
  - Roll form taps with inlaid carbide strips
  - Cutting taps with inlaid carbide strips
  - Solid carbide threadmills
    - Thriller BGF
KOMET
What We Will Cover

- Basic Thread Nomenclature and Background
- Tap Styles and Geometry
- Chip Formation
- Roll Taps
- Tool materials, coatings and coolants
- Tool holding
- Gaging
- Examples
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Thread Nomenclature

**Included Angle**

**Internal thread:**
- **D** = Nominal diameter
- **D1** = Minor diameter
- **D2** = Pitch diameter
- **P** = Pitch

**Thread axis**

**Truncation**
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Metric Thread Designation

**Internal Thread**
- Thread code letter for metric ISO-thread
- Thread dimension (Nominal diameter x pitch)
- Tolerance field pitch diameter
- Tolerance field minor diameter

**External Thread**
- Thread code letter for metric ISO-thread
- Thread dimension
- Tolerance field pitch diameter
- Tolerance field major diameter

Only necessary when this tolerance field differs from tolerance field of pitch diameter.
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Metric Thread Examples

- **M10 x 1.5 – 6H**
  - Common designation of internal thread with 6H tolerance for pitch and minor diameter, if tolerance class is same for both tolerance fields
  - i.e. 6H6H is designated as only 6H

- **M12 – 6H**
  - Lack of pitch designation means it is coarse pitch (1.75 in this case)

- **M12 – 6H – LH**
  - Same as above but with left handed helix

- **M6 x 1 – 4g6g**
  - External thread with different pitch and major diameter tolerance

- **M20 x 2.5 6H/4g6g**
  - Designation for fit, 6H for internal thread, 4g6g for bolt

- **M8 x 1 – 6g - 0.100R**
  - External thread with minimum root radius of 0.100mm

- **M14 x L6 – P2 – 6H**
  - M14 coarse thread with three starts = lead of 6mm, pitch of 2mm
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Imperial Thread Designations

Internal Thread
Nominal Major Thread Diameter
Threads Per Inch (Pitch = 1/TPI)
Thread Type Designation
Thread Tolerance

External Thread
Thread Tolerance, External Uses
“A” Designation Instead of “B”
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Background

- Threading is often one of the last operations performed in any machining operation. This leads to a high cost of scrapping the part if there is a tool failure.

- Threading in general is one of the most difficult operations to perform correctly and produces the highest stress load on the tool face relative to other operations.

- For these reasons threading tools are often ran very conservatively or even too slow in order to avoid a tool breakage, however this is often counter-productive and causes more problems than it solves.

- Modern threading tools are designed to operate at high speeds to be effective, however they must be matched to the application to fully achieve this.

- The entire threading process must be viewed as a system, tool failure is not often caused by only the threading tool, errors in the machine, work or tool holding, pre-thread hole diameter or quality, coolant, etc... can all lead to process failure.
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Threading As A System

- General considerations

- Machine accuracy, stability and speed

- Tooling design, material, coating, toolpath and tool holding

- Component complexity, tolerances and material combined with fixture rigidity and clearances for tooling
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Threading As A System

- Machine design can greatly influence process stability, machine rigidity is a real concern in high speed operations.

- Machine drive type
  - Box way machines are typically less accurate and not as fast as linear way machines, but are more rigid for heavy cutting or large workpieces.
  - Linear drive machines can achieve ultra high acceleration, but will generally have reduced machine rigidity and harmonic dampening capacity.

- The component should be mounted solidly to the machine table/fixture; any instability can cause position errors, tool chatter and other problems that will reduce process efficiency.

- Coolant can cause significant issues with threading operations, tapping is more sensitive than thread milling or other operations to coolant issues.
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**Cutting Tap Flute Geometry**

- With cutting taps, matching chip flow direction to type of hole is critical to creating any stable tapping process.

- Spiral pointed taps are used in thru holes that are threaded completely thru pushing the chips in front of the tap.

- Spiral fluted taps are used in blind holes or in thru holes where the thread is not completely thru the component, the flute design pulls chips out of the bore similar to a twist drill.

- Straight fluted tools are best used in short chipping materials like cast iron and hardened steels.
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### Cut Tap Geometry by Application

<table>
<thead>
<tr>
<th>Bore type</th>
<th>Tool type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Through hole</td>
<td>Form B / 3.5 – 5.5 Spiral point</td>
</tr>
<tr>
<td>2. Through hole, hole not completely threaded</td>
<td>Form C / 2 – 3 Straight flute / low helix spiral flute</td>
</tr>
<tr>
<td>3. Blind hole thread depth ≤ 2 x d</td>
<td>Form C / 2 – 3 Form E / 1.5 – 2 Form F / &lt; 1.5 Straight flute / low helix spiral flute</td>
</tr>
<tr>
<td>4. Blind hole thread depth &gt; 2 x d</td>
<td>Form C / 2 – 3 Form E / 1.5 – 2 Form F / &lt; 1.5 High helix spiral flute</td>
</tr>
</tbody>
</table>
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Chip Root in Partially Threaded Holes

Tapping – Chip formation

Shearing-off the chip root at tap reversal
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Tap Chamfer

- $d_3$: Point diameter
- $l_4$: Chamfer length
- $K_r$: Set-up angle

Chamfer length $l_4$ is determined in # of leads
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**Tap Chamfer Form Designation**

<table>
<thead>
<tr>
<th>Form</th>
<th>Number of leads in chamfer area</th>
<th>Set-up angle</th>
<th>Flute Geometry</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6 -8</td>
<td>5°</td>
<td>Straight fluted</td>
<td>Short through holes</td>
</tr>
<tr>
<td>B</td>
<td>3.5 -5</td>
<td>8°</td>
<td>Spiral pointed</td>
<td>Through holes</td>
</tr>
<tr>
<td>C</td>
<td>2 -3 up to 3.5 on roll taps (DIN 2175)</td>
<td>15°</td>
<td>Straight or spiral fluted</td>
<td>Blind and through holes in long chipping materials</td>
</tr>
<tr>
<td>D</td>
<td>3.5 -5</td>
<td>8°</td>
<td></td>
<td>Mostly through holes</td>
</tr>
<tr>
<td>E</td>
<td>1.5 -2</td>
<td>23°</td>
<td></td>
<td>Bottoming taps for blind holes</td>
</tr>
</tbody>
</table>

The chamfer code letter is placed just before the thread designation on JEL taps i.e. **MG CM6-ISO2 SIREX SR IK VHM**
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Chip Formation

- All cutting or forming action of a tap is done by only the chamfer.

- Long chamfer taps typically produce very thin chips which can be difficult to manage but will have a long tool life from a larger wear surface.

- Short chamfer taps typically produce a more manageable chip but may see reduced tool life.

- The number of chamfer teeth can have a great affect on cutting performance.

- Number of engaged cutting teeth is equal to # of flutes x chamfer (# of teeth)
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Chip Formation

- Chip evacuation is critical for efficient cut tapping

- There are two methods of chip evacuation with tapping
  - Short broken chips that can evacuate with coolant or inertia
  - Long chips wrapped tightly together that do not wrap around the tool

- Short broken chips are not always possible depending upon material
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Cutting Geometries

- The tap cutting geometry is a combination of many characteristics
  - Flute shape
    - Rake and hook angle
  - Helix angle
    - Higher helix angle is typically used for deeper holes
  - Relief angle
- Geometry must be matched to material requirements to be effective at high speeds
- Machine capability could be limiting
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Cutting Geometries

- Some taps can come with no radial relief which are called concentric relieved taps used for very unstable conditions (hand taps), modern taps are generally made with an eccentric relief.

- A suitable relief angle of the tool is critical to provide support for the cutting edge but reduce heat generation by the tool flanks.

- High speed taps typically have a high relief angle which make them less able to guide themselves and require a synchro chuck to ensure proper stability.

- The high relief angle creates the least amount of “un-useful” heat in the tapping process.

<table>
<thead>
<tr>
<th>blind hole tap</th>
<th>through hole tap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tap type DOMINANT N38</td>
<td>tap type VARIANT N</td>
</tr>
<tr>
<td>2 tap type DOMINANT HZ38</td>
<td>tap type VARIANT H</td>
</tr>
<tr>
<td>3 tap type DOMINANT VA45</td>
<td>tap type VARIANT VA / TIH</td>
</tr>
<tr>
<td>4 tap type DOMINANT MHST45</td>
<td>tap type VARIANT MHST / NI</td>
</tr>
</tbody>
</table>
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Roll Form Tapping

- Roll form tapping is a process of creating a thread profile by cold forming the part material to the correct thread shape

- In roll forming no chips are created as no material is removed; only displaced, which can greatly improve process stability

- The tap geometry does not need to have any chip management characteristics which makes them much more flexible; such as machining thru and blind holes with same tap

- Without large chip flutes the core diameter of the tap is also increased which translates to more torsional load it can take before failure

- In many cases the thread strength is also increased from the forming process
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Roll Forming Application Requirements

- Material elongation of rupture should be minimum 8%
- Tensile strength of material should not be more than 1,250 N/mm²
- Max. pitch of 6mm or 5 TPI, diameter is not a limiting factor
- Good lubricant containing high pressure additives
- Precise bore hole Ø (very small tolerance required)
  - Bore hole Ø is larger than for same thread size cut tap
- The expected torque is up to 2.5 times higher than for thread cutting
- Wall thickness of part should be 2xP minimum to avoid distortion
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Roll Forming Material Application Area

- Steel < 700 N/mm²
- Alu Alloys / Castings
- Wrought Aluminium
- Stainless Steel
- Nickel Alloys
- Steel < 1000 N/mm²
- Steel < 1300 N/mm²

Tensile Strength Rm [N/mm²]

Elongation of Rupture A₅ [%]
Roll Form Tapping

Roll Form Tapping is most effectively done as a high speed process.

- Since no chips are created it is easier to consistently use a higher spindle speed.

- Since it is a forming process at high speed it will generate a lot of heat which must be handled by the tap or reduced tool life and potential tap welding will occur.

Cut tap

Roll tap

Interrupted grain structure

Continuous grain structure in shape of thread for increased thread strength.
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Forming Geometries

- The “Polygon” shape and number of lobes of the tool act as the forming geometry
- Some materials need a more aggressive forming profile to form without work hardening
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Thread Forming Process
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Thread Profile

- minor thread diameter not formed completely
- thread is not true to gage due to oversized minor diameter
- insufficient pull out strength causes stability deficiencies

• too big

- small gap at minor thread diameter

• correct

- thread is true to gage, tolerance class 7H DIN 13 part 50

• too small

- gap at minor diameter is nearly closed

- non-standard minor diameter

- higher torque may lead to tool breakage
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Tool Materials

- HSS – typical high speed tool steel
  - Base material typically used in hand taps for simple applications

- HSSE – premium grade high speed tool steel, generally with a higher cobalt or vanadium content
  - Increased tool life vs HSS

- HSSE-PM – Powdered metal construction of tool steel
  - Greatly increased tool life and performance vs HSS or HSSE
  - Ability to tap harder or more difficult materials

- Solid carbide or carbide stripped (VHM)
  - Used in applications requiring a high wear resistance such as high silicon cast aluminum, cast iron or hardened steel above 45 HRC
  - Carbide tap applications are much more limited than HSSE-PM
  - Carbide stripped tools combine features of HSSE and VHM
Effects of Coating on Chip Formation

- Coated taps work well to reduce friction and reduce wear however reduced friction reduces chip thickness that can cause issues with chip evacuation.

- Different coatings have different optimal operating temperatures and should be matched accordingly to tap geometry and workpiece material.

- A tap that is running too slowly will not generate enough heat to effectively manage chips like it was designed to do.

- Operators tend to reduce speed to try to solve this problem which only makes the situation worse.

- The result is reduced tool life and reduced productivity.
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**Common Tool Coatings**

<table>
<thead>
<tr>
<th>abbreviation</th>
<th>micro hardness in HV</th>
<th>friction against steel (dry)</th>
<th>max. temp. (°C)</th>
<th>color of the coating</th>
<th>application</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIN</td>
<td>2300</td>
<td>0.4</td>
<td>600</td>
<td></td>
<td>steel materials tensile strength &lt; 1000 N/mm</td>
</tr>
<tr>
<td>TICN</td>
<td>3000</td>
<td>0.4</td>
<td>400</td>
<td></td>
<td>steel, grey cast iron, abrasive materials &gt; 1000 N/mm</td>
</tr>
<tr>
<td>FNT (TiAIN)</td>
<td>3300</td>
<td>0.25</td>
<td>900</td>
<td></td>
<td>abrasive materials cutting speed &gt; 40 m/min</td>
</tr>
<tr>
<td>HL (TiAIN + WCC)</td>
<td>3000</td>
<td>0.15-0.20</td>
<td>800</td>
<td></td>
<td>for dry cutting / MQL / emulsion with low oil content steel materials with a low contents of carbon, aluminum or titanium alloy</td>
</tr>
</tbody>
</table>
High Productivity Tapping
Coolant / Lubricant Considerations

- Tapping generates a lot of friction and also needs the coolant to help manage chip flow.

- Matching the coolant design of the tap to the application is very important; i.e. axial or radial coolant, roll taps with or without grooves.

- Coolant should be clean and of good quality.

- Fluctuations in coolant concentration will generally first be seen in tap tool life and thread quality.

- Roll form taps have a greater need for lubricity and the concentration requirement should be minimum 8%.

- Oil tends to work better for difficult to machine materials.
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Minimum Quantity Lubrication Considerations

- MQL applications are becoming very common due to the cost savings and reduced environmental effect.

- Taps are very difficult to use with MQL due to very poor chip control with reduced lubrication and cooling.

- Design of the tap coolant channels often times have to be optimised for each individual application.

- The sealing ability and flow volume of the tap holding system has a huge affect on the success of the operation.

- Spray pattern tests can help identify problems with complex tool designs.
High Productivity Tapping
Degrees of Freedom and Limitations

- Unlike thread mills, taps are limited on adjustable parameters.

<table>
<thead>
<tr>
<th>Degrees of Freedom</th>
<th>Tapping</th>
<th>Thread Milling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Feed</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Depth of Cut</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- Chip formation is determined by the design of the cutting geometry and the bore condition.
  - Diameter
  - Cylindricity
  - Position
  - Surface finish

- These factors make it critical to plan for success and use not only a tool but a system that is designed for the application.
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Drill Sizing and Percent of Thread

- Selecting the proper drill size is key to successful threading operation

- Too often a smaller than optimal drill is used and it causes early failure

- Bore size relative to thread size is typically referred to as percent of thread and is calculated as the theoretical height of the thread profile

- Recommendations
  - Cut threads - 65-75% (70% lower limit for large pitches)
  - Rolled threads - 65-70%

- Short threaded bores (less than 1.5xD) are commonly at a higher percent of thread than deeper bores for added strength

- Using a higher percent of thread only makes the tap work harder for little gain as the pull out strength of thread is not noticeably increased
High Productivity Tapping
Calculating Drill Size (cut taps)

- Basic calculation
  - Tap Drill Size = Major Diameter – Pitch
  - Always yields a percent of thread of 77%
  - Examples
    - M12x1.75 = 12-1.75 = 10.25mm
    - 1”-8 UNC = 1-.125 = .875”

- Calculation by percent of thread
  - Tap Drill Size = Major Diameter - (.01299 x % Thread x Pitch)
  - Examples
    - M12x1.75 @ 65 = 12-(.01299 x 65 x 1.75) = 10.522mm
    - 1”-8 UNC @ 65 = 1-(.01299 x 65 x .125) = .8945”

- It is critical to remember that the drill size is not as important as the bore size it leaves for the tap

For UN Threads
Pitch = 1 / TPI
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Calculating Drill Size (roll taps)

- With roll form taps, the drill size to use can be more complicated

- Too many factors to calculate an accurate drill size easily
  - Material flow
  - Tool and spindle runout
  - Spindle synchronization accuracy

- Calculation method by percent of thread
  - Tap Drill Size = Major Diameter - (.0068 x % Thread x Pitch)
  - Examples
    - M12x1.75 @ 65 = 12-(.0068 x 65 x 1.75) = 11.227mm
    - 1”-8 UNC @ 65 = 1-(.0068 x 65 x .125) = .9448”

- Increased productivity can be achieved by customizing the drill diameter to the application requirements after testing to see how the minor diameter is formed
# High Productivity Tapping

## TECHNICAL THREADING CHART

<table>
<thead>
<tr>
<th>Thread Size (UN)</th>
<th>Diameter (inch)</th>
<th>Depth (inch)</th>
<th>Pitch (inch)</th>
<th>Lead (inch)</th>
<th>Flute Length (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>0.625</td>
<td>0.5</td>
<td>0.020</td>
<td>0.020</td>
<td>1.0</td>
</tr>
<tr>
<td>3/32</td>
<td>0.625</td>
<td>0.5</td>
<td>0.015</td>
<td>0.015</td>
<td>0.5</td>
</tr>
<tr>
<td>1/16</td>
<td>0.625</td>
<td>0.5</td>
<td>0.015</td>
<td>0.015</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Threading Techniques

- **Basic UN or M6 Thread Form**: Use for socket head cap screws and captive nuts. Taper pilots are recommended for UN and M6 threads.
- **Heli-Coil THREAD**
- **Taper Pilot Thread Cross Section**: A diagram showing the cross-sectional view of a threaded tap.

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page 36
## High Productivity Tapping

### Pre-Tap Bore Size

<table>
<thead>
<tr>
<th>Thread</th>
<th>Series</th>
<th>Pitch or in / Rev</th>
<th>Minor Dia Min (2B / 3B)</th>
<th>Minor Dia Max (2B)</th>
<th>Minor Dia Max (3B)</th>
<th>Pitch Dia Min (2B / 3B)</th>
<th>Pitch Dia Max (2B)</th>
<th>Pitch Dia Max (3B)</th>
<th>70% Thread Engagement</th>
<th>75% Thread Engagement</th>
<th>65% Thread Engagement</th>
<th>70% Thread Engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>#0-60 (.060&quot;)</td>
<td>UNF</td>
<td>0.012500</td>
<td>0.0465</td>
<td>0.0514</td>
<td>0.0514</td>
<td>0.0519</td>
<td>0.0542</td>
<td>0.0536</td>
<td>0.0486</td>
<td>0.0478</td>
<td>0.0545</td>
<td>0.0541</td>
</tr>
<tr>
<td>#1-64 (.073&quot;)</td>
<td>UNC</td>
<td>0.015625</td>
<td>0.0561</td>
<td>0.0622</td>
<td>0.0622</td>
<td>0.0629</td>
<td>0.0655</td>
<td>0.0648</td>
<td>0.0588</td>
<td>0.0578</td>
<td>0.0661</td>
<td>0.0656</td>
</tr>
<tr>
<td>#1-72 (.073&quot;)</td>
<td>UNF</td>
<td>0.013889</td>
<td>0.0580</td>
<td>0.0634</td>
<td>0.0634</td>
<td>0.0640</td>
<td>0.0665</td>
<td>0.0659</td>
<td>0.0604</td>
<td>0.0595</td>
<td>0.0669</td>
<td>0.0664</td>
</tr>
<tr>
<td>#2-56 (.085&quot;)</td>
<td>UNC</td>
<td>0.017857</td>
<td>0.0667</td>
<td>0.0737</td>
<td>0.0737</td>
<td>0.0744</td>
<td>0.0772</td>
<td>0.0765</td>
<td>0.0698</td>
<td>0.0686</td>
<td>0.0781</td>
<td>0.0775</td>
</tr>
<tr>
<td>#2-64 (.085&quot;)</td>
<td>UNF</td>
<td>0.015625</td>
<td>0.0691</td>
<td>0.0752</td>
<td>0.0752</td>
<td>0.0759</td>
<td>0.0786</td>
<td>0.0779</td>
<td>0.0718</td>
<td>0.0708</td>
<td>0.0791</td>
<td>0.0786</td>
</tr>
<tr>
<td>#3-48 (.099&quot;)</td>
<td>UNC</td>
<td>0.020833</td>
<td>0.0754</td>
<td>0.0845</td>
<td>0.0845</td>
<td>0.0855</td>
<td>0.0885</td>
<td>0.0877</td>
<td>0.0801</td>
<td>0.0787</td>
<td>0.0898</td>
<td>0.0891</td>
</tr>
<tr>
<td>#3-56 (.099&quot;)</td>
<td>UNF</td>
<td>0.017857</td>
<td>0.0797</td>
<td>0.0865</td>
<td>0.0865</td>
<td>0.0874</td>
<td>0.0902</td>
<td>0.0895</td>
<td>0.0828</td>
<td>0.0816</td>
<td>0.0911</td>
<td>0.0905</td>
</tr>
<tr>
<td>#4-40 (.112&quot;)</td>
<td>UNC</td>
<td>0.025000</td>
<td>0.0849</td>
<td>0.0939</td>
<td>0.0939</td>
<td>0.0958</td>
<td>0.0991</td>
<td>0.0982</td>
<td>0.0893</td>
<td>0.0876</td>
<td>0.1010</td>
<td>0.1001</td>
</tr>
<tr>
<td>#4-48 (.112&quot;)</td>
<td>UNF</td>
<td>0.020833</td>
<td>0.0894</td>
<td>0.0968</td>
<td>0.0968</td>
<td>0.0985</td>
<td>0.1016</td>
<td>0.1003</td>
<td>0.0931</td>
<td>0.0917</td>
<td>0.1028</td>
<td>0.1021</td>
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<tr>
<td>#5-40 (.125&quot;)</td>
<td>UNC</td>
<td>0.025000</td>
<td>0.0979</td>
<td>0.1062</td>
<td>0.1062</td>
<td>0.1088</td>
<td>0.1121</td>
<td>0.1113</td>
<td>0.1023</td>
<td>0.1006</td>
<td>0.1140</td>
<td>0.1131</td>
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<tr>
<td>#5-44 (.125&quot;)</td>
<td>UNF</td>
<td>0.022727</td>
<td>0.1004</td>
<td>0.1079</td>
<td>0.1079</td>
<td>0.1102</td>
<td>0.1134</td>
<td>0.1126</td>
<td>0.1048</td>
<td>0.1029</td>
<td>0.1150</td>
<td>0.1142</td>
</tr>
<tr>
<td>#6-32 (.138&quot;)</td>
<td>UNC</td>
<td>0.031250</td>
<td>0.1040</td>
<td>0.1140</td>
<td>0.1139</td>
<td>0.1177</td>
<td>0.1214</td>
<td>0.1204</td>
<td>0.1096</td>
<td>0.1076</td>
<td>0.1242</td>
<td>0.1231</td>
</tr>
<tr>
<td>#6-40 (.138&quot;)</td>
<td>UNF</td>
<td>0.025000</td>
<td>0.1110</td>
<td>0.1190</td>
<td>0.1186</td>
<td>0.1218</td>
<td>0.1252</td>
<td>0.1243</td>
<td>0.1153</td>
<td>0.1136</td>
<td>0.1270</td>
<td>0.1261</td>
</tr>
<tr>
<td>#8-32 (.164&quot;)</td>
<td>UNC</td>
<td>0.031250</td>
<td>0.1300</td>
<td>0.1390</td>
<td>0.1388</td>
<td>0.1437</td>
<td>0.1475</td>
<td>0.1465</td>
<td>0.1356</td>
<td>0.1336</td>
<td>0.1502</td>
<td>0.1491</td>
</tr>
</tbody>
</table>
High Productivity Tapping

Spindle Drive Type

- Machines can be equipped with “rigid tapping” which is the ability of the machine to match spindle rotation position to axis feedrate. Machines without rigid tapping are not recommended for high speed tapping or high performance taps.

- Rigid tapping is only as good as the machine is set to and is subject to error due to spindle acceleration and deceleration.

- When the spindle slows to stop or change direction it can lose accuracy of axial position relative to spindle orientation, this will cause excess torque and axial force on the tap often causing breakage – this can be mitigated with proper tool holding.

- Spindle acceleration is also a limiting factor for high speed threading, some spindles can accelerate at a higher rate more accurately than others. Programming a higher rpm may not be achieved before the spindle must start to decelerate to stop at the bottom of the hole, reaching the maximum achievable speed of the machine. For taps around 3/8"-16 in size 120 SFM is usually close to maximum attainable RPM with average thread depths on most machines.
High Productivity Tapping
Tap Reaction Forces

- The reaction force created when tapping is always in the opposite direction of chip flow.
High Productivity Tapping

Miscutting

- Misalignment or miscutting of a tap can be caused by spindle error but also by the reaction force.

- This can commonly be heard by listening to the tap “squeak” on the reversal motion of the tap where the tap is dragging on the thread flanks generating excess heat and dulling the tap reducing tool life.

- This can be seen in thru hole threads where one side of the thread may look much rougher in comparison to the opposite side.

- Any miscutting of a tap will limit maximum achievable tap speed and efficiency.
High Productivity Tapping
Tap Holding Methods

Various methods exist for tap holding depending on machine capabilities and needs

- Tension and compression compensating chuck
- Collet chuck for rigid tapping
- Synchro tapping chuck for rigid tapping
- Self-reversible tapping device
A synchro chuck is specifically designed to absorb the axial alignment errors of the tap caused by machine error and reaction forces when cutting.

The spring rate of the chuck is matched to a range of tap sizes to be most effective with a very limited movement range unlike tension compression holders which are much too loose to support HP taps.
High Productivity Tapping
Synchro Chuck Forces

- M8 spiral flute tap in 4140
High Productivity Tapping
Synchro Chuck Forces

- M8 roll form tap in low carbon steel
High Productivity Tapping
Thread Measurement and Gaging

To verify that a thread is within tolerance class the major/minor and pitch diameters must be measured.

For external threads the major diameter can be directly measured with a caliper or micrometer.

To measure the pitch diameter of an external thread there are three methods to do so:
- Non-contact measurement with camera or laser
- Measurement using a special micrometer designed for measuring thread pitch diameter
- Measurement using a standard micrometer and three gage wires using a correction factor

For internal threads the minor diameter should be measured with a pin gage set.

To measure the pitch diameter of an internal thread a thread master gage of known size must be used.
High Productivity Tapping
Cylindrical Pin Gage

The go gage has to fit in smooth into the drilled hole, the no-go gage is allowed to fit in only at the front, not over the entire gage length.

The cylindrical plug gage is often used to check the achieved minor diameter when roll form tapping, and when working with very tight tolerances such as 4H or 3B.
The plug thread gage checks the minimum pitch diameter and the minimum major thread diameter at the same time. The gage should turn easy into the thread.

The no-go gage has a smaller major thread diameter than the go-gage. This makes sure that only the maximum pitch diameter will be checked. The no-go gage is allowed to fit in max. 1.5 threads in the machined threads.
High Productivity Tapping
Tapered Thread Gaging

Tapered threads like NPT and NPTF are gaged with a tapered gauge. The thread is within the tolerance when the engagement of the bolt is between the minimum and maximum shoulders (flats on the thread gage).
High Productivity Tapping
Gaging Considerations

It is very important to remember what thread and plug gages do NOT tell you.

The gages do NOT tell you that you have a good thread, only that the minor diameter, pitch diameter are within spec and that the major diameter is not too small, that is it.

Gages do not measure peak or trough shape, flank angle, straightness, or any other thread feature. All of these can add up to a non-conforming thread shape or failure in stringent applications like aerospace or high stress engine components.
High Productivity Tapping
Common Problems With Tapping

- "Oversized" threads
- Undersized threads
- Chip Management
- Poor tool life
- Poor thread quality
- Tool chipping
- Tool failure
High Productivity Tapping
What is possible?

Carbon Steel - M10 BASS Dominant MHST45 cutting tap

- Speed – 131 SFM (40 SMM)
- RPM – 1273 RPM
- ~75 IPM feedrate

Carbon Steel - M10 JEL MOREX R roll form tap w/ carbide strips

- Speed – 197 SFM (60 SMM)
- RPM – 1910 RPM
- ~113 IPM
High Productivity Tapping
Application Example

**Task:**
Thread: M5x0.8-6H  
Blind hole  
Drill depth: 10.5mm (0.334”)  
Thread length: 8.5mm (0.413”)

**Material:**
Bearing cover  
Diecast aluminum with 9% silicon

**Solution:**
Solid carbide roll form tap  
MOREX VHM M5-6HX  
Coolant through, chamfer bottoming style, rigid tapping

**Cutting Data:**
3000 rpm  
v_c = 47 m/min (154 SFM)

**Cycle Time:**
t_h = 1.3 s

**Note:**
Vs coated HSS tap customer could increase tool life from 18,000 to 340,000 threads
# Roll Form Taps with Carbide Strips

**Tool Life**

HSS body with brazed-in carbide strips. Coolant: water soluble. This combination – elastic body and tough form strips are resulting in a high bending strength and wear resistance of the tool.

Therefore it’s possible to achieve amazing results in economy and tool life!

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Thread length mm(inch)</th>
<th>Machining</th>
<th>Part</th>
<th>Material</th>
<th>Cutting speed Vc in mm/min (SFM)</th>
<th>Tool life # of threads</th>
</tr>
</thead>
<tbody>
<tr>
<td>M6</td>
<td>20 (0.787)</td>
<td>vertical</td>
<td>Intake manifold</td>
<td>Diecast aluminum</td>
<td>14 (46)</td>
<td>900,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>With 10% silicon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M6</td>
<td>20 (0.787)</td>
<td>horizontal</td>
<td>Oil pump housing</td>
<td>Diecast aluminum</td>
<td>11 (36)</td>
<td>950,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>With 9% silicon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M8</td>
<td>23 (0.9)</td>
<td>horizontal</td>
<td>Clutch housing</td>
<td>Diecast aluminum</td>
<td>18 (59)</td>
<td>950,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>With 9% aluminum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M10x1</td>
<td>28 (1.1)</td>
<td>horizontal</td>
<td>Camshaft</td>
<td>Steel</td>
<td>9 (30)</td>
<td>23,000</td>
</tr>
<tr>
<td>M12x1</td>
<td>36 (1.41)</td>
<td>horizontal</td>
<td>Crankshaft</td>
<td>Nodular grey iron</td>
<td>8 (26)</td>
<td>28,000</td>
</tr>
<tr>
<td>M6</td>
<td>25 (0.98)</td>
<td>horizontal</td>
<td>Valve housing</td>
<td>Aluminum with 6% Silicon</td>
<td>22 (72)</td>
<td>1,500,000</td>
</tr>
<tr>
<td>M10</td>
<td>24 (0.94)</td>
<td>horizontal</td>
<td>Cylinder head</td>
<td>Diecast aluminum</td>
<td>18 (59)</td>
<td>1,300,000</td>
</tr>
</tbody>
</table>
### Challenge
- **Material:** Forged 8822H Steel case hardened
- **Machine:** Okuma VMC 40 taper
- **Diameter:** M16X1.5 Thread
- **Length of Cut:** Metric: 21mm
- **Present Tooling:** Competitor cut tap

### Solution
- **Tool:** JEL Morex R M16x1.5
- **Cutting data:**
  - RPM: 969
  - M/M: 50
  - Feed: 1.5 Rev
  - MMPM: 1,453.5
  - CUT TIME-sec.: 3 per hole

### Customer’s Benefit
- **Previous Tool Life:** 500 parts or 6,000 holes
- **Tool Life JEL:** 2600 Parts or 31,200 holes
- **Tool Life Competitor SC:** 5 Parts or 30 holes

- **Cutting data:**
  - RPM: 650
  - M/M: 35
  - Feed: 1.5 Rev
  - MMPM: 975
  - CUT TIME-sec.: 5 Per hole
**Challenge**

**Material:**
Nodular Cast Iron GGG50

**Part:**
Housing

**Thread:**
16x M20, 35-55mm (1.37-2.16") long, blind and through hole

**Situation:**
Previously HSSE-PM taps been used since no safe process with carbide taps possible

**Goal:**
Increase current tool life of 2.080-2.400 threads

---

**Solution**

**JEL tap M20-6H SIREX HML**
(HSS Body, carbide strips)
Article-# 90421001005028

**Cutting data:**
\[ v_c = 35 \text{m/min (115 SFM)} = 560 \text{ r.p.m.} \]

---

**Customer’s Benefit**

- Increase of tool life by 713% up to 17,120 threads
- Tools can be re-tipped achieving same tool life than new ones
- Based on the good results customer ordered additional tools in M14 and M16
High Productivity Tapping
Difficult Applications

- Tapping in difficult applications can become very easy if a stable system is created and maintained
## High Productivity Tapping

### Threading Methods Comparison

<table>
<thead>
<tr>
<th>Influencing Variables</th>
<th>Manufacturing Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tapping</td>
</tr>
<tr>
<td><strong>Machine</strong></td>
<td></td>
</tr>
<tr>
<td>- machining center</td>
<td></td>
</tr>
<tr>
<td>- transfer line</td>
<td></td>
</tr>
<tr>
<td>- drilling machine</td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td></td>
</tr>
<tr>
<td>- long chipping</td>
<td></td>
</tr>
<tr>
<td>- short chipping</td>
<td></td>
</tr>
<tr>
<td>- hardness &gt; 35 HRC</td>
<td></td>
</tr>
<tr>
<td><strong>Lubricant</strong></td>
<td></td>
</tr>
<tr>
<td>- emulsion / oil</td>
<td></td>
</tr>
<tr>
<td>- minimum lubricant</td>
<td></td>
</tr>
<tr>
<td>- dry</td>
<td></td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
</tr>
<tr>
<td>- single</td>
<td></td>
</tr>
<tr>
<td>- serial</td>
<td></td>
</tr>
<tr>
<td><strong>Thread depth</strong></td>
<td></td>
</tr>
<tr>
<td>- short = 1-2 xD</td>
<td></td>
</tr>
<tr>
<td>- long = &gt; 2 xD</td>
<td></td>
</tr>
</tbody>
</table>

- Suitable
- Conditionally suitable
- Not suitable
Threading Help

THREADING TECH LINE

844-4-THREAD

Expert support for your technical threading questions
Threading Tech Line
1-844-4Thread

- Questions?
  - Thank you for your time and attention!
  - Cullen.Morrison@kometgroup.com