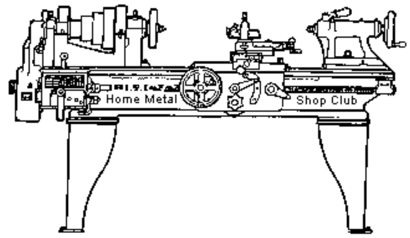
Home Metal Shop Club

August 2010
Newsletter

Volume 15 - Number 8



http://www.homemetalshopclub.org/

Since its founding by John Korman in 1996, The Home Metal Shop Club has brought together metal workers from all over the Southeast Texas area.

Our members' interests include Model Engineering, Casting, Blacksmithing, Gunsmithing, Sheet Metal Fabrication, Robotics, CNC, Welding, Metal Art, and others. Members always like to talk about their craft and shops. Shops range from full machine shops to those limited to a bench vise and hacksaw.

If you like to make things, run metal working machines, or just talk about tools, this is your place. Meetings generally consist of a presentation with Q&A, followed by ***show and tell*** where the members can share their work and experiences.

President *Vance Burns*	Vice President *John Hoff*	Secretary *Martin Kennedy*	Treasurer *Emmett Carstens*	Librarian *Dan Harper*
Webmaster/Editor *Dick Kostelnicek*	Photographer *Jan Rowland*	CNC SIG *Dennis Cranston*	Casting SIG *Tom Moore*	Novice SIG *Rich Pichler*

About the Upcoming September 11 Meeting

The September general meeting will be held on the second Saturday of the month at 1:00 p.m. in the Parker Williams County Library, 10851 Scarsdale Boulevard, Houston, TX 77089. Visit the web link http://www.homemetalshopclub.org/events.html for up-to-the-minute details.

Speaker: John Stranahan. Topic: Gunsmithing to Racing Cars.

Recap of the August 14 Regular Meeting

Thirty-four members and seven visitors, *Jeff Laver, John Wyckoff, Chuck Griffin, Charles Bornstein, Shannon DeWofe, Chris Evans and Corwin King,* attended the 1:00 p.m. meeting at the Parker Williams County Library. President Vance Burns led the meeting.

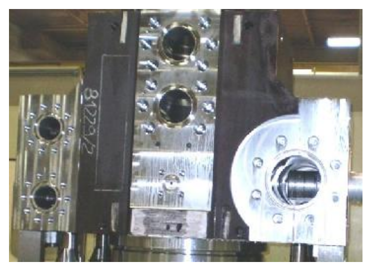
We have been video recording the regular meetings since last May. It has been quite a trial to produce quality and fast downloading videos. The May meeting is now available for viewing on the Club's video page. More recent meeting videos will be posted as they become available.

Presentation

Bubba Vaughn, a manufacturing engineer from [FMC Technologies](), spoke on "Advanced Milling – Subsea Christmas Tree Machining". FMC Technologies manufactures subsea and drilling equipment for use offshore.

FMC has a large machine shop in Houston that includes a total of 13 large Horizontal Boring Mills (HBM). Most are Giddings and Lewis G60 (6-inch spindle) and one is a G50 (5-inch spindle). The HBMs are driven by a 50 HP motor and cost $1.5 - $1.7 MM (million $) each without tooling. Tooling adds another $0.75 MM. FMC employs 10-15 machinists. Their primary product is subsea trees, and they build as many as 60 a year. The major machined component of the subsea tree is the spool body. The spools begin with a casting forged in Italy by MetalCAM. After machining, a finished spool is worth about $250,000.

Bubba's presentation focused on common tree spool body machining operations – seat pockets, face milling, ring groove cutting, slot cutting, gun drilling and ejector drilling.



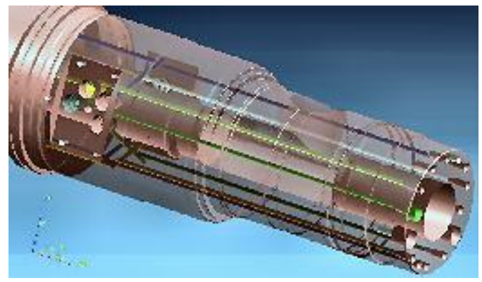
Seat Pockets – Tthese are a difficult machining challenge requiring specialized tooling. Pockets are cut inside the tree, up to 55" down inside the body. The tool used to cut the ID can also be used to cut an OD. An example was shown where lathe-like operations were performed, with the difference being that the stock was stationary and the tool rotated around it.

Face milling – The most difficult facing operation is to remove inconel welded inlays. FMC started using ceramic inserts instead of carbon steel inserts in the last 2 years. A dramatic reduction in time to machine was experienced. With carbon steel inserts, face milling a 4" diameter x ¼-inch deep area took 30-90 minutes. Using a ceramic insert without coolant reduced the time for the operation to about 90 seconds! Feed and speed for the operation was 75 inches/minute at 3,000 RPM. A video was shown of the operation, which produced an amazing amount of sparks and fire being produced by the tool. Bubba said that all of the heat was in the chips, and that the machined part was cool to the touch after machining. The inserts used are round in shape, and are rolled after each cut. Inserts can be used to cut 3-4 features before needing to be replaced.

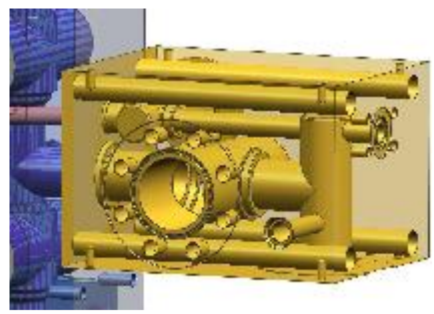
Ring Groove Cutting – This is one of the most common features machined. The profile of the cut is a v-shaped bevel with a flat bottom. The profile is plunge cut with ceramic cartridges made to the exact profile of the groove. In the past, a conventional carbide insert took about 90 minutes to cut a VX 152 profile. A video was shown where a ceramic insert made the same cut in 90 seconds, to 0.002" accuracy. The cut is made in two plunges – the first leaves about 0.005" to assure the final cut will be to the exact dimension. Then, the cut is measured with a specialized gauge. After measurement, the final cut is made to tolerance. The bit is flipped over after cutting each groove.

Slot and Groove cutting – This operation is performed on a majority of the parts. It can be performed with either the HBM or a large CNC lathes. Internal slots are cut using angle heads, which have a milling bit at a 90-degree angle on the end of a long shaft.

Gun Drilling – Used for deep holes of small diameters. Most holes are less than 0.8-inch diameter. The tool manufacturer guarantees a drift accuracy of 0.002-inches per inch of depth, although FMC has seen 0.001-inches per inch in practice. The hole to be drilled is first prepared with a conventionally drilled pilot hole 3 diameters deep before inserting the gun drill bit. Without this pilot hole, the gun drill tends to throw off its inserts, then the entire shaft tends to bend and break off. The holes are cut at 600 – 1,100 RPM. An example was shown where a 0.312-inch diameter hole was cut to 40 – 50-inches deep, and then intersected another hole.

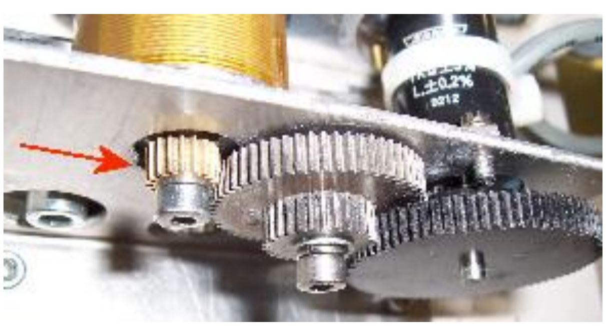


Ejector drilling – Similar application to gun drilling, but for holes up to 5-inches diameter and 65-inches deep. Before using ejector drilling, it took 8 – 12 hours to drill 4 x 2 5/8-inch holes with a spade drill. The ejector drill uses inserts and takes about 25 minutes to perform the same operation, cutting at a rate of 8-inches / minute, or 0.011-inches / revolution at 728 RPM. Bubba said that the operation is something to watch. When they first started using ejector drilling, it was throwing chips completely out of and over the top of the room-sized enclosure. A deflector baffle had to be installed to keep the chips inside of the enclosure. The drilling takes lots of power, and draws 60 – 80% load on the 50 HP motor.



Slides from Bubba's presentation are available at this web link.

Show & Tell



Shannon DeWolfe of St. Luke's Hospital was the recipient of a small 18-tooth gear made by HMSC's Dick Kostelnicek. Shannon showed pictures and movies of the equipment that contained the gear, which was a large X-ray machine used to perform Myelograms. He recounted that the replacement part from the manufacturer was long delivery from Denmark, and would have cost $8,000! Shannon's presentation can be viewed at this web link. Download the x-ray machine video 8 Mb.

Dick Kostelnicek made an interesting instructional presentation on “Determining the Pressure Angle of Spur Gears”. An article on this subject is included in this newsletter.

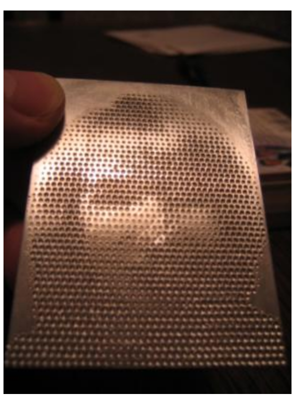
Dick Kostelnicek showed a “B” style insert tool holder that he made to hold worn out inserts used by his boring bar. The boring bar used up the two 80 degree points on the inserts, and the “B” style insert tool holder was able to use the two unused 100 degree points on the same inserts. See the article “B-Style Insert Tool Holder**”** below for details.

Dennis Cranston showed an example of some parts that he purchased that were custom laser cut from sheet metal. He said he was looking for a local place that could do small quantities cheaply. Dennis then showed an example of a freight car side frame that he had produced using Rapid Prototyping. He was forming it up in a mold to be used to produce a RTV mold that he could use to produce a pewter or resin cast, from which an aluminum casting could be made.

Lee Morin showed a silhouette profile picture that had originally been cut from black paper. Lee had made a replica of the original artwork by scanning it and cutting it with his plasma cutter. He passed around some modular tooling that he purchased for his Tormach mill tool holder.

Joe Scott recounted that he had found some excellent oil resistant paint for lathes at a farm tractor supply store. The paint was called Implement and Machinery Enamel and was similar to this. He passed around a copy of the 1941 Army Machinist Manual that he obtained.

J. R. Williams showed a collet backstop that he made to allow easily and accurately facing multiple small ¾-inch diameter x 1/8-inch thick parts. He passed around a data sheet on a spring loaded version available from Hardinge.



Martin Kennedy showed the results of a project where he used dithering and a custom program he wrote to turn a photograph into a series of different-diameter holes in metal using his CNC mill.

Rich Pichler passed around an Acme-thread tap having three leads.

Problems and Solutions

Scott Jenson wants to be able to cut and solder a bandsaw blade. It was suggested that he use silver solder. See the article by J. R. Williams on Band Saw Brazing.

Chuck Rice had a box of unknown parts and tools that he wanted identified. Among the tools identified was a saw set used to alternately bend the side of a saw blade's teeth left and right.

Cliff Johnston said that he had spare contact points for indicators that he did not want, and said that since there was interest from the club that he'd bring them in at the next meeting.

Jeff Laver wanted a recommendation on good places to buy tooling. Several places were suggested – Wholesale Tools, Bass Tools, Rutland and Rex Supply.

Dick Kostelnicek replaced the screen on his laptop computer. He disassembled the old broken screen into components, and had it set out on a table for viewing.

Shawn DeWolfe passed around a contact print he made of an engine gasket. He solicited advice on making a third-world style lathe out of engine blocks. For those interested, here are instructions on how to build one type.

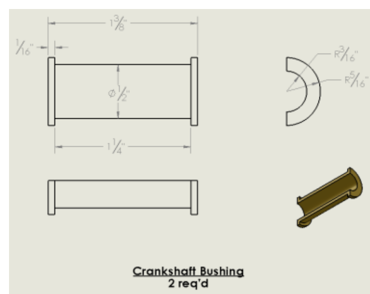
Novice SIG Activities

SIG coordinator *Rich Pichler* continued last month's demonstration on how to thread on a lathe, but ran out of time when the meeting room had to be vacated.

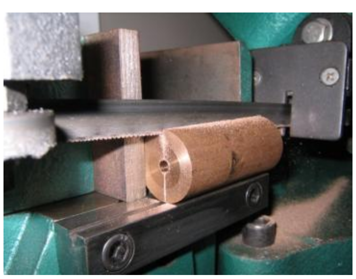
Articles

Making a Split Bronze Sleeve Bushing

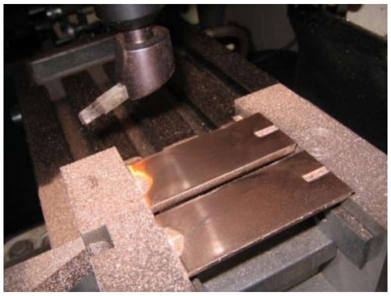
By *Martin Kennedy*



When I designed the details of the steam engine I'm building, I used a split sleeve bushing between the crankshaft and the engine block (right drawing). I thought that it might prove very difficult to make, but it turned out to be fairly easy. I started with a piece of sintered bronze rod, which is a porous metal that's made by heating powdered bronze just below its melting point until the powder adheres together in such a way that small voids exist throughout the metal - think about the voids in sugar or salt. Although it was not obvious by looking at it, the piece I used had been saturated in some sort of green oil. The piece was about 1-inch longer than the completed bushing, to allow chucking in the lathe. It was also larger in diameter, since I'd lose some diameter due to the width of the cut.



First, I split the sintered bronze on my bandsaw. I cut it approximately through the center. The sintered bronze proved to be difficult to cut. At first, the blade cut just fine. Then, as the piece heated up, impregnated oil in the sintered bronze with began to be released. The oil made a great lubricant for the saw blade, and it cut slower and slower, until it was barely cutting at all. This would make more heat, and more oil was released. I thought that my blade was dulling, but I finally discovered that if I waited for the piece to cool off, it would cut quickly again!



Next, I put the two halves on my mill. I made them fairly level by laying a straight edge across the top of both of them at the same time. I then ran a fly cutter across the top to get them flat and smooth. The holes you can see at the ends were already present in the surplus stock when I started. You don't need to drill these!

I then ran the halves through several sandpaper grits (120-240-320-400-600) on a granite surface plate. This granite block is a great way to be sure you have an absolutely level surface under your sandpaper. Some people put them in a tray of water for wet sanding, but I didn't. After sanding, the two halves fit tightly together with no gaps.

I took the two halves and clamped them together with a hose clamp. I considered some alternate ways to hold the halves together. I was originally going to drill and tap some holes on the ends. One of the club members suggested that I temporarily solder the halves together (this was when I had a plain piece of bronze and before I got the sintered metal and knew about the oil saturation). As it turned out, the clamp worked even better than I had hoped. I was able to move the clamp up and down the length of the bushing to get it out of the way when making cuts. It would easily adjust to the different diameters. I thought that the halves might shift a bit under the clamp during machining, but they didn't.

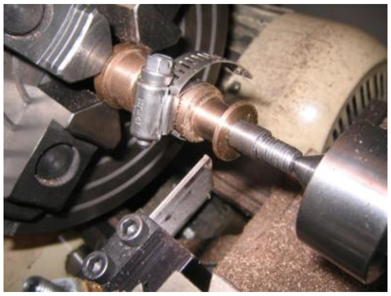
I used my 4-jaw chuck to hold the piece. When I split the stock and cleaned up the faces, the stock was out of round due to losing the width of the saw kerf, and looked somewhat oval. It would have been difficult to clamp in a 3-jaw, but I suspect that it could be done.

The stock needs to be well centered in the chuck, since the split needs to be at the exact center when drilling. I put the piece in the chuck such that the wide (oval) dimension was on one set of jaws, and the narrow dimension was on the others. I used a dial indicator to successively check the jaw positions to make sure the piece was exactly centered (within 0.001") in two directions.

I used a center drill to put a hole in the far end for the live center, and made sure it was exactly on the split. I drilled through the center of the stock with a slightly undersize drill.

I then reamed out the hole. When reaming on the lathe, I chuck the reamer and just leave the tailpiece loose on the ways, and push the tailpiece and ream in by hand. It goes in fairly easily.

Now that the inside is finished, it's time to do the outside. To keep the bushing exactly aligned, I put a scrap piece of rod inside, and clamped down firmly to hold it. I formed up the flange and



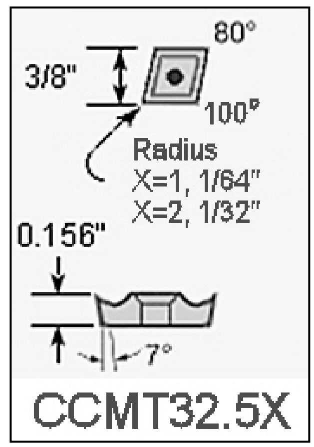
cut down the middle, moving the clamp several times as necessary. I just made sure that the clamp was fairly close to the section that I was machining.

Now that the piece is completed, I use the cut-off blade to part it. While I was making the bushing, I could just barely detect the split in the two pieces. I had to look very closely to see a hairline. The tools never caught on the split during machining.

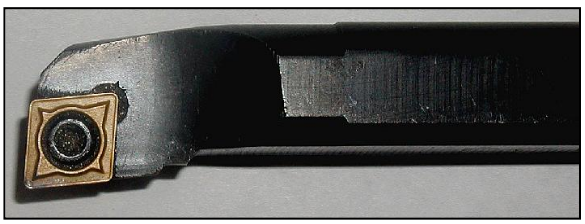
Here's the completed bushing. I did mark one end so I could assemble the bushings the same way that they were machined, but they're very close to identical.

B-Style Insert Tool Holder

By *Dick Kostelnicek*



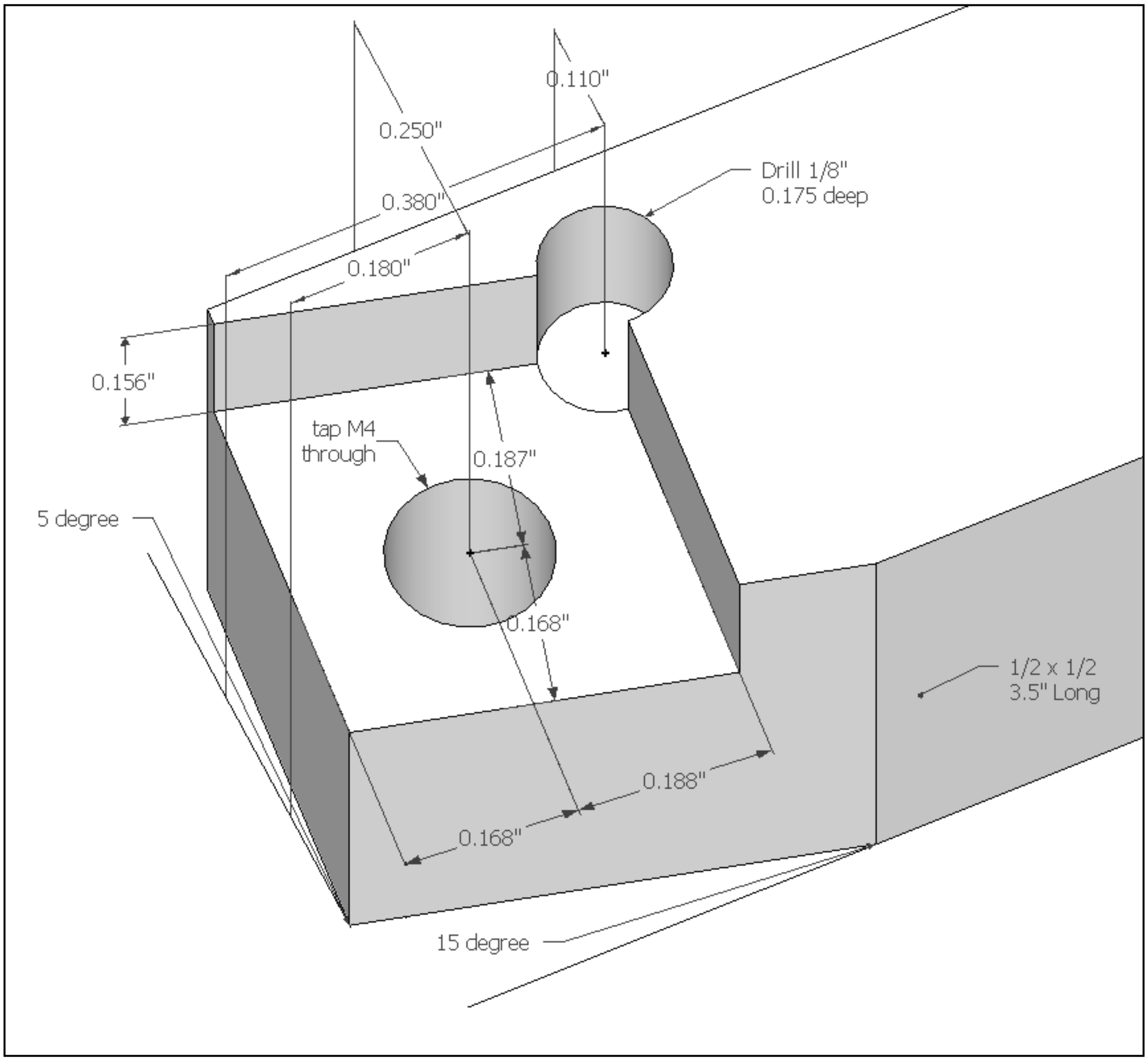
The CCMT32.5X indexable carbide insert is used on many boring bars (photo below). It has two 80-degree points that provide cutting edges with 5-degrees clearance along both the side and bottom of a bored recess. I use these inserts with a 1/64 or 1/32-inch point radius (X=1 or X=2, see right illustration). Additionally, they have two 100-degree cutting points that are never used for boring. One of the curses that plague a mechanic is that he expects to obtain full utility before discarding a tool bit. Spent CCMT inserts were accumulating in my *dead insert bin*, each having two good 100-degree points.



I machined both right BR and left BL style tool holders from ½-inch square key stock (left photo). Both holders present the insert's 100-degree cutting point for lathe turning. The cutting edge is inclined at 75-degrees to the lathe's axis while the clearance angle is 5-degrees behind the cut (right photo).

A 1/8-inch drilled blind hole protects the unused cutting point and provided corner relief while machining the 100-degree intersecting sides of the insert's recess. The mounting hole is tapped M4 - 0.70 and uses the same Torx© driven screw (Wholesale Tool #1038-0205, $0.95) as my boring bar.

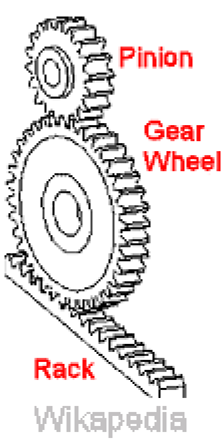
In order to "jazz up" a rather dull looking project, I stamped the insert's ANSI designator CCMT32.5X along with my initials and date on the side of each tool holder. Stamping upset the metal around each letter, so I leveled the displacement by sanding with emery paper over a flat plate. The tool holders were Parkerized and rubbed with car wax. The surface color should turn from gray to dark green in a couple of years.



Drawing for B-Style tool holder using 80 /100-degree indexable inserts

Determining the Pressure Angle of Spur Gears

By *Dick Kostelnicek*

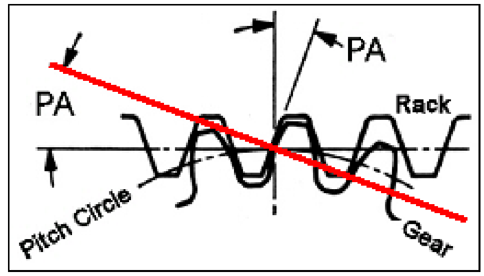


I determine the Pressure Angle or PA of an involute spur gear from an imprint of its rack. The rack is generated by rolling the gear through Plasticine modeling clay. The PA is simply the slope from the vertical of the clay rack's teeth. As a bonus, Dimetral Pitch or DP can be obtained from the impression. If you are already familiar with spur gearing, jump to the section on **Determining the Pressure Angle.**

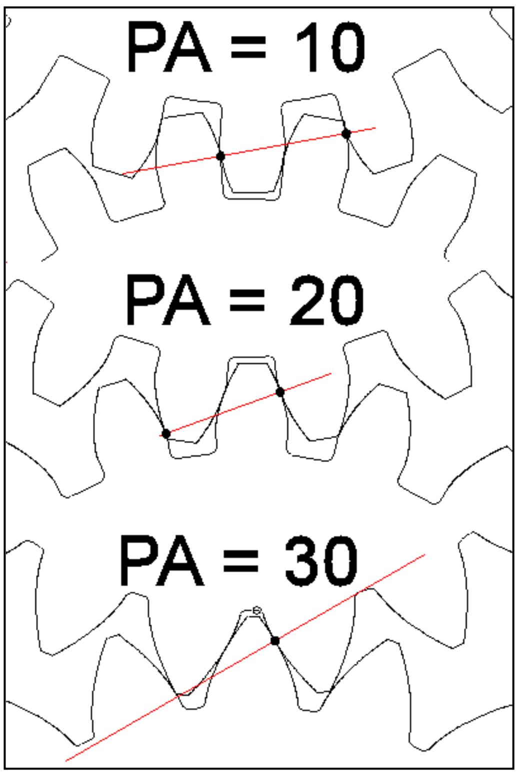
Properties of a Spur Gear

A spur gear is specified by four values: Number of Teeth, Face Width, Diametral Pitch, and Pressure Angle. All except the PA can be obtained by either visual inspection or measurement with a caliper.
Teeth on spur gears are constant across their face and are parallel to the

axis of rotation. When gears are in mesh, the pinion is the smaller and the wheel, sometimes called just the gear, is the larger (above left drawing). A straight gear, one having infinite diameter, is referred to as a rack. Meshed spur gears turn on parallel shafts. Most have an involute-curve tooth profile, whose exact shape I'll leave to another article.



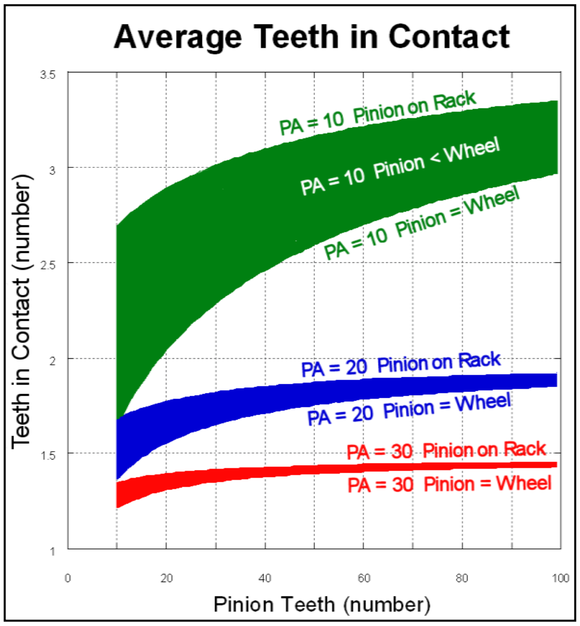
The PA of an involute spur gear is the angle between the perpendicular or normal where two teeth touch and the tangent to its pitch circle (see right illustration). During rotation, the PA remains constant as the point of contact moves along a tooth's profile and eventually jumps to succeeding teeth. The trace of this contact is called the *line of action* (red straight line). The PA is the slope of this line and determines the direction of force that one gear exerts upon another (illustration below). Click here for a web based animation of gears in mesh for three different pressure angles.

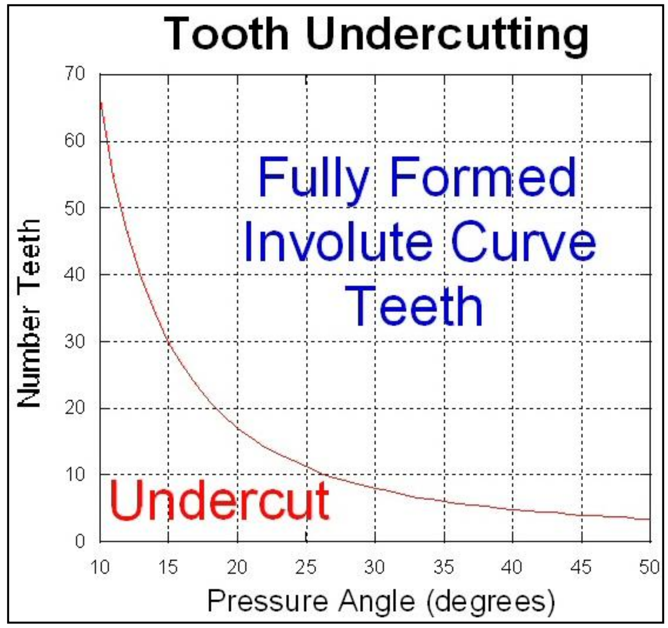


It's a consequence of the straightness of the *line of action* and the fact that that it passes through a point where the two pitch circles touch, called the *pitch point,* that gears exhibit uniform rotary motion when one drives another. There's no speed variation as contact transfers from tooth to tooth. Furthermore, though tooth contact moves away or toward a gear's center of rotation, the transmitted torque experiences no undulation. Put simply, without visual observation, you can't determine which teeth are engaged nor can you tell their relative position as the gears turn. It's as if one smooth faced wheel was driving another without slipping.

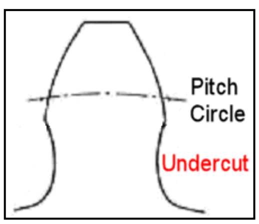
For large PAs, the force is directed toward a tooth's wide base rather than across the thinner mid section on low PA gears (left diagram). Furthermore, the steeper slope of the PA produces a larger component of radial force that tends to separate meshed gears. Gears with large PAs can carry increased loads but require stout shaft bearings to support the extra radial force. Their teeth have more curvature, so they are less tolerant to improper center-to-center spacing and may run noisier because of excessive backlash. By contrast, low PA 14.5-degree gears are very tolerant to variations in center-to-center spacing and are frequently used as change gears on lathes.

At mid-tooth, near their pitch circles, gear teeth are in rolling contact with one another. The contact between two meshed teeth travels from mid-point to crest on one gear tooth while on its mate it moves from mid-point to root. The curved distances along these opposite half-tooth surfaces have different lengths. Hence, teeth must slide as well as roll over one another. As the PA increases, this difference in surface distance increases. Larger PA gears do more sliding and may require lubrication to cool the results from additional friction.





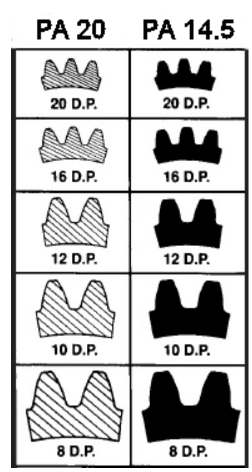
The average number of teeth that are simultaneously in contact decreases as the PA increases (above left graph). Consequently, the load is born by fewer teeth but this is somewhat compensated for as the force along the *line of action* is directed toward a wider tooth base.



For low PAs and those gears having fewer teeth, the teeth themselves become increasingly *bulbous* (left drawing). Eventually, the base of each tooth is undercut since the involute-curve can't extend fully down into the root area of the tooth. Instead, a clearance curve replaces the lower part the profile. Undercut teeth have reduced strength. The graph, above right, shows the conditions for tooth undercutting.

Determining the Pressure Angle

Three methods for determining PA are: (1) Fit to a gear gauge. (2) Compare with tooth profiles shown in gear supplier's literature. (3) Roll the gear in Plasticine modeling clay to generate an impression of its rack.



Method 1. A 20-tooth, 10 DP, 20 PA gear is shown in the left photo. In the *Imperial System*, DP is an index of tooth size and is determined as the number of teeth per inch diameter of the gear's pitch circle (see above right illustration). The gear in the left photo almost fits the 10 DP leaf of a 14.5-degree PA gear gauge, but <u>not</u> well enough. Unless you have a gauge with rack leaves of the correct pressure angle, you'll remain uncertain as to the gear's PA. Spur gears are manufactured with 14.5, 20, 22.5 or 25-degrees PAs, 14.5 being used for smooth quiet running (e.g. lathe change gears), 20 for power handling (e.g. vehicular transmissions), while 22.5 and 25 are rarely encountered. The current ISO standard for metric gears is a 20-degree PA.

Method 2. Pictured above right, but not to scale, are tooth profiles for PAs of 20 and 14.5-degree gears of various DPs. Correctly scaled tooth profiles are available in the Boston Gear Catalog Engineering Section. This comparison technique isn't recommended for gears having fewer than 20 teeth, since the tooth shape will deviate considerably from that pictured.

Method 3. The teeth on an involute-curve rack are straight-sided and sloped at the PA from the vertical (see right illustration above). Every gear having the same DP and PA, regardless of the number of teeth, will closely mesh with its rack. Hence, all of those gears will imprint identical copies of the rack as they are rolled through Plasticine modeling clay.

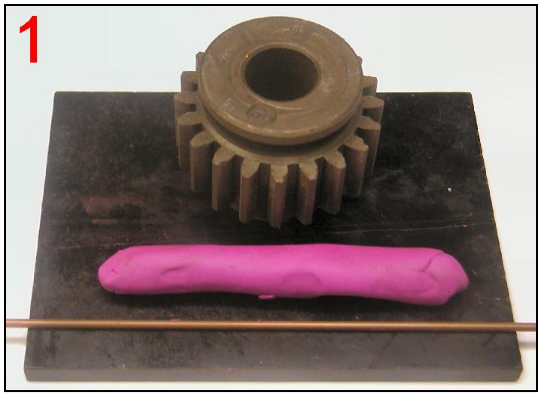
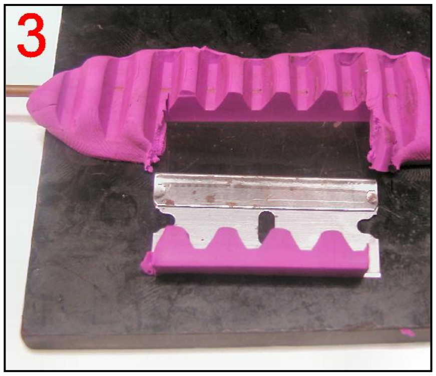
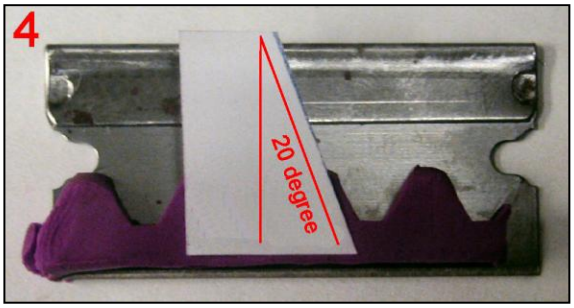


Photo 1 shows the equipment used to create an imprint of a gear's rack. The flat plate supports the Plasticine modeling clay. The clay is formed over a welding rod so that the gear's teeth will not bottom-out on the plate. Then, the resulting clay rack will have a backbone thickness equal to the rod's diameter.

Photo 2 shows a gear being rolled through clay, taking care to keep it pressed tight against the buried rod. Maintain vertical alignment. Don't wobble form side-to-side, otherwise, the rack's backbone will not be of equal depth along both margins of the impression. Tip: Use two rods, like a train track, to insure stability of the rolled gear.





Next, cut a thin section from the clay rack (photo 3). Use downward thrusts of a straight razor blade. If you slice along the rack's length, the teeth may lean in the direction of the cut since the clay might drag against the blade. Photo 4 shows the clay rack's profile being compared to the angle of a 20-degree paper wedge. This demonstrates that indeed this gear has a 20-degree PA.

Additionally, you can measure the gear's Circular Pitch or CP, which is the distance between adjacent teeth along the curved pitch circle. It should be the same as the flattened-out spacing between teeth on the clay rack. Then, you could determine the gear's tooth size index or DP from the relationship DP = π / CP, where $\pi = 3.14159$. However, the measured CP, here called CP_m, will be larger, and the calculated DP smaller, than anticipated. This occurs because the gear was rolled about its outer edge having the *gear-blank* diameter rather than that of its smaller pitch circle (see right illustration above).

For the 20-tooth gear in photo 1, the CP_m = 0.34 as determined from the average over 12-teeth on its clay rack. Compare the actual value CP = 0.314 with the measurement of 0.34. We can compensate for not having rolled the gear about its pitch circle because we know that full sized teeth protrude above the pitch circle by the distance 1 / DP (stub gear teeth stick out by 0.8 / DP). Consequently, the outside diameter of a gear is the same as the pitch circle of a gear having 2 extra teeth. The DP is then given by the following correction formula, where N is the number of teeth:

$$DP = \left(1 + \frac{2}{N}\right)\frac{\pi}{CP_m}$$

The corrected value DP = 10.1, obtained from the clay rack impression, compares well with actual value of 10.

For more information on gearing, here are some web references.

- Simplified overview of gear types
- Technical tutorial on gearing in 20 parts
- Training course on automatic transmissions in 28 parts.
- Gear design overview
- Discussion of gear tooth stress and strength

The following comments are offered to Gear Gurus.

The clay impression is not an exact copy of a gear rack. Aside from its elongation due to the improper roll about the gear-blank diameter rather than the pitch circle, the impression is an inverted image of a rack. The gear’s tooth crests form the rack’s troughs, while the rack’s tooth crests are generated from the gear’s troughs. Hence, the rack’s teeth are higher by the gear’s root clearance and its roots are shallower by the same amount. But here, I’m only interested in the slope of the straight sides of the rack’s teeth in order to determine the pressure angle.

I’ve shown how to compensate for the incorrect roll about the gear-blank diameter in determining the DP from the measured CP_m. It would be more accurate, however, if I had written the correction formula for DP in terms of the chord length between each tooth crest. The gear takes a “bumpy” roll from tooth-to-tooth in the clay along the supporting rod. The formula would then be:

$$DP = \frac{(N+2)\sin\left(\frac{\pi}{N}\right)}{CP_m}$$

However, for more than 6 teeth, the gear-blank diameter is close enough to the N-sided polygon that circumscribes the gear teeth. So, I stand by my original correction formula. Recall, I’m a mechanic. “Close enough works just fine for me!”