January 2021
Newsletter

Volume 26 - Number 01

http://www.homemetalshopclub.org/

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

Our members' interests include Model Engineering, Casting, Blacksmithing, Gunsmithing, Sheet Metal Fabrication, Robotics, CNC, Welding, Metal Art, and others. Members enjoy getting together and talking 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 ***general announcements***, an ***extended presentation*** with Q&A, a ***safety moment***, ***show and tell*** where attendees share their work and experiences, and ***problems and solutions*** where attendees can get answers to their questions or describe how they approached a problem. The meeting ends with ***free discussion*** and a ***novice group*** activity, where metal working techniques are demonstrated on a small lathe, grinders, and other metal shop equipment.

President *Brian Alley*	Vice President *Ray Thompson*	Secretary *Joe Sybille*	Treasurer *Gary Toll*	Librarian *Ray Thompson*
Webmaster/Editor *Dick Kostelnicek*	Photographer *Jan Rowland*	CNC SIG *Martin Kennedy*	Casting SIG *Tom Moore*	Novice SIG *John Cooper*

This newsletter is available as an electronic subscription from the front page of our website. We currently have over 1027 subscribers located all over the world.

About the Upcoming 13 February 2021 Meeting

The next general meeting will be held on 13 February 2021 at 1:00 P. M. on-line via Zoom. A week before the meeting invitees will receive from the webmaster the meeting ID and passcode to join the on-line meeting.

Visit our website for up-to-the-minute details, date, location maps, and presentation topic for the next meeting.

General Announcements

Video of the January meeting can be viewed up to 30 days after the meeting.

The HMSC has a large library of metal shop related books and videos available for members to check out at each meeting. These books can be quite costly and are not usually available at local public libraries. Access to the library is one of the many benefits of club membership. The club has funds to purchase new books for the library. If you have suggestions, contact the Librarian *Ray Thompson*.

We need more articles for the monthly newsletter! If you would like to write an article, or would like to discuss writing an article, please contact the Webmaster Dick Kostelnicek. Think about your last project. Was it a success, with perhaps a few 'uh ohs' along the way? If so, others would like to read about it. And, as a reward for providing an article, you'll receive a free year's membership the next renewal cycle!

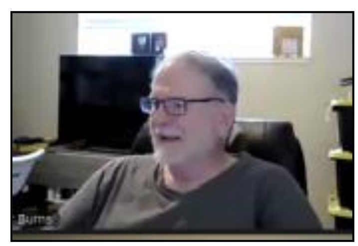
Ideas for programs at our monthly meeting are always welcomed. If you have an idea for a meeting topic, or if you know someone that could make a presentation, please contact Vice-President Ray Thompson.

Members are requested to submit to the club secretary the name, address, telephone number, and website address, if any, of any metal or other material stock supplier with whom the member has had any favorable dealings. A listing of the suppliers will appear on the homepage of the club website. Suppliers will be added from time to time as appropriate.

The club is looking for a member to serve as webmaster. After over ten years of service, our current webmaster would like to pass the webmaster torch to a successor.

Recap of the 09 January 2021 General Meeting
By *Joe Sybille*

Nine members attended the 1:00 P.M. virtual meeting on Zoom. There were three visitors in attendance, Ken Strauss, Norman Gouger, and Hudson Smith. There are twenty members in good standing with the club.



President emeritus, Vance Burns, led the meeting (right photo).

Presentation

Club member *Dick Kostelnicek* gave a presentation on Pitch Diameter and the Unified Thread System (UTS). He began by revealing that the use of pitch diameter enables the uniformity of threading made from different sources. This uniformity facilitates interchangeability of threaded connections. Dick explained the differences among several common threads such as Sharp V, ISO Metric, Acme, and Square, among others. For example, metric trapezoidal and acme threads are both used for lathe lead screws. The former thread is found on metric lathes and the latter on imperial lathes.

The UTS thread is similar to the sharp V thread; however, the UTS thread has both the crest and root truncated. UTS is used primarily in the United States of America and in Canada. Specification standards are determined by ASME/ANSI. Depending on the threads per inch, threaded items may be designated as coarse, UNC, fine, UNF, and extra fine, UNEF.

Dick then discussed parts of a UTS thread and gave equations to determine pitch diameter and the minimum diameter for a given pitch. From there, he discussed thread cutting on a lathe using triangular turning inserts and how far one should plunge into the stock to make the UTS thread with the proper pitch diameter. Selecting and determining tap drill sizes for the intended fit between the nut and the bolt or screw were explained. Fit could be loose (class 1), free [most common] (class 2), close (class 3), tight [now obsolete] (class 4), or interference (class 5). An example of specifying an external thread is as follows:

¼-20-UNC-2A-PD 0.2175 – 0.2147.

Here ¼ is the nominal size of a screw with 20 threads per inch, coarse, free fit, external thread, with a tolerance given for the pitch diameter.

A worn out lead screw on a half-nut served as an example of thread engagement, albeit poor engagement. Poor thread engagement occurs when the pitch diameter of the screw is less than the pitch diameter of the nut. This condition is referred to as backlash. Ideally, one would want the pitch diameter of the lead screw to match the pitch diameter of the half-nut.

A demonstration on the use of thread wires and a screw thread micrometer to determine the pitch diameter provided an insight as to which method is easiest and more accurate. When cutting internal threads, one will have a choice as to which fit is of interest. Designations on taps refer to limits on pitch diameters. H2 and H3 are common tap designations. Internal threads made with an H1 tap fit tighter than those made with an H2 tap.

Tables providing pitch diameters for threads, whether coarse or fine, may be found in some reference books on machining and the Home Metal Shop Club website for imperial and metric threads. Slides for Dick's presentation may be viewed at this link.

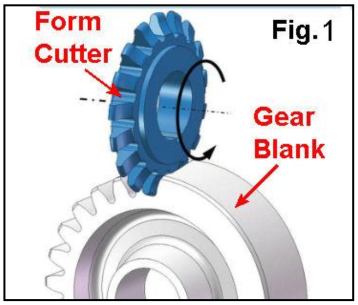
Problems and Solutions

A member requested suggestions on the best way to reduce the speed of a wood cutting bandsaw converted to cut metal. Among suggestions offered was to use a gearbox. Another member revealed he had used pulleys and pillow-blocks to reduce the speed of his converted bandsaw.

Articles

Close Enough Gear Cutting

By *Dick Kostelnicek*



In my home shop, I have older imperial, inch based, metal working machines. Today, most inexpensive tooling that can be used by those machines is manufactured overseas, often to metric or millimeter standards. I want to cut imperial sized gear teeth that are specified by diametral pitch **DP**. I have some metric form cutters (Fig. 1). They are sized a bit differently than my imperial requirement. Specifically, they conform to the metric specification, module **M**. Is it possible to use an off-sized metric cutter to make an imperial based gear, and vice versa? This is similar to my desire to cut metric threads on a lathe with an imperial lead screw (see the article Close Enough Metric Threading).

Table 1	Imperial - Metric Gears		
DP	CP(inch)	CP(mm)	M
2.540	1.2368	31.4159	10
3	1.0472	26.5988	8.467
3.175	0.9895	25.1327	8
4	0.7854	19.9491	6.350
4.233	0.7421	18.8496	6
5	0.6283	15.9593	5.080
5.080	0.6184	15.7080	5
6	0.5236	13.2994	4.233
6.350	0.4947	12.5664	4
7.257	0.4329	10.9956	3.5
8	0.3927	9.9746	3.175
8.467	0.3711	9.4248	3
10	0.3142	7.9796	2.540
10.160	0.3092	7.8540	2.5
12	0.2618	6.6497	2.117
12.700	0.2474	6.2832	2
16	0.1963	4.9873	1.588
16.933	0.1855	4.7124	1.5
20	0.1571	3.9898	1.270
20.320	0.1546	3.9270	1.25
24	0.1309	3.3249	1.058
25.400	0.1237	3.1416	1
31.750	0.0989	2.5133	0.8
32	0.0982	2.4936	0.794
48	0.0654	1.6624	0.529
50.800	0.0618	1.5708	0.5
64	0.0491	1.2468	0.397

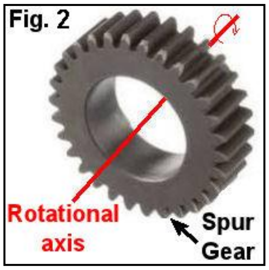
Each row in table 1 represents a gear tooth size that you might encounter as a home shop machinist. They're expressed in both imperial and metric measure. Tooth size increases as you move upward. The colors highlight common **DP** and **M** values.

For example, the tooth size for DP20 and M1.25 are quite close. Their widths, expressed in circular pitch **CP,** differ by a mere 1.6%. Fortunately, metric and imperial gear teeth have congruent shapes.

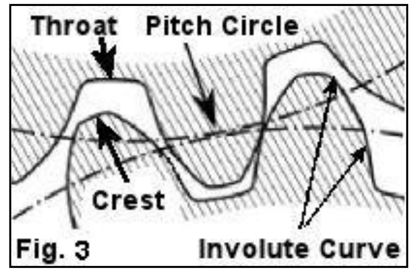
There is, however, one limitation. You won't be able to employ an off-sized form cutter when its pressure angle differs from that of the gear you want to make.

If you're familiar with gearing nomenclature such as: **DP, M**, **CP**, pressure angle, etc; then jump ahead to the section *Close Enough Gear Cutting***.**

Spur Gear Nomenclature



A spur gear's shape doesn't vary along the direction of its rotational axis (Fig. 2). Modern gear teeth have an involute curve profile (Fig. 3). Each tooth has a crest and throat. The pitch circle is an imaginary curve passing through each tooth close to ½ its height. Pitch circles represent the surfaces of two wheels in non-slip contact that will produce the same rotational speed ratio as their gears. The tooth size is specified by its circular pitch **CP,** the tooth-to-tooth distance along the pitch circle. Larger **CP** means bigger teeth. The diameter **D** of a pitch circle having **N** teeth is:



$$\mathbf{D} = \mathbf{N} * \mathbf{CP} / \pi \quad (1a)$$

Module **M**, from *modulus,* is used to designate tooth size. It's the ratio of pitch circle's diameter per **N** teeth and has dimension (distance / tooth):

$$\mathbf{M} = \mathbf{CP} / \pi \quad (2)$$

The pitch circle's diameter **D** with **N** teeth is:

$$\mathbf{D} = \mathbf{N * M} \quad (1b)$$

Tooth size grows, as **M** increases.

Imperial gears use diametral pitch **DP** to reference tooth size. It's the number of teeth in a gear for each inch of diameter. It has dimension (teeth / distance). Larger **DP**s reference smaller teeth.

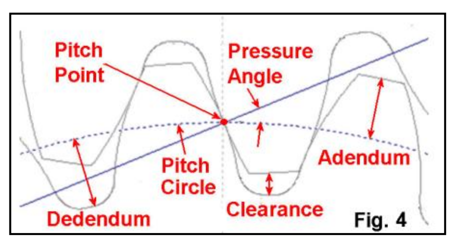
DP and **M** are inverses of one another, like turns per inch relates to a screw's pitch.

$$\mathbf{DP} = 1.0 / \mathbf{M} \quad (3)$$

DP is usually expressed in inches^{-1} while **M** in millimeters.

But, **M** and **DP** apply to all gears, imperial and metric. In what follows, I'll use **M** rather than **DP**. To convert units of length, recall there are 25.4 millimeters per inch.

The height that a tooth's crest raises above the pitch circle is called the addendum **AD** (Fig. 4). In terms of module:



$$\mathbf{AD} = 1.0 * \mathbf{M} \quad (4)$$

When two gears are in mesh, the tooth crests of one gear plunge into the throats of the other. The depth that they reach beneath the pitch circle is the addendum of the plunging tooth. Hence, the working depth **WD** of the teeth is twice the addendum:

$$\mathbf{WD} = 2 * \mathbf{AD} \tag{5}$$

However, we need additional space or clearance so a tooth crest on one gear doesn't touch the throat base of the other. Clearance **C** is 5% of **CP**:

$$\mathbf{C} = 0.157\ \mathbf{M} \tag{6}$$

A throat's depth below the pitch circle is **AD** + **C** and is called the dedendum **DD**:

$$\mathbf{DD} = 1.157 * \mathbf{M} \tag{7}$$

Hence**, DD** is slightly greater than **AD**.

A tooth's whole depth **F** is the addendum plus dedendum. **F** is also the amount of feed into a gear blank for a form cutter (Fig. 1).

$$\mathbf{F} = 2.157 * \mathbf{M} \tag{8}$$

A gear blank's outer diameter **OD** is the sum of the pitch circle's diameter **D (**eqn. 1b) and twice the addendum **AD**. Recall, teeth are on diametrically opposite sides of a gear.

$$\mathbf{OD} = \mathbf{M} * (\mathbf{N} + 2) \tag{9}$$

Meshed gears, with $\mathbf{N_1}$ and $\mathbf{N_2}$ teeth, have center-to-center distance **X**:

$$\mathbf{X} = ½ * \mathbf{M} * (\mathbf{N_1} + \mathbf{N_2}) \tag{10}$$

The factor ½ indicates we're dealing with radii rather than diameters.

One thing more, pressure angle refers to the direction a gear tooth presses against a meshing tooth (Fig. 4). The larger the pressure angle the more gears push one another apart. Older imperial gears have a 14.5^o degree pressure angle. Today, imperial and metric gearing mostly use 20^o.

Gear Cutting Recipe

1. Choose the gear's tooth size **M** and number of teeth **N**.
2. Make the gear blank's diameter **OD = M** * (**N** + 2).
3. Form cut a tooth's throat to a depth of **F** = 2.157 * **M**.
4. Rotate the gear blank by 360^o / **N.**
5. Repeat steps 3 and 4, **N** times.

Approximations

Each form cutter may cut gears only within a fixed range of teeth. A set of 8 form cutters covers from 12 to rack or an infinite number of teeth. For example, the #8 cutter covers 12 and 13 teeth, #4 includes 26 – 34, and #1 cuts 135 - rack. An individual cutter produces the correct tooth profile only for the smallest number of teeth in its range. Gears with the highest number of teeth allowed in the range are less than perfect. The point is that form cut gears are all not ideal.

A form cutter's involute curve profile extends beyond that required for the specified circular pitch **CP**. In other words, form cutters can cut wider and deeper than specified by their module **M**. This means that you can push the working depth beyond the stated rating. For example: My set of eight DP32 form cutters can cut 39% – 74% deeper and wider than specified by their **DP** as the number of teeth varies from 12 to rack. Therefore, you can use this form cutter to make teeth up to at least 20% larger than the cutter's specs suggest. Such teeth might not be perfectly shaped but you can always cut them deeper so the backlash increases, thereby preventing tooth interference.

Close Enough Gear Cutting

Suppose we have on hand a form cutter of module $\mathbf{M}_{available}$. However, we want to cut a gear having module $\mathbf{M}_{desired}$. The two modules designate different teeth size. Furthermore, one might be an imperial cutter, the other metric. We'll require:

$$\mathbf{M}_{available} \le \mathbf{M}_{desired} \qquad (11)$$

Hence, a tooth's throat will be cut narrower than required, but we'll widen it later. Also, we don't want the teeth to be too stubby. So, the modules should be close to one another:

$$\mathbf{M}_{available} \approx \mathbf{M}_{desired} \qquad (12)$$

How close, that'll be determined later in this article.

We'll be cutting shorter $\mathbf{M}_{available}$ teeth than required for the $\mathbf{M}_{desired}$ pitch circle. So, reduce the gear blank's **OD** so the teeth crests just reach its surface.

$$\mathbf{OD}_{close\ enough} = N * \mathbf{M}_{desired} + 2 * \mathbf{M}_{available} \qquad (13)$$

Make the depth of cut as you would for the $\mathbf{M}_{available}$ form cutter:

$$\mathbf{F}_{close\ enough} = \mathbf{M}_{available} * 2.157 \qquad (14)$$

The result is stub height teeth. This will be a problem only for pinions gears that have fewer than 16 teeth.

The teeth also have a shallower dedundum and clearance. But, the teeth on a similarly made gear in mesh with ours also has stub teeth. So, reduced clearance is not a problem.

A tooth's throat is created when metal is removed between its crests. Our throat is too narrow and the crest too wide. Along the pitch circle the throat and crest widths must equal to one another, their sum being the desired circular pitch **CP**. The tooth features made by the $\mathbf{M}_{\mathbf{available}}$ form cutter are:

$$\text{Throat Width} = \tfrac{1}{2} * \pi * \mathbf{M}_{\mathbf{available}} \qquad (15)$$

$$\text{Crest Width} = \mathbf{CP} - \text{Throat width} \qquad (16a)$$

Using eqn. 1a and 1b yields:

$$\text{Crest Width} = \pi * (\mathbf{M}_{\mathbf{desired}} - \tfrac{1}{2} * \mathbf{M}_{\mathbf{available}}) \qquad (16b)$$

To make the throat and crest widths equal, decrease the crest width by **Δ** and increase the throat's by **Δ,** where:

$$\mathbf{\Delta} = \tfrac{1}{2} * \pi * (\mathbf{M}_{\mathbf{desired}} - \mathbf{M}_{\mathbf{available}}) \qquad (17)$$

We do this by cutting more metal away from each side of adjacent crests by an amount **W.**

$$\mathbf{W} = \tfrac{1}{2}\, \mathbf{\Delta} \qquad (18a)$$

$$\mathbf{W} = \tfrac{1}{4} * \pi * (\mathbf{M}_{\mathbf{desired}} - \mathbf{M}_{\mathbf{available}}) \qquad (18b)$$

When making a gear by the *close enough* method, start by displacing the form cutter away from the plane passing through the gear's center and a current tooth throat by an amount **W**. As usual, cut all the teeth to full depth **F (**eqn. 14). Then, displace the cutter from the center plane in the opposite direction by a like amount **W**. With the cutter remaining at full depth, re-cut all the teeth.

The percent **FIT** of *close enough gear cutting* is expressed as the ratio of available tooth working depth to that desired:

$$\mathbf{FIT} = 100 * \mathbf{M}_{\mathbf{available}} / \mathbf{M}_{\mathbf{desired}} \qquad (19)$$

A stub tooth's working depth is 80% of the standard depth. Keeping **FIT** above 80% leaves your *close enough gear teeth* between regular and stub tooth length.

The *close enough gear cutting* technique keeps the pitch point (Fig. 4) of the $\mathbf{M}_{\mathbf{available}}$ form cutter at the $\mathbf{M}_{\mathbf{desired}}$ pitch circle's (Fig. 2) depth, thereby maintaining the pressure angle.

Close Enough Gear Cutting Recipe

1. Choose the gear's tooth size $\mathbf{M}_{\mathbf{desired}}$ and number of teeth **N**
2. Use a $\mathbf{M}_{\mathbf{available}}$ form cutter smaller than $\mathbf{M}_{\mathbf{desired}}$ but with the same pressure angle
3. Make the gear blank's diameter $\mathbf{OD}_{\textbf{close enough}} = \mathbf{N} * \mathbf{M}_{\mathbf{desired}} + 2 * \mathbf{M}_{\mathbf{available}}$

4. RIght offset the cutter by **W** = ¼ * π * ($M_{desired}$ - $M_{available}$)

5. Cut metal to depth $F_{close\ enough}$ = $F_{available}$

6. Rotate the gear blank by 360^o / **N**

7. Repeat steps 5 and 6 **N** times

8. While still at full depth $F_{close\ enough}$, left offset the cutter by **W**

9. Repeat steps 5 and 6 **N** times

An Excel spread sheet for calculating the parameters for 'exact' and 'close enough' gear cuttihg is avaliable at this link.

Exmple 1

Cut an imperial gear **N** = 40 and **DP** = 20
From Table 1 for DP20, $M_{desired\ =}$ 1.27 mm
From Table 1, choose $M_{available}$ = 1.25 mm
The gear blank's diameter $OD_{close\ enough}$ = 53.30 mm = 2.098 inches
The depth of feed = $F_{close\ enough}$ = 2.70 mm = 0.106 inches
The **W** set over is 0.016 mm = 0.0006 inches
The **FIT** is 98 %

Example 2

Cut an metric gear **N** = 55 and **M** = 5.0
From Table 1 $DP_{desired}$ = 5.080 and $DP_{available}$ = 6
From Table 1 $M_{desired}$ = 5.0 and $M_{available}$ = 4.23 mm.
The gear blank's diameter $OD_{close\ enough}$ = 11.160 inches or 283.46 mm.
The depth of feed = $F_{close\ enough}$ = 0.359 inches or 9.12 mm
The **W** offset is or 0.0238 inches or 0.605 mm.
The FIT is 85%