PARTS IS PARTS: Gear Terminology Meshes With Little Susie

● by Morgan Berry

Every builder — even the most seasoned veterans — have experienced more than one "Oh no, what have I gotten myself into?" moment when working on a bot. Apart from the complications that can happen while building, ordering parts brings up a whole other set of issues. Even a simple wedge bot with no moving weapons can require dozens of parts, and with the dozens of varieties of those dozens of parts, an inexperienced builder might be tempted to just give up and walk away entirely. However ... fear no more! The Combat Zone's guide to gears is sure to make one of the most intimidating steps in the build process much simpler.

Meet little Susie. After attending a combat robotics competition, little Susie was inspired to build a metal-tearing, pain-bringing death machine of her own. A trip to the local hobby shop left Susie with a bargain box with a variety of parts. Now, all she needs to build her bot is a shell and gears.

The metal shop teacher at her school agreed to help her build a shell. So, smiling at how simple the process is, Susie sits down at the computer to purchase some gears. Susie's motors run at 1,000 RPM, and she is envisioning a wedge bot, so she needs to increase her torque to provide the pushing power a wedge needs. Susie calculates that her bot's wheels should turn at 100 RPM. She'll reduce the RPM using gears. (If she was using her motor to drive a saw blade for a weapon, Susie would instead need to increase the RPM to enhance the cutting ability using the same gear ratio.)

FIGURE 1

After clicking onto the first website, the smile quickly fades from Susie's face. Pressure angle, bore size, diametral pitch? Susie is completely lost. She realizes she has a lot to learn about gears.

The first thing Susie researches is the type of gear she needs. She quickly rules out a rack and pinion gear (**Figure 1**) which is used to convert circular rotation into a linear motion, or a bevel gear (**Figure 2**) which is used to change the direction of the gear rotation, usually by 90°. Since her wheels turn in the same direction her motor spins, she doesn't need to worry about direction of rotation (but, if Susie's bot had a blade mounted on top, a bevel gear might be necessary). She also rules out a worm gear (**Figure 3**) which is used when large reductions in RPM are needed.

Now she must decide between the two remaining types of gear: a spur gear or a helical gear. A spur gear (**Figure 4**) is the most common gear and has parallel teeth, so when they rotate, each set of teeth on the gears come into direct contact with

FIGURE 2

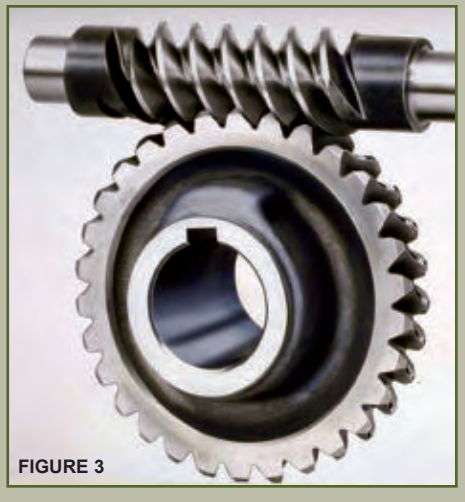

FIGURE 3

SUSIE'S LIST OF ADVANCED GEAR TERMS

While you probably won't need to worry about many of these specifications when deciding what gear to purchase for your bot, it is important to understand the following terms in order to have a working knowledge of how a gear works. Because gears are circular, you should also be familiar with circle terminology (diameter, chord, tangent, etc.).

- *Addendum:* The distance from the pitch circle to the addendum circle.
- *Dedendum:* The distance from the pitch circle to the root circle.
- *Outer Diameter:* The diameter of a gear measured from the top of the teeth.
- *Root Diameter:* The diameter of a gear measured from the base of the teeth.
- *Pitch Diameter:* The diameter of a gear measured from the pitch circle.
- *Addendum Circle:* An imaginary circle drawn at the top of the teeth.
- *Root Circle:* An imaginary circle drawn at the base of the teeth.
- *Pitch Circle:* An imaginary circle drawn at the point of contact when two gears mesh together.
- *Circular Thickness:* The thickness of a tooth measured as an arc along the pitch circle.
- *Chordal Thickness:* The thickness of a tooth measured between two chords that extend from the points where the pitch circle passes through both ends of a tooth. This measurement will be slightly less than the circular thickness, as it is a measurement taken from a straight line whereas circular thickness is the measure of a curved line.
- *Circular Pitch:* The distance between a point on one tooth and the corresponding point on the next tooth; the distance between two teeth. To function properly, two corresponding gears must have the same pitch.
- *Whole Depth:* The measurement of the distance between the top of a tooth and the bottom of a space between gears.
- *Working Depth:* The amount of space the tooth of one gear occupies when meshing into the space between two teeth on the corresponding gear.
- *Clearance:* The amount of space between the top of one gear and the bottom of the space between two teeth on the corresponding gear. When two gears mesh, the tooth of one gear does not actually come into contact with the base of the second gear. Simply put, this is the gap between the tooth of one gear, and a space on another gear.

Toolbox Tearout

Cut out this sheet or download the file at the article link and keep it handy as a quick reference for the next time you sit down to plan a bot. These terms are practical and will influence how well your gears work.

each other. The helical gear (**Figure 5**) has angled teeth to reduce the impact between two teeth while they rotate. Helical gears are used when noise reduction is important (less impact = less noise), but since Susie doesn't mind a loud bot, she decides a spur gear will do the job.

Now that she has determined the type of gear, Susie turns her attention to the issue of how to reduce her RPM. She discovers that the key is the gear ratio. A gear ratio is the relationship between the number of teeth of two gears. Susie can figure out the gear ratio she needs by working backwards from the existing RPM of the motor and the desired RPM of her wheels. Remember that she wants to reduce her RPM from 1,000 to 100, so as a ratio this would be 1,000:100 or 10:1.

Keeping this ratio in mind, Susie looks through the spur gears on the online store and finds one with 12 teeth and one with 120. This will give her the increased torque she needs for her bot. When she is building her bot, she will attach the smaller gear to her motor and the larger one to the wheel so that after 10 spins of smaller gear, the larger gear will spin once, thus slowing down the wheel's RPM.

The gears Susie selected also have options of "with" or "without" hubs, face width, and material. Hubs are the protruding part of a gear that have a hole for attaching to a motor or wheel using a setscrew. This is a must for Susie's bot. As for the face width (the width of the gear teeth), it is important to keep in mind the purpose of the gear.

Newton's third law says that for every action, there is an equal and opposite reaction. In the world of combat robotics — where the bot is being designed for collisions — the gear teeth will be exposed to a lot of reactive force. If the teeth are exposed to too much force, they could become stripped. So to compensate for this, it is generally better to use a gear

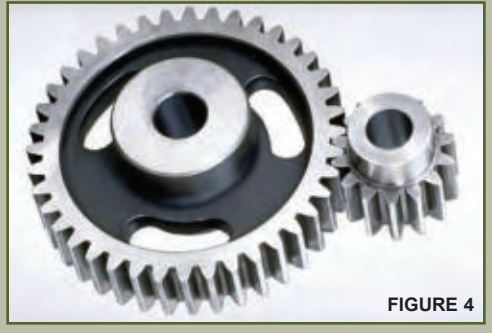

FIGURE 4

FIGURE 5

- *Gear Type:* Use a rack and pinion gear to change circular motion to linear motion. Use a bevel gear to change the direction of rotation. For a large reduction in RPM, use a worm gear. For everything else, use a spur or a helical gear.
- *Gear Ratio:* The relationship between the number of teeth on two gears. Changing the gear ratio will influence the amount of torque or speed a gear has. To increase torque, a smaller gear should be mounted on the motor and a larger one on the wheel. To increase speed, do the opposite.
- *Hubs:* The protruding part of the gear that contains a bore for mounting gears. Using a gear with a hub is generally recommended because if you use a hubless gear, you will need to bond the gear to the shaft by using glue, epoxy, or solder. This also makes replacing the gear much more difficult, so if you do use a hubless gear, use a more durable metal one in lieu of plastic.

Hub Diameter:

- *Diametral Pitch:* The number of teeth in an inch of the pitch diameter. The diametral pitch of two corresponding gears determines if the gears will mesh together properly. The ratio of the number of teeth between two gears must be the same as the ratio between the two gears' diametral pitch.
- *Bore Size:* The diameter of the bore (hole used for mounting gears). It is obviously important to choose a bore size that will allow you to mount the gear properly. The bore size should be slightly bigger than the motor shaft on which you are mounting it and should fit snuggly. If you find yourself unsure about which size to choose, it is better to choose a slightly smaller size which can then be reamed out with a drill to the size you desire.
- *Pressure Angle (angle of obliquity):* The pressure angle is a term that shows the angle between the line of contact (an imaginary line drawn through the point where gears come into contact from the beginning to the end of meshing) and the tangent line (an imaginary line drawn at the point of contact between the two pitch circles of corresponding gears). For practical purposes, it is really only important to note that the pressure angles of two corresponding gears must be the same, and that the smaller pressure angles tend to indicate weaker gear teeth. Older gears typically have a 14.5° pressure angle; newer gears most often have a pressure angle of 20° or 25°.
- *Face Width:* The width of the gear teeth. Because combat robots are exposed to a lot of force, using a gear with a wider face width can distribute the force of impact during a fight over a wider surface area, making it less susceptible to damage.
- *Material:* Gears come in plastic and a variety of metals such as aluminum, brass, or steel. Plastic is obviously cheaper and lighter, but more susceptible to wear, while metal can add weight and expense to your bot but are more durable.

with a larger face width because the increased surface area will distribute the force over a larger area.

Susie selects the highest face width that will fit inside her Antweight shell. For the material, Susie chooses plastic because it is less expensive and weighs less than other materials. If Susie was building a bigger bot, she might want to consider a metal gear that could better withstand the force of an impact with another heavy bot.

After her research, Susie has learned enough about gears to make her basic bot, but she has barely scratched the surface of gear terminology. She resolves to learn more about gears and eventually has an entire list of advanced nomenclature, which she kindly provided with this article. SV

Figure 1 is courtesy of ***www.directindustry.com****. Figures 2-5 are courtesy of* ***www.howstuffworks.com***