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PARTS IS PARTS: Screws For You!

● Original Text by Professor Marco Antonio Meggiolaro; Summarized by Kevin M. Berry

For this month's Parts Is Parts section, we dip once again into the bottomless well that is known as the *RioBotz Combot Tutorial*. Professor Marco Antonio Meggiolaro authored the tutorial. His book is available free for download at **www.riobotz.com.br/en/tutorial.html**. All information here is provided courtesy of Professor Meggiolaro and RioBotz.

Screws are joining elements which have helical threads around their perimeter. They are used in countless applications to apply forces, to fasten joints, to transmit power (in worm gears), or to generate linear motion. The helical threads (in general, wrapped according to the right hand rule) are inclined planes that convert the applied torques in the screws into axial forces. The main types of screws are presented in **Figure 1**.

Screws used in a robot structure should have hex a (hexagonal) or Allen head because they allow the highest tightening torques. Screws used in the electronics can be flathead or Phillips types.

- *Hex head* — Easily tightened with open-ended wrenches. Always use the 8.8 or 10.9 class types (made out of hardened steel); they have twice the strength of regular (mild steel) screws. Stainless steel screws have higher strength than mild steel ones, but much lower strength than hardened steel screws. They should not be used in structural parts (besides, they are much more expensive).

- *Allen* — The highest strength screws. Use the 12.9 or 10.9 class types (made out of hardened alloy steel), as they have three times the strength of regular screws. Despite their higher impact toughness, don't use stainless steel screws. Their low yield strength will let them bend easily during combat, making it difficult to disassemble the robot. Stainless steel Allen bolt heads are also easier to strip than hardened steel ones. **Figure 1** shows the button, standard, and flathead (flush head) types. The flathead types are good for thick plates used in the robot's exterior because they are embedded flush to the plate surface so have less chance of being knocked off by spinners.

Avoid using flathead screws to fasten thin sheets. In this case, the button head ones should be used; they also work well against spinners. Flathead screws require that the plates are countersunk, which reduces joint strength. As a general rule, at least 0.5 mm (0.02 in) of the plate thickness should not be countersunk.

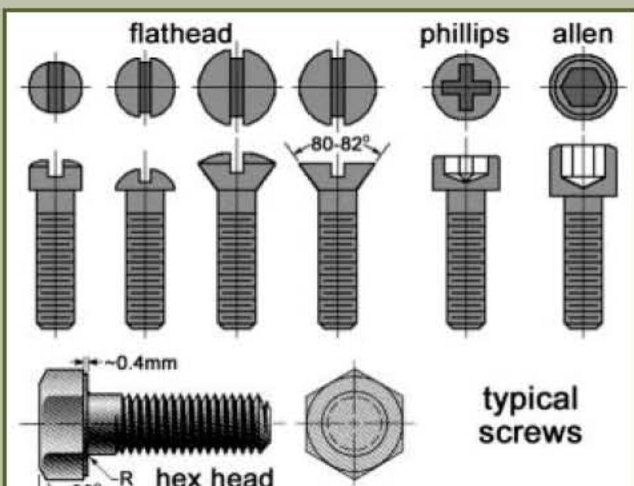

FIGURE 1

- *Self-drilling* — These

screws don't require tapped holes since they cut their own thread as they're fastened. They're good for wood and sheet metal, but they're a bad option to fasten thicker sheets and plates in the robot structure. They're made out of low strength steel, and they're easily knocked off due to the lack of nuts or properly threaded holes.

- *Sandwich mounts* — These are basically two screws held together by a piece of rubber or neoprene. Besides the male-male version, there are also threaded ones such as the female-female and male-female. They are excellent dampers to mount the electronics into the robot, leaving it mechanically and electrically isolated from the structure.

To hold the screws, nuts and washers are used. Washers are important to evenly distribute the force of the screws onto the part. Nuts have the inconvenience of needing two wrenches to be tightened: one open-ended to hold the nut and another open-ended (or Allen) for the screw head. To avoid that, robots make use of threaded holes.

A hole is drilled in the piece with a diameter a little smaller than the one of the screw (there are specific tables for that). A tap is used to generate threads. Threaded holes make the robot assembly much easier because you don't have to deal with nuts, which can be hard to reach and secure during a quick pitstop, or that might fall inside the robot.

The thickness in the piece being tapped should be at least equal to the thickness of the nut that would be used with the screw. This helps to avoid stripped threads. In addition, avoid tapping low strength aluminum (such as 6063-T5) and Lexan, as their threads will have relatively low resistance. Also avoid tapping deep holes in titanium by hand. Besides being tough to tap, there's a good chance that the tap will break inside the piece.

A rule of thumb for a good screw diameter is to make it a little smaller than the sum of the thicknesses of the parts being joined. For instance, to fasten a 5 mm thick plate to a 4 mm one (totaling 5 + 4 = 9 mm), an M8 screw (with 8 mm diameter) is a reasonable choice.

What about the number of screws? In robot combat, the word "overkill" doesn't exist; it is just a matter of your opponent super-sizing his/her weapon for your armor to suddenly become undersized.

Therefore, the most critical parts should have the largest possible number of screws, but use common sense. If you drill too many holes to use more screws, your plates will look like Swiss cheese and they will be weakened. A rule of thumb is to leave the distance of at least one washer diameter between the washers of two consecutive screws. In other words, the distance between the centers of the holes should be at least twice the diameter of the washer.

Screws shear much more easily than they break due to traction forces. Therefore, pay attention to the forces that would most likely act on each part of your robot. For instance, in **Figure 2** two parts are joined using a screw to transmit a vertical force. The configuration with the horizontally mounted screw is a bad idea, since it will be loaded in shear. Change the design so that the screw will be under traction, as on the right. In this way, the screw will be able to take up to twice the load.

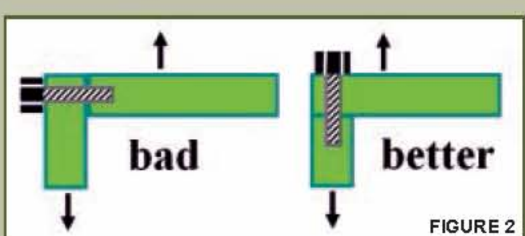

FIGURE 2

Another important thing is the tightening torque of the screw. Impact forces are transmitted entirely to a screw that is loosely tightened and it will end up breaking. A well tightened screw, on the other hand, distributes the received impact loads evenly through the surrounding material, receiving just a smaller portion of the impact force. This results in a structure with greater stiffness and strength.

Always check for loose screws during a pitstop. Usually, open-ended and Allen wrenches have an appropriate length (lever arm) for a single person to be able to manually generate appropriate tightening torques without leaving it loose or breaking the screw. A torquemeter can be used to deliver a higher precision when tightening bolts.

Now, how do we guarantee that a screw won't get loose during a match? The tightening torque by itself is not enough to hold the screws in robot combat since vibration and impacts are very high. A well tightened screw from the top cover of our spinner Titan ended up getting unscrewed after four full turns, until it was knocked off by our own weapon bar. To avoid this, there are five methods:

- *Spring lock or Belleville washers:* These guarantee that the screw remains tightened, working as a spring to load them in the axial direction. Most of the time you can tighten the screw until these washers become flat.
- *Locknuts* have a nylon insert that holds well onto the threads of the screws, resisting vibration and holding in place anywhere along the threads of the mating part. The locking element also limits fluid leakage and it won't damage or distort threads.
- *Counter nuts:* If in the middle of a frantic pitstop you don't find any spring lock washers or locknuts,

simply add a second nut to the screw (the counter nut) and tighten it well on top of the other one. The pressure between the two nuts will help preventing the screw from becoming unfastened.

- *Threadlockers:* These literally glue the screw onto the nuts or tapped holes. Loctite 242 (blue) has medium strength and it holds very well. It is enough to use a single drop on the screw thread before tightening it. There is also the Loctite 222 (purple), which is relatively weak for combat, and Loctite 262 (red), with high strength for a permanent bond. High strength threadlockers could be a problem if you need to disassemble the robot. You might need to heat up the part and deliver a great blow with a hammer to break the Loctite 262 bond. It is a good idea to clean up the screw and the nut or threaded hole with alcohol or acetone before using the threadlocker to improve bonding. Don't use threadlockers in Lexan because they react with it and weaken the material. Loctite is a form of "super glue" which some people are allergic to. Handle with care. SV

EVENTS

Completed and Upcoming Events

Completed Events for Sep 15 to Oct 13, 2009

HORD Fall 2009 was held on September 19th in Strongsville, OH.

Franklin Institute 2009 was held on October 3rd and 4th in Philadelphia, PA.

RoboCore Eneca 2009 was held October 3-4, in Joinville, Brazil.

Robothon Robot Combat 2009 was held on October 11th in Seattle, WA.

Upcoming Events for Dec 2009 - Jan 2010

Combots Cup IV will be held in San Mateo, CA on December 19th and 20th. Go to **www.combots.net** for more information.

Kilobots XVI at Spectrum 2010 will be presented by the Saskatoon Combat Robotics Club in Saskatoon, Saskatchewan Canada on January 16th and 17th. Go to **www.kilobots.com** for more information. SV

EVENT REPORT: Franklin Institute 2009 Robot Conflict

● by Thomas Kenney

The 2009 Franklin Institute Robot Conflict was held by NERC on October 4th in Philadelphia, PA. This was the third annual competition at the institute, with numerous robots competing in the one, three, 12, 30 lb, and Sportsman classes. The 15 lb Battlebots IQ weight class was also open this year, but no robots in that category attended.

The competition began with a fierce round robin tournament among the four antweights attending. The outrunner drum spinner Poco Tambor eventually came out on top, with the lifter Otis following in a close second.

In the beetleweight round robin tournament, horizontal spinner Maniac Kathy maintained its winning streak up until the very end, where it lost a close decision to the drum spinner Rolling Pin. The normally dominant ramming brick Cloud of Suspicion lost