PAPER BOTS • ANIMAL BOTS • HYBRID BOTS

SERVO MAGAZINE

FOR THE ROBOT INNOVATOR

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The Rock-afire Explosion

Gettin' the band back together!

✦ **Bots in Brief**
UAV Fire Brigade, Robot Baseball

✦ **Building Blocks**
Build a dual serial motor controller

✦ **Evolution Of Robotic Animals**
Robot animals strive to match humanoids in realism

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Current trends in robot software development

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no more. The other driver was gracious enough not to get in a free hit. I made sure to properly attach both gearboxes to their mounts before the second match. In UFO's previous match, their shell had been dented inward to the point that it was irreparable and completely prevented the weapon spin-up. The team opted to replace their shell with a large steel bar angled at the tips. Shaka was able to drive fine this time, but due to the huge twisting force, UFO flipped over upon spin-up.

There are several things I plan to improve on in Shaka when I get the chance. First, I'm going to decrease the width of the robot at least 1.5" by removing the Dewalt pillow blocks and supporting the shaft by pressing bushings into the UHMW side. I also plan to remove the weapon bearing blocks and replace them with a pair of bushings pressed into the weapon support rails. I've already replaced the battery with one that has a more adequate discharge rate.

Overall, I'm happy with the little combat performance that this robot has had, and will be taking it along with the rest of the MH robotics fleet to the upcoming Franklin Institute event to find any other bugs that need to be worked out. SV

MANUFACTURING: RioBotz COMBOT TUTORIAL SUMMARIZED: Materials — Part 2

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

Professor Marco Antonio Meggiolaro, of the Pontifical Catholic University of Rio de Janeiro, Brazil, recently translated his popular book, the *RioBotz Combot Tutorial*, into English. Last month, *SERVO* summarized the first part of Chapter 3 — "Materials" — focusing on commonly used metals in combat bot building. This month, we switch focus to non-metals.

Marco's book is available free for download at **www.riobotz.com.br/en/tutorial.html**, and for hard copy purchases (at no profit to Marco), at **www.lulu.com/content/7150541**. All information here is provided courtesy of Professor Meggiolaro and RioBotz. Let's get started!

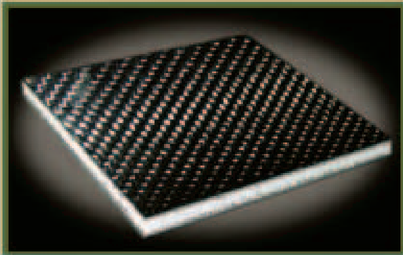
The main non-metals that need to be mentioned in combat robot design are:

Polycarbonate

This popular plastic — commonly known as Lexan (trademarked by SABIC Innovative Plastics, Inc.) — is a polymeric thermoplastic (which softens and melts when heated, instead of burning) that is transparent to light waves and radio-control signals. It has high impact toughness, and it is very light, with a density of 1.2. When used in combat robot armor, it absorbs a lot of energy as it is deformed during an impact. In spite of that, fewer and fewer combat robots have been using this material, because of its disadvantages: it has very low Young modulus (E = 2.2 GPa — about 1% of the stiffness of steels — making the robot structure very flexible even for high thicknesses), it cracks easily (the cracks usually appear starting from the holes, and they propagate without absorbing much of the impact energy), and it is cut easily (becoming vulnerable to sawbots).

Antweight Babe shows the toughness of Kevlar/Nomex honeycomb against spinners.

Wood makes for showy displays, but unfortunately loses matches.



CF layered with foam makes a tough, light structural panel. Dragonplate substitutes balsa wood for the foam.

To avoid cracking, chamfer all holes to remove sharp corners and edges, and provide the polycarbonate with support along with some damping, for instance using a thin layer of rubber or neoprene. Avoid tapping polycarb, but if you must do it then guarantee that the hole is tapped very deeply with several threads or else they might break. Never use threadlockers such as Loctite 242 in Lexan, because (besides not locking) it causes a chemical reaction that makes it brittle. Acetone should also be avoided. Polycarbonate is almost universally the material used to construct combat arenas.

Acrylic

This is a good material to build fish tanks, but do not use it in combat because it has the same density as Lexan but with 20 to 35 times less impact toughness. (Note: Marco implies, but does not clearly state, that it shatters spectacularly, leaving razor sharp splinters everywhere. Please do not email *SERVO* asking how I gained this knowledge!)

As bot armor, acrylic makes a great trophy shelf!

PETG

This is a modified type of PET (polyethylene terephthalate) with an impact toughness in between the values for acrylic and polycarbonate. It is a cheap substitute for polycarb, but with worse properties. We've tried it in combat and decided that it would be better used to make a nice transparent trophy shelf.

Teflon

Teflon is a well-known household material (trademarked by DuPont). Its acronym soup name is PTFE (polytetrafluoroethylene). Having very low friction, it can be used as a sliding bearing for moderate loads or as a skid under the robot to slide in the arena. Its main problem is its high cost.

UHMW

UHMW (Ultra High Molecular Weight) plastic is a high density polyethylene that also has very low friction. Known as the "poor man's Teflon," it doesn't slide as well as Teflon but it is cheap and it has higher strength. Shell spinners, such as Megabyte, use internal spacers made out of UHMW between the shell and the inner robot structure, guaranteeing that the shell won't hit the internal metal parts of the robot even if it is bent, allowing it to slide with relatively low friction in case it makes contact. The high toughness of UHMW makes it a good choice even for structural parts, such as the motor mounts of the hobbyweight Fiasco, shown in the photo.

Nylon, Delrin (acetal)

These are thermoplastic polymers with high strength, low density, and relatively high toughness. They are good for internal spacers in the robots and even as motor mounts (similar to UHMW). Nylon is a generic term, while Delrin is a registered trademark of DuPont.

Rubber, Neoprene, Hook-and-Loop Fastener (Velcro)

These are excellent materials to dampen the robot's critical internal components, such as receivers, electronics, and batteries. High-strength mushroom-head hook-and-loop is also excellent to hold light components. This is, of course, a high strength version of the ubiquitous "Velcro," another common household material (Velcro is a registered trademark of Velcro Industries). Mushroom-head is a "male-male" system, instead of the traditional "male-female" system with Velcro.

Epoxy

Excellent adhesive; good to glue fiberglass, Kevlar, and carbon fiber onto metals. Clean the metal part with alcohol or acetone before applying it to maximize holding strength. Always use professional epoxy which cures in 24 hours — not the hobby grade.

Phenolic Laminate

This is an industrial laminate —

very hard and dense — made by applying heat and pressure in cellulose layers impregnated with phenolic synthetic resins, agglomerating them as a solid and compact mass. Also known as Celeron (trademarked by GRT Genesis), it is an excellent electric insulator.

We mount all the electronics of our robots on such laminates, which are then shock-mounted to the robot structure using vibration-damping mounts or mushroom-head hook-and-loop resulting in electrical insulation, as well. The regular phenolic laminates are relatively brittle, but a high strength version called garolite (available at **www.mcmaster.com**) has already been used even in the structure of antweights and beetleweights. Garolite — a generic term for a family of phenolics — is transparent to radio signals and very impact resistant. However, avoid tapping it since its threads are prone to stripping.

Wood

Wood has low impact toughness if compared to metals. It should not be used in the structure, unless your robot is very skillfully driven, such as the wooden lightweight The Brown Note, which got the silver medal at RoboGames 2008 after losing to the vertical spinner K2. A few builders have mounted wooden bumpers in front of their robot when facing spinners, to work as ablative armor. While a shell spinner chews up the wooden bumper of its opponent little by little, it loses kinetic energy and slows down, becoming vulnerable.

Ceramics

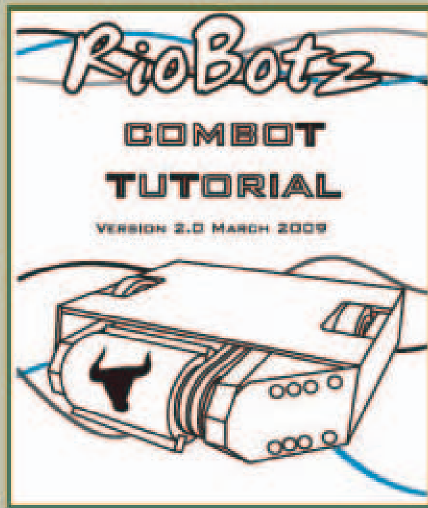
Ceramics are very brittle under traction, but under compression they are the most resistant materials in the world, so much so that they are used underneath the armor plates of military tanks. The ceramic breaks up the projectiles, while their fragments are stopped by an inner steel layer. Ceramics are also extremely resistant to abrasion. The famous lifter BioHazard used 4" square 0.06" thick alumina tiles (Al_2O3_3, which forms sapphires when in pure form) glued under its bottom to protect it against circular saws that emerged from the BattleBots arena floor.

Fiberglass

Formally known as GFRP (glass fiber reinforced polymer), it is made out of very thin glass fibers held together by a polymeric adhesive (known as the polymer matrix) such as an epoxy resin. It is used heavily in boats. It has potential use in the robot structures since it is rigid and light, however, its impact toughness is low, compared with most metals.

Kevlar

Kevlar, another DuPont trademarked material, is also known as KFRP (Kevlar fiber reinforced polymer). It is sometimes seen as a yellow fabric made out of aramid fibers — a type of nylon, five times more resistant than steel fibers of the same weight. Used in bulletproof vests, it has extraordinary impact toughness. Touro uses a Kevlar layer covered with professional epoxy (the polymer matrix) sandwiched between the aerospace aluminum



walls of the structure and the external Ti-6Al-4V plates of the armor to increase its impact toughness.

The fabric is very difficult to cut; it is recommended to use special shears, available at **www.mcmaster.com**. Kevlar fabric is not expensive. We've paid less than US$12 in Touro – more specifically, we've used the aramid fabric KK475, which costs about US$60/m2 (less than US$6/ft2) in Brazil.

Carbon Fiber

Sometimes called CF or CFRP (carbon fiber reinforced polymer), it is available in several colors. CF is very expensive but extremely rigid and light, and because of that it has been used in racing cars and aircraft for years. It is excellent to mount the robot's internal parts to because

UHMW is an ideal structural material.

Self inflicted damage is the worst kind!

of its high stiffness. It is a myth that carbon fiber has high impact toughness, though. It surely has a high strength under static loads, but it does not take severe impacts.

The undercutter Utterly Offensive is a good example of that; its carbon fiber baseplate (see photo) self-destructed when it was scraped by its own spinning blade. The plate was later switched to titanium. Carbon fiber is not a good armor material, unless it is combined with Kevlar to achieve high impact toughness.

Other Polymer Matrix Composites

There are several other composites that use a polymer matrix (such as epoxy or polyester) besides plain GFRP, KFRP, and CFRP. For instance, you can tailor lay-ups of aramid and carbon fibers cured (bonded) together with a polymer matrix to achieve optimum impact toughness (due to Kevlar) and stiffness (due to carbon).

It is possible to generate complex unibody structures by combining several parts into a single cured assembly, reducing or even eliminating the need for fasteners and saving weight and assembly time. One technique is to use adhesive bonding where composites or metals are bonded to other composites, honeycomb cores foam cores, or metallic pieces.

An example is where a rigid unit is made with a polymethacrylimide foam core, sandwiched by CFRP sheets (see photo). Besides increasing the panel bending stiffness, the foam core also works as a shock mount, increasing the impact strength. It also becomes a good option for the robot structure and even the armor.

An even the higher stiffness-to-weight ratio can be obtained if the core is made out of balsa wood, as shown in the photo of DragonPlate. However, its impact toughness is relatively low.

We use a Kevlar/Nomex honeycomb material, purchased from **www.acmeindustrialsurplus.com**, in all of our insect class bots, and have several sheets up to 1" thick we plan to use in bigger bots. It has proven extraordinarily effective against spinners. Babe (see photo) spent a whole event giving spinner rides with minimal damage).

Professor Marco notes that, while these composites are tough, a metallic overlay such as the titanium side panels on Babe significantly increase long-term damage resistance.

Metal Matrix and Ceramic Matrix Composites

Instead of having their fibers embedded and held together in a polymer matrix, these composites use either a metal or a ceramic matrix. The fibers (or even tiles in a few cases) can also be made out of metal or ceramic, which tends to increase the ultimate strength and stiffness of the matrix material. However, most ceramic matrix composites have low impact strength, which limits their use in combat — not to mention their very high cost.

On the other hand, when part of a multi-layer composite armor plate such as the Chobham armor, ceramic tiles embedded in a metal matrix can be very effective to shatter kinetic energy weapons. SV

EVENTS

Completed and Upcoming Events

Completed Events for July 16 to Aug 15, 2009

PA Bot Blast 2009 was held July 18th in Bloomsburg, PA. Twenty-seven robots were registered.

Upcoming Events for Oct-Nov 2009

Franklin Institute 2009 will be presented by North East Robotics Club in Philadelphia, PA October 4th and 5th. For more information, go to **www.nerc.us**.

Mecha-Mayhem 2009 will be presented by the Chicago Robotic Combat Association in Rosemont, IL October 23rd through 25th. For more information, go to **www.theCRCA.org**.

Robothon Robot Combat 2009 will be presented by Western Allied Robotics in Seattle, WA October 11th. For more information, go to **www.westernalliedrobotics.com**. SV