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MATERIALS TO EVALUATE FOR DESIGNING ROBUST ROBOTS

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ABSTRACT - The exterior of a robot might come as an afterthought to some robotics developers, but your choice of materials will affect its safety, durability, and even aesthetics. Any design project should include considerations of how a robot will move, whether it will operate around people, what tasks it will perform, and the anticipated environment. Other considerations include ease of cleaning and repair, weight (which affects overall power requirements), design for manufacturing, and, of course cost. Collaborative robot arms, or cobots, are very different from autonomous underwater vehicles, aerial drones, or other field robots. A robot that works inside an MRI machine must be made of certain materials, while a stationary robot in a factory may need other characteristics.

STEEL

Steel is one of the materials used most often by robot builders. This sturdy metal is a smart choice if you're building a robot that needs to stand up to harsh conditions. It's possible to harden the steel to between 100,000 and 300,000 pound-force per square inch (psi) in many cases. If you plan to harden the steel, look for some with high carbon content. Usually, the more carbon that steel contains, the more suitable it is for making harder through heat treatments. Ultra-wear resistant kinds of steel are also available, as well as steel that stands up to frequent impacts. Bear in mind that this material can be challenging to work with if you don't have the proper tools, such as those used for welding. That's especially true if you need to make the steel conform to a particular shape to streamline your robot's body. Russia's Uran-9 robotic tank obviously has steel construction, and its problems in the field were because of communications problems, not materials.

COPPER, BRASS, AND BRONZE

Brass and bronze are copper alloys occasionally used for structual purposes. Brass refers to an alloy of copper and zinc, bronze to copper and other elements, most commonly tin, but sometimes, aluminum, silicon, or other metals. They have about the same density as steel, and generally half to two-thirds its strength (density 8.4 gm/cc, yield point 25,000-60,000 psi). Both melt at around 900 C, a good red-orange heat. Pure copper melts at 1080 C, bright orange. Copper alloys are non-magnetic, non-sparking, and some of them are very corrosion resistant. They are used instead of steel when these properties are important enough to justify the cost, which is 4-5 times that of normal carbon steel in small amounts and more in large pieces. Brass is sometimes used in bearings as it has self-lubricating properties both against itself, and against steel. An unlubricated steel-on-steel bearing will rapidly self destruct, as will aluminum (which is generally not hard enough for bearing purposes in any case). Most common brasses machine easily. The machinability of bronzes varies from easy to difficult. Many copper alloys can be joined by soldering. Pure copper is rarely used structurally as it is very soft, but it is used nearly universally as an electrical conductor, and sometimes in heat exchangers in applications where aluminum would corrode. It is used in plumbing due to the combination of corrosion resistance, strength and heat resistance (compared to plastics), and easy solderability.

TITANIUM

Titanium is an exotic metal sometimes found in high-tech applications. It is about half the density of steel (4.3 gm/cc) but some alloys can be made almost as strong (yield 150,00 + psi). It is high-melting (1670 C), extremely corrosion resistant, and biologically inert. It is also very expensive, difficult to machine (more so than stainless), and can only be cast, forged, or welded with very specialized equipment. Thin shavings will burn in air if ignited, so turnings are a fire hazard. It will also burn in carbon dioxide and even pure nitrogen, which makes extinguishing such a fire tricky (dry sand will work). Titanium is generally used only when biological inertness is essential, or the application requires an unusual combination of light weight and high strength.

OTHER METALS

Magnesium has properties similar to aluminum, but is lighter (density 1.7 gm/cc), more expensive, more corrosion prone, and its shavings will burn intensely in air (machining it is a fire hazard). It is used only when the low weight outweighs all the negatives. We probably won't use it.

Zinc is sometimes used for low-cost metal components in cars, locks, toys, and low-quality machinery. The advantage is that components can be quickly die-cast at low temperature. The down side is that the material is weak and not very heat resistant for a metal, and nearly as heavy as steel (density 7.1 gm/cc).

Lead is also easy to cast at low temperature, and some of its alloys have better mechanical properties than zinc. It is also traditionally used to make weights due to its high density (11.3 gm/cc). Some of the best low-temperature solders contain lead. Unfortunately some of its compounds are toxic if eaten or inhaled, and can cause cumulative brain damage in children at low dosages. The extensive use of lead carbonate as a white pigment in house paint in the 19th and early 20th centuries resulted in widespread exposure as deteriorated paint chipped and peeled directly into living spaces. Lead thus became widely known as a very bad thing, and most uses have been discontinued. Some electrical solder still contains lead as it is easier to use than any of the lead-free alternatives so far discovered. Large amounts are still used in automotive batteries. Use lead solder only in well ventilated areas. Don't eat solder or batteries, and wash your hands after handling them.

Mercury (not a structural metal!) is primarily interesting because it is liquid at ordinary temperatures. It was widely used in household thermometers and in mercury switches, which provide a very nice spark-free, position-sensitive electrical contact. Mercury is significantly more toxic than lead, and the free element is a hazard because it evaporates slowly into the air and can be inhaled. If you drop a mercury switch, the glass tube can shatter and then little droplets of mercury will race all over the floor and into every crack and corner. UR would have to send in a decontamination team, and we would probably be closed down forever. So

I'm not putting out the old mercury switches we got once as robot orientation sensors. Interesting factoid: mercury is denser than lead (13.5 gm/cc).

Depleted uranium is even better for weights than lead or mercury (density 19.1 gm/cc). It is used to ballast the keels of some high-performance sailboats and in military armour-piercing bullets. Unfortunately it is slightly radioactive and can cause lung cancer if inhaled as dust, and probably other cancers if eaten in a bio-available form. Fine shavings will burn in air if ignited, producing uranium oxide as finely divided, inhalable smoke. We would need to get special permission to use it in a robot.

RUBBER

Demand is growing for commercial robots with flexible exteriors, such as human-like "skin." Moreover, it's advantageous for cobots that work alongside humans to have soft surfaces. Rubber and soft plastics can meet that goal. At the University of Houston, a research team used a rubber composite material to make a semiconductor. The electronics retained functionality even after researchers stretched the rubber by 50% working with traditional semiconductors while building robots is tricky because they're easy to break — certainly not an ideal characteristic for a robot that needs to flex. While showing off their work, the researchers designed a robotic skin that can sense the temperature after being immersed in a cup of water. Then, to prove the breadth of potential applications of the project, they made the hand able to receive computer signals and reproduce them as American Sign Language. Teams at Stanford University and the National University of Singapore are also working on robots with polymer skins for a sense of touch. Even if your robot has a rubbery exterior, it typically houses hard components inside it, including processors and actuators. However, a more recent project involved engineering a soft robot with a computer also made from rubber. Robots with rubber bodies are typically safer than those made from harder materials. Plus, they work well for handling delicate products like fruit. Soft Robotics grippers conform to such objects in pick-and-place tasks without damaging them. At some Disney theme parks, robots interact with guests, and there are plans to eventually expand upon animatronics that are behind glass or removed from people to the point of robots that walk around the parks. It's easy to see why rubber and plastics are useful for robots that are both lifelike and safer to operate around people.

ALUMINUM

Although aluminum has a higher price point than steel, it's easier to shape and is lighter. Aluminum is also a good material if you're worried about a robot's exterior becoming rusty over time because aluminum does not rust. However, because it can corrode in some wet environments, you might consider treating the surface to give it more protection against possible corrosion. Another thing that makes aluminum a popular option for robot exteriors is that it can be polished to a high shine. So, if you're building a commercial robot that your client will eventually want to show off, aluminum makes the body look nice while offering ample durability. You can also work with specialists that provide aluminum polishing technology with three-way machines, which enable programming to meet double-sided processing needs. Some designers also use aluminum on robot bodies to protect more fragile parts. In one example, Italian scientists made a robot strong enough to pull a 7,200-pound airplane down a runway. The robot, which had four electric motors, four hydraulic actuators and a pair of computers, housed its parts in an aluminum roll cage.

KEVLAR

Kevlar is a synthetic fiber frequently used for bulletproof vests. Some of its characteristics make it worth evaluating for robot exteriors, too. You could use it as a covering on robots that require safeguarding from extreme temperatures. Many heat-resistant gloves feature Kevlar because the material does not melt or drip when exposed to hot environments. Also, Kevlar does not degrade in Arctic temperatures of -50 degrees Fahrenheit, nor do cryogenic conditions adversely affect the fibers. Roboworld Molded Products LLC makes Robosuits many of which contain Kevlar to protect sensitive parts of your robot’s exterior in demanding temperatures. While Robosuits are custom-designed depending on needs, one that includes Kevlar would be suitable for a welding application. The Robosuit fits over the robot’s body without affecting its articulation or reach. This easy-to-use protection could maintain the robot’s functionality by helping it tolerate exceptionally hot or cold temperatures. Without a covering like these Kevlar designs, cold temperatures can adversely affect the grease or other lubricants for internal parts, while heat can make motors get too hot and shut down. An external cover keeps the robot within its recommended operating temperature range by giving radiant heat protection.

BIODEGRADABLE SMART MATERIALS

The materials mentioned above are all relatively easy to source and have different levels of durability depending on the need. However, you may not know about efforts to create biodegradable materials. Researchers in Italy have ways to create robots from bioplastics composed of food waste. Since most conventional plastics contain petroleum — a substance that contributes to climate change — researchers think their alternative would help the planet, especially in seafaring probes. In addition, these so-called biodegradable smart materials are versatile. Scientists have created a robot skin from them and said the bioplastics could be hard enough for internal parts, as well. In the U.K., experts at the Bristol Robotics Laboratory have worked on a robot that decomposes after completing its mission. It might assist with a search-and-rescue effort at a disaster site and start breaking down its body afterward. Then, humans would not have to find and retrieve the robots, and the biodegradable materials wouldn’t harm the planet. Investors and developers have become increasingly aware of the need for eco-conscious and sustainable robotics development. Recycled materials and biodegradable plastics would go a long way to helping them achieve that goal.

CONCLUSION

This is just an introductory list to some of the most commonly used materials for robot exteriors. Of course, the material a robot uses will depend primarily on its purpose. For instance, materials used in robot-assisted surgery must be able to withstand rigorous sterilization techniques. In this case, a polymer like acrylonitrile butadiene styrene (ABS) would fare far better than a material that can’t stand up to medical requirements and regulations. Some soft robotics materials can even “feel” pain and heal themselves. Robots used in clean rooms, food handling and aquatic settings also have special needs to consider. A buoyant robot, for example, will require a lightweight and water-resistant material. On the other hand, a biomimetic robot would need a soft and flexible substance that can grip and move around comfortably. Reflecting on these unique demands is a crucial part of the creation process.

REFERENCES

[1] Albrecht, T., Bührer, C., Fähnle, M., Maier, K., Platzek, D., and Reske, J. 1997. "First observation of ferromagnetism and ferromagnetic domains in a liquid metal." Applied Physics A: Materials Science & Processing 65(2): 215.
[2] Amend, J. R., Brown, E., Rodenberg, N., Jaeger, H. M., and Lipson, H. 2012. "A positive pressure universal gripper based on the jamming of granular material." IEEE Transactions on Robotics 28(2): 341–350.
[3] Bar-Cohen, Y. (ed). 2004. Electroactive Polymer (EAP) Actuators as Artificial Muscles – Reality, Potential, and Challenge. Bellingham, WA: SPIE press (2nd edition).
[4] BBC News. 2003. "Octopus intelligence: jar opening." http://news.bbc.co.uk/1/hi/world/europe/2796607.stm. 2003-02-25. Retrieved 2016-10-10.
[5] Cao, W., Cudney, H. H., and Waser, R. 1999. "Smart materials and structures." PNAS 96(15): 8330–8331.
[6] Curie, J., Curie, P. 1881. "Contractions et dilatations produites par des tensions dans les cristaux hémièdres à faces inclines" [Contractions and expansions produced by voltages in hemihedral crystals with inclined faces]. Comptes rendus (in French) 93: 1137–1140.
[7] Haines, C. S., et al. 2014. "Artificial muscles from fishing line and sewing thread." Science 343(6173): 868–872.
[8] Ilievski, F., Mazzeo, A. D., Shepherd, R. F., Chen, X., and Whitesides, G. M. 2011. "Soft robotics for chemists." Angewandte Chemie 123: 1930–1935.
[9] Jahromi, S. S., Atwood, H. L., 1969. "Structural features of muscle fibres in the cockroach leg." Journal of Insect Physiology 15(12): 2255–2258.
[10] Jin, S., Koh, A., Keplinger, C., Li, T., Bauer, S., and Suo, Z. 2011 "Dielectric elastomer generators: How much energy can be converted?" IEEE/ASME Transactions On Mechatronics 16(1).
[11] Keplinger, C., et al. 2013. "Stretchable, transparent, ionic conductors." Science 341(6149): 984–987.
[12] Kier, W. M., and Smith, K. K. 1985. "Tongues, tentacles and trunks: The biomechanics of movement in muscular-hydrostats." Zoological Journal of the Linnean Society 83: 307–324.
[13] Kim, D. H., et al. 2011. "Epidermal electronics." Science 333(6044): 838–843.
[14] Knoop, E., Rossiter, J. 2015. "The Tickler: A compliant wearable tactile display for stroking and tickling." Proc. CHI 2015, 33rd Annual ACM Conference on Human Factors in Computing Systems: 1133–1138.
[15] Lendlein, A., Kelch, S. (2002). "Shape-memory polymers." Angew. Chem. Int. Ed. 41: 2034–2057.
[16] Mather, J. A. 2006. "Behaviour development: A cephalopod perspective." International Journal of Comparative Psychology 19(1).
[17] Meller, M. A., Bryant, M., and Garcia, E. 2014. "Reconsidering the McKibben muscle: Energetics, operating fluid, and bladder material." Journal of Intelligent Material Systems and Structures 25: 2276–2293.

[18] Morin, S. A., Shepherd, R. F., Kwok, S. W., Stokes, A. A., Nemiroski, A., and Whitesides, G. M. 2012. “Camouflage and display for soft machines.” Science 337(6096): 828–832.

[19] Pelrine, R., Kornbluh, R., Pei, Q., and Joseph, J. 2000. “High-speed electrically actuated elastomers with strain greater than 100%.” Science 287(5454): 836–839.