Robot Design Ideas

1.

- Small tube that runs the length of the fixture that we can feed the wire through.
- The end would need a small device to coil the wire once it was fed through.
- Passive design would be difficult to control.
- Active design would probably take up more space.

2.

- Could we make the coil out of a material that would naturally degrade in a short amount of time?

3.

- Use memory shape polymer in the fixture and memory shape alloy for spring and heat both by varying frequency of magnetic field.
- Could use a lattice of nanoparticles spaced evenly with different widths for different frequency
- Induction heating -The frequency utilized is relatively high (≈10^4–10^6 Hz) (http://iopscience.iop.org/article/10.1088/0964-1726/25/4/045022/meta)
- May need to find Eddy Current Frequency
- Magnetic Field depends on geometry of the material, so will the change in geometry effect the induction heating process?
- SMP can be biodegradable (http://www.pnas.org/content/103/10/3540.full)
- Linear actuation and bending/rotational actuation

4.

- Use thermal stimulated SMP with carbon nanotubes inside.
- Carbon Nanotubes (CNTs) produce heat when subject to a microwave radiation

Frequencies: 1.6-30 GHz
Wavelengths: 187 - 10 mm

- Can you safely expose humans to this?
- SMPs can have Tg engineered between –30°C to 260°C (–22°F to 500°F) - http://www.crgrp.com/rd-center/shape-memory-polymers/transition-temperature-and-activation-methods-shape-memory-polymers
- In “Shape memory polymer/CNT composites and their microwave induced shape memory behaviors” they use a sonicator and a crosslinking agent to mix the CNTs into the SMP
- Have to buy CNTs separately.
- Sonicator is expensive (most are over $1000). We could see about finding one in the chemistry department

- Cross link - a bond, atom, or group linking the chains of atoms in a polymer, protein, or other complex organic molecule.
- Ways to put composites in SMPs
    - Leng paper – SMP/CNT composites section. (http://pubs.rsc.org/en/content/articlepdf/2014/ra/c3ra43258k)
    - We could try injecting the nanotubes into already formed SMP
    - I would be skeptical about mixing them in while 3D printing
    - Magnetite particles (Ø = 20–30 nm) (30) were incorporated in TFX by an extrusion process. Results and Discussion of (http://www.pnas.org/content/103/10/3540.full)
    - ultrasonic vibration – Experimental Work of (http://www.sciencedirect.com/science/article/pii/S0266353807001832)

Materials

Body Temperature Ni-Ti Alloy

- As (austenite start temperature), fully annealed, measured by DSC = 15°C ± 5°C
- Af (austenite finish temperature), fully annealed, as measured by DSC = 35°C ± 5°C

More Ni-Ti: http://216.71.103.52/documents/Shape%20Memory%20Alloys.pdf

Shape Memory Polymer

- http://www.pnas.org/content/103/10/3540.full
- Can be 3D printed (filament – Essemplex)
- The magnetically induced shape recovery of SMP composites could be realized by incorporating magnetic nanoparticles (e.g., Fe_2O_3 and Fe_3O_4) in SMPs [16], [17], [236],[237], [238], [239] and [240]. The shape-memory effect of the composites can be triggered by inductive Joule heating in an alternating magnetic field, i.e., transforming electromagnetic energy from an external high frequency field to heat [241]. The magnetically induced SMPs can be remotely controlled to induce heating energy locally and selectively. (Shape-memory polymers and their composites: Stimulus methods and applications - Jinsong Leng, 2011)
- carbon nanotubes (CNTs) were selected as the additives not only because of their superb electrical, mechanical and thermal properties,[28] but also because of their strong microwave absorbing ability.[29] (**Kai Yu** [a], **Yanju Liu** [b] **and Jinsong Leng)**
- Crosslinking material for making nanocomposite SMP

Where to buy CNT

- Shenzhen Nanometer Gang Co., Ltd. (China)
- www.sigmaaldrich.com
- **https://www.americanelements.com/nanomaterials-nanoparticles-nanotechnology.html**
-

Bowden Wire

- Pneumatic actuation (windings to stiffen tubing)

Meshworm - (Sangok Seok, 2013)

- **IPMC (Ionic Polymer Metal Composite)** actuators are light and enable large bending displacements, but can generate only a small force.
- **EAP**s (Electroactive Polymer) generate large deformations, but generally require a large electric field and rigid frame structure, with a small force output
- **SMA (Shape Memory Alloy)** actuators are able to generate large displacements with simple mechanisms. They, however, exhibit slow cycle frequencies due to the passive cooling on the restoration phase.
- **SMA spring** actuators have an extremely large energy density per cycle (1314 J/kg) and are promising for soft robots with modest speed requirements.

Heating Memory Shape Materials

Utilizing two different magnetic strengths at the same radiofrequency (RF), the material was sequentially heated to two equilibrium temperatures. (http://onlinelibrary.wiley.com/doi/10.1002/adma.201100646/full)

Nanoparticles may also be resonantly excited. This allows heat transfer to the surrounding tissue.(

Constraints/Bio-materials

- Average body temperature – 98.6°F (37 °C)
- Distance needed to cover would be around 10 cm
- The most abundant type is hyaline, found as supportive tissues in the nose, ears, trachea, larynx, and smaller respiratory tubes. (Tissues of the Human Body, McGraw-Hill)

Bio Mechanics of Cartilage

- The aggregate modulus is a measure of the stiffness of the tissue at equilibrium when all fluid flow has ceased. (typically in the range of 0.5 to 0.9 MPa)
- The higher the aggregate modulus, the less the tissue deforms under a given load
- using the aggregate modulus and representative values of Poisson's ratio, the Young's modulus of cartilage is in the range of 0.45 to 0.80 MPa.

Variations in the Intrinsic Mechanical Properties of Human Articular Cartilage with Age, Degeneration, and Water Content

TABLE II

SUMMARY OF DATA FOR ALL SPECIMENS

Variable	No.	Minimum	Maximum	Mean	Standard Deviation
Age *(yrs.)*	103	16	85	56.40	19.13
Sex (m = 1, f = 2)	97	1 (n = 56)	2 (n = 41)		
Histological grade					
I	72	0	5	1.88	1.42
II	72	0	3	1.93	0.73
III	72	0	4	1.90	0.97
IV	72	0	1	0.60	0.48
Total	72	1	12	6.33	2.58
Permeability $\times 10^{14}$ (m^4/N.s)	103	0.05	1.95	0.47	0.36
Modulus *(Mpa)**	103	0.13	1.91	0.79	0.36
Thickness *(mm)*	103	1.69	5.17	3.12	0.72
Water content *(per cent)*	58	72.80	88.40	78.63	3.86
India-ink staining	48	1	3	2.06	0.78

* One megapascal = 145 pounds per square inch.

Procedures for Making SMP with CNT Composite

Leng paper –Used a styrene-based shape memory resin (VeriFlex®S VF 62, Tg = 62 C, density = 0.92 g/cm^3) and its curing agent (dibenzoyl peroxide hardener) purchased from Cornerstone Research Group, Inc. (USA). Multi walled CNT (avg. length = 1 um, diameter = 50 nm) purchased from Shenzhen Nanometer Gang Co., Ltd. (China)

- shape memory resin was mixed with the crosslinking agent at a weight ratio of 24 : 1
- CNTs were mixed with the resin mixture with stirring
- resin/CNT suspension was placed in a high-energy sonicator (SONICS-44349N) with an output amplitude of 60% for a total of 40 min, in intervals of 10 min
- the mixture was placed in an air-tightened box to completely remove the air bubble, and then transferred into a close mould
- the resin mixture was cured in an oven in three heating steps:
    - the temperature was increased with a ramp of approximately 1 C per min from room temperature to 75 C (167 F)
    - the temperature was held at 75 C for 3 hours before being ramped to 90 C (194 F) at a rate of 15 C (59 F) 180 per min
    - the temperature was then ramped to 110 C (230 F) at a rate of 20 C (68 F) 120 per min

Test Material Notes

All

Load capacity/force (how much weigh it can lift)

Hardness

Reach destination (yes or no)

Pneumatic Actuator

Curvature/pressure relationship

3D SMP

fiber 1: DM8530, Tg~57 ℃

fiber 2: DM9895, Tg~38 ℃

curvature over time

curvature at specific temperature

SMP/CNT Composite

Change in Tg

Max heat capacity/ heat-to-frequency relationship

Frequency-to-curvature relationship

Toxicity (yes or no)

Carbon Nanotubes

Outer Diameter: 50-80nm

Inside Diameter: 5-10nm

Ash: <1.5 wt%

Purity: >95 wt%

Length: 10-20um

Specific Surface Area: 60 m2/g

Electrical Conductivity: >100 S/cm

Bulk density: 0.18 g/cm3

True density: ~2.1 g/cm3

Paper

Discussion

The coil in Dr. Qian's paper has an 11 mm diameter [4].
We also looked at shape memory alloys and sh

References

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