

Spherically Actuated Motor (SAM) - Steven Peeples

The idea for SAM came to me when building robots at home. It takes at least three actuators to make a robot arm or leg articulate enough to be useful. Why can't a single actuator be built that operates like a shoulder or hip joint to take their place? Why hasn't NASA developed one of these? It would certainly save a lot of volume and mass. My research turned up some work on what is commonly called spherical motors. Although academic units exist, none have been commercialized because of the poor performance of current designs. I came up with a new "what if" idea and started bouncing it off fellow engineers, managers and technicians regarding manufacturability, viability and reliability. This led to a proposal which first won some internal branch seed funding and later center innovation award (CIF) funding. Now, a three degree of freedom (DOF) spherical actuator is under development that will replace functions requiring three single DOF actuators in robotic manipulators providing space and weight savings while reducing the overall failure rate.

The spherical motor has properties making it useful for a rolling/walking rover (Figure 1). In normal mode the rover would turn its wheels to accomplish exploration missions as always. If difficult terrain or sandy soil is encountered and wheels rendered useless, the walking property of SAM can be used to traverse the area. This innovation will add new versatility to NASA robotic missions.

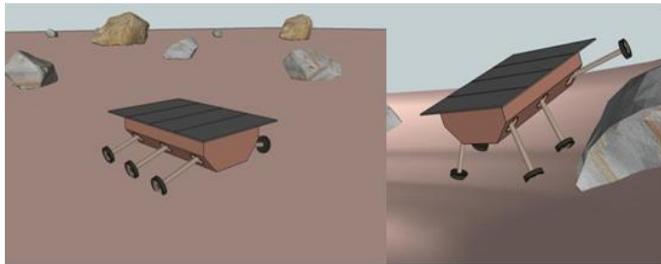


Figure 1 – rolling/walking rover

The problem with spherical motors not being in production is that everything in this proposal has to be made from scratch. The task required production of a sphere of magnetically conductive material containing coils of copper wires that make up the electromagnets. A model of one half of the rotor is shown in figure 2.



figure 2 - top and bottom of one half of a model of the rotor

A lever arm also had to be embedded to act as the output shaft. This unit fits inside of another sphere with similar magnetic materials and electromagnetic coils. Work began on the rotor first.

The first attempt required modeling the inner sphere in Styrofoam, making a mold of the Styrofoam, removing the Styrofoam and pouring the mold with the magnetic material. A router was used to cut the intricate grooves in the foam model.

Unfortunately, this process was not only messy, but the cutting bit was too wide to create the

proper grooves. Also, the grade of Styrofoam was poor, yielding unsatisfactory structural integrity for mold making.

A second attempt using a better grade of closed cell foam and a hot wire knife instead of a router to cut the grooves led to ideal results shown in figure 3.

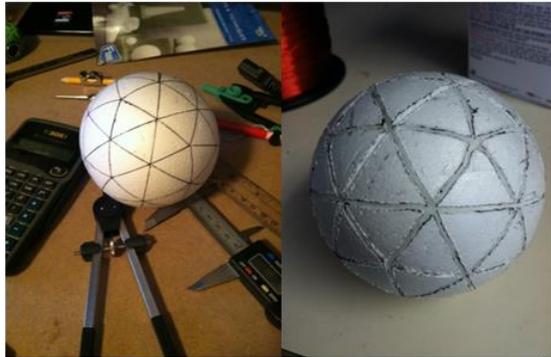


figure 3 - Styrofoam mold model with wire channels

The resulting mold model had a lever arm embedded and was cast in plaster in two halves. Once separated, the mold model was melted away with acetone.

Next, the mold was poured with the magnetic material and was allowed to set. It was noted during pouring that the plaster absorbed a great deal of the liquid present in the magnetic material making it difficult to completely fill the mold. Once cured, the outer mold was chipped away to reveal the magnetic core. Many details were not transferred due to the flow issue. Chipping the plaster from outside the sphere was labor intensive; removing it from the grooves was impossible. The process is illustrated in figure 4.



figure 4 – first mold attempt using plaster

A new mold using silicon rubber was poured around a plain sphere with lever arm inserted. The sphere was removed and wire grooves cut as before.

Electromagnet wires were inserted in the grooves and the model placed back in the mold.

The mold was filled with a white plastic resin filling the wire channels and encapsulating the electromagnet wires. Acetone was used to remove the Styrofoam as before.

The unit was cleaned and reinserted back into the mold to be filled with magnetic material. This method yielded an excellent prototype. Figure 5 highlights the new method. This construction method will be used for the stator as well.

There have been many failures that I've learned from and overcome to get this far; I'll certainly make many more moving forward toward the development of the working prototype. Being outright wrong, failing to produce a prototype and having to answer for those shortcomings are worthwhile risks for the potential reward of successful innovation.

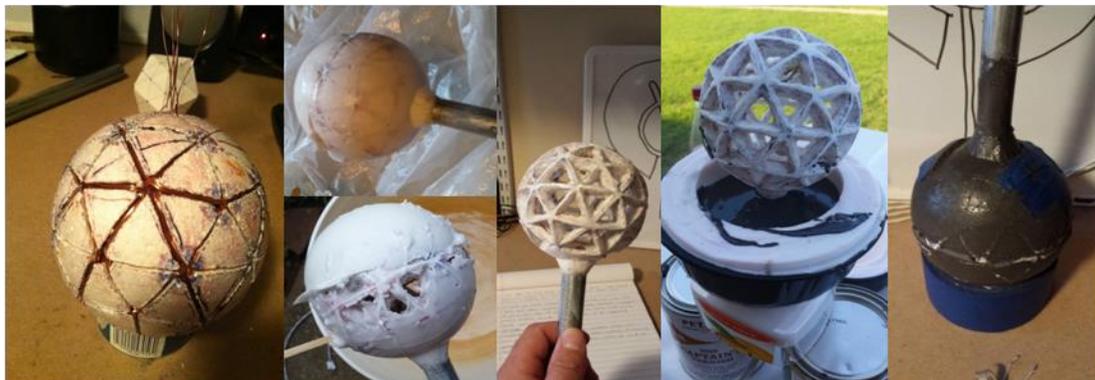


Figure 5 – final encapsulated wire process