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Preliminary Work on Gasket Making for Cooking Pots

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Preliminary Work on Gasket Making for Cooking Pots

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Introduction

Previous studies of the HotPot (see TR-04) and other panel-type solar cookers have indicated that lid gaps are a major cause of heat loss, and hence a limitation on the power and efficiency of low-power solar cookers. As they are heated slowly with solar radiation, internal temperature is the net effect of heat gain minus heat loss. This is a *transient heat transfer* problem. The same situation exists with electric-powered slow cookers, such as the CrockPot™. In order for the pot to reach temperatures sufficient to cook food with low input power (i.e. 75 W), it is critical to control heat loss. Users are even instructed not to lift the lid to view the food during cooking.

Figure 1. Closeup of the edge of the gasket of a CrockPot™

Well-engineered products such as the CrockPot™ use a carefully designed gasket to seal the lid tightly to prevent heat loss. In one model (Figure 1), the rubber gasket is molded into a shape with a "C" cross section, in order to maximize flexibility of the gasket to seal uneven gaps. This sophisticated gasket shape illustrates the attention that was paid to controlling the heat loss in this well-established commercial product.

The Dutch Oven pot selected by Roger Haines for his solar cooker has a molded silicone rubber gasket that does an excellent job of heat retention. Figure 2 below shows a closeup of this gasket. Its shape conforms closely to the inside of the pot.

Figure 2. Gasket of the Haines Dutch Oven lid.

Of course, all pot lids should include a small steam vent to prevent pressure or vacuum buildup, which is necessary even though it contributes a small amount to the heat loss. If the lid does not have a hole for a vent, the gasket must have two to four small notches cut in the gasket to provide a steam vent.

For future field projects, Solar Household Energy, Inc. seeks to develop efficient solar cookers using cooking pots that are locally available at low cost. This will eliminate the cost of shipping cooking pots with the solar cooker reflectors. Unfortunately, most locally-available pots do not have a lid gasket, and tests have shown that this limits their heat gain in slow cooking situations. However, tests have also shown that if the lid is well sealed, these pots can be efficient in solar cooking applications. (See TR-33 for these findings).

If a low-cost method could be devised to add a gasket to the lid, then many locally-available pots could be transformed into efficient pots for cooking with panel-type cookers -- which are generally the lowest-cost solar cookers.

This report documents our preliminary attempts at manufacturing gaskets for sealing the lid gap on the SHE-designed HotPot. The HotPot consists of a steel bowl, a glass lid, and a glass liner that rests under the steel bowl to contain internal heat. There are two lid gaps; neither of these has a gasket. Previous studies (TR-04) indicate that there are slightly uneven variations in the parts, which create small gaps. A resilient rubber gasket could fill these gaps and thus improve the performance of the HotPot, or any other similar pot/lid combination.

Prototype gasket maker design

This design is based on the properties of silicone rubber. It assumes that the viscosity and surface tension of freshly injected silicone can form a smooth bead without the need for a mold, provided that the silicone can be injected uniformly onto a pot lid. For the preliminary test we used GE Silicone I window and door caulk.

http://www.caulkyourhome.com/ge-silicone-I-window-and-door.php

The design is uses a commercially-available battery-powered caulking gun, the Ryobi 18-volt tool, which costs about $40. The interchangeable battery pack and charger costs another $40. This tool offers a variable-speed drive and works with any commonly available caulking or adhesive materials.

The gun was mounted in a cradle cut from pine wood, set at an angle and arranged to produce a bead along the rim of a pot lid. Figures 1 and 2 show the arrangement. A scissors jack was mounted under the gun cradle to permit precise adjustment of the position of the injector point on the pot lid.

Figure 2. Arrangement of caulking gun and turntable with HotPot mounted, side view.

Figure 3. Arrangement of caulking gun and turntable with HotPot mounted, top view.

A rotator for pot lids was constructed from a 20-inch diameter plastic “lazy susan” turntable which had ball bearings for stability. The turntable was rotated by use of a rubber wheel attached to an Arduino-driven stepper motor. (The code for the stepper motor is listed in the Appendix).

Gasket making procedure

For the preliminary test, a tube of GE Silicone Type I was used. The flow rate on the caulking gun was set to the slow speed. A tube of this caulk was cut open to provide a ¼-inch diagonal hole for injecting silicone. This material is non-toxic and cures in 24 hours. It has a Durometer A rating of 20, which is relatively soft.

Before the gasket was created, a series of preliminary rehearsals was conducted using sheets of paper and cardboard, just to learn the best speed to operate the turntable and the best flow rate for the silicone. We concluded that the flow rate should be set at the lowest speed on the gun, and the turntable was rotated at slightly less than 2 rpm, when used with a lid diameter of 12 inches.)

The stepper motor was started and the turntable was observed carefully. It was noted that the pressure of the rubber wheel against the turntable required a critical adjustment. If it was too tight, sometimes the stepper motor would stall. If it was too loose, sometimes the wheel would slip. Proper operation required continuous, smooth motion, so the pressure adjustment required a substantial amount of time.

The height and position of the injection point was set by adjusting the height of the scissors jack and turning the cradle. Several turns were taken while observing the lid for proper centering.

The actual making of the gasket thus only took 30 seconds. The caulking gun has a manual trigger which has to be pulled while holding very still. As soon as the rotation is complete and the starting point of silicone is reached, the trigger was released and the nozzle was moved away from the part.

The resulting bead of silicone was allowed to remain undisturbed for 24 hours for curing.

Evaluation of first gasket results

Despite all of the difficulties, I was able to make my first gaskets on the HotPot (lid and liner). Figures 4, 5 and 6 show closeups of the irregularities in this first attempt.

Figure 4 above shows a thin spot in the lid gasket when injection stopped at the end of the rotation.

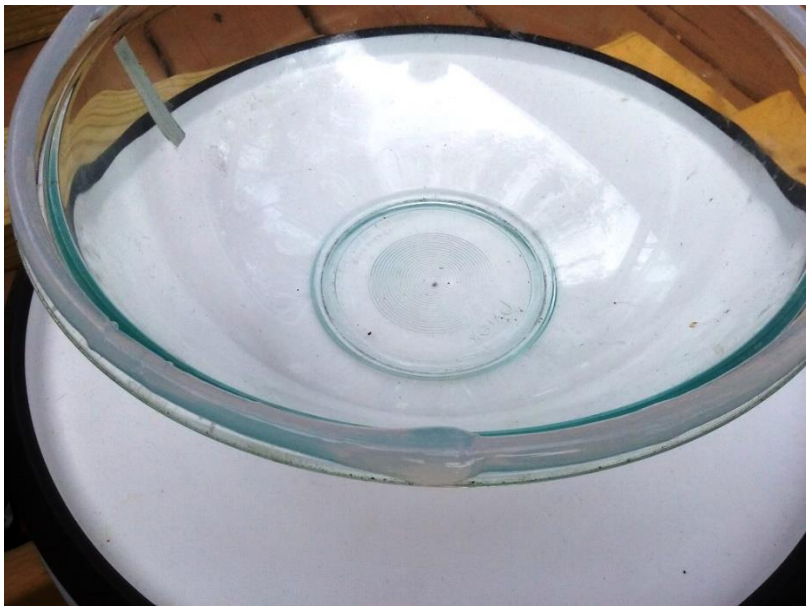

Figure 5 above shows a bulge in the silicone material on the liner gasket, which was a consequence of a momentary release and re-start of the trigger on the caulking gun.

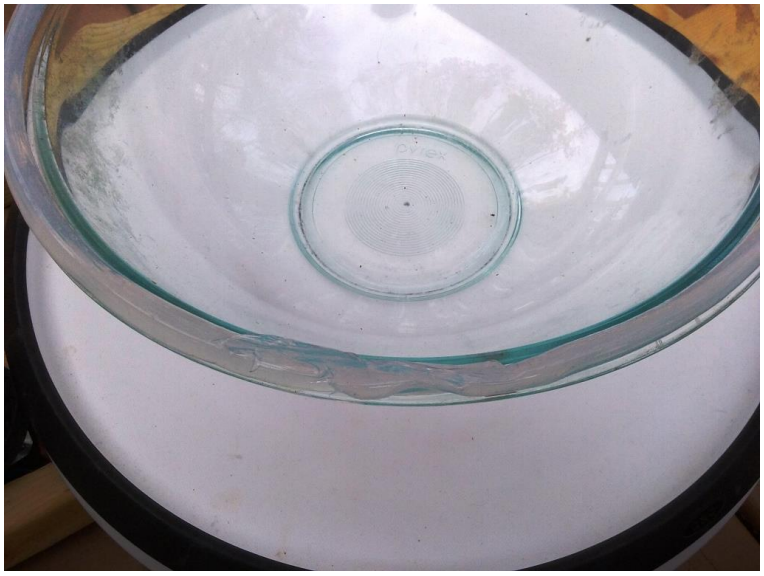

Figure 6 above shows a thin spot at the ends of the liner gasket. An effort to smooth this out manually was not successful.

Both the lid gasket and the liner gasket were rather thick, and the softness of the silicone material was not sufficient to permit it to seal lid gaps. Thus, as Figure 7 shows, it was possible to pass a strip of paper through the gap in some places.

Figure 6. HotPot lid with new silicone gasket, resting on HotPot metal bowl. A strip of paper could pass easily through the gap.

In summary, the results were as follows:

- The silicone rubber has very strong adhesion to glass. This is a desirable feature.
- There were a few variations in the diameter of the bead, due to unevenness at the start and end of the injection. These variations caused small but long gaps in the seal. These could be detected by sliding a strip of paper around the lid.
- The bead was too thick, because the hole in the caulk nozzle was cut too large. The thick bead was stiff, so it was not sufficiently flexible to fill in the lid gaps.

Evaluation of operation of the gasket maker

Injection of the silicone was a manual operation. The following steps were done:
1. Set the lid to be sealed on the turntable. Turn on the motor and watch it for a while, to ensure that it does not slip or stall.
2. Center the lid on the turntable. Rotate the turntable with the nozzle in position, to see that it is properly placed all the way around the lid.
3. Get into a comfortable position and pull the caulking gun trigger and hold it down.
4. Watch the nozzle carefully, and release the trigger when the bead is complete.
The trigger has to be released immediately, and the nozzle has to be moved out of the way. This means that the assembly cannot be completely rigid; it has to have a way of moving up or back very quickly.

During this operation, several things can happen to cause the bead to be non-uniform:

- If strong pressure is not maintained on the trigger, it may stop.
- The motor may slip or stall.
- After a few minutes, the exposed caulk within the tube gets stiffer. It may be necessary to start the bead on a sheet of paper before on the real piece, so fresh caulk is being injected.
- The size of the bead will be somewhat larger than the size of the hole in the tube. Start with a small hole and make it larger if necessary. Make sure to puncture the inner foil with a nail!
- Avoid any movement of the gun while operating. It is necessary to hold very still with a hand on the trigger. A solenoid or an external connection would be highly recommended.
- Obviously the trigger must be released as soon as the bead is complete. This is done by eye, so the piece must be well lit. However, the timing is so fast that it will probably result in either a small overlap or a gap. The silicone is viscous and the flow does not start and stop immediately.

Summary of evaluation:
Making a gasket by this method requires a high degree of stability and precise positioning. This was facilitated with the use of a scissors jack to adjust the height. However, the jack purchased had a small platform; a larger and more rigid one should be used. The assembly was too unstable to make uniform gaskets.

Recommended improvements in the gasket maker

The whole design needs to be more robust. The stepper motor slips if too loose a contact; it chatters if too tight. A lot of trial and error is needed to get it adjusted correctly. A larger stepper motor might perform better. Possibly a smaller drive wheel would help to reduce the load on the motor. However, the large wheel provides about the right speed (a bit under 2 rpm). If a smaller wheel were used, the Arduino code would have to be changed.

The manual trigger presented problems. There was barely enough room inside the cradle for a hand to hold the trigger, and only on one side. Because of the risks of movement, it would be much better to control the gun by an external switch rather than the manual trigger. The gun has Philips screws and can be taken apart to add external wiring. This would also allow the cradle to be smaller.

Note that only gaskets that have a round cross section can be made this way. To make a gasket in another shape, such as a the "C"-shaped cross section on the CrockPot™, it would be necessary to make two molds, coat them with a mold release, and inject the silicone into the molds. When cured, the gasket would be cemented to the lid.

Conclusions

The goal of this research was to find a low-cost method to make food-grade silicone gaskets for any cooking pots or lids. The result was not satisfactory. Sometimes it is necessary to report failures, not only successes. Perhaps this work will prevent others from similar attempts.

But even if the equipment and operations were perfect, would the gasket seal properly? This depends entirely on the softness of the cured rubber and how much it would bend to fill gaps. The answer is NO -- any kind of rubber, in a round cross section, is not soft enough to provide a seal if there are irregularities of any significant amount in the flatness of the pot lids (revealed by the paper test).

Instead of a round cross section, the bead has to be much more flexible, like the CrockPot™ gasket: thin and curled, i.e. "C"-shaped or thin walled tubing. In fact, these kinds of designs are very common in industry. Figure 7 below illustrates samples of several typical seals.

Figure 7. Sample industrial seals. Note the use of hollow spaces to add flexibility.

Future gasket making research

There are two tough problems, one technical and one economic:
1. How to make a very flexible, thin silicone rubber gasket.
2. How to make high-quality gaskets in low quantities at low cost.

The original gasket maker concept and design were based on the assumption that no mold would be necessary; the surface tension and viscosity of the liquid silicone would be enough to maintain a uniform gasket. This was found to be too difficult. A way to deal with this problem would be to make a mold for the silicone. That is the way that gaskets are manufactured in industry. But can that process be done in small quantities, at low cost? In other words, is it necessary for first-world, high-tech industry to be involved?

Making a mold:
1. A trivial way to make a "mold" would be to simply place the lid on the pot while the silicone is still curing. (Vaseline is a good mold release). However, this would simply

perpetuate the irregularities in the pot lid. If it were placed on the pot in a different alignment, gaps would appear. Also, it would not be flexible, tall and thin, as desired. (The proper alignment could be forced by using a pot that could only be oriented at one angle. But that would create another manufacturing requirement. And it would preclude interchangeable parts.)

2. Cut two long narrow strips of aluminum. Construct a mold and glue it in place. (A bad, messy idea.)

3. Shape the bead while it is curing with a special tool that removes the excess. For instance, a sharp edge placed on the rotating turntable would trim all silicone above a certain level. This would create a perfectly flat gasket, at least in principle. It would be messy. But it would not conform to the irregular shape of the pot edge, which is not flat.

4. Make two gaskets: one on the lid and one on the pot. Trim them both so that they are perfectly flat. Actually, if there is some flexibility in the bead, this might work even without trimming.

5. Find a much softer silicone, or a foam rubber that is very flexible. No mold.
(My first job with GE I was durometer 20.)
For example:
http://www.theengineerguy.com/Mold-Max-10.html

6. Glue a piece of silicone tubing to the lid to make the gasket. I tried this earlier; silicone caulk does not bond to cured silicone rubber tubing. And the tubing was too stiff. Maybe another adhesive and tubing would work.

7. Design a general-purpose gasket material that has the desired cross-section and that can be cut to any desired length, and glued to the lid. There will be a small gap at the ends, but this is needed in any case as a steam vent. This could be made of very thin-walled tubing, or split tubing.