![McGill]

New Honey Extractor for the McGill Apicultural Association

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Design 3 – BREE 495

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Executive Summary

For Engineering Design 2 and 3, BREE-490/495, we decided to undertake a project for the McGill Apicultural Association (MAA, see Appendix B). The project involves the construction of a new and improved honey extractor. The MAA has been around since 2007, and is fully student-run and governed. The mission of the MAA is to increase awareness about the usefulness of honeybees for sustainable agriculture, and to form a fully-functioning apiary at the Macdonald Campus of McGill University. As our client, they requested a honey extractor that is more efficient and easier to use than the one they have presently. They have conferred us with issues such as frames failing at a relatively high velocity (RPMs), a manual extraction process leading it to be extremely tedious, and finally having a significant amount of honey go to waste.

ANALYSIS AND SPECIFICATIONS

Goals and Objectives

In order to assure the satisfaction of our client, we needed to keep their needs and priorities in mind while designing our product. Our designs were focused mostly on creating a stable, easy to use extractor that maximizes efficiency, while keeping the costs low. With the new extractor, a motor will be added and the configuration of the frames will be changed so that they are all positioned radially around the center. These small, relatively inexpensive changes will make the extraction process much more efficient and less time-consuming.

The overall success of our project will be determined by the extraction and time-efficiency of the extractor. The operators will be mainly members of the MAA and any attendees of the honey extraction events hosted by the organization. Making the extractor more user-friendly and especially less time consuming are priorities when considering the different design options.

The tasks that the MAA gave us were relatively simple: to create an extractor with a motor, and the configuration of the frames are changed so they are in a radial position. Everything else that we designed for the honey extraction process were things that are considered to be helpful but not necessary. It is our goal to go beyond our client's basic needs and improve the process so that it is more enjoyable for everyone in the long run.

The bees at the apiary produce 250 kilograms of honey per year (Evan Henry, personal communication, 2014). The current extractor holds frames in a combined tangential/radial configuration. The extraction is done by hand, with the operator turning a hand crank to generate the force required to spin the frames around in the extractor. Honey extractors are generally very well made, and they last for a long time. This means that our design must be as sturdy and durable as possible, with little maintenance required.

Constraints

Because the MAA is a small student-run organization, their budget is extremely limited. This makes cost an important constraint to consider. Also, while the organization has several aspects it would like to improve, it has two very important needs that are considered to be priorities. The first priority is adding a motor to reduce the operator fatigue and breakage of the frames, and the second is to place the frames in a radial configuration only so that they do not need to be flipped halfway through the process.

Several times a year, the MAA hosts workshops which many local families attend. Because children will be in the vicinity of the honey extraction, or perhaps even performing some of the tasks themselves, it is important that the tools designed are not dangerous, and as easy to use as possible. Additionally, the materials used for our product need to follow the Canadian Food Safety Regulations. Because our product is exposed to honey which is sold to the students as well as the general public, it is our job to make sure no contaminations occur.

Overall, all designs must be done with operator safety as the first concern. Considering there will be a wide range of users of the extractor, our design must be simple and intuitive. By the end of the design, our clients must be fully satisfied with our project and see a significant improvement on their previous design.

Rheology

Rheology is the study of the flow of matter, which is usually in a liquid state but it can also be applied to “soft solids” (Wikimedia Foundation, 2015). Soft solids respond to applied force with plastic flow instead of deforming elastically. In the study of rheology, Newtonian fluids are the small group of fluids that have a single viscosity coefficient for a certain temperature (Wikimedia Foundation, 2015). This means that for a given temperature, the viscosity will remain the same even if the strain rate is increased (i.e. if it is mixed). Examples of Newtonian fluids include water, air, and thin motor oil (Wikimedia Foundation, 2015). In general, rheology is used to describe the behavior of fluids labeled as non-Newtonian. Some functions are required to quantify the relationship between the application of strain to a fluid and the subsequent reduction in viscosity (Wikimedia Foundation, 2015). For example, shaking or mechanically stirring a bottle of ketchup will reduce its viscosity. These kinds of fluids are called shear-thinning, or thixotropic (Wikimedia Foundation, 2015).

For most honey types, the rheological properties are described as Newtonian (Minerva Scientific, 2012). As mentioned in the previous paragraph, this means is that when the honey is mixed (shear is applied), the viscosity will remain constant even if the shear is increased. The viscosity of honey is dependent on two main factors: the temperature and the composition of the honey (moisture and sugar content, for example) (Minerva Scientific, 2012). When it comes to measuring viscosity, the temperature is usually kept constant so only the composition comes into play (Minerva Scientific, 2012).

Not all types of honey are fully Newtonian. Some types, notably makuna honey and heather honey, exhibit non-Newtonian characteristics (Minerva Scientific, 2012). When shear is applied in a viscometer, the apparent viscosity decreases (meaning it gets more liquid). If the honey is removed for a time and allowed to sit still, the apparent viscosity increases back to the original value. The main reason why this happens is because these honeys have a higher protein content than others (Minerva Scientific, 2012).

It is important to talk about viscosity when dealing with honey production, because it affects both the quality of the product and the specifications required for the processing equipment. Viscosity comes into play during every step of the production process, from extraction, to mixing, and finally the packing (Yanniotis et al, 2006). As mentioned earlier, viscosity is dependent on temperature, moisture content, and the presence of colloids or sugars in the honey. Moisture content can vary from year to year and is dependent on the harvesting and processing conditions (Yanniotis et al, 2006). Most commercial samples seem to vary between 15-25% (Yanniotis et al, 2006). If the moisture content is too high, it could cause the honey to crystallize rapidly, or it could even fuel the growth of yeasts (Yanniotis et al, 2006). The relationship between viscosity and temperature can be modeled using the Arrhenius equation, as follows:

$$\mu = \mu_0 \exp(Ea/RT) \qquad (1)$$

Where

μ = viscosity (Pa s)

= a constant (Pa s)

Ea = activation energy (kJ/mol)

R = gas constant (0.00831434 kJ/mol K)

T = temperature (K)

Many experiments have been performed to analyze the relationship between temperature, moisture content, and viscosity in honey. Figure 1 shows the relationship between moisture content and viscosity for temperatures ranging from 25 to 45°C.

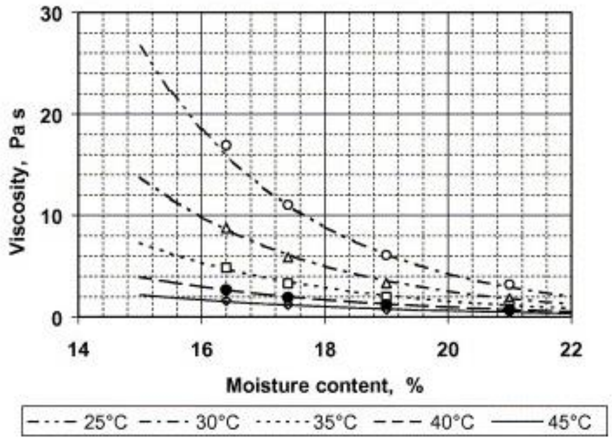

Figure 1: Viscosity of thymus honey vs moisture content at 25, 30, 35, 40, 45°C (Yanniotis et al, 2006)

What we can determine from this graph is that the changes in viscosity are much greater between moisture contents of 15-19%. At a moisture content higher than 19%, the variation in viscosity is much smaller. Similarly, the effect of temperature on viscosity is much weaker above 30 or 35°C. Although the above graph only shows the curves for thymus honey, the relationships for other types of honey are very similar (Yanniotis et al, 2006).

It is known that honey is a Newtonian liquid, although there is some literature demonstrating that it can exhibit dilatant or thixotropic behavior (Yanniotis et al, 2006). Six types of honey (listed next to the figure below) were tested for non-Newtonian behavior. Figure 2 shows that shear stress was always a linear function of shear rate. This indicates Newtonian behavior.

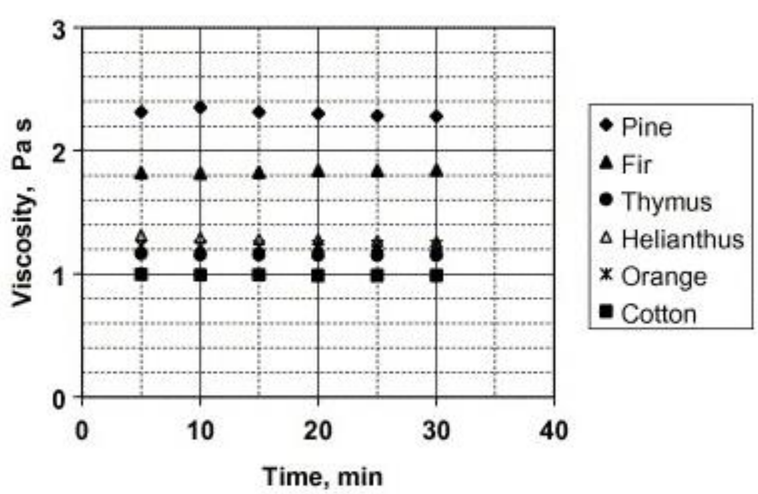

Figure 2: viscosity of 6 honey types vs. time at 45°C and 40s^{-1} shear rate (Yanniotis et al, 2006).

Although these honey types exhibit Newtonian behavior, that doesn't necessarily mean that our honey will be the same. The properties of honey depend largely on its botanical origin (Yanniotis et al, 2006). The MAA has never attempted to trace the botanical origin of their honey, so it is hard to know which flowers the nectar originates from. Furthermore, the honey has never been tested for moisture or sugar content. In our experience, the honey was very light and not very viscous, although this probably varies every season. These characteristics will make it easier to deal with during the extraction process.

Flow in a Pipe

In our design, we use a ½ inch (0.0127m) ball valve as the outlet for the honey. As shown in our schematics, this valve will be located on the bottom of the stockpot. In this situation, we must consider fluid mechanics concepts. For fluid flow in a pipe, we must first ask ourselves whether it is laminar, transitional, or turbulent flow. The Reynolds number is often used to determine the flow conditions. The Reynolds number is defined as the ratio of the forces of inertia to the viscous forces. For pipe flow, the Reynolds number can be calculated as follows:

$$\text{Re} = \frac{\rho\ V\ D}{\mu} = \frac{\left(\frac{mfr}{A}\right)D}{\mu} \qquad (2)$$

Where

ρ = density of liquid (kg/m^3)

V = velocity of flow (m/s)

D = diameter of pipe (m)

μ = viscosity of liquid (Pa s)

A = cross-sectional area of pipe (m^2)

mfr = mass flow rate of liquid (kg/s)

If the Reynolds number is between 0-2100, the flow is classified as laminar. A Reynolds number between 2100-4000 indicates transitional flow, and anything higher than 4000 is turbulent (MIT, 2015).

Before we can calculate the Reynold's number, there are several unknowns that we must determine. The diameter of the pipe is known, but the flow velocity and density/viscosity of our honey are not. The density and viscosity can be estimated using values found in literature. Estimating velocity is a little bit trickier. During our Design 2 course, we performed some experiments and found that it took about one minute to extract 9 kilograms of honey (there is about 1 kilogram of honey per frame on average). Assuming that our extractor will operate at the same speed, we can calculate the mass flow rate using this data.

$$9\frac{kg}{min} * \frac{1min}{60s} = \mathbf{0.15\ kg/s} \qquad (3)$$

Taking the density of honey to be 1420 kg/m³ (http://physics.info/density/), we can now calculate the volumetric flow rate.

$$q = \frac{0.15kg/s}{1420kg/m^3} = \mathbf{0.000106\ m^3/s} \qquad (4)$$

With this information, we can now calculate the velocity of flow in a pipe using the following equation:

$$V = \frac{1.273q}{D^2} \qquad (5)$$

Where
q = volumetric flow rate (m^3/s)
D = diameter of pipe (m)

Plugging in the values to (5), we obtain a flow velocity of **0.834 m/s.**

Using the data calculated above, we can now determine the Reynolds number. For our purposes, we will use the viscosity of pine honey with a moisture content of 18% and at a temperature of 25°C. Its viscosity is 14 Pa s (Yanniotis et al, 2006). By plugging our data into the Reynolds equation, we get find **Re = 1.07**. This is a very small Reynolds number, and it is due to the very small flow velocity (0.834 m/s) and its high viscosity (14 Pa s). As we expected, the flow of honey exiting the extractor can be classified as laminar. However, there is a major source of error in this calculation. The estimated time to extract the honey (one minute) also includes the time it takes for the honey to be extracted from the frames, flow down the side of the extractor and then out through the valve. Therefore, the time component is larger than it would be otherwise and the Reynolds number is no doubt an underestimation of the true value. Nevertheless, we can be quite certain that the flow will always be laminar due to honey's high viscosity.

While designing our extractor, we wanted to be sure to leave enough room between the bottom of the stock pot and the rotating basket. If not enough space was given, the level of honey could potentially rise to the point that it would interfere with the movement of the basket. Keeping this in mind, we left $2^{7/8}$" (0.0730m) between the bottom of the stock pot and the bottom of the lowest supporting ring. Knowing that the width of the stock pot is $21^{7/8}$" (0.556m), we can calculate the volume of this space.

$$V = \pi r^2 h \qquad (6)$$

Where
r = radius of cylinder (m)
h = height of cylinder (m)

By plugging in the appropriate values in (6), we find that the volume is **0.0177 m^3**. Taking the density of honey to be 1420 kg/m^3, we find that it would take **25.1 kg** of honey to fill up this space. Because there is on average one kilogram of honey per frame, and 8 frames in the extractor, there will never be more than roughly 8 kilograms of honey in the extractor. As long as the valve is kept open, there is no danger.

Physics of Honey Extraction

After removing the wax covering the honeycomb, a process known as "uncapping", a force must be applied to the honey to remove it from the honeycomb. In our honey extractor, the uncapped frames are placed inside a basket, which then rotates inside a drum. The rotation of the frames creates a force which allows the honey to be extracted. To explain how this works, we need to talk about centripetal and centrifugal forces.

First, centripetal force is a *real* force that counteracts centrifugal force and prevents objects from flying out when they are going in a circle or along a curved path (Diffen, 2015). Thus, it keeps the objects going at a uniform speed. The direction of this force is along the radius of the circle, and points towards the center from the object. A good example of this would be the moon orbiting around the Earth. The force of gravity provided by the mass of the Earth keeps the moon tethered, much like the tension in a rope keeps the ball in place during a game of tetherball. The following image helps illustrate this concept:

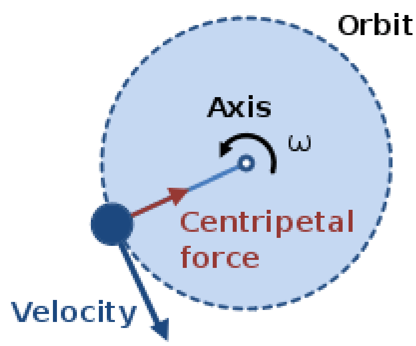

Figure 3: Direction of centripetal force (Diffen, 2015)

Second, centrifugal force is not a *real* force. It is the *tendency* of an object moving along a circular path to be pushed away from the center (Diffen, 2015). This means that there is a lack of centripetal force. This tendency is observed because objects moving in a straight line want to continue moving in a straight line. This property is called inertia and is what makes objects moving in a straight line resist forces attempting to make them move along a curved path (Diffen, 2015).

Applied to our situation, the frames are held in place by the basket and therefore do not fly out from the center when we rotate them at high speeds. In other words, the centripetal force is equal to the centrifugal force. However, because the wax has been removed, there is no significant force holding the honey in place, only the shear between the honey and the sides of the honeycomb (which is due to the viscosity of the honey). The honey is subjected to centrifugal "force", and is removed from the honeycomb by flying outwards towards the inner face of the stock pot.

Inertia

The moment of inertia of an object is also known as rotational inertia and indicates an objects resistance to rotational acceleration. In our design, the moment of the inertia of the basket must be calculated to determine the drill strength required to spin the basket. Inertia is an additive property. Therefore, the parts of the basket can be calculated separately. Once calculated, the moment of inertia multiplied by the angular acceleration is used to calculate the torque required.

The moment of inertia had to be calculated for the entire basket. The basket is composed of the brackets, shaft, concentric circles, and the horizontal and vertical flat bars.

The circles are treated as cylinders, their moment of inertia given by the formula:

$$I = Mr^2$$

M = Mass, lb
r = radius, in

The shaft follows the same equation. The brackets and vertical flat bars are assumed to be point masses and also follow the same equation. The horizontal flat bars that hold the basket together are treated as rods and follow the equation:

$$I = \frac{ML^2}{12}$$

Adding all of the moments together, a total moment of inertia was calculated to be 1016.25 lb in^2 (0.30 kg $m^{2)}$). See appendix A for complete calculations. Calculated previously in BREE 490, an angular acceleration of 20.94 $radS^{-2}$ was found by using the formula:

$$T = I.\alpha$$

T = torque, N m
I = moment of inertia, kg m^2
α = angular acceleration, rad/s^2

A torque of 6.28 N m, or 4.63 lb ft was calculated. The torque was then used to calculate the power required from the drill using the following:

$$T = \frac{P * 33000}{2 * \pi * rotational\ speed}$$

T = torque, lb ft
P = power, hp
Rotational speed = 104.72 rad/s (From design 2)

The power of the drill required was 0.095 horsepower. Considering the average hammer drill has approximately 1100 W (~1.5 hp) of power (Dewalt, 2015), almost any drill will be capable of spinning our basket.

Food Safety Regulations

Kitchen stock pots can be made from a diverse range of materials. These materials can possibly diminish the food quality, in this case honey. In some cases, there are certain materials which need to be analyzed. When it comes to Canada's Food Safety Regulations, as long as the stock pot is well maintained and used appropriately, it will be considered safe.

With honey having an average pH of 3.9, it is relatively acidic (Carolina Acquarone et al, 2006). When aluminum is exposed to acidic substances, a layer of aluminum oxide is deposited on the surface of the aluminum material (CA Grubbs, 1999). This phenomenon is known as anodization. When aluminum is anodized, it has a hard non-stick surface making it not only resistant and durable but easy to clean as well. In the end, anodization reduces aluminum leaching into foods.

For tear resistance, stainless steel is a material to be considered made from a combination of metals and iron. Like aluminum, it is inexpensive and long-lasting. Health effect concerns relating to stainless steel are attributed to iron, nickel and chromium. However, under Canadian Food Safety Regulations, the surface, equipment, utensils, and containers of the metals we are dealing with, must be:

I. Durable and corrosion-resistant;
II. Can be taken apart and withstand washing, cleaning or disinfection;
III. Non-toxic and not rotten or in the process of rotting;
IV. Nonabsorbent and waterproof;
V. Unaffected by the products and manufactured in such manner that it does not alter the products
(Brigitte Cadieux, personal communication, 2015)

Furthermore, these surfaces must be smooth as well as free of loose particles, bumps, cracks, pitting, and flakes. All parts of the extractor manufactured by methods other than welding must be able to be taken apart for washing, cleaning, disinfecting, maintenance and inspection. Aluminum and stainless steel are well known in the food industry today and successfully follow the guidelines of these regulations.

In addition to the metals, the ball bearings supporting the shaft are also in contact with the honey. The powdered paint coated on the stainless steel ball bearing follows safety guideless as there are no restrictions on the use of powdered paint in a food facility (Brigitte Cadieux, personal communication, 2015). This is because the paint is lead free and does not result in any flaking or peeling. The ball bearing surface is also smooth, which avoids bacteria build up, and is able to withstand repeated sanitation. Still, there is a possibility of a grease leak from the ball bearing. For grease contamination prevention, a stainless steel cage was built around the ball bearing for protection.

Lastly, the valve located underneath the aluminum food grade stock pot also interacts with the honey. Initially, a polyvinyl chloride (PVC) valve was purchased to be installed on the extractor. Even though PVC pipes are widely used for piping and food packaging, World's Health

Organization’s International Agency for Research on Cancer (IARC) claims PVC is the most toxic plastic. Phthalate DEHP is an organic compound that is often added to PVC to increase flexibility. This harmful chemical has been found to leach out of the PVC when in contact with food. Not only is it unsafe when in contact with food, but PVC is also extremely damaging towards the environment since the construction of PVC releases dioxins such as carcinogens (Quebec Provincial Government, 2009). Therefore, the PVC valve was replaced most favorable material: an aluminum valve.

The surfaces of equipment must be resistant with interactions of honey so there is prevention for risks of pollution, contamination and deterioration. Surfaces must not be responsible for any impact of flavors, odors and impurities on the honey.

PROTOTYPING

Modeling and Simulation

For design 2, our original extractor proposal was 9 framed with a cone shaped bottom:

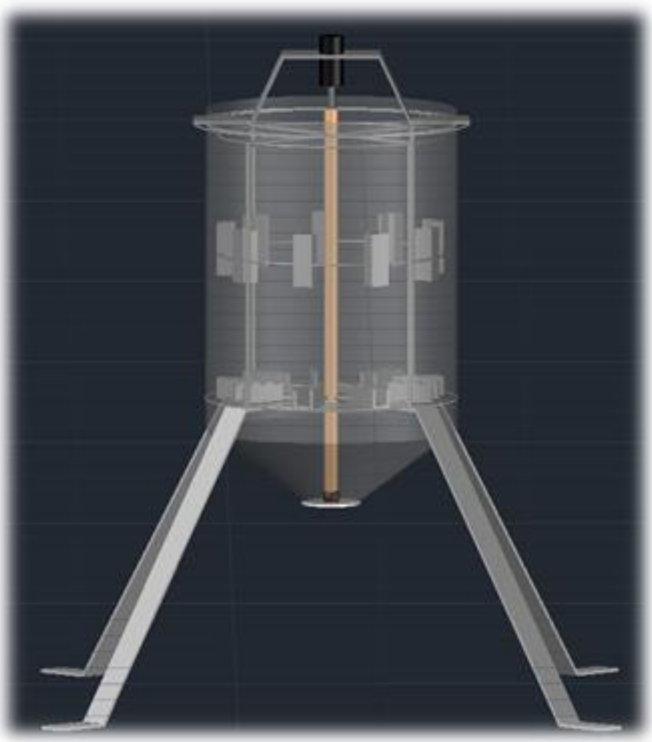

Figure 4: Original Design ((Produced on AutoCAD, 2014)

However, major modifications had to be made once the proper stock pot was purchased. The 9 frame extractor became 8 due to downsize of the stock pot. Moreover, the cone shaped bottom had to be disregarded considering we didn’t want to risk the structural integrity of our stock pot. Since our budget was limited, buying a second stock pot was not an option. During design

3, we then decided on appropriate dimensions shown in the figures below. Note that all dimensions are represented in inches.

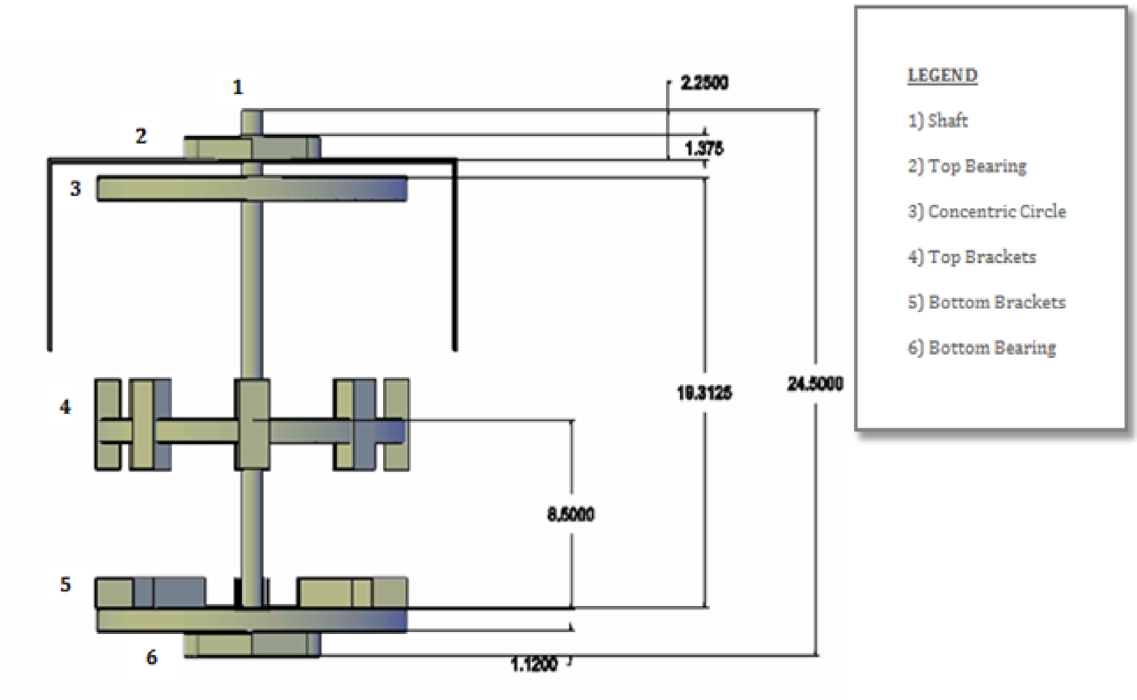

Figure 5: Adjusted Dimensions of 8 Frame Basket (Produced on AutoCAD, 2015)

Figure 6: Overview of Final Design (Produced on AutoCAD, 2015)

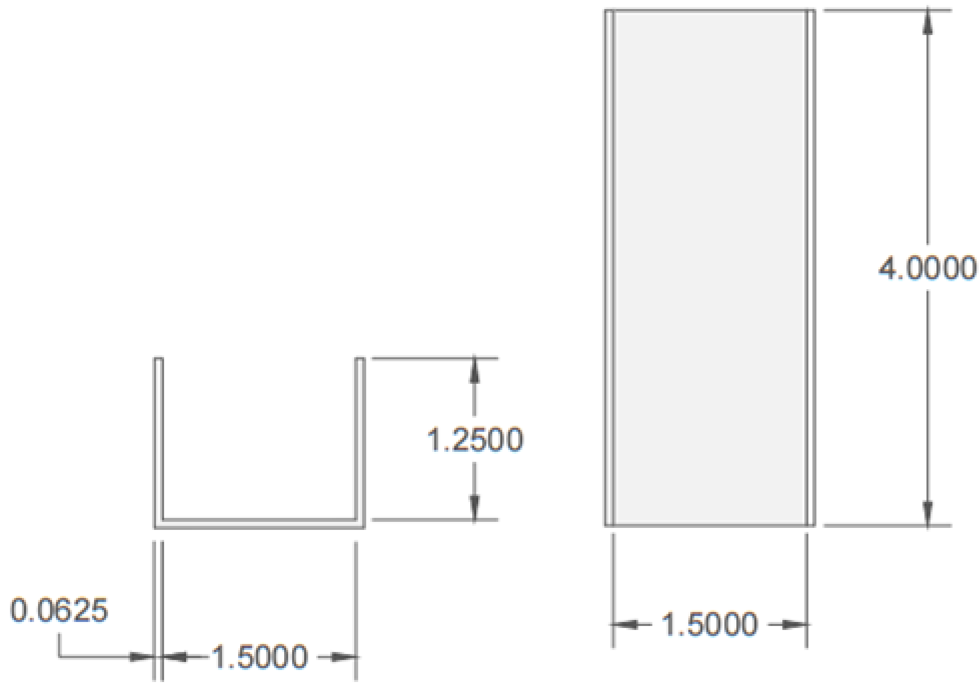

Figure 7: Bracket Dimensions (Produced on AutoCAD, 2015)

Construction and Documentation

After completing our design, we made multiple AutoCAD models and started collecting parts needed to build our honey extractor. We needed different materials for this process keeping in mind the safety, cost and food standards. All of the stainless steel flat bars were purchased at Acier Lachine, the aluminium stockpot from Tzanet a kitchen supply store in Montreal and the specific bolts, nuts and more from Reno depot or online. The shop at the Macdonald Campus of McGill University was open for us to use the different machines available to make our prototype thanks to Scott Manktelow, the shop manager. His expertise and insights were of great help throughout the project.

Below is a list of all the materials and tools needed as well as the different steps completed for the construction of our honey extractor.

Materials:

- 36 feet 1 inch thick stainless steel flat bar
- 12 feet 2 inch thick stainless steel flat bar
- 50 cm x 60 cm stainless steel sheet
- Two 1 in ball bearings
- Four 5/16 in bolts, nuts and washer
- Two 3/8 in bolts, nuts and washer
- Two 3/8 flat headed screws, nuts and washer
- 120 quarts aluminium stock pot
- 80 cm long stainless steel 1 in hollow shaft
- 3/4 in stainless steel shaft (10 cm long)
- Thread seal tap

Tools:

- Band saw
- Bending brake
- Tin shear machine
- Drill press
- Mill
- Corded drill
- Grinder
- TIG welding
- Stick welding
- Spot welding
- Bench grinder
- Stand clamp
- Sand blower
- Radial arm drill
- 3/8 in countersink bit
- 3/8 drill bit
- 5/16 drill bit
- Lathe
- Wrench set
- Allen key set

After collecting the required material, we decided to start building our honey extractor by making the brackets supporting the honey frames. To do so we took a flat sheet of stainless steel that we measured and marked according to the dimensions in the **Figure 8** below:

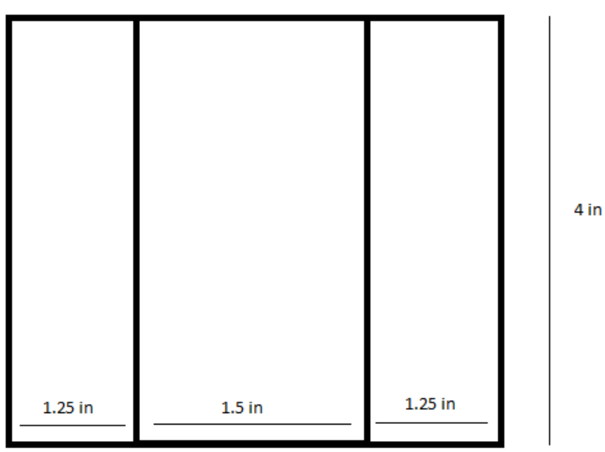

Figure 8: Bracket Model

We used the tin shearer to cut out 4x4” plates. After cutting all sixteen plates we used a bending brake machine at the 1.25” mark to bend at a 90 degree angle the side of the plate. We also grinded the edges of the brackets to reduce sharpness and potential hazard during operation of the extractor.

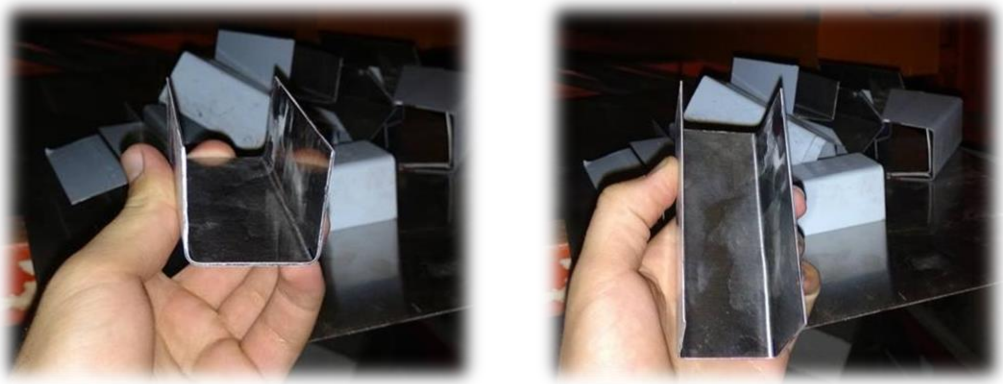

Figure 9a & 9b: Bending of stainless steel sheet to make brackets

After the brackets were made, we measured and cut the 1” flat bars to make the three outer circles, the two bottom circles supporting the brackets as well as the vertical bars connecting the outer circles. We cut the three outer flat bars with a band saw to 54” and rolled them into circles. The bottom circles are also rolled with 34.6” and 44.6” respective circumferences. The circles are then TIG-welded. The welds were grinded and cleaned. The four 19” vertical flat bars were then spot-welded to the top two outer circles.

Figure 10: Busch band saw used for cutting stainless steel flat bars

Figure 11: Roller used to make the three outer circles as well as the two bottom support circles

Figure 12: Grinding process

As shown in figure 12, the brackets are also spot welded to the middle circle. 1
They are positioned at 8.25” from each other except for the last one that was placed 7.75” from the previous bracket. The small error is due to the curvature of the flat bar. The spot welding method allowed us to save a lot of time compared to TIG welding. This method is a process in which contacting metal surfaces are joined by the heat obtained from the resistance to an electric current. The TIG-welding method on the other hand uses a non-consumable electrode and a stainless steel filler to produce the weld where the weld area is protected from atmospheric contamination by argon gas.

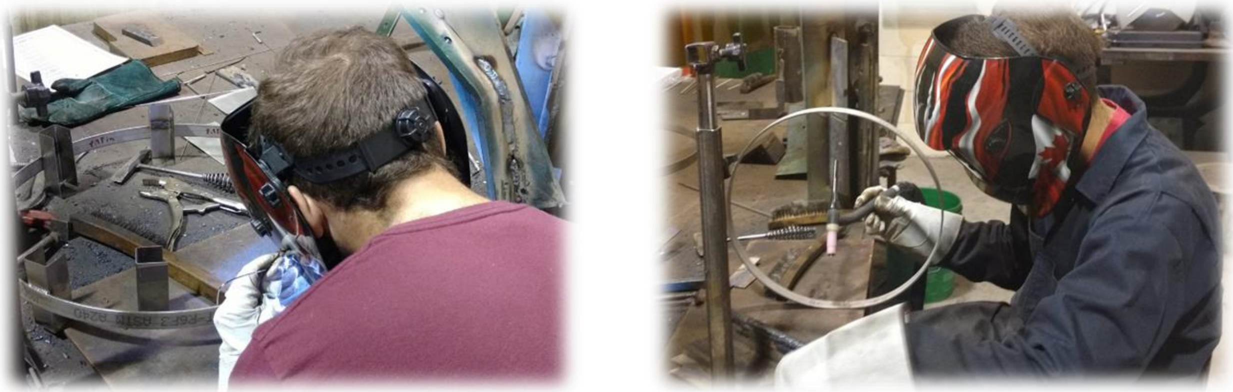

Figure 13a & 13b: TIG welding of supporting circles

Figure 14a & 14b: Spot welding of vertical flat bars and brackets

To connect the bottom circles we will use a 2" wide flat bar that goes across the three bottom circles as shown in the AutoCAD drawing below

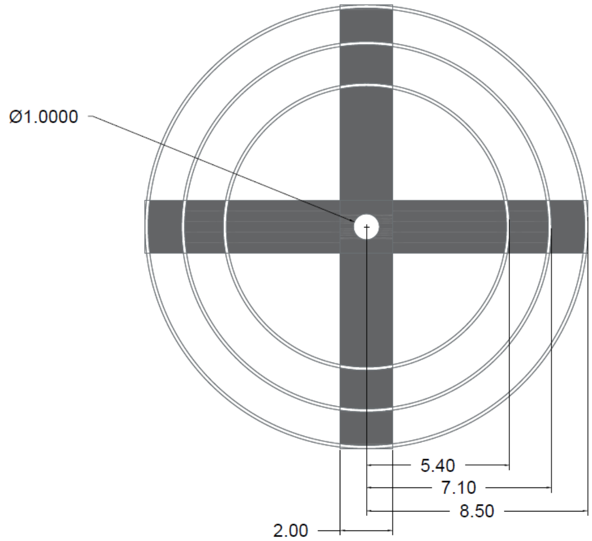

Figure 15: dimensions of the three bottom circles with respect to the flat bars across

Before welding the circles to the bars we need to drill a 1 inch hole for the shaft to go through. We also need to drill a 1" hole in the 2" wide flat bar supporting the top bearing, so all three flat bars are drilled together. The milling machine was used for this process, it was done incrementally since stainless steel is difficult to machine.

Figure 16: Drilling of the 1" hole in the stainless steel plates

When the 1" hole was drilled, we fit the shaft in the hole and measure 2.5" from the bottom to leave room for the bearing that will connect the basket to the aluminium stockpot. The 17" long (2" wide) flat bar was then TIG welded to the shaft and onto the three bottom circles forming the bottom half of the basket. The brackets were then spot welded over the circles at 8.25" apart as shown in the **Figure 17** below (except the last bracket that's at a spacing of 7.75in due to curvature error).

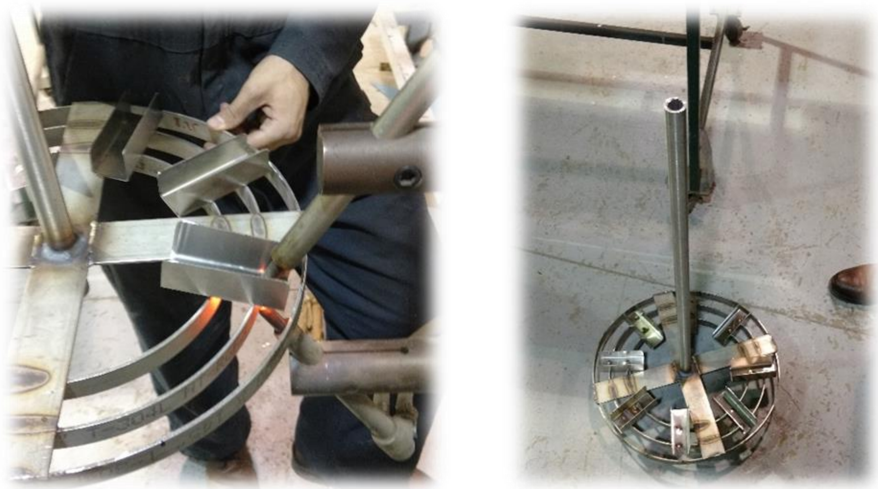

Figure 17a & 17b: Spot welding of brackets over bottom circles and overall view of the bottom half basket

Before connecting the bottom and top half of the basket we also needed to weld the top 2” flat bar to the shaft 19 3/8” above the bottom weld. The bottom and top half of the basket were finally be connected and TIG-welded together. Before welding it is important to make sure the top 2” flat bar across does not stop the frames from entering the basket and resting on the brackets. **Figure 18** below shows the finished basket.

Figure 18: Finished basket holding a honey frame

Once the basket is made, we needed to connect it to the 120 qt aluminium stockpot. First we measured and mark the position of the bottom bearing. We had to make sure the bearing is well centered at the bottom of the stockpot. Using a corded drill with 3/8” bit safely mounted we drilled the two bearing holes. After ensuring the two flat headed screws fit well through the bearing and the hole we flipped the stockpot and with a countersink 3/8” drill bit we made sure the flat headed screws were flush with the outside of the stockpot. The bearing was then bolted to the aluminium stockpot and the basket was mounted and tested for the first time.

The drainage valve needed to be made as well before mounting the basket onto the bearing. We used a radial arm drill to make the ½” hole at the measured location on the edge of the stockpot. Drilling through aluminium didn’t require us to use as much oil as for the stainless steel since this metal is much easier to machine. The aluminium valve is then taped using a polytetrafluoroethylene film to better seal the valve that was then mounted in the hole and tested with water for leakage. The basket is then attached to the bearing and tightened around the shaft.

Before attaching the top bearing to the shaft we need to mount on the stockpot the bearing support. First using a 5/16” drill bit we drill two holes on each side of the stock pot at 4 and 13 centimeters below the edge. To make the bearing support, a 38’’ long and 2’’ wide flat bar is measured and cut. The flat bar had a 1” hole previously drilled in it with the mill to allow the shaft to fit through it before attaching it to the top bearing. Using a bending brake both ends of the bar are bent at the 8” measured mark to make a 90 degree angle as shown in **Figure 19** below.

Figure 19: Top bearing mounted on support

This was done so that there is enough height to raise the bearing above the basket. The drill holes as well as the bearing marks are labeled on the stainless steel flat bar. Due to the properties of this material a drill press is required to drill the flat bar. We mounted a 5/16” bit and drilled the side holes and used a 3/8” bit to drill the bearing holes to attach it. Before mounting the bearing support on the stockpot we need to grind the 1” hole to make sure the hole is loose around the shaft so it doesn’t rub on the flat bar when spinning. Once this done, the top bearing is mounted on the support and the bearing is tightened around the shaft.

Figure 20: Drill press used to drill holes in the top bearing support flat bar

Finally, before connecting the drill to the shaft we machined using the lathe a metal piece that has a 0.75” diameter on one end and a 0.5” diameter on the other. This piece is then mounted and stick welded to the top of the shaft. The weld is cleaned using a grinder.

Figure 21a & 21b: Machining the drill connector piece using a lathe

The extractor is now complete and can be tested:

Figure 22: Final extractor

Throughout the construction of the extractor we came across multiple challenges that we overcame either by changing our method or redesigning a specific part of the extractor. The most important change in the design happened when no stockpot larger than 120 qt was found in the Montreal area and we had to lower the size of our basket to 17”. Another example is how we originally meant to use circular rods to connect all three outer circles but ended up using flat bars. The reasons behind it are simple. First, it is easier to roll flat bars compared to rods and a flat bar maximizes the contact surface which help strengthen the weld. Different methods of welding were also used throughout the project. Initially we started with the stick welding method but quickly realised that the area needs to be cleaned afterwards as a layer of dirt covers the weld which doesn’t meet the food standards for our extractor. We then started using TIG welding and spot welding instead. TIG welding is much cleaner but more complicated, so assistance was often needed and spot welding was easy and quick to do but could only be used for thinner metal pieces.

TESTING

Motor Test

One issue noticed immediately was that the drill wobbled as soon as it rotated. This was easily attributed to the machined connector piece. Considering the piece did not fit as tightly as originally intended, it might have been welded on a slight angle. If not corrected, this small problem will not only damage the drill being used, but it also will be uncomfortable for the operator of the extractor.

Before delivering the extractor, this piece must be corrected. To do so, the top of the shaft will have to be cut and a new connection piece must be constructed and installed. This would require a small piece of steel rod that has a diameter greater than 0.760".This size is important in order for the rod to be machined down to fit as tightly as possible into the shaft.

Hitachi Drill

This drill fit well on to the piece made to reduce the shaft diameter to ½". The metal chuck fit snuggly onto connection piece and did not loosen or slip off. This metal chuck is ideal since it can be tightened well with its key. However, tightening and untightening after each use might be inconvenient for the user. The corded drill of course would not run out of power throughout extraction. However, this drill only had one speed and after long-term use, would fail. The high rpm, lower torque, and the unknown use factor this drill, although effective for short term use, does not suit our needs.

Figure 23: Bosch Drill (Rona, 2015)

Two-Speed Drill

During our testing phase, we also experimented with a two-speed drill unit. The model used was the Hitachi FDV16VB2 5/8" hammer drill. A switch located on the top of the drill allows us to switch between two modes. The first mode allows the drill to rotate at 0-1000 rpm, providing an increase in torque. The second mode allows it to turn at 750-2500 rpm. Considering our extractor only needs to rotate between 150 and 200 rpm, using this drill will make it easier to achieve the lower speed required if used in the first mode. The lower rotations per minute will result in a higher torque, which will reduce the stress on the drill parts in the long run.

Water Flow Test

To simulate a honey extraction process, we poured water into the extractor to see how the liquid would behave. We wanted to see if the honey on the bottom of the stock pot would have the tendency to flow to a certain area. What we observed was that the honey tends to flow towards the outer edges of the stock pot, indicating that the bottom is not completely flat, but slightly raised in the middle. This could be a problem in the future because there will be a layer of honey on the bottom of the pot that will pool away from the outlet and will not drain on its own. If this is the case, the extractor will need to be tilted sideways slightly in order to extract the remaining honey.

Risk Analysis

Building an efficient product also includes it being safe and minimizing all potential risks. Since the MAA attracts many families during extraction season, our product needs to be safe and user-friendly to the public, especially to those who do not have experience with honey extractors. Because we had to downsize our stockpot from 140 to 120 qt, the top section of the frames were exposed openly;

Figure 24: Top Section of Extractor

We therefore decided to build circular barriers of our leftover stainless steel sheets to prevent any risks of materials or frames flying out while the extractor is spinning, and causing injuries.

The weight of the entire extractor is also a concern. Because it is a heavy and large product, it is important to make sure it is stable at all times to minimize the risk of it falling. This is why we are designing a tripod stand for the extractor to sit on, with enough room for a bucket to sit underneath the valve. Not only will this assure stability, but will be efficient for honey collection.

Cost Analysis

Currently, the MAA has a MAXANT Nine Frame Extractor, Power 9-F. If purchased brand new, this extractor retails for a total of $794.99. Because MAA is a student run association, budget is extremely limited. Addressing this constraint meant that building a new honey extractor should total to a significantly lesser price. During design 2, we applied for a fund application (see Appendix D), and were unsuccessful with the grant. Though we were lucky enough to receive a budget from MAA and after discussion with MAA president, Kamil Chatila, we were granted $450.00 for materials.

After thorough research as well as references from Scott Manktelow (see Appendix C) and head of the dietetics food lab Mr. Paul-Guy, we were able to attain the materials needed with the best cost to quality ratio. Our product totaled to:

Stainless Steel Rod 1/8 x 1 inch (3)……………………………………………………………………$56.04
Stainless Steel Rod 1/8 x 2 inches (1)…………………………………………………………………$38.22
Ball Bearing (2)………………………………………………………………………………………………$18.40
Screws/Nuts/Bolts/Washers………………………………………………………………………….$28.00
Aluminum Stock Pot………………………………………………………………………………………$215.58
Porter Cable Drill 7.0 AMPS…………………………………………………………………………..$110.00

TOTAL: $466.24

With this, $16.24 over the budget provided by the MAA. Although we could have split the remaining cost by four, we decided to help the MAA by fundraising with samosas and succeeded by raising $70.00. All remaining money went towards MAA future projects.

Comparing the cost of a brand new MAXANT honey extractor versus one built from scratch, a total of $328.75 was saved. It is important to note that the MAXANT Nine Frame Extractor is a manual one with no motor mounted, whereas the one we produced includes a drill. Although the one we produced does only have room for eight frames, they are all placed radially instead of three tangentially. This in end saves additional time since there is no need to switch the sides of the tangential frames halfway through the extraction process. Overall, although we went over our budget, we were still able to cover all of our costs.

OPTIMIZATION

Cylinder

Although the stockpot was a simple and effective piece to collect all the honey while also meeting food standards, a custom built cylinder with certain features would improve the extraction process. An aluminum cylinder would firstly have an increased height. The basket on the built extractor currently protrudes 2" from the cylinder, which may be a hazard to users and possibly result in honey escaping. If our cylinder were to be approximately 4" taller, these issues would be avoided.

Secondly, a custom cylinder would include a sloped bottom that would funnel the honey to one side. Although our extractor should drain properly, it may require tilting similar to the MAA's old one.

Finally, a custom extractor with a larger diameter would allow for the large frames to fit in the extractor, making it more flexible to users. Although the apiary uses primarily smaller frames, they often lend their equipment to other beekeepers in the area. The capability to use both frame sizes would make the extractor practical for all users. A larger extractor would also allow more frames to fit.

Weight

The weight of the basket is 20.23 lbs. This weight combined with the wide stock pot makes the extractor awkward to carry by one person. If a new model was created, lighter materials could be used depending on the machinery available. Specifically, aluminum produced in the required shapes would reduce the weight of the basket by 63% (assuming density of aluminum to be 0.098 lb/in^3). A lighter extractor may reduce the stability of the extractor while spinning, but would make it much less difficult for users of different strengths to move.

Speed Control

One of the problems with the honey extractor that the Apicultural Association uses currently is if the hand crank is turned too rapidly, the frames will get damaged because the force is too great. The model of drill used for testing the extractor, the Hitachi DV16VSS, has a maximum speed of 2900 rotations per minute, which is much greater than the maximum recommended speed of about 160 rpm. If a similar type of drill is used for the extractor in the future, we can expect that more frames will get damaged if the operators are not careful enough. To reduce the risk of this happening, we could implement a safeguard to prevent the drill or basket from turning too fast. On the DV16VSS, there is a stopper located just behind the trigger that could be used to this end. Pulling the trigger and pushing the stopper keeps the drill turning at the desired speed, which is useful for continuous operation. It is simply necessary to find the desired speed of rotation so the stopper can be pushed to keep the drill turning at a constant speed. This prevents the user from accidentally pushing the trigger too far in. The location of the stopper button is shown on this image:

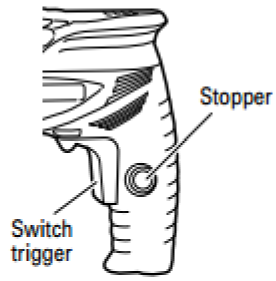

Figure 25: Location of stopper just behind trigger (Hitachi, 2015)

In the User Manual for the Hitachi DV16VSS, it is mentioned that when the drill is operated in a continuous fashion, the operator must conduct a no-load operation for 5 seconds after completing every job (Hitachi, 2015). So, after the honey is extracted, the drill must be disconnected and operated with no load for 5 seconds.

In our experience, the operator's arm and wrist experience a lot of torque when the drill is operated. If the user is unprepared, injuries could potentially occur. For this reason, we recommend that the operator establishes a foothold, and holds the drill firmly with both hands before pulling the trigger.

Stability

As mentioned earlier, the piece to connect the shaft to the drill was not welded on straight. Machining a new piece that will fit tightly will be welded on perfectly vertically in order to correct the slight shaking when rotating.

CONCLUSION

Taken into account our constraints and persevering through manufacturing issues, we were able to produce a working extractor that suits the needs of the MAA. Not only did we learn a great deal in all areas of engineering from constructing the extractor, but we also appreciate the opportunity given to us to strengthen the Macdonald Campus community as a whole. Though there are still minor details needed to be worked on the extractor, such as mounting a permanent drill, we aim have the extractor completed by extraction season in September.

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APPENDICES

Appendix A

<u>Exterior ring @ 8.5”</u>
Density of 304 stainless steel = 7480 kg/m^3 = 0.270 lb/in^3 (Engineering toolbox)

Flat bar dimensions:
Thickness, t = 1/8”
Width, w = 1”
Length, l = 2πr = 2π(8.5”) = 53.38” → 54”

Volume, v = twl = 6.75 in^3

Mass, M = density x volume = 1.82 lb

I = Mr^2 = (1.82 lb) $(8.5”)^2$
I = 131.50 lb in^2

3 rings of this radius

3 x 131.50 lb in^2 = **394.50**

<u>Middle ring @ 7.1”</u>
Length, l = 2πr = 44.6 in
v = thl = 5.58 in^3
M = 1.51 lb
I = Mr^2 = **76.12 lb in^2**

<u>Small ring @ 5.5”</u>
Length, l = 2πr = 34.6”
v = thl = 4.33 in^3
M = 1.17 lb
I = Mr^2 = **35.39 lb in^2**

<u>Brackets</u>
Assume bracket is point mass

Bracket volume = 4” x 4” x 1/16” = 1in^3
M = 0.27 x 1 in^3 = 0.27 lb

Bracket is in between the smaller circles,

r = (7.1 + 5.5)/2 = 6.3”

I = Mr^2 = 10.72 lb in^2

8 x 1.13 x 10^{-2} lb in^2 = **85.76 lb in^2**

Vertical brackets on middle-exterior ring

r = 8.5”
I = Mr^2 = 19.51 lb in^2

8 x 2.06 x 10^{-2} lb in^2 = **156.08 lb in^2**

<u>2” Flat bars holding bottom circles & top support</u>
Assume as a rod with the center of rotation in the center of the rod

I = ML^2/ 12
L = length of bar
M = Mass of bar

Mass = Density x Volume
= 0.270 lb/in^3 x (17” x 2 “ x 0.125”)
= 1.15 lb

I = [(1.15 lb) x $(17)^2$]/ 12
I = 27.70 lb in^2

Total of 3 bars:

I = 3 x 27.70 lb in^2 = **83.10 lb in^2**

<u>Vertical bars at 8.5”</u>
Assume vertical bars are point mass’

I = Mr^2
Bars are 19” long
M = (lwt) x (Density)
M= (19” x 0.125” x 1”) x 0.27 lb/in^3 = 0.64 lb

I = Mr^2
I = 46.24 lb in^2

There are 4 bars:
I = 4 x 46.24lb in^2 = **184.96 lb in^2**

<u>Shaft</u>
I= Mr^2
R = 1” ÷ 2 = 0.5”
M = (pir^2 –$pir_2{}^2$) x l x density
= (pi x 0.5^2 – pi x 0.375^2) x 19” x 0.270 = 1.76 lb

I = **0.44 lb in^2**

<u>Total Moment of Inertia</u>

I_{total} = 1016.25 lb in^2

I = 0.30 kg m^2

<u>Total weight</u>

M_{total} = 20.23 lbs

<u>Torque and Power</u>
T = I alpha
T = 0.30 kg m^2 x 20.94 rad/s^2 = 6.28 N m = 4.63 lb ft

$$T = \frac{P * 33000}{2 * \pi * rotational\ speed}$$

P = T *2 * pi* rotational speed / 33000
P 4.63lb ft * 2* pi * 104.72 rad/s/ 33000
= 0.095 Hp

Appendix B

Client Information

McGill Apicultural Association
McGill University – Macdonald Campus
Email: maa.beeclub@gmail.com
Tel: 514-996-3198
Mailing Address:
21111 Lakeshore rd
Ste. Anne de Bellevue
Quebec, Canada
H9X 3V9

The MAA was very open to our ideas when it came to building them a new, motorized honey extractor. They gave use a budget to work with as well as guidance along the way. Whether it was questions about honey or finances, they were willing to help and motivated us to deliver them an exceptional product.

Appendix C

Mentor Information

Evan Henry
McGill Apicultural Association - Member
Email: evan.henry@mail.mcgill.ca
Tel: 514-996-3198

Our group had multiple mentors throughout the design process. Firstly, we had Evan Henry from the MAA who helped us learn and understand the entire extraction process. Evan was available for us whenever we needed his input. Our knowledge of honey extraction was very primitive initially and Evan was able to explain to us simply why and how each step took place.

Scott Manktelow
Laboratory Superintendant
Department of Bioresource Engineering
McGill University
Email: Scott.manktelow@mcgill.ca
Tel: 514-398-7788

Another mentor we had was Scott Manktelow. Scott was present in the machine shop at all times while constructing the extractor. He showed us how to safely and effectively use any tool we needed in the shop and gave us extremely important and productive advice during design and construction phases.

Appendix D

Macdonald Student Experience Enhancement Fund: 2014-2015 Application Form

You must be a full-time student in the Faculty of Agricultural and Environmental Sciences to be eligible

It is understood that students/groups who receive funding will be requested to provide a summary of outcomes once the program or project is completed. Some groups might be invited to present during a McGill event. It is also understood that should any program or project require the use of McGill facilities, it is the responsibility of the student to get authorization prior to submitting the application.

1. Name of the project: **MacDonald Campus' Improved Honey Extractor**
2. Number of participants: **4**
3. Names, academic programs/year and McGill emails of participants (name/program/year/email)

   Jais Abecassis/Bioresource Engineering/U3/jais.abecassis@mail.mcgill.ca

   Saad Benjelloun/Bioresource Engineering/U3/saad.benjelloun2@mail.mcgill.ca

   Daniel Duquette/Bioresource Engineering/U3/daniel.duquette@mail.mcgill.ca

   Sowsen Khatib/Bioresource Engineering/U3/sowsen.khatib@mail.mcgill.ca

4. Indicate the type of project (internship, community project, travel support for a research or outreach project, student competition, prototype or product development, business incubation, etc.)
   Engineering Design 2 (BREE 490). Course required for graduation.
5. Start date/timeline for the project: **September 2nd 2014**
6. Amount of funding requested: **$700 for building different prototypes, experimental tests, purchasing equipment, proper tools, as well as travel expenses to meet with professionals in the field. For reference an average honey extractor costs approximately $ 750 (http://www.maxantindustries.com/extractors.html)**

7. Describe how the funding will be used:

This funding would be used to build a new and more efficient honey extractor for the McGill Apicultural Association (MAA) at McGill's MacDonald Campus. The MAA has been running into many problems with their current extractor. These problems include: Breaking of the frames, wasted honey (since the extractor doesn't remove all the honey from the frames), as well as having the entire process be unnecessarily time consuming. After being approached by the MAA, our goal is to use the funds and assemble a new extractor which will solve all these problems.

8. Please provide details around the expected outcomes/takeaways from the completion of this project/program:

By completing this project, not only will the apiary at Mac have a more efficient honey extractor, but our group will gain crucial experience that will benefit us in our future careers as engineers. In working with the MAA, we will develop communication skills that are essential when working with professionals outside your area of expertise. The design process itself will improve our team-working skills which are required in a real-world work environment. Finally, building the new honey extractor will teach us about the differences between design and conception. During design and construction, our problem solving skills will be put to the test, and make us use all the resources at our disposal.

Please submit your completed application, along with your case for support,
via email to lisa.allsopp@mcgill.ca by October 10, 2014