Nasa Toroidal Tank Wrapping Machine
Final Report
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Instructions for Operation:

Basic Instructions:

Use this set of directions if the table is already correctly oriented and a spool is loaded. If not, see below.

1. Remove Gear
   a. Remove back frame piece of the table assembly. This is the bar opposite the motor.
   b. Slide the two furthest rigid casters out toward the open edge of the table
   c. Lift both latches and pull both pins from their holes to release the gear
   d. Pull apart the gear and remove the half that is not meshing with the pinion. The other half may remain in place, constrained by the casters and pinion.

2. Install Tank:
   a. Lift the bottom shaft of the support.
   b. Lift the tank onto the top two rollers. The tank should be inside the three legs of the table.
c. Release the bottom shaft.

d. Ensure the radius of curvature of each roller contacts fully with the tank.

3. Reattach Gear

a. Hold the loose gear half level with the other half still on the table frame

b. Insert each pin into the corresponding hole

c. Close the latches

d. Ensure gear is resting on each swiveling caster and pressed against each rigid caster

e. Slide the two rigid casters closest to the open edge of the table tight against the gear and secure

f. Reattach the back frame piece of the table

g. Wrap the fiber around the guide roller and tape end of fiber onto desired wrap start location

4. Turn on Machine

a. Pull Emergency Stop on the box

b. Turn toggle power switch to On position

c. Wait 5-10 sec for frequency drives to warm up

d. Press Start on Motor 1 and Motor 2
To change the spool, follow the directions below:

1. Loosen the nut and remove the bolt securing the support bracket
2. Remove the support bracket
3. Loosen the set screw securing the lock collar
4. Remove lock collar
5. Remove cone and hub
6. Replace spool
7. Reattach cone and hub and tap lightly with a mallet to tighten in place
8. Reattach lock collar and tighten set screw
9. Reattach support bracket
10. Secure bracket to gear with nut and bolt
11. Go to Basic Instruction 3.g.
To TILT Gear Table, follow the directions below:

Note: Directions are given with the understanding that operating personnel is facing front of machine (facing head on with control box). Loosen black bolts on lower horizontal table support. (All white screws should are permanently set)

1. Loosen black screws on left front and rear square leg support brackets.
2. Loosen the 2 motor mount screws located on the diagonal Aluminum channel.
3. Loosen the left side of the aluminum channel from left supporting leg.

   NOTE: Have one person lift the left side of table until upper stop has made contact with square supports. While table side is being lifted, push outer table side in toward the upright base until horizontal support bracket makes contact with outer stop. Actual angle of table is 15 degrees.

4. Tighten left front and back square leg support brackets.
5. Loosen black screws on bracket that connects table to upright base support.

   Pullout/push in table until all sides of the doughnut is of equal distance from edges of the ring gear.

   Rear View
   To adjust the table from the angular wrap, back to the original zero degree wrap, one should follow the recommended steps.

   Front View
1. Loosen black bolts on lower horizontal table support.

2. Loosen the 2 motor mount screws located on the diagonal Aluminum channel.

3. Loosen the left side of the aluminum channel from left supporting leg.

4. Loosen black screws on left front and rear square leg support brackets.

   Warning: Table will want to lower due to weight on top of it.

5. Tighten left front and back square leg support brackets.

6. Loosen black screws on bracket that connects table to upright base support. Pullout/push in table until all sides of the doughnut is of equal distance from edges of the ring gear
Matt Uhrig  
NASA project, Auburn University

**Toroid Support System Technical Memo**

This memo focuses on one of the two major structures constructed during the project, the Toroid support system, and its evolution through the design process. The main function of this system is to support the Toroid as well as its drive components (i.e. roller arms, drive belt and motor) while at the same time maintaining structural integrity during the wrapping process. The system is composed of an Aluminum 6105 alloy and manufactured to allow for quick and easy construction with bolts and joining plates, much like a child’s erector set.

The cross section of the material makes it very easy to linearly adjust the pieces. This is a significant feature when trying to align the gears of the actual wrapping system. If the gear needs to move over a quarter, the roller supporting the gear can slide to allow new positioning. The cross section of the material also allows for simple addition of different components to the structure itself. For example, everything from the drive shafts to the electrical box is mounted to this framing.

Numerous changes were made to this structure throughout the semester to comply with another system’s needs, or simply to reduce overkill. The Y-shaped supports that supported the toroid from underneath were deemed unnecessary once the torrid tank was placed on the drive shafts. The toroid moves with the motor without them. The arms that hold the drive shafts were stronger than expected and could adequately hold the tank in place without deflection or slippage. It was also feared that the underneath support would hinder the movement of the tank at such slow speeds. During the initial testing, it was also discovered that the tank could rotate freely on the three rollers without the
application on a force on the bottom roller. The weight of the framing, roller, bearing and shaft provides enough downward force to adequately hold the roller snug with the tank surface. As a result, the tension spring and all related supports were scrapped. This simplifies the loading and unloading process significantly.

Modification to the spool and tensioner caused a problem with interference between the spool and the support arms of the frame. This problem was discovered though the CAD animation even before the tensioner device had been built. The easiest solution was to move the support arms from underneath the main arm to above the main arm (See Figure one). The impact of this movement is negligible and has no impact on beam deflection.

As mentioned before, the simple erector set beam arrangement of this structure made construction and later modifications quick and effortless. The Y-shaped supports and the tension spring were seen as excess and were removed with nothing diminished from the structures’ function or movement of the tank itself. These changes were minor in detail, but significant in the fact that the changes enhanced the operation of the entire machine by complying with the needs of other design components.
Adam Epling

NASA Project, Auburn University

**Gear Table Support Assembly**

The project involves wrapping a toroidal-shaped fuel tank with composite carbon fibers to increase strength. The wrapping is done by way of a ring gear, which holds the spool of fiber tow and wraps around the toroid. The ring gear and pinion are mounted to an adjustable table, and the gear table support assembly is what supports the table. The function of the assembly is two-fold. Its primary function is to provide structural support for the weight of the ring gear, pinion, motor, shaft, and gear table. Secondly, it can be adjusted by lengthening one pair of legs while shortening the other, in order to create an angular wrap.

The assembly is made of four legs, each one of which consists of two separate 21-inch pieces of 1515 series 8020© aluminum, joined to each other by a four-hole joining plate. The nuts are inserted into the slots of the pieces of 8020, and the screws tightened to attach one piece to the other. The bottom piece of each leg is then fitted in the same manner with two 90º gussets, which will help add surface area to the bottom of the legs, and stabilize each one. Once the gussets are attached, the top piece of each leg is fitted with an 8020 15-series 90º living hinge. The hinge is attached in the same manner as the fastening plates.

The legs are attached together in pairs by two 28-inch long pieces of 8020, which are mounted horizontally to each leg by two 90º gussets, one on top and one on bottom. These two members run parallel to each other from left to right along the front face of the base. They are mounted 10.75 inches from the bottom of the legs.
These parallel pieces are then attached to one another by an adjustable member made of two 22-inch long pieces of 8020, which are attached to one another by a 4-hole joining plate. This member is attached 7.25 inches from the right leg. It runs perpendicular to the two parallel pieces, and the bottom of the member should mate with the top side of each one of the parallel bars. Two 90° gussets on each end of the perpendicular member are used to attach it to the parallel members.

Next, a diagonal slotted member, made of a 36-inch long piece of c-channel aluminum is attached to the front and back right legs. It should be mounted at roughly a 15° angle with respect to the horizontal. It is attached to the legs much in the same manner as the previous parts, by two bolts and two nuts, one set on each leg, which fit into the slots of the 8020. There are 3/8-inch holes drilled on each end of the member through which to attach the bolts. This member, once attached, will add support to the base, making it sturdier and decreasing the vibration of the base once the machine runs. It will also add support to the ring gear motor, which will have two screws that attach to the middle of the member, through the slot. The slot allows for adjustability when the table is tilted, by simply loosening the screws on the motor mount.

The final piece is a dual-slotted, 9.25-inch long, 3-inch wide plate of ¼-inch aluminum, which attaches the back left leg to the torus support base. The slots are 3/8-inch wide and 7.75 inches long. The slots are 1.5 inches apart from one another, and are .75 inches from the top and bottom of the plate. Each of the two slots has one bolt which attaches to the torus base, and one which attaches to the back left leg of the gear support frame. Both attach in the same manner as the rest, by sliding the nuts through the slots of the 8020, then placing the screws through the plate, and tightening them.
Jonathan Grant Tyler

NASA Project, Auburn University

Table Support Operating Instructions

The design of a table to firmly support the wrapping drive mechanism on a parallel plane and on a plane that would provide an angular degree wrap on the doughnut was of great concern. The tilting process is not automatic and should be done by 2 persons. When attempting to tilt the table, the necessary personnel should us the provided directions. All Directions are given with the understanding that operating personnel is facing front of machine (facing head on with control box).

1.) Loosen black bolts on lower horizontal table support. (All white screws should are permanently set)

2.) Loosen black screws on left front and rear square leg support brackets.

3.) Loosen the 2 motor mount screws located on the diagonal Aluminum channel.

4.) Loosen the left side of the aluminum channel from left supporting leg.

NOTE: Have one person lift the left side of table until upper stop has made contact with square supports. While table side is being lifted, push outer table side in toward the upright base until horizontal support bracket makes contact with outer stop. Actual angle of table is 15 degrees.

5.) Tighten left front and back square leg support brackets.

6.) Loosen black screws on bracket that connects table to upright base support.

Pullout/push in table until all sides of the doughnut is of equal distance from edges of the ring gear.
To adjust the table from the angular wrap, back to the original zero degree wrap, one should follow the recommended steps.

1.) Loosen black bolts on lower horizontal table support.

2.) Loosen the 2 motor mount screws located on the diagonal Aluminum channel.

3.) Loosen the left side of the aluminum channel from left supporting leg.

4.) Loosen black screws on left front and rear square leg support brackets.

Warning: Table will want to lower due to weight on top of the table

5.) Tighten left front and back square leg support brackets.

6.) Loosen black screws on bracket that connects table to upright base support.

Pullout/push in table until all sides of the doughnut is of equal distance from edges of the ring gear.
Leigh Pipkin  
NASA Project, Auburn University

**Gear Support System Technical Memo**

The senior design group, sponsored by NASA, is building a toroid wrapping machine to wrap toroidal fuel tanks with pre-impregnated epoxy tow to increase their strength. The machine utilizes a large gear to carry the spool package around the tank while a set of rollers rotates and supports the tank. The gear is held up by a system of casters which also constrain forward, backward, and side to side motion of the gear, holding it centered around the tank. Four Teflon and aluminum pieces hold the gear down. These casters and the aluminum pieces are attached to a table which tilts to allow angular wrapping of the tow. This memo will describe the system of casters and aluminum pieces which support and constrain the gear.

Eight swiveling casters maintain the vertical position of the gear. These casters, purchased from The Caster Store, are 2.4 inches tall, with a 1.2 inch swivel radius. They are attached to an L-bracket made of 80-20, which holds the casters in the correct position under the table. The casters can swivel 360 degrees to enable them to align radially with the motion of the gear. The position of the spool package affects the contact between the gears and supporting casters – not all casters are holding weight at all times. However, this does not hinder their ability to hold up the gear.

Eight rigid casters constrain the horizontal movement of the gear in all four directions. Four of these casters are attached directly to the table, and four require a 2 inch spacer between them and the table frame. These casters are squeezed tight against the gear to keep it centered around the tank. To insert the gear, the two casters on the
removable bar must be slid out. After placing the gear, push the two casters back up against the gear and tighten.

Four machined aluminum and Teflon assemblies keep the gear from popping up out of place. Presumably the weight of the gear with the spool package and the counterweight will hold the gear down. However, these pieces were added as a precaution. They overlap the gear by .4 inches. The Teflon on the underside keeps the friction between the aluminum and the gear at an acceptable level.

Due to time and money constraints, the gear meshing is currently exposed, posing a safety concern. Two simple corrections for this problem have been identified for possible future addition. The cheapest idea is to add twelve inch tall plastic sheets along three sides of the table. This could be done using McMaster-Carr part number 8560K829, a 36”x36” piece of clear acrylic that could be cut into 3 32”x12” pieces. These pieces must be spaced out four inches away from the table frame to allow clearance for the spool package. This option would only safeguard people from the moving gear. The second option, which is easier but more expensive, is to buy a three sectioned folding protection panel and simply set it up around the machine. The clear acrylic panel is 79” tall, with three panels each 29” wide (McMaster-Carr part number 5356T31). See Appendix A for information on these parts.

The gear is supported and constrained by a system of eight rigid casters, eight swivel casters, and four aluminum and Teflon assemblies. This design is successful in constraining the gear in all directions and holds it centered around the tank. For future improvements, a safety device should be added.
Ring Gear and Ring Gear Drive

The request of NASA for a device that accomplishes toroidal wrapping was contingent upon a uniform placement of the composite carbon fiber tow. An internal ring gear drive fulfilled this design requirement but also presented certain disadvantages that had to be addressed. The main concerns were cost of fabrication, tribological characteristics between pinion and ring gear, and ease of detachment and reassembly of the ring gear. To go along with the advantage of precise wrapping that is accomplished by the internal ring gear, AC motor control provides added precision and adjustability. Furthermore, AC motor control is a cost efficient alternative to other speed control options. Selecting AC motors over these other alternatives produced a significant drop in overall project budget while still meeting the necessary wrapping requirements.

Existing ring gears were examined but they did not meet the dimensional requirements of this design. Custom fabrication was the next alternative, however, cost of manufacturing brought about considerable concerns. Quotes received from industry to machine typical gear materials presented a cost that was well beyond budget possibilities. To meet the cost restraint, an internal gear made from aluminum 6061 and cut by a water jet process, was regarded as a possible alternative. This decision brought about concern over tribological characteristics of the system.

Extensive calculations were performed to determine the feasibility of an aluminum gear/steal pinion power transmission. Several calculated considerations such as tooth bending and surface fatigue all provided sufficient evidence that an internal ring gear made from aluminum 6061 would fulfill the design criterion while significantly
reducing cost. If fact, due to the large (10:1) ratio between the gear and pinion, calculations actually showed that the steel pinion would fail before the aluminum ring gear but only after a suitably long life.

The final challenge that had to be incorporated into the ring gear design was the capacity for toroid insertion. Water jet fabrication allowed for this to be accomplished with relative ease, however, reattaching the ring gear presented a slightly more difficult challenge. A clamping design was chosen to provide an effective solution to disassembly and reattachment. Adjustable clamps along with steel pin reinforcements produced an efficient solution. After building and testing a prototype of this detachment and reassembly concept, the clamping devices were installed. Proper meshing is ensured by a rigid yet adjustable table support and caster system while the versatility of 80-20 was entrusted to take care of the rest.

Due to the drastic advances in AC motors and controllers over the past few years, variable AC speed control was a plausible solution to the precise control of wrapping required. With the capability to control motors down to 1Hz at full output torque, a standard sensorless vector AC drive provided plenty of speed options in the form of adjustable digital frequency readout. It also offered exceptional speed precision.

The success of the entire wrapping design was contingent upon many of the engineering problems presented by the ring gear system. This system is an efficient means of accomplishing its task within overall budget restraints. Testing has shown that while slightly more advanced devices in the ring gear system may ensure an even greater meticulousness of wrapping, the toroidal wrapping device is an effective apparatus that has accomplished its design criterion.
Shaun Rhudy
NASA Project, Auburn University

**Pinion**

The pinion is driven by motor two. It is a three inch pitch diameter steel pinion with a two and a half inch face width. It is a stock Martin spur gear. The smallest bore shaft diameter available is one and one eighth inch. I had to couple this pinion to the one horsepower motor two which has a shaft diameter of seven eighths of an inch. I did this by custom fabricating a six inch mild steel shaft, and using a flexible coupling. This is held in place by a journal bearing and mounting block.

The steel shaft was one and a quarter inch in diameter by twelve inches long. I cut the shaft in half and milled the diameter to one and one eighth of an inch. The mild steel shaft is then press fitted into the steel pinion so that there is absolutely no slippage.

To couple the motor shaft to the pinion shaft combination I used a flexible Love Joy coupling that we ordered from McMaster Carr. The coupling has an inner bore diameter of seven eighths of an inch on one end, and a bore of one and one eighth of an inch on the other end. The middle of the coupling is a flexible polyurethane “spider” which must be ordered along with the other two parts of the coupling. Both shafts are held securely with a steel rectangular key and a set screw. The keys were made from key stock. This flexible coupling provides a safety factor in case the pinion suddenly stops. The coupling will absorb some of the shock and hopefully the motor shaft will not shear or the motor will not be damaged. However this design did not secure the pinion to the motor two in the vertical direction.

To secure the pinion we used a journal bearing with a collar and set screw. The journal bearing (or pillow block bearing) has a one and one eight inch inner diameter to
fit securely onto the pinion shaft combination. The shaft is also secured with a set screw. The journal bearing is mounted securely to the frame of the gear table assembly by a two inch spacer block. The journal bearing allows for precise alignment of the pinion gear so that it contacts the large ring gear. The center distance between the pinion and the gear must be exact so that there is contact between the gears with out too much friction. If the gears are not in contact correctly then there will be excessive wearing on the gear faces resulting in failure.
Eric Nickoli  
NASA Project, Auburn University  

**Toroid Drive Assembly – Support**

To properly design a machine that has the capability to wrap a toroidal tank with composite material, support of the toroid was a major design consideration. The two design teams initially assigned this problem came up with two separate support ideas and orientations. A final solution for both the support of the toroid and the fashion in which it was to be rotated was designed and is outlined in this memo.

The first major decision to be made was the orientation of the toroid. A vertical orientation was decided upon to utilize the effects of gravity for supporting the toroid. Because of the nature of the wrapping system of the machine, only minimal contact between the toroid and the support structure could occur. A three point contact support system on the inner radius of the toroid was designed. This three point contact design not only took advantage of the forces of gravity to hold the toroid on the contact points, but also provided ample space for the wrapping system assembly. The three point contact design also provided outward radial support uniformly, allowing for more accurate and supported rotation of the toroid.

The three point contact support design for the toroid drive assembly also allows for motive power to be applied to the toroid. With all three contact points rotating at the same time, a uniform rotation of the toroid could be achieved. Drive rollers were decided upon to transfer the motive power to the actual toroid itself. By driving the toroid at three separate points, a much more effective transfer of power is possible and a uniformity in rotation is reached. Also, by utilizing the three point drive design, a much smaller
likelihood of interference of the layers of composite will occur between the layers and the drive rollers.

Finally, the interface between the drive rollers and the toroid had to be considered. Due to the nature of the shape of the toroid, a curved surface drive roller was required. Many applications of these curved surfaced drive rollers are available but for much smaller applications and at a very expensive price. An engineering plastic (polyethylene) was decided upon due to its strength, durability, and machineability. The drive rollers with an 8 inch radius of curvature surface were produced on a CNC lathe in house. This was a very cost-effective and efficient solution.

The final toroid drive assembly design utilizes the drive rollers press-fit upon steel shafting that are supported by pillow block bearings. These shafts are then belt driven by a motor (more details of the toroid drive assembly motor can be read in the corresponding memo). See figure below for final toroid drive assembly design.

By combining motive power and support into one system, the toroid can effectively be supported and rotated by the same system. The three point contact design maximizes the efficiency by which the toroid can be supported and driven. Using the curved surface drive rollers allows for more complete contact between the rollers and the toroid allowing for a more uniform rotation. This design is not only effective and efficient, but it very cheap to create and easy to maintain.
Kenneth J. Nebrig  
NASA Project, Auburn University

**Toroid Motor Drive**

The toroid drive system is the component of the assembly that moves the toroid tank in a motion so the pre-impregnated carbon material can be wrapped efficiently. The system must allow for several specifications:

The drive motor system has many of variables that can be changed to meet many types of user-defined parameters. This system can be adapted to different sizes of spool gage. With the use of programming capabilities in the variable frequency drive, the operator can dial in the desired frequency and begin the wrapping process.

The variable frequency drive can be programmed in 80 different parameters. In testing this product with the motor acquired, the operator has the freedom to drive the toroid down to a frequency of 0.7 Hz. The motor is desired 6-90 Hz. with total torque capability of 650 in-lbs. at 6 Hz. Again with further testing it is found that at 0.7 Hz. the same torque is acquired.

The motor drive system operates a shaft that is equipped with a ¾ in. bored synchronous drive sprocket that has 1 in. belt width and 21 teeth. These drive sprockets also are placed on the three shafts of the rollers which support the torroid tank directly. A 114 in. outer diameter synchronous drive belt is then place around the three sprockets with the rollers and placed on the sprocket with the motor. The motor is then placed in position when the belt becomes tight using the 80-20 bracket railing.
The motor drive system is arranged in a three point system where all three shafts and rollers are moving at a constant speed relative to each other by a synchronous drive belt. This allows for a more consistent movement of the toroid tank by greatly reducing the possibility of slipping if driven by a single roller.

If the operator has any problem with the wrapping process, the machine is equipped with emergency stops on both sides of the machine. One is located on the electrical box where the frequency drives are located, and the other is on the opposite end of the L-base frame. The placement of these stops are for efficiency and safety where one doesn’t have to reach across any rapid moving parts.
Thomas M. Duran  
NASA Project, Auburn University

**Electrical Components and Controls**

The purpose of this memo is to describe the electrical components and controls of the toroidal tank wrapping machine. The machine has two motors, one that turns the ring gear and one that turns the tank. Each motor is controlled separately.

Figure 1 is an electrical schematic of the machine. 240 Volt, 3 phase power flows from the power source at the bottom of the page to the motors at the top. Each leg of the 3 phase power source, except for ground, enters a fuse box. The fuse box contains three, eight amp fuses.

From there two of the legs go through two emergency stop buttons and a power switch. The other leg goes to both speed controls. Each emergency stop button is located on opposite sides of the machine. There is also a green light that indicates if the power is on or off.

Each speed control is wired the same. Two AC Tech TCF Series Variable Frequency Drives are used to control each motor separately. The frequency drives allow each motor to have its’ own start button, stop button, and forward/reverse selector switch. The motor controllers also allow each motor to operate at different frequencies controlling their speeds.

The power enters a fuse box after each of the speed controllers and then the motors. The fuse box for motor 1 uses three, 2 Amp fuses. The fuse box for motor 2 uses three, 6 Amp fuses.

The two AC Tech TCF Series Variable Frequency Drives were a good choice for controlling the motors. They were fairly easy to set up and easy to operate.
Figure 1
Tension Device and Spool Carrier

An integral part of the design of the wrapping machine is the spool carriage. The carriage acts as a device that will secure the filament spool, apply tension to the tow, and guide the tow onto the toroid. Design of the carriage device had to be very precise in order to avoid collision with the other parts of the machine during the wrapping process.

Applying tension to the fiber tow was a tricky process, due to the fact that most filament tensioning devices apply the tension by electrical means. The tensioning device in our design will be rotated about the toroid; therefore, no wiring could be run to the device. In other words, using an electrical device for this process is unacceptable. The chosen method for applying the tension is to use a braking device called a permanent magnet brake. Permanent magnet brakes are ideally suited for tension control. The torque is generated magnetically as a function of the unit’s mechanical setting, which is controlled by a knob on the unit. The larger the unit, the larger the torque the can be applied. The company that manufactures the unit we have chosen, Warner Electric, supplied us with the following calculations to help us decide upon the right size unit.

\[
\text{Average} \_ \text{radius} = \frac{(\text{Full} \_ \text{roll} \_ \text{diameter} + \text{Core} \_ \text{diameter})}{4} = \frac{(4 + 3)}{4} = 1.75\text{in}
\]
\[
\text{Torque} = \text{Avg} \_ \text{tension} \times \text{Avg} \_ \text{radius} = 5 \times 1.75 = 8.75\text{lb} \cdot \text{in}
\]
\[
\text{Tension} \_ \text{Range:}
\]
\[
\text{Max} \_ \text{tension} = \text{Torque} \times \frac{2}{\text{Core} \_ \text{diameter}} = 8.75 \times \frac{2}{3} = 5.83\text{lbs}
\]
\[
\text{Min} \_ \text{tension} = \text{Torque} \times \frac{2}{\text{Full} \_ \text{roll} \_ \text{diameter}} = 8.75 \times \frac{2}{4} = 4.375\text{lbs}
\]
\[
\text{Slip} \_ \text{Watts} = (\text{Max} \_ \text{tension} \times \text{velocity}) / 44.2 = (5.83 \times 62(\text{fpm})) / 44.2 = 8.177\text{watts}
\]
Once that torque is set, it is generally stable, regardless of speed. The units require no electrical power source, which means no wiring and no malfunctions due to power fluctuations. Since the units are sealed, and there are no rubbing parts, there is no chance of contaminates causing wear in the unit. Figure 1, below, shows a typical configuration of the units. Also, since the torque is created magnetically, there is no static friction induced for the roller to break away from, giving us a soft start.

Most units contain a hysteresis disk, which is directly attached to the hub that passes through the brake. Two circular multiple pole magnets are solidly attached internally within the unit. The magnets face each other with the hysteresis disk between them. There is an air gap between the magnets and the hysteresis disk, so the hysteresis disk can turn without any frictional contact. The opposing circular magnets set up magnetic flux, which causes drag on the hysteresis disk, which in turn, causes drag to the hollow hub in the unit. (10)
The maximum tension is achieved when the magnetic poles are aligned directly opposite at the north and south poles. When the alignments of the poles are changed, a magnetic flux is created through the hysteresis material that causes a higher drag, thus creating a higher tension.

The tension will not be applied directly to the fiber tow. The fiber spool is fixed to the same shaft that is attached to the magnetic brake. The actual tension is applied by the resistance of this shaft to rotate. As the spool rotates about the toroid, the filament is pulled off of the spool. In order for the filament to come off, the spool must rotate. The resistance to rotation causes the tension in the filament.

The spool is attached to the shaft by means of a clamping system designed specifically for this process. The design uses two cone shaped hubs that were machined to have the proper profile to clamp and fix the spool into place. Keyways were cut into the shaft and the hubs in order to insure no free rotation between the two.
The entire device is attached to the internal ring gear by means of a spacer and a bracket. The bracket was carefully designed to fully constrain the carriage, and at the same time, avoid collision with other parts of the design. The spacer is mounted below the bracket. It serves the purpose of lifting the carriage approximately one inch above the ring gear. This space is required in order to avoid the ring gears mounting and position devices. **Figure 2**, below, shows a snapshot of how the brake is attached to the gear.

![Figure 2](image)

It was important that the fiber tow always be laid onto the toroid at the same point. In order to achieve this, a roller was machined and attached to the carriage by a series of brackets. The roller is positioned in line with the filament and fixed at the center of the spool. The filament is laid around the roller, and as the carriage rotates, is continually laid off this roller. **Figures 3 and 4** illustrate the design and application of the guide.
The price of this design was kept to a minimum. The magnetic brake was donated to the project by Warner Electric. This relieved a large piece of the total design cost. The rest of the carriage and brackets were all machined from extra stock and scrap found in the machine shop. Although, due to the use of scrap parts to relieve cost, the carriage may look like a rough creation, it was very carefully designed and is a very effective piece of equipment.