Team 5 - Magnet Insertion Process

Operating Manual

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Functional Operation

The purpose of this magnet insertion system is to reduce the amount of manual input required by the technician to complete a proper assembly of a bearing. With this system, the insertion process will change from inserting eight to twelve magnets by hand to selecting a bearing, placing it onto the turntable and pressing start. The basic operational flow steps that will be outlined are shown below.

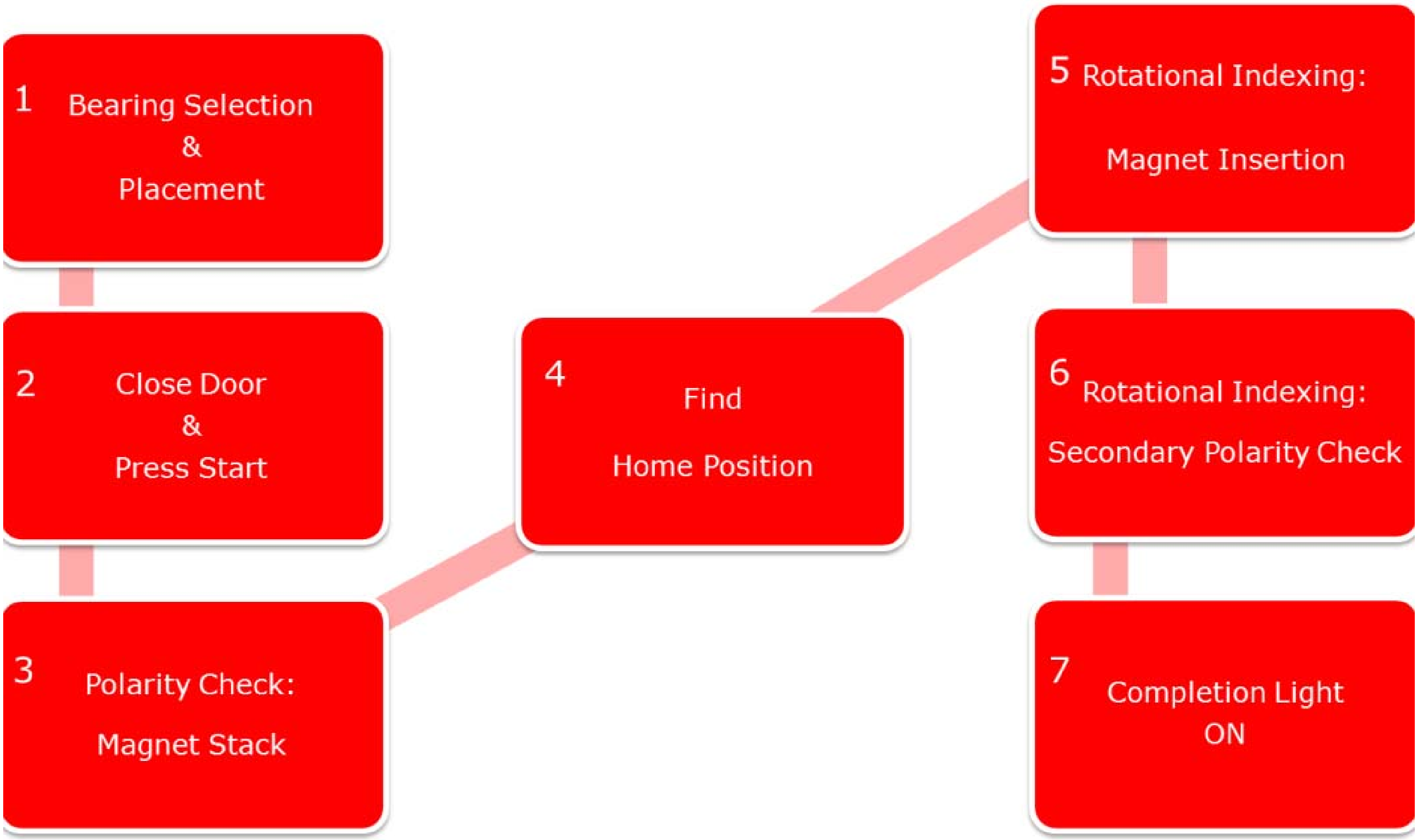


Figure 1

1. Bearing Selection and Placement

To review, there are three bearing styles that are used in production, each with unique spacer geometries and thicknesses. The bearings will be referred to as the "big", "small" and "twin" in this manual. To account for this difference and simplify the operation, fixture parts were created that mate to the bearing geometries and align their insertion surfaces to the same height. These fixtures will be referred to in this manual as "nests". An example of what a nest will look like is shown in Figure 2. A proper nest and bearing match is shown in Figure 3. There is a specific nest for each bearing. The nests are located in shelves underneath the workstation surface shown in Figure 4. The shelves will be labeled as to which nest is which.

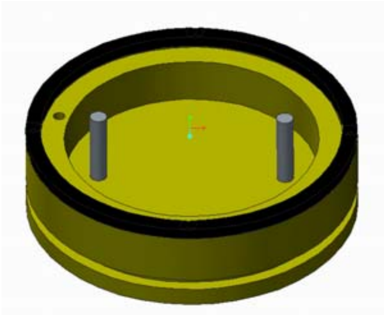


Figure 2 – Nest for big bearing

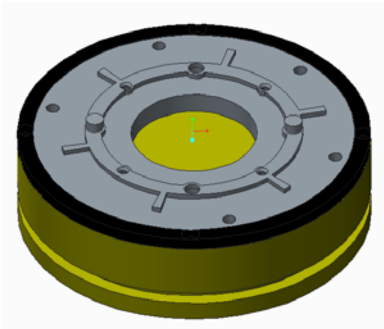


Figure 3 - Nest with big bearing

The proper nest must be selected that matches its respective bearing in order for the bearing to fit inside. For example, if the assembly of a big bearing is needed, the big nest must be selected from the shelving. If a small nest or twin nest were selected instead, the big bearing would not fit inside, as its outer diameter is too large. There are potential areas for operator error when choosing the small and twin nests as they are the same diameter. However, in the event that a twin bearing were to be put into a small nest, its insertion surface would extend above the nest. Similarly, putting a small bearing into a twin nest would result in the bearing resting too low. The machine would run as usual and many issues could arise. Because of this, a crucial step must be added to the operator's task list to verify that indeed the correct bearing is placed into the correct nest.

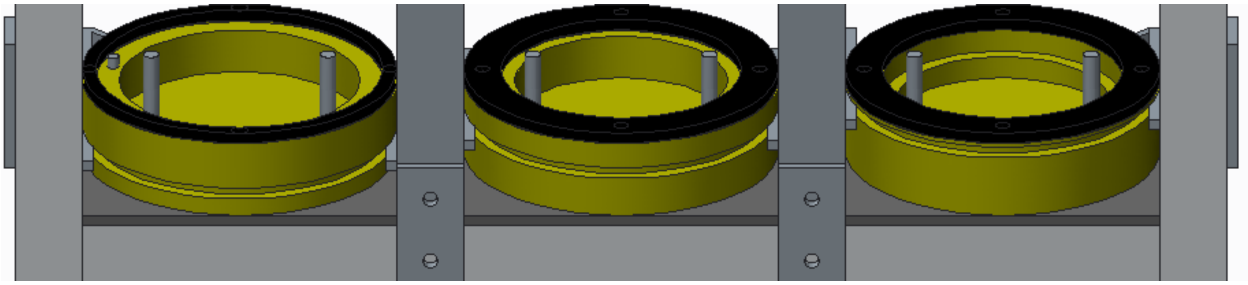


Figure 4 - Nest shelving. From left to right: big, small and twin nests

Once a nest is selected and removed from its shelf, a limit switch located in the back of the shelving will depress. This alerts the processor of which nest is present and which specific code program to run. This code includes the rotational indexing locations of the bearing, the magnet type and orientation that must be present as well as the timing of the pneumatic actuators to push the magnets. This will prevent any issues with the system potentially performing the incorrect function on a bearing.

Once a nest is selected and a bearing is fixed inside of the nest, the operator must open the system door and place the nest onto the turntable surface, shown in Figure 5. This will require some rotating of the nest until it slips into the pins sticking out of the turntable. Once the nest is properly fixed, the operator must load the magnets. There are two magnet styles, which will be referred to as “long” and “short” in this manual. The short magnets are used on the big and twin bearings. The long magnets are used on the small bearing. Once the proper magnets are loaded into the magnet stack, the operator must move the polarity checker arm over the bearing surface. This is done by loosening the screw of the checker arm and readjusting the checker location. When the checker arm is resting over the bearing surface, the operator must tighten the screw to keep the arm in place. With the completion of these tasks, the operator can move to step 2.

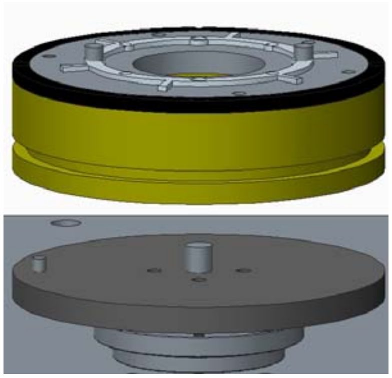


Figure 5 - Nest with bearing being placed onto turntable

2. Close Door and Press Start

To ensure safety, the door must be closed before the machine will run. A limit switch is mounted to the door and is activated when the door is closed, which tells the processor that the station is clear to begin. A control box containing a start button, fault light and a three position switch will be located off to the side of the frame. If there are any issues, a red button below the start button will turn on and the operator must begin troubleshooting. The red button could illuminate for a number of reasons. A troubleshooting list will be drafted that will highlight the common issues and how to resolve them. The operator can consult this list at any time if encountering a red light fault. If there are no issues, a green light will show and by pushing the start button, the magnet insertion process will begin. Steps 3 through 7 are automated functions and are done without any additional operator input.

3. Magnet Stack Polarity Check

The first step in the automated process is to read a polarity sensor that rests underneath the magnet stack. The sensor will detect whether the stack is present and if so, whether the orientation is correct for the nest and bearing combination that is selected. If this is not the case, a red light will display on the control box and the operator will have to troubleshoot the magnet issue. If the sensor reads the correct magnets and orientation, the system will move to step 4.

4. Find Home Position

The system is equipped with a magnetic sensor to find a home orientation to calibrate the motor for the specific bearing. The sensor rests facing the bottom of the nest and reads the presence of ferrous material. There is a hole tapped into each nest that contains a metal screw. The motor will rotate the nest until the magnetic sensor detects the ferrous material, at which point, the nest will stop rotating. This point coincides with the first insertion location for the bearing, shown by the dotted line in Figure 6. A signal will be sent to the solenoid valves of one of the pneumatic actuators to begin insertion. The system will then move to step 5.

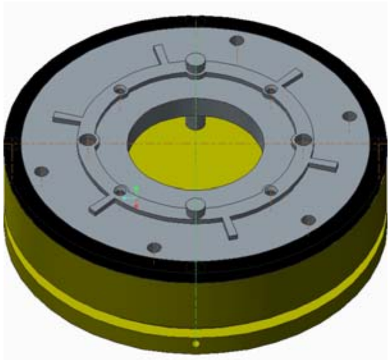


Figure 6 - Hole in nest that locates first magnet position

5. Magnet Insertion

This step is the main idea of the entire project. This phase involves the stepper motor indexing the bearing to its magnet placement locations and inserting the eight to twelve magnets via pneumatic actuation. A basic example is shown in Figures 7 and 8. Once the magnets are on the bearing surface, the system will move to step 6.

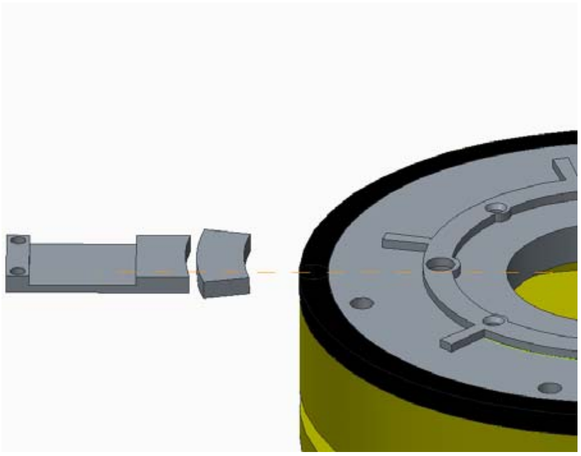


Figure 7 - Pre insertion

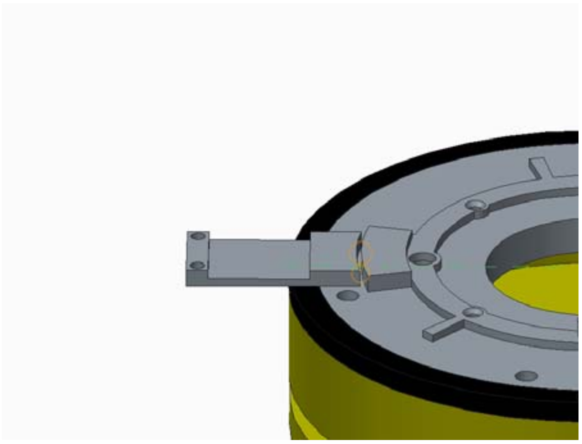


Figure 8 - Post insertion

6. Secondary Polarity Check

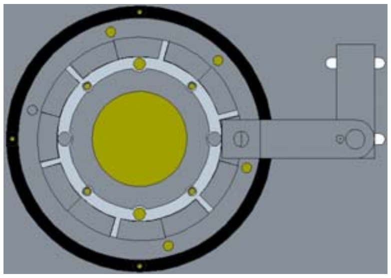


Figure 9 - Top view of polarity checker resting over magnet surface

The system will then reference the polarity sensor in the checking arm to perform a secondary scan of the magnets that were inserted. The bearing will rotate around once more at each magnet location and the checker will verify that the magnet orientations are correct. In full assembly mode, this check will be superfluous, as the magnet stack sensor would have generated a fault if a magnet was oriented incorrectly during the pre-insertion process. The polarity checker arm will only display a fault in the "checking" mode of the system, determined by the three position switch. An assembled bearing would be placed inside the system and the checker would confirm that the orientations are correct. If not, the red fault light would display. If the secondary check is successful, the system will move to step 7.

7. Completion Light ON

When the magnet insertion process is complete, the start button will display green. This will alert the operator that the door can now be opened safely. The operator can remove the bearing and nest and repeat the process once again.

Product Specifications

The assignment was to make a machine that would replace a technician, whom would manually insert magnets into a bearing. This machine is required to hold magnets and properly place these magnets into a bearing with the correct indexing increments. The first expectation of this machine is to properly index the appropriate bearing. This is accomplished by the stepper

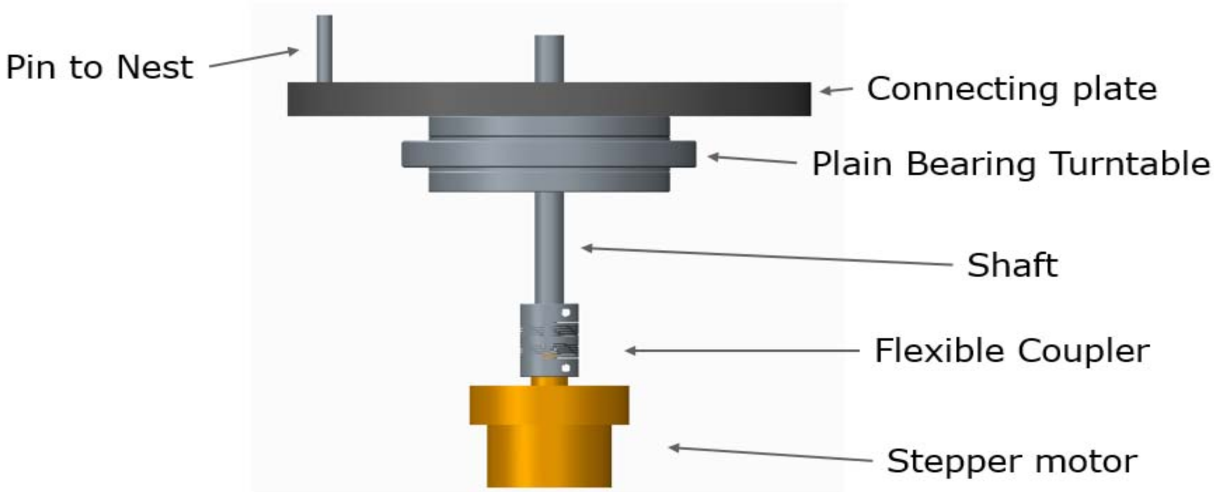


Figure 70 – Stepper motor to nest assembly

motor and the logic board. The nest is rigidly attached to the connecting plate; which in turn, is connected to the stepper motor via a shaft and flexible coupler. Figure 10 above shows the 3D model of how the indexing component appears.

As previously stated, the nest sits upon the connecting plate which places the nest in an exact position by the center pin and the offset pin to nest. Lying on the baseplate is the plain bearing turntable and it allows for only rotational motion; the linear axis motion is eliminated by this bearing. The shaft is connected to the connecting plate and the flexible coupler and it allows for the motor to turn the nest from a specified location. The flexible coupler allows for any misalignment between the stepper motor shaft and the extended shaft. The stepper motor is programed through the logic board to give precise indexing locations for the given nest.

After the indexing is completed the next step is insertion. There are two different insertion techniques. First is the magnet insertion into the bearing. With the use of actuators this machine will essentially push the magnets from a magnet stack into its respected location on the bearing. The bearing is placed on its respected nest then from here the nest is placed upon the connecting plate. Once the height is measured, the inserting assembly is adjusted to insert the magnets at the same height as the bearing. The entire actuating assembly is seen below in figure 11.

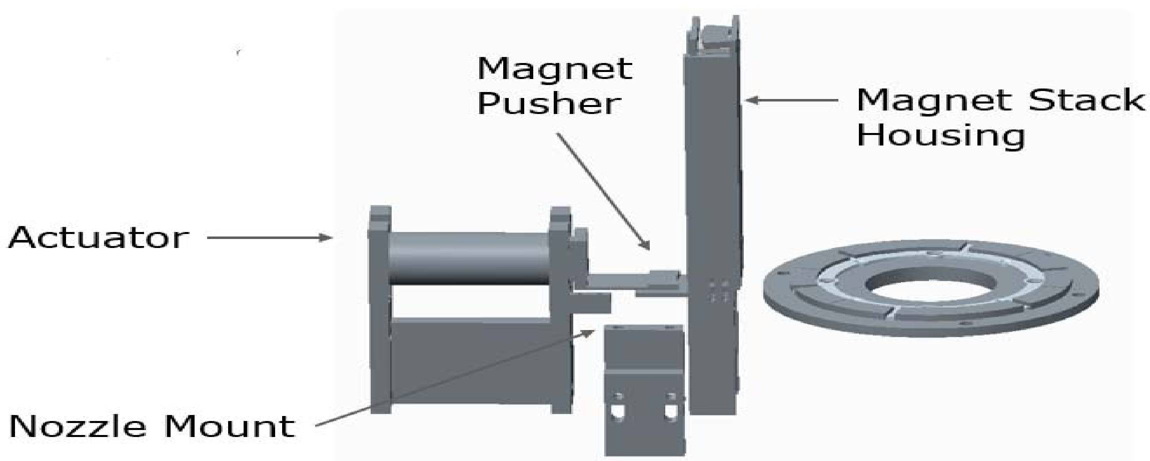


Figure 81 – Actuator assembly

From this image the bearing is at the furthest to the right is the bearing where the magnets shall find their finial resting place. First the magnets start inside the magnet stack housing, they stay in this position by the force of gravity alone. The housing for the magnets has a prescribed height for the front wall that only allows for a single magent to pass under. The magnet is pushed by the magnet pusher which is connected to the actuator. The actuator has air supplied to it and the logic board relays to the actuator when to expand or retract. The magnet pusher is a high toleranced tool that will only push a single magnet with the forward stroke and retrieve a single spacer, which separates the magnets from one another, on the retracting stroke of the actuation motion. The nozzle mount is there to hold the nozzle that blows off the spacer.

Going along with the magnet insertion, the nest insertion is also important. To determine which program to run, the logic board must know which bearing is placed on the machine. With the use of limit switches, the program is decided by which nest is no longer present in the nest housing thus proper nest insertion is pivital in running the operation. In order to accommodate this delima, the nest has removed material in a ring around the nest at a specified height. The nest housing has key slots that allow for its respected nest to slid into. Figure 12 illustrates how the nest housing works.

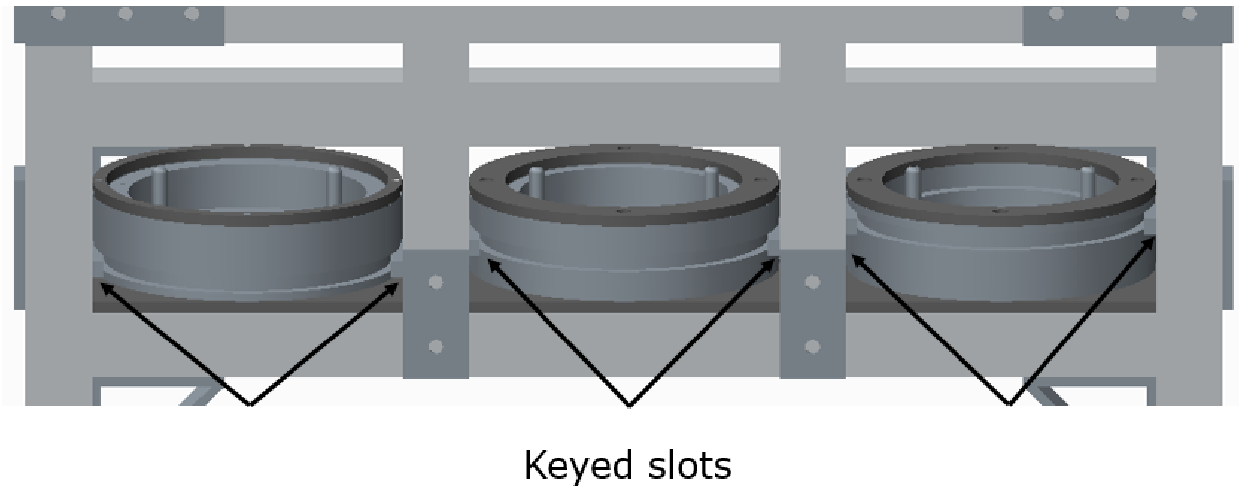


Figure 92 – Nest housing

The last operating function of the process in the machine is the polarity checking. To ensure the magnets are properly placed on the finished bearing correctly the, north and south pole, orientation of the magnets need to be checked. Due to the fact that the bearings are placed in a high precision compressor the quality of the magnets orientation is exceedingly important. Before the magnets are even inserted, the orientation is checked while the magnets rest in the

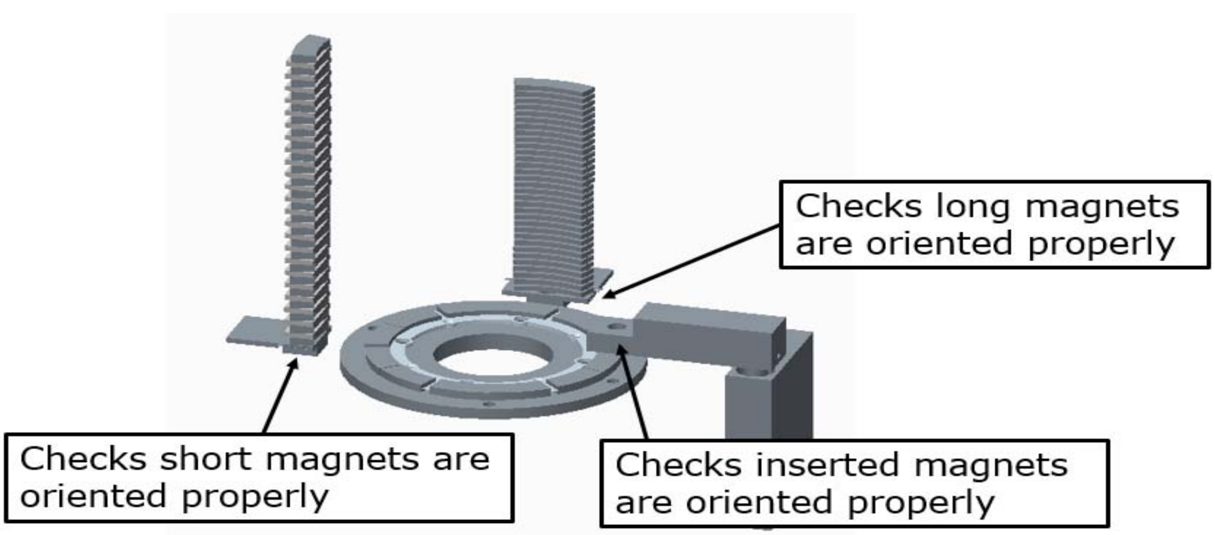


Figure 103 – Polarity checkers

stack housing. After the magnets are inserted, the orientation is checked once agin to confirm the orientation is correct for that bearing. All the polarity checking sensors are the same for the before and afer orientation measurements. The polarity checker is located at the botton of each magnet stack housing to measure the orientation before insertion, and the polarity checker is located on the polarity checking arm to measure the orientation after insertion. All of which are seen above in figure 13.

The machine stands at an ergonomically efficient height, which can change if needed, with the use of an 80/20 frame. Not only does this frame give adjustable working height, it also allows for the technician to be safe while using the machine. The 80/20 frame permits the use of transparent plastic to surround the working area of the machine, so if any magnets fracture while being inserted it would hit the plastic instead of the technician. Also the implement of making the machine automated limits the inputs of the technician which lessens the risk of injury.

Standard Procedure for Operation

- To begin operation of the insertion machine first turn the machine on by plugging in the power cable coming from the power supply into a 120 volt AC socket (U.S. standard).
- Ensure that the red emergency shutoff button located at the front of the machine is not pushed in. In the case where the button has already been pushed, twist the knob clockwise to release.
- Select the bearing which you wish to perform operations on and pull out the corresponding nest from the nest housing located underneath the baseplate and place it on the connecting plate on top of the machine, then place the bearing onto the nest.
- Check that the magnet stack which holds the respective magnets for the bearing chosen has a full stack of magnets placed into it and check that they are orientated properly. This can be done by lifting the sliding back door from the rear of the stack. The magnet stack in the rear holds the long magnets and the stack on the left holds the short magnets.
- Place the polarity checker arm located on the right size of the operating table over the bearing and tighten the set screw to ensure that the arm does not move during operation.
- On the control panel located on the front left side of the machine, using the switch, choose whether you would like to perform a full magnet insertion (turn switch to the left) or a polarity check of the magnets that have already been inserted (turn the switch to the right).

- Check that the unused nests are properly placed (pushed all the way back) into their respective nest housings.
- Close the door and press the green start button located on the control panel.
- Once the machine has completed the operations, the green start button will light up indicating that everything has been completed correctly.
- Open the door, replace the polarity checker arm to its original position and remove the nest and bearing, replacing the nest to its respective nest housing.
- To shut down the machine after operation, press the red emergency stop button then unplug the power cable from the power outlet.

Additional Assembly

The machine is designed to work most efficiently by performing insertions on the same size bearing repetitively before switching to another size bearing. This is due to the fact that for the twin and large bearings although they use the same magnet size, the proper magnetic orientation needed for each bearing differs from one another. Therefor when switching the bearing which operations are to performed on it is important to empty and replace the magnets in the magnet stack ensuring that they have been orientated properly for the next bearing which is to be operated on.

Additionally, before the machine is to be used each day, it is important for the operator to check that the individual components of the machine are adjusted correctly. The magnet stacks sensor plates both need to be set at the same height of the surface of a nest that has been placed onto the machine. The magnet pushers on the actuators both need to be set at this respective height, and their horizontal positions need to be set so that when the actuator is fully extended, the magnet pusher can push a magnet all the way to its final position on the bearing. The blow off nozzles height needs to be set according to the height or slightly above the height of both the magnet pushers and sensor plates. Lastly, the front plates of both magnet stacks should be set so that the distance in between the bottom edge of the plates and the top surface of the sensor plates are equal to or slightly greater than the thickness of each stacks respective magnets.

Trouble Shooting and Diagnostics

There are a few potential problems an operator may face when using this insertion machine. The most hazardous issue to arise is if a spacer from the magnet stack is lying on the bottom of the stack when insertions are to be performed. The machine will not be able to sense this and when insertions begin, the actuator will hit the rear end of a spacer and a magnet but will not be able to push the magnet through the slot in the front of the stack because of the spacer underneath it, this can cause the stack housing to be damaged and the magnet itself can potentially fracture. To avoid this, it is very important to check the magnets in each stack housing have magnets at the bottom before performing any insertions.

Another issue that could arise during operation involves the big and small bearings. Due to the fact that the polarity checkers are only set off with a south orientated magnet, since the big and small bearings need magnets to be inserted with the North pole facing up. If it is chosen that solely a polarity check is desired, the machine will set off the green light indicator (indicating everything has been completed correctly) for the cases where magnets are inserted properly (North pole facing up) and if the bearing was placed into the machine with no magnets placed onto it. This is due to the fact that the secondary polarity check (used during polarity check operation) checks if the orientation of the pole at the top of the magnet is south, and in the case for these two bearings, no signal will be received for North pole up facing magnets or if there are no magnets present whatsoever. To avoid this, it is important that there is a human operator to check that bearings that undergo solely a polarity check already have magnets placed onto them. When performing a full insertion on these two size bearings, this is not much of an issue due to the face that the first polarity check (of the magnet stack) checks the polarity from underneath the magnet, while the second checks from above. To avoid any potential issues that may arise from this, during any operation, it is important for the operator to check that magnets are properly placed in each stack before operation, and also that once the operations have been completed, it should be checked that a magnet has been inserted in every location needed for that respective bearing.

If the machine stops during regular operation, the red light located on the control panel should be illuminated indicating something has gone wrong. This means that the polarity of either the magnet stack or the magnets which have already been inserted are orientated incorrectly. To determine where the problem is originating from, take note of where the machine has stopped its operation. If magnets have already been placed onto the bearing, then the polarity of one or more of those magnets are incorrect, if magnets have yet to be inserted, then the problem has originated from the magnets inside the magnet stack that have been orientated incorrectly. To fix this problem, remove the magnets from the bearing or stack and orientate them properly. If operations are still desired to be performed, hit the emergency stop button and then release it to reset the system.

Routine Maintenance

The system, as with any machine, should be inspected and checked for issues. It should also be serviced as a preventative means of avoiding future issues.

The following items are predicted to be the areas that should be checked after each completed bearing:

1. Lift magnet stack shield and clear any extra magnets or debris.
2. Check that rejected spacers are clear from work station.
3. Check that no debris are obstructing sensors.

The following items are predicted to be the areas that should be checked around every six months:

1. Check that protective rings are not worn. If so, replace them.
2. Check alignment of magnet pusher and bearing surface. Realign if necessary.
3. Check pins on connecting plate and nests. If worn or broken, replace them.
4. Check limit switches on door and each nest shelf and ensure they are still contacting properly. If not, replace them.
5. Ensure pneumatic hoses are not tangled or damaged and actuators are working properly.
6. Check that flexible coupling is still fastened properly.
7. Remove motor and perform routine service check.
8. Check nest key slots for wear. Replace if needed.
9. Ensure wiring for sensors and switches are not tangled and that no wires are damaged.

Major Future Repair or Replacement

A major replacement would be needed for the system if a new bearing design was created or if a current bearing design was adjusted. A change in a bearing's magnet location would require a change in the code program of the stepper motor. This entails removing the processor and opening up the code in a compiler and changing variable definitions. A change in a bearing's magnet geometry would require an entirely new stack housing design or perhaps a simple realignment of the current ones. A change in a bearing's thickness would require a new nest to be machined. More material would have to be ordered and the nest would have to be designed to mate to the bearing. This would also call for a new shelf be made to house the new nest. Slight changes such as magnet location or spacer geometry would require some machine downtime. Large changes would require extensive analysis and rework. Regardless of the amount of rework required, the goal of the system is still intact as it is adaptable to new designs.

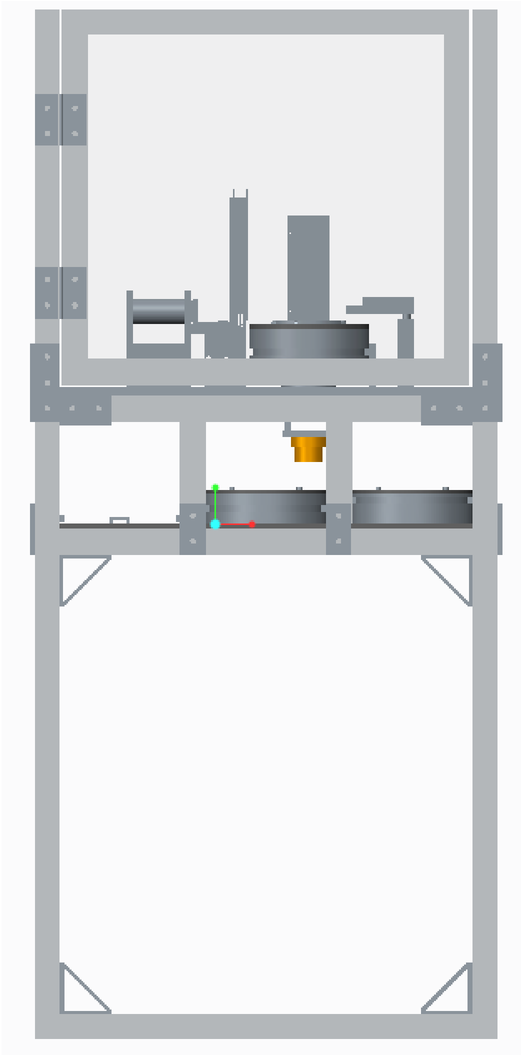
A major replacement for the future of the system could also be integrating the industrial standard of using a programmable logic controller (PLC). All of Turbocor's current stands on their manufacturing line are controlled by PLCs programmed by ladder logic. This replacement would standardize the system with the other stands in Turbocor's warehouse. A changeover such as this one would be time consuming as the sensor data and logic would have to be interpreted and converted. However, the advantage of this is that automation technicians in industry are more familiar with ladder logic than the C code used for the MicroDragon. This could speed up the diagnosis and repair of electrical or programming issues with the system, whereas currently a technician would have to reference the team's C code and comments.

In the event that the system were to be used on the order of years at a time, some components may need to be replaced. The nests with their replaceable wear resistant rings and pins were designed for durability and should not require major maintenance at all. The actuator cylinder seals would need to be checked and replaced. The motor may need to be replaced and reprogrammed. The soldering of the sensors should be checked to ensure proper contact.

Spare Parts

As mentioned before, a number of parts are replaceable. Any of the pins can be replaced by referencing the McMaster part numbers and ordering the pin that is needed. There are spare limit switches available as they were inexpensive to purchase. There are spare stepper motors, pneumatic hoses, solenoid valves, buttons and wiring materials on site at the Turbocor facilities. In the event that a part breaks, the drawings and order forms can be referenced for material needed and dimensions and tolerances of the part. For reference, the tentative list of items for the current design is shown below in the appendix as table A-1, sorted alphabetically by vendor.

Appendix



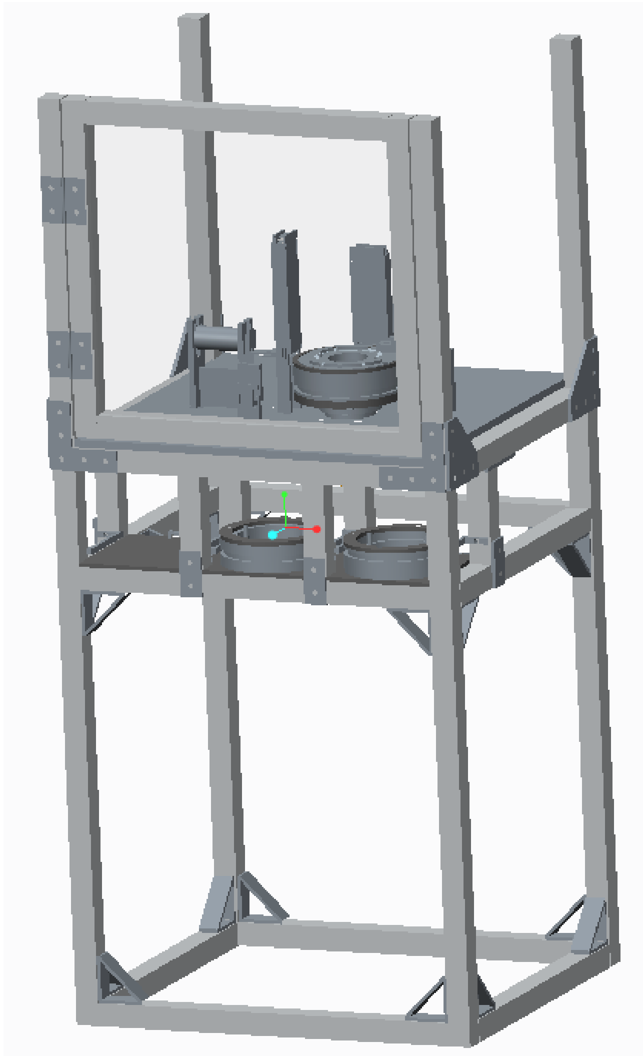


Figure 114 – Full machine assembly

1	Polarity Checker	3	Allied Electronics	720207637
2	Alpha Wire	1	Allied Electronics	70136541
3	Proto Board	1	Allied Electronics	70012509
1	3 position switch	1	Auber Instruments	SW3
2	Magnetic Sensor	1	Automation Direct	PFM1-BN-1H
3	Control Box	1	Automation Direct	SA108-40SL
1	Power Supply	1	DigiKey	454-1203-ND
2	Transistor	7	DigiKey	1026-STSA851-CHP
3	Diode	7	DigiKey	1N4001-TPMSCT-ND
4	Resistor	7	DigiKey	CF14JT1K00CT-ND
5	Resistor	7	DigiKey	CF14JT1K00CT-ND
1	Dragonboard	1	EVBplus.com	DVB-009 SM
1	Rubber Tubing	1	Festo	567948
1	Turntable	1	McMaster Carr	8700K1
2	Nest Material	1	McMaster Carr	85035k71
3	Actuators	2	McMaster Carr	5036K12
4	3/8 Aluminum Sheet	1	McMaster Carr	89155K28
5	DC Solid State NPN Switch	2	McMaster Carr	4211K302
6	ABS Plastic for Nest Surface	1	McMaster Carr	8586K471
7	Precision Adjust Air Flow Control Valves	2	McMaster Carr	4076K23
8	Air Nozzle	2	McMaster Carr	5329K63
9	Plug Tap 15/32"- 32	1	McMaster Carr	2595A237
10	Dowel Pins	1	McMaster Carr	8116K38
11	Ball Plunger	1	McMaster Carr	3408A73
12	Shoulder Bolt	1	McMaster Carr	91259A712
1	Aluminum Baseplate	1	Misumi	L-PNLNM-609.5-609.5-12
1	Proximity Sensor	16	Mouser	101-61-05-033ST-Q-EV
1	1/8 Aluminum Sheet	1	Online Metals	
1	Motor Driver	1	Robot Shop	RB-Sbo-24
1	Motor	1	Turbocor	
2	Flexible Coupling	1	Turbocor	
3	Pneumatic Hoses	1	Turbocor	
4	Machining	1	Turbocor	
5	Buttons/Switches	3	Turbocor	
6	Dinrail	1	Turbocor	
7	Triple Regulator	1	Turbocor	
8	Solenoid Switches	5	Turbocor	

Figure 125 – Items purchased