Concepts Generation

EML 4551C – Senior Design – Fall 2012 - Deliverables

Team 5 – Sensor Test Rig

Team Members

Christopher Brink

Omar Izaguirre

Quy Nguyen

Mark Palmieri

Project Sponsor

Kevin Lohman
Mechanical Engineer

Boris Bayevsky
Manager of Hardware Design

Dr. Farrukh Alvi
Project Advisor

Dr. Kamal Amin
Dr. Chiang Shih
Project Instructors

Department of Mechanical Engineering, Florida State University, Tallahassee, FL

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I. Introduction

The purpose of this project is to design and build a sensor test rig that will allow a sensor ring to be tested in the XYZ dimensions. The main constraint on the entire project is that the test rig must move in each direction independently and also there must be zero backlash as it moves. This is to allow the proper testing and evaluation of the sensor rings. The shaft that fits into the ring only has a clearance of 400 microns, 200 microns on each side of the shaft. An accurate micrometer or other displacement-measuring device is required to get a correct reading. Turbocor has provided the necessary sensor ring in order to design and build around it.

II. Existing Technology

Turbocor already has a test rig in use right now. It calls for a test ring to be placed on rotating shaft. The shaft rotates, but it is off center so that a point on the outer circumference of the shaft is in contact with a point on the inner circumference of the ring. As the shaft rotates, there is a displacement of 400 microns on the opposite side were the shaft is touching the ring. The main issue with this rig is that each test ran cannot be replicated, therefore no baseline can be set for the sensors. It is caused by the fact that an assumption was made between the off-center rotating shaft and the inner circumference of the sensor ring, the assumption was that the shaft was in contact with the ring and there were zero displacements between the two at that contact point. Another contributing factor is that the motor used is a step motor, which allows for severe backlash.

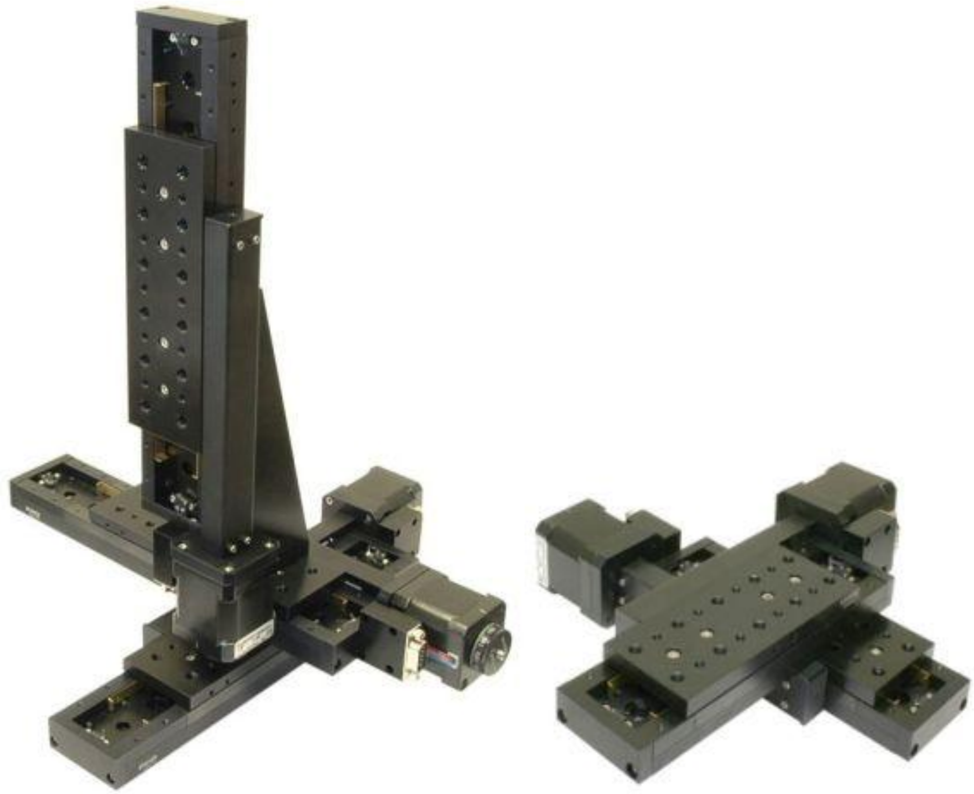

Figure 1: X-Y-Z Displacement platforms

In existence there are several XYZ movement platforms, such as those used in machining or in microscopes. Other manufacturers also have specific use XYZ tables that use linear actuators to move the platforms. These have almost zero backlash and are a primary focus of this senior design project.

There are no retail or commercial solutions to this project, just components that can be used to satisfy the requirements provided by Turbocor.

1. Linear Micro Positioner/Micrometer

Various types of precision linear movement mechanisms are in use today. One such system is a micro positioner. This device uses a precise screw mechanism to linearly position the attached base. Extremely fine threads translate rotational displacement into measureable linear displacement. Displacement can be measured to the order of 10^{-6} meters. Linear micro positioners serve both as the displacement measuring device and the movement system itself.

These devices can be extremely precise and have minimal backlash. They are also continuously adjustable. One of the biggest advantages is that these systems are already equipped with its own displacement measuring system, which is required to test or sensor ring. This is the only movement concept that we have that tracks its own motion.

A major disadvantage is that it can require several turns to move the base and bracket into the desired position. This means that speed of adjustment is relatively slow compared to other devices. A stepper motor could possibly be attached to the knob to create quicker controlled movement.

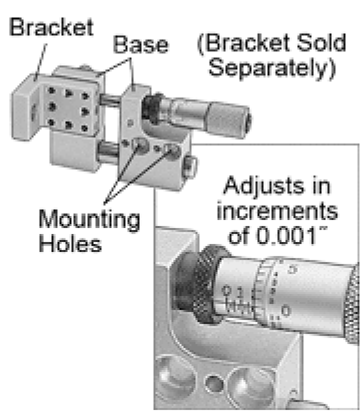

Figure 2: Linear Micro Positioner

2. Solenoid Actuator

Another useable concept is the solenoid actuator. This device converts electric current into linear force using a magnetic current. Since only three-position linearly movement is required in each direction, continuous adjustment is not required.

A "clapper" solenoid does just that. With this type of solenoid, the center position is given when the solenoid is neutral. The two extreme positions are achieved when current is run through the solenoid in either direction. This three-position motion can also be achieved by utilizing two standard two-position solenoids facing each other. When both solenoids have no current running through them, our apparatus is positioned in the center. When only one of them is engaged, the apparatus is moved to one side. When only the other is engaged, the opposite happens.

Physical, solid "stops" can be put in place to restrict the maximum displacement of the end of the solenoid shafts. Speed and repeatability are two great advantages to a solenoid system. However, an independent displacement measurement system is required for this system.

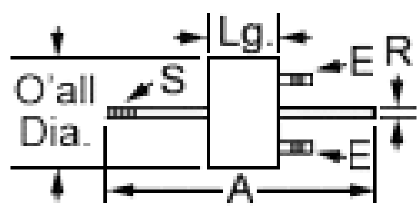

Figure 3: "Clapper" Solenoid

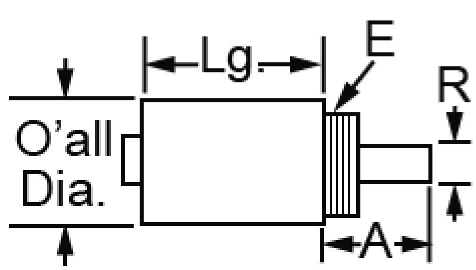

Figure 4: Two-position "Pull" Solenoid

3. Hydraulic Actuators

Hydraulic means can also be used to achieve the same effect as a solenoid system. Air pressure applied to a piston-cylinder system will give linear movement. Again, to achieve the desired displacement, physical "stops" may be required to prevent the shaft from over-extending. This mode can also be used to stop the shaft in the center position as it will be at rest (zero position) when there is no air pressure applied.

One major advantage to this system is that Turbocor already has air lines run to the station where our sensor ring tester will be used. This method is also relatively fast. A challenge to this system will be to precisely stop the shaft in the desired positions. Similar to solenoid systems, these systems do not measure their own displacement so independent measurement systems must be utilized.

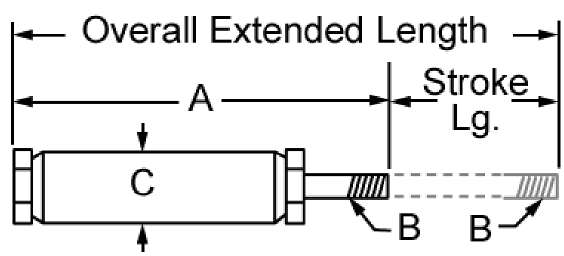

Figure 5: Low-Pressure Hydraulic Cylinder

4. Linear Variable Differential Transformer (LVDT)

A Linear Variable Differential Transformer is a device that is used to accurately and precisely measure displacement. These systems use a magnet passing through electrically conductive coils to produce a voltage difference. The displacement of the magnet is linearly proportional to the direction and magnitude of the displacement that the magnet experiences.

LVDT's can be used to track the displacement of our apparatus if movement systems that do not already possess measurement systems are utilized. They also possess the required accuracy for this project. This device may be ideal to use with solenoid and hydraulic systems. The magnet would possibly be placed on the shaft of the solenoid or hydraulic actuator and the rest mounted to the base. If our system can track its own displacement, fewer assumptions about displacement can be made. This will make our device more reliable.

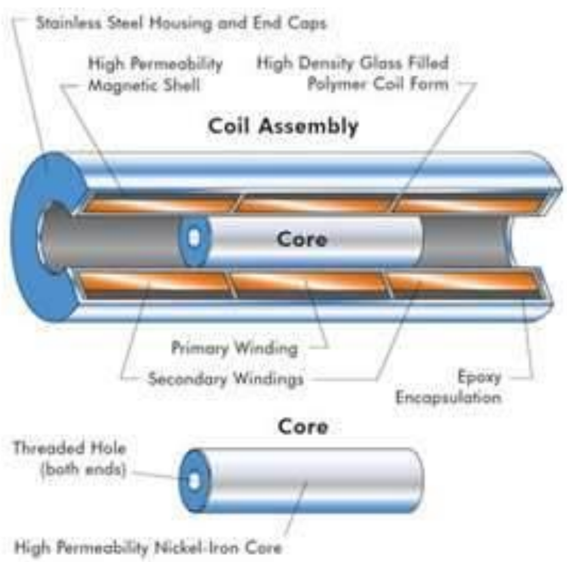

Figure 6: Linear Variable Differential Transformer

5. Stepper Motor

Currently in use at Turbocor is a rotational movement apparatus to conduct the sensor ring testing. The testing rig consists of shaft that rotates about an axis that is not the geometrical center, and a step motor to control the position of the shaft. The shaft is drilled with a new off-axis center to control the spacing between it and the sensor ring. The oscillation from the elliptical path generated by the shaft creates the displacement. Currently Turbocor test engineers must assume the displacement created by the off-centered shaft to be some arbitrary amount in order to correctly calibrate each sensor ring.

However, the consistency with positioning the off-axis rotation center is poor and when the test calls for a different shaft for the larger compressors, the artificial center is rarely in the same position, relative to the actual center, as the test shafts for the other compressors.

Also, the consideration of the motor must be taken into effect. The motor is connected to the shaft through a belt-drive. This setup is effective in transferring rotational motion to the shaft with minimal friction yet introduces back-lash into the system. This creates shaft position alterations that cannot be determined and thus unacceptable error into the testing procedure.

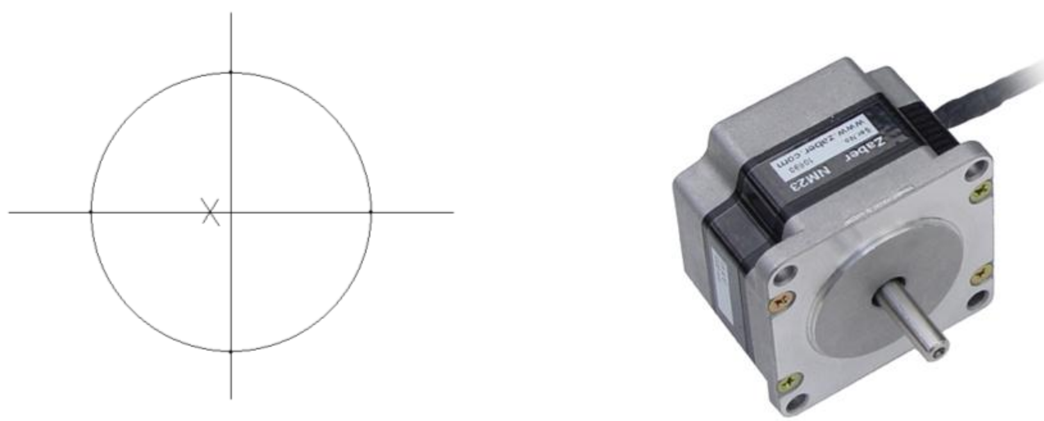

Figure 7: Step Motor

6. Slide Stopper

In order to test the sensitivity of the sensor rings effectively, linear displacement must be precise and maintained as straight-lines as possible to ensure independent testing of each sensor direction. Turbocor has expressed great importance in the testing rig using independent testing of each dimension. If one direction was being tested, and the rig moved in another direction, the test data could be compromised. To prevent any possible veer off course, The design must incorporate slide-style guides. This will guarantee the test rig only has the possibility to translate in the plane being tested.

Figure 8: Solenoid Actuator

The actuation is done using either a solenoid powered by electricity, or a linear actuation shaft energized by compressed air. When the actuation occurs, the displacement is controlled by mechanical stoppers positioned at arbitrary locations on the slide guides. The exact position of the stopper, besides before maximum displacement, is not important because the displacement of the testing rig will be tracked and observed using either a micrometer or linear differential transformer (LDT).

Another important aspect of the testing rig is how to actuate motion in the Z direction. For testing of the X and Y directions, the testing rig assembly is moved and measured. However for the Z direction, it would be easier to implement controlled motion of the shaft alone and monitor the displacement with micrometer or LDT. Again the motion will be controlled using a linear actuator either with solenoid, or compressed air actuator, and slide guides used to maintain linear translation with limited veer off track, thus preserving independent testing.

III. Concept 1:

Figure 9 – Piezo M-545 microscope stage with micrometer heads

Shown in Figure 1 is the Piezo M-545 microscope stage. The first concept is to purchase this microscopic stage, then a mount would be built on top of the plates to hold the sensor ring. This table has dual axis displacement in the x and y direction. In order to move the plates, two micrometer head (shown in green) attached that work similar to a screw. The top plate is moving along with the bottom plate, however the movements are still independent relative to the static axis.

The advantage of using this table is that it is very precise. The minimum increments are of 1 micrometer with a resolution of less than 1 nanometer. These micrometer heads can be replaced by linear actuators that are automated. The table allows smooth motion without vibration. It is self-locking when powered down, thus it consumes no energy.

The disadvantage of using the Piezo M-545 is that it has a low load capacity of only 5kg, limiting the weight of the mount that would be made, along with the sensor rings. The model comes with only x-y displacement and the z as an optional feature. These microscopic stages are very accurate and would be a beneficial factor in our design.

IV. Concept 2:

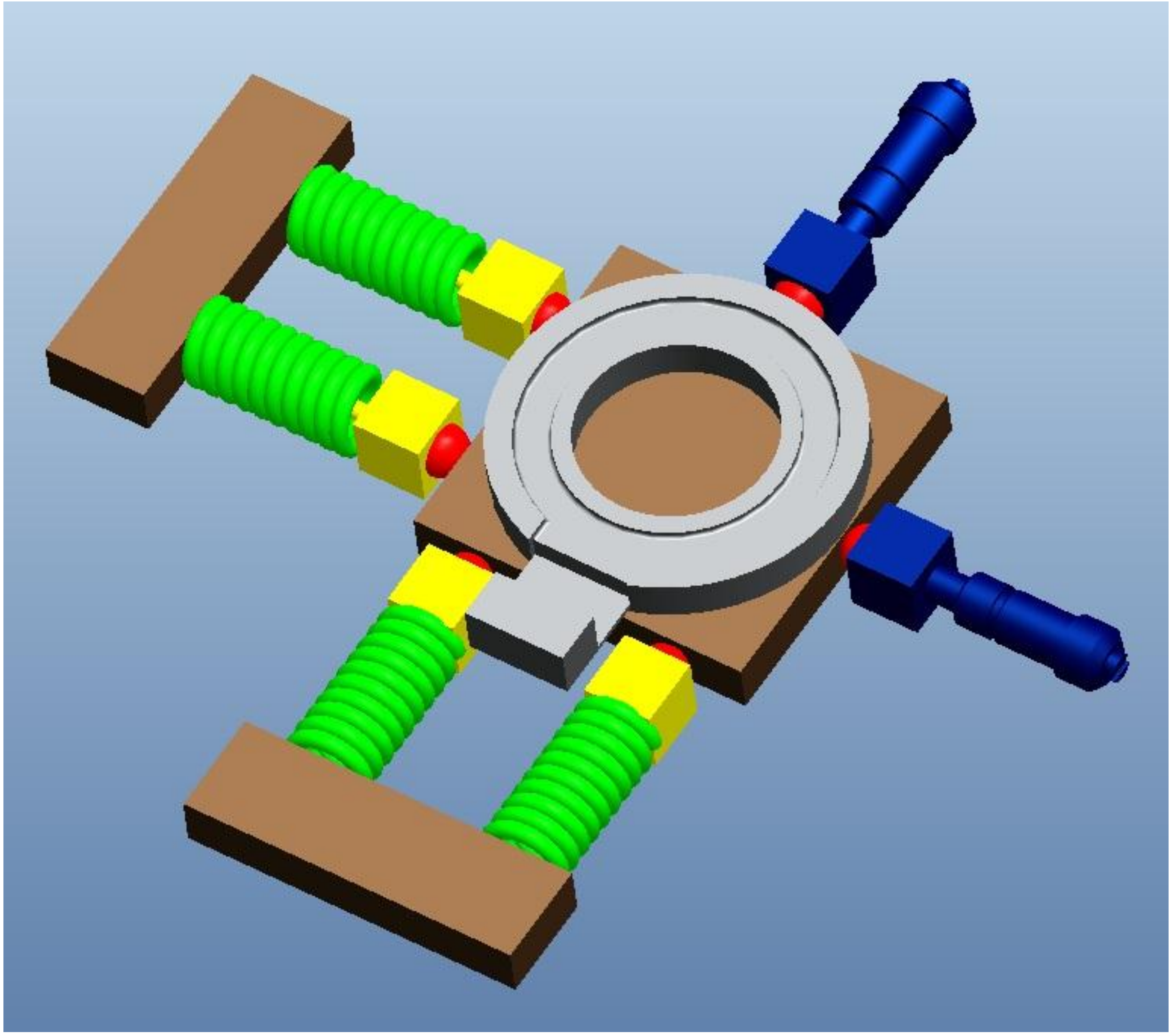

Figure 10: Micrometers X-Y displacement table

Gray----	Sensor Ring
Red------	Spherical ball
Blue- ----	Micrometer head
Green---	Spring
Brown---	Plate
Yellow ---	Ball joint/bearings

This concept uses a similar design layout as the M-545 microscopic stage. The X-Y displacements are completely independent due to the ball joints. Displacement in the Z direction is also controlled using micrometer heads (shown in blue). The micrometers would displace the plate in the center, which the sensor ring is placed. This design is cost-efficient, each micrometer has increments on it, however it could be upgrade to also have LCD's displaying the measurements for a pricier cost. The springs used in concept 2 are to keep the plates in place and furthermore to eliminate backlash.

The disadvantage of using this concept is that it would have to be controlled manually. It would take some time to control the micrometer heads moving it to the extreme positions and returning it to the initial position. Moreover, the design requires a lot of machining which can lead to errors in tolerances. The accuracy needed is in micrometers and to achieve this level of precision requires a great amount of time to machine. Guides must be used in the design in order to prevent the plates from turning or being knocked out of position.

V. Conclusion

Furthermore, most of the design features a representation of a table that can displace in the X-Y direction, and the Z direction using similar method. It is very difficult to be able to machines the parts to the micrometer level of precision and be cost-efficient. There are vast technologies at a cost, which will be beneficial to our final design. Incorporating different existing technologies, and using engineering knowledge is the best method to ensure the requirements of the project are met.

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