

EML 4552C – Senior Design – Spring 2013 Deliverable

Design for Manufacturing, Reliability, and Economics

Team # 5 – Production Test Fixture for Sensor Ring Testing

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Introduction

The production test fixture was design to test and the sensors ring to be use in the productions line. The sensor ring is an essential component of Tubocor's magnetic compressors.

Testing of the sensor rings is imperative for the successful operation of the compressor.

For simplicity, the design will be divided into 2 parts as follows:

1. The Test Fixture
2. Stepper Motor, DragonBoard, LVDT, Data acquisition

The first components is our main design. The second component is our electrical component. A DragonBoard is used to program the stepper motor using code warriors as our data input. The board communicates with the motor directly, commanding it to rotate a number of steps. The stepper motor is connected to the test fixture via a coupler and a threaded shaft. The thread on the shaft will match with the thread on the table of the test fixture. Rotating the stepper motor will moved the table, causing a displacement. For the testing of a Z-direction sensor, it is tested using a micrometer which displace a rod from the sensor. LVDT's are connected the test fixture with a data acquisition component, and records any displacement made.

Design for Manufacturing

In order to make it easy to machine and assemble our final design. It needed to be simple and functional Turbocor provided all machining, however they do not have a CNC machine readily to be use. We took this into consideration while designing to keep our parts simple to machine. All of the components that needed to be machine are either shaped rectangular, or cylindrical. There are not many layers to them, just flat surfaces. By keeping the design simple we were able to save the time spent machining the parts. We also saved money by having our own machinist and not pay any expenses to make parts.

Materials selection for the design was aided by our sponsor. They had specific guidelines that needs to be followed. Heat treated aluminum and stainless steel were used in all parts of the design. Aluminum alloys were use since it is lightweight, corrosion-resistant, and cost-efficient. The structural supports for the fixture also use aluminum to minimize the weight. Stainless steel were chosen for its strength and because it is corrosion-resistant. Steel were used for our shafts, and rods. Steel were used because the sensor are able to sense it more effectively. Shown bellow is our bill of materials, which lists all of the parts that were order for the project.

Issues during the machining phase of our design included tolerance, drills and tap size, and dimensioning. While creating the first set of drawings and turning it in to our sponsor, there were dimension that were missing. Thus, we have to recreate the drawings and resubmit for machining.

DESCRIPTION	VENDOR	Qty
	P/N	
Micrometer Head	McMaster-Carr	1
Spring Plunger	McMaster-Carr	1
10-24 Set Screws	McMaster-Carr	1
Compression Springs	McMaster-Carr	2
Linear Bearings	McMaster-Carr	8
AC to DC Converter	McMaster-Carr	1
Sleeve Bearings	McMaster-Carr	2
Springs for stage	McMaster-Carr	2
1/4-20 set screws	McMaster-Carr	1
Al 6061 5/8" thick 10" width 6' length	McMaster-Carr	1
Al 6061 1" thick 10" width 1' length	McMaster-Carr	1
303 SS Rod	McMaster-Carr	2
18-8 SS Shoulder Bolts	McMaster-Carr	2
Al 6061 Rod	McMaster-Carr	1
Bellows Shaft Coupler	McMaster-Carr	1
Grade 2 Titanium Rod	McMaster-Carr	1

Table 1

Assembly:

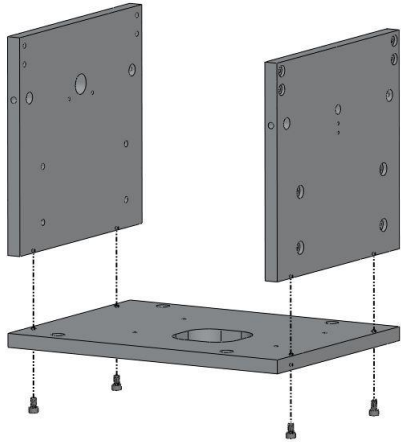


Figure 1

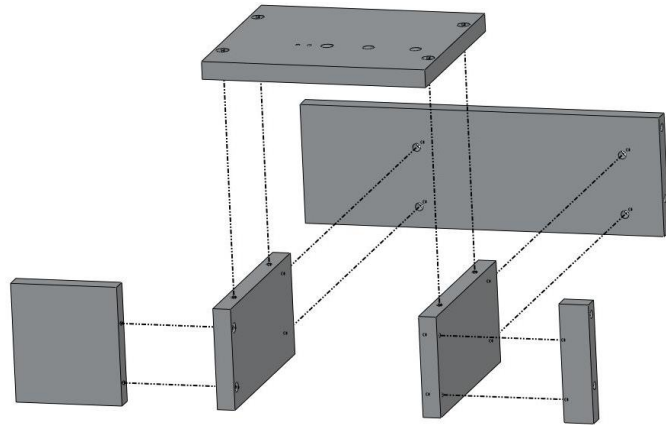


Figure 2

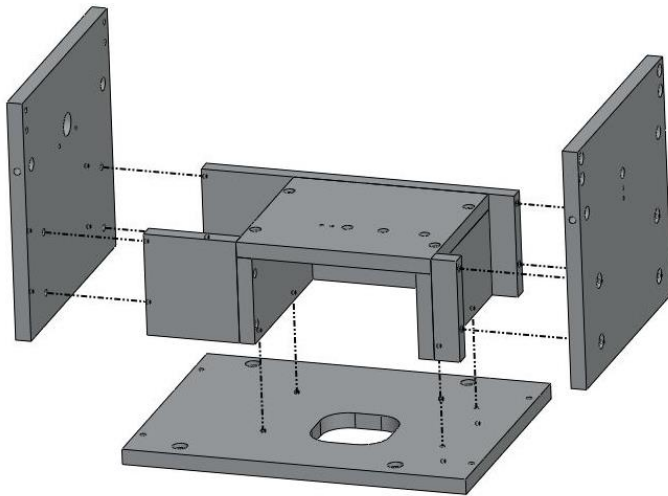


Figure 3

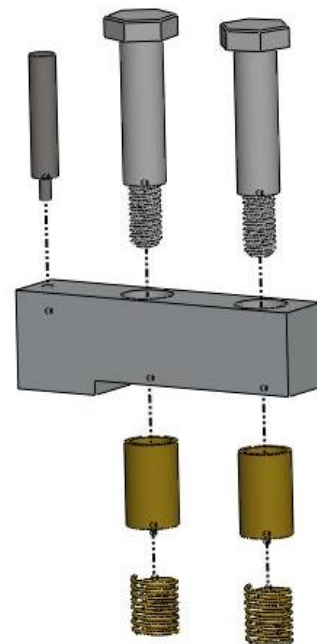


Figure 4

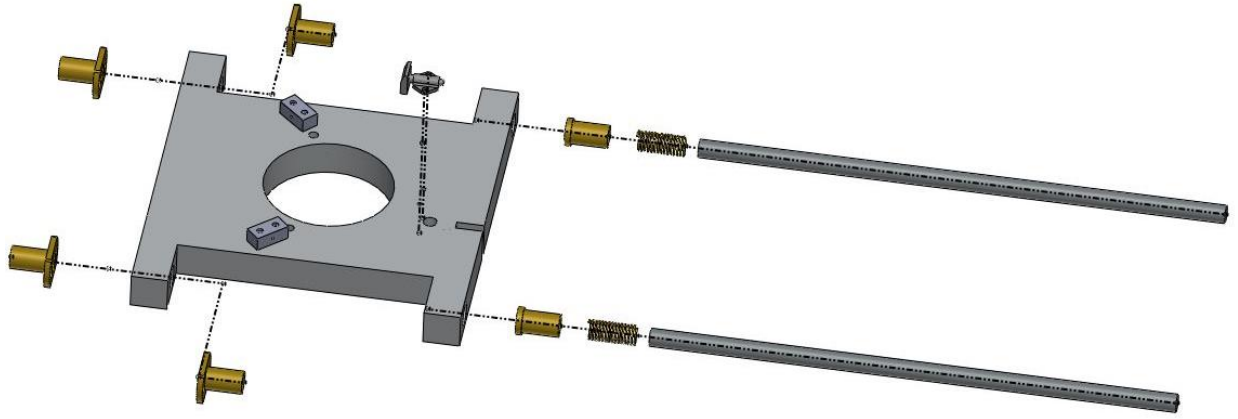


Figure 5

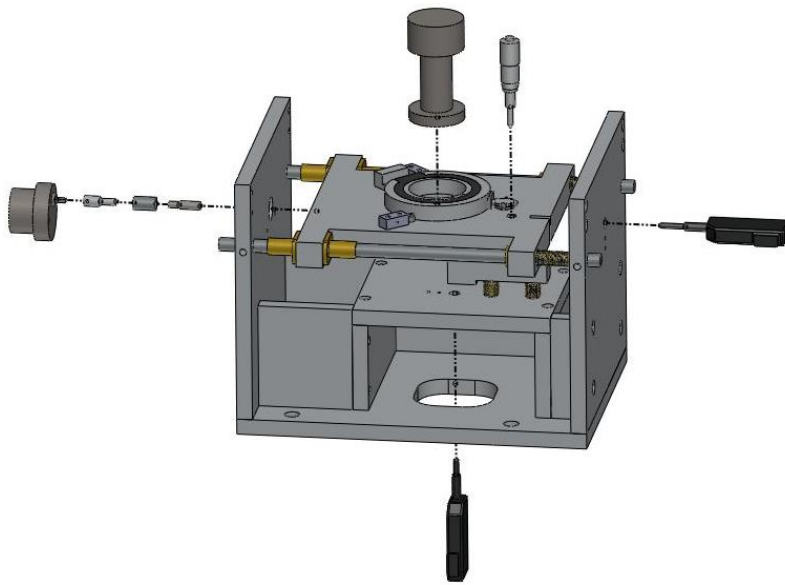


Figure 6

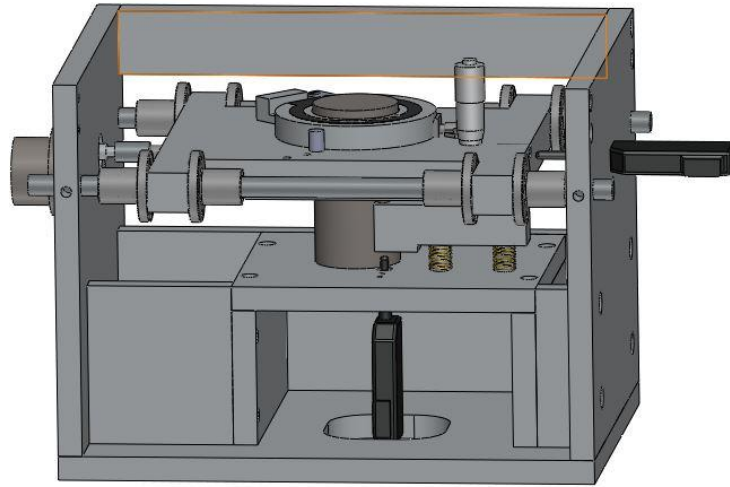


Figure 7

Assembling Instructions:

A. Assembling Test Fixture:

1. Place the main base plate on a flat surface, then join the two large side plates making the external structure support for the fixture.
2. Assemble the internal structure support of the shaft as shown in figure 2.
3. After assembling the internal structure from figure 2, join it with the external structure as shown in figure 3.
4. To assemble the Z-mechanism, press in two linear bearings into the z-platform, then press-in two shoulder bolts through the bearings. Press-in the z-rod into the platform. Insert two compression rings where the shoulder bolts are located.
5. Mount the z-mechanism on to the middle platform. Secure using shoulder bolts.

6. Assemble the guide rails with the sensor platform. As shown in figure 6. 8-flange linear bearings are attached to the sensor platform, then the two guide rails are pushed through along with two compression rings. Make sure to push the guide rails into the large side plate before pushing it through the sensor platform.
 7. Finally attached the springs plunger, and micrometer, and LVDT. A set screw is use to hold the micrometer, and 2 LVDT clamps are use to hold the LVDT. Attach the stepper motor along with the connection shaft and screw onto sensor platform.
 8. Attach the LVDT to the corresponding data acquisition program. Attach the stepper motor to the DragonBoard.
- B. The required data acquisition for the LVDT's is owned by Turbocor. Due to sponsorship proprietary, the assembly cannot be shown.

Design for Reliability

The scope of the project requires that the sensor test rig be reliable so that it can be used in production to test sensor rings. In order to achieve this many things have been taken into consideration. The movement is to be controlled by a screw driven by a stepper motor, by calculating the number of turns required to move a prescribed distance, the system will always move that distance every time the motor is evoked to move. Moreover, the use of LVDTs to capture and record the measurement ensures that distance is accurately accounted for. The LVDTs can sense displacement up to half a micrometer, more than what is needed for the scope of the project. Utilizing the LVDTs, if there was some unnecessary or miscalculated movement,

it can be considered as negligible because the LVDT will have measured it and any discrepancies will be accounted for. To further reduce any unnecessary movements, springs have been placed so that any backlash that would occur would be dampened significantly. This allows for a smooth transition as the stepper motor turns and pushes the sensor table – eliminating any jerkiness that would be caused.

Unfortunately the way that the test rig is machined and assembled it is unpractical to make any major repairs. The LVDTs and Micrometer head are held in place by setscrews and clamps so those can be removed and replaced as needed. The stepper motor can also be disassembled if it begins to malfunction; this is accomplished by removing the adapter that is set screwed into the bellows coupler. Any structural repairing that needs to be done has to be evaluated on a case-by-case analysis. Initially the rig is assembled roughly and then the machinist goes over the entire rig ensuring that everything is aligned properly, the main center hole is then bored through the entire rig. This is done in order to achieve perfect concentricity between the shaft and the table. If any of these components are removed or disturbed it can completely throw off the alignment that was made previously. The majority of the test fixture is made of Aluminum 6061, primarily for its light-weight and its ease of machinability. While it may not be as durable as Stainless Steel, it does provide some durability so it should be able to be used for quite some time. A compromise had to be made, the fixture was required to be somewhat light and it had to withstand some rough usage, Aluminum 6061 was the ideal choice for this. If a problem begins to arise it must be taken care of immediately for the sake of the test fixture not needing to be disassembled. It is imperative that a regularly maintenance routine is put into place.

The test rig does not have high kinematic movements and the distance that is traveled is on the scale of micrometers. These factors contribute to the safety of the machine. The entire rig is compact and relatively lightweight. As a precaution there is an emergency shut off button located on the Dragonboard to shut off the stepper motor, not necessarily to protect a worker but more so to prevent and damage to the sensor table. Aside from the power supply there are no other dangerous electrical components in the fixture. There is not much concern for any safety hazards for a worker operating the test fixture.

Design for Economics

The design of this production-testing fixture was developed with economics in mind. The simple solution would have been to purchase a surgical grade three-axis stage used for microscopes and such. However the sponsor, Turbocor, wanted to develop a test rig that would not only be as effective as the expensive option, but also stay within a small budget. This ensures the product repeatability. In the event Turbocor desires to produce another version of this test rig, it can be done at relatively low cost, and still boast high precision and accuracy.

All of the machined parts were made out of Al-6061. This temper is strong and corrosion resistant as well as relatively cheap compared to the higher tempers of aluminum. The goal of this design project was to develop a high precision testing fixture, without surpassing a \$2,000 budget limit. At the current stand point, the budget of the project is well below the upper limit. That being said, during the design process of the project it was brought to our attention that Turbocor would donate several of the required parts. This, however, does not affect the budget

of the overall project because Turbocor would always build the test rig, and these donated parts will always be at hand at any of their locations.

Another instance where the selection of parts was driven by economics was the decision to make the locomotion for the test stage done by a step motor. Before the step motor was made available to the design, air pistons were the main means of displacement. Although these are not expensive to attain from several vendors due to the small size, the idea of using a step motor proved beneficial because of the abundance Turbocor has on hand. There would be no need to purchase a means of test stage locomotion.

All of the machining was done at Turbocor, which exposes another budget increase that wasn't analyzed during the project. Building one of these test rigs does involve a significant amount of machining, which Turbocor would again do on site. Therefore this aspect does not reveal any increase in total development cost for Turbocor.

The main cost of the build was definitely the cost for aluminum stock for machining. The sheer size of the test fixture requires a significant amount of aluminum to make. After further extensive research and development, the size of the test rig could be minimized to avoid using an unnecessary amount of aluminum.

A general budget was compiled to demonstrate the expenditures that arise from a development project of this caliber. Below the actual purchase order forms that were sent to Turbocor for parts are shown.

Micrometer Head	8578A67	1	\$72.00	\$72.00
Spring Plunger	3351A13	1	\$7.94	\$7.94
10-24 Set Screws	92158A248	1	\$4.82	\$4.82
Compression Springs for Axial	9657K317	2	\$8.38	\$16.76
Linear Bearings	6483K53	8	\$30.80	\$246.40
AC to DC Converter	70235K96	1	\$16.56	\$16.56
Sleeve Bearings	6381K111	2	\$2.15	\$4.30
Springs for stage	1986K25	2	\$13.93	\$27.86
1/4-20 set screws	92158A417	1	\$5.50	\$5.50
3/8"-24 Threaded Rod (drive screw)	6516K21	1	\$7.90	\$7.90

FREIGHT:

A) PREPAID (included)

B) PREPAID & CHARGE

C) COLLECT

D) FIXED AMOUNT

	Amount	
TOTAL		\$410.04

Al 6061 5/8" thick 10" width 6' length	1614T973	1	\$237.13	\$237.13
Al 6061 1" thick 10" width 1' length	8975K103	1	\$86.09	\$86.09
303 SS Rod	88915K223	2	\$29.34	\$58.68
18-8 SS Shoulder Bolts	94731A480	2	\$21.19	\$42.38
Al 6061 Rod	8974K731	1	\$24.62	\$24.62
Bellows Shaft Coupler	59925K91	1	\$80.28	\$80.28
Grade 2 Titanium Rod	89145K169	1	\$17.49	\$17.49

FREIGHT:

A) PREPAID (included)

B) PREPAID & CHARGE

C) COLLECT

D) FIXED AMOUNT

	Amount	
TOTAL		\$546.67

Seen above in the purchase orders, the bottom sheet shows the high cost of the materials for the machining of the main test fixture structure, while the top sheet displays the other components used for maintaining precision and assembly of the fixture. The machining and manufacturing costs are calculated on an hourly basis, and due to the fact that the machining was done intermittently, a cost was estimated to demonstrate the effect on total budget. At \$70/hour and a total of approximately 10 hours the machining cost would be a staggering \$700. This is yet another cost that would not affect Turbocor because they machine all their parts on site.