EML 4552C – Senior Design – Spring 2013 Deliverable

Operation Manual

Team # 5 – Production Test Fixture for Sensor Ring Testing

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Introduction

This sensor ring test fixture is used to test the quality and accuracy of shaft displacement sensor rings for Danfoss Turbocor's compressor shaft systems. This system acquires data from the sensor ring using Danfoss Turbocor's data acquisition system and compares that data to the know displacement data independently measured by the sensor ring test fixture. Sensor ring data is retrieved for three separate axes of movement.

There are two major systems that must work in harmony for this fixture to work properly. The first is the movement system itself. This consists of a series of rails with a stage that actuates across them. The X and Y directions utilize the same horizontal system of rails with a stepper motor to create the actuation. The Z axis movement is created using a spring and micrometer head system. The second system consists of the data acquisition electronics. One portion of this is Danfoss Turbocor's sensor ring data acquisition system. The other portion is the LVDT measurement system equipped to the test fixture to obtain a separate measurement from the sensor ring data acquisition system.

Component Flow Diagram

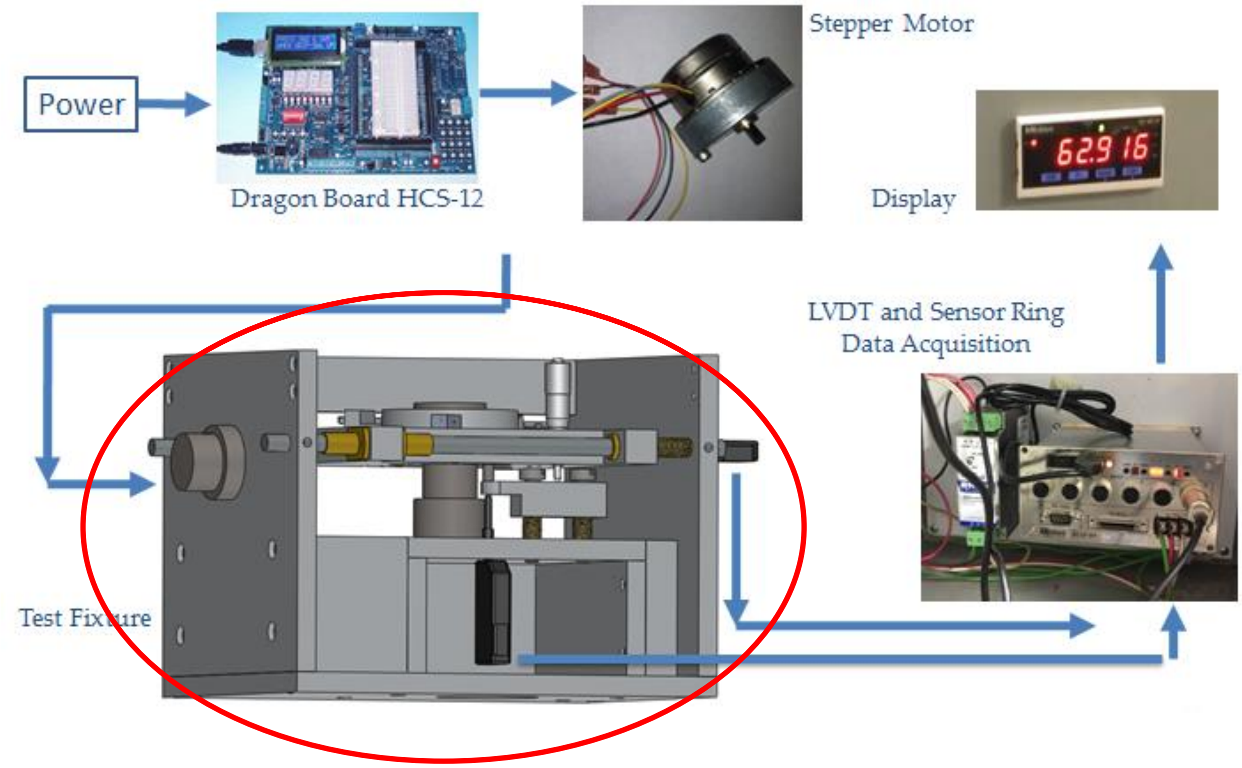

Figure 1 - Flow Diagram

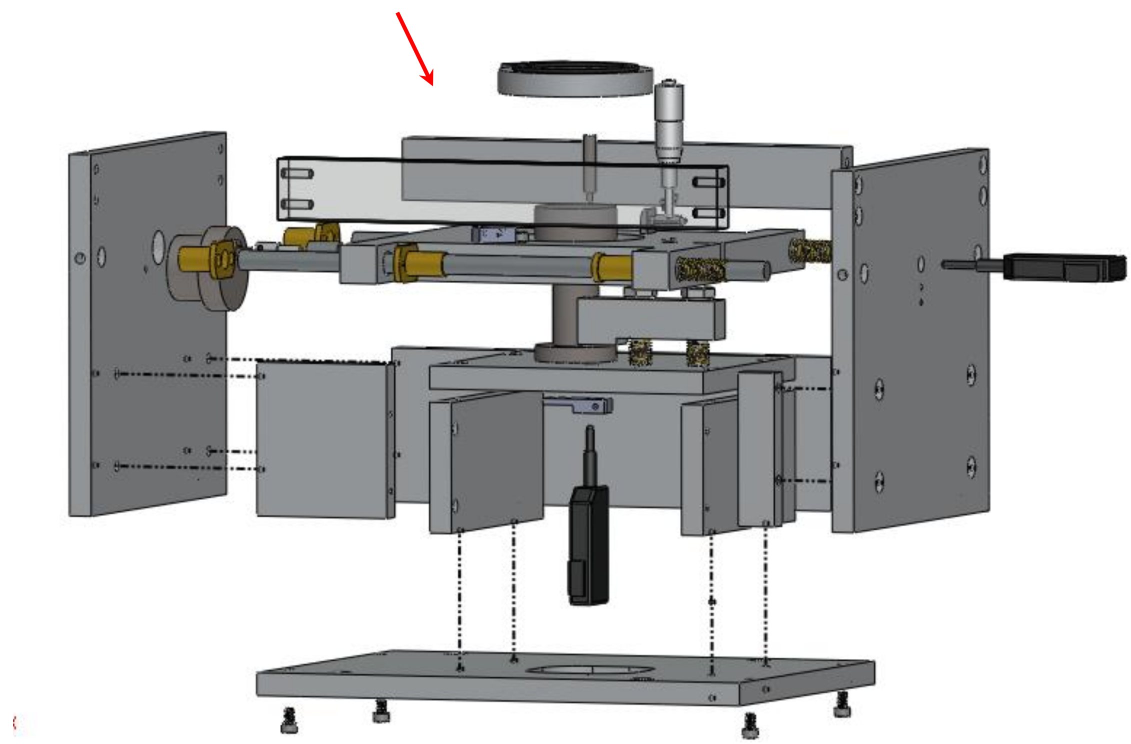

Figure 2 Exploded View

Component List

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Sensor Table		1
2	Z Sensor Rod		1
3	Z-Rod Bracket		1
4	Micrometer Head		1
5	Sensor Ring		1
7	Large Side Plate		2
8	Cross Beam		2
9	Middle Platform		1
10	LVDT		1
11	Base Plate		1
12	Main Shaft		1
13	Guide Rod		2
14	Stepper Motor		1
15	Vertical Plate Platform		2
17	Shaft Coupler		1
18	Bellow Coupler		1
19	Drive Screw		1
20	Left Brace		1
21	Right Brace		1
22	Full Brace		1
23	Z Bracket Springs		2
24	Set Screw		1
26	Platform Mount		1
28	LVDT Clamp		2
31	Shoulder Bolts		2
32	Locating Pins		2
33	Flange Linear Bearings		8

Table 1 - Components List

Expected Performance of Components

Several components of this test fixture are expected to meet certain operation requirements for optimal operation of the system.

First, the stepper motor should be able to run using a power supply of 12 volts at 1 ampere. In addition, the motor also should be able to move with a resolution of 0.25 degrees per step. This is utilizing a full step method. It is also important that all wires from the Dragonboard to the stepper motor and power supply remain secure at all times.

The LVDT's used for displacement detection need to have a precision of 0.5 micrometers as indicated by the manufacturer. They should also have a total displacement detection range of at least 10 millimeters. It is important that all wires from the LVDT's to the data acquisition box remain secure at all times.

The sensor ring rotation stops must be adjustable to provide a range of motion of exactly 90 degrees of the sensor ring. They must also be securely fixed at all times to prevent any variation from the required 90 degrees of sensor ring rotation.

The micrometer head must be able to displace the Z sensor detection rod a total of 400 micrometers while at the same time creating one extreme of this displacement no more than 2 micrometers from the Z sensor itself. Furthermore, the system will operate optimally if the micrometer head is fixed securely in place at all times by its clamp system.

The test shaft itself must remain in its center position in relation to the test stage at all times. If the test shaft becomes out of alignment, it is extremely important to have the test fixture recalibrated to ensure proper measurement and data acquisition. The target sleeve can be used to calibrate the machine if the shaft becomes out of alignment. Alignment should be checked on a regular basis.

Operation Procedure

1. Check all wires and cables to ensure secure connection. Secure any disconnected wires prior to any use of the test fixture.
2. Plug in the power supply to a typical 120 volt, 15 ampere wall socket.
3. Insert sensor ring over the compressor shaft, snap into place, and rotate the sensor ring to the left extreme until it is flush with the rotational stop screw.
4. Press the “SW2” button shown below on the Dragonboard.

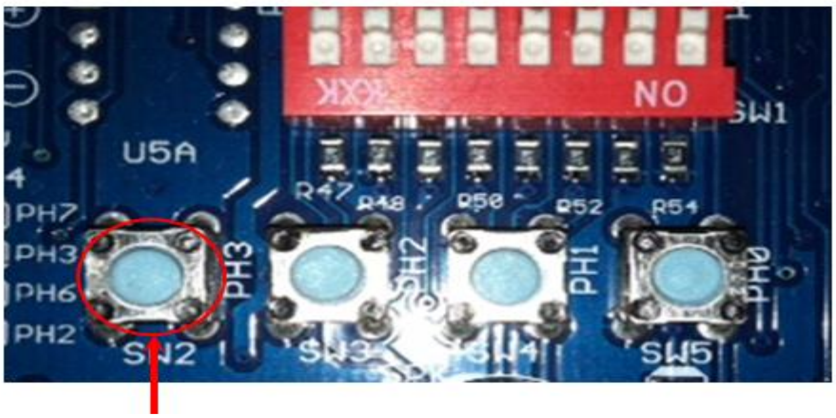

Figure 3-Dragon Board

5. The system will then indicate on the Dragonboard LCD screen when to rotate the sensor ring 90 degrees. Do not touch the system while it is moving.
6. Once the system has acquired the X axis data, rotate the sensor ring 90 degrees until it has reached the opposite rotational stop screw.
7. Again, press the “SW2” button on the Dragonboard.
8. Wait until all movement has stopped and the LCD indicates that the data has been acquired.
9. Rotate the micrometer head so that the LVDT read out indicates a displacement of 2 micrometers, then pause for 5 seconds.
10. Rotate the micrometer head clockwise until the LVDT read out indicates 200 micrometers, then pause for 5 seconds.
11. Rotate the micrometer head clockwise until the LVDT read out indicates 400 micrometers, then pause for 5 seconds.
12. At this point, the test is complete and the sensor ring can be removed from the test fixture.
13. The micrometer head should be rotated counterclockwise until the LVDT read out indicates a displacement of 20 micrometers to prepare for the next test.
14. When testing is finished, the system should be powered off by unplugging the power supply.

Motor and Power Supply Wiring to the Control Board

Figure 4 - DragonBoard

Motor:

1. Red wire goes to terminal "M1"
2. Grey wire goes to terminal "M2"
3. Yellow wire goes to terminal "M3"
4. Black wire goes to terminal "M4"

Power supply:

1. Positive wire goes to terminal "V_EXT"
2. Negative wire goes to terminal "GND"

Safety

1. It is imperative that none of the power supply wires are inserted into the incorrect terminals to avoid destroying the control board and to prevent risk of fire. Always check the wire connections prior to use.
2. To avoid damage to the motor driver, be sure that the motor is not exceeding 1 ampere during use.
3. To avoid pinching, keep hands and other body parts away from the test fixture while the motor is moving. The LCD display on the control board will indicate when it is safe to touch the fixture.
4. Always be sure that the system is powered down prior to leaving the test fixture unattended to avoid equipment damage and fire hazards.

Troubleshooting

Symptom	Cause	Solution
Stepper motor will not rotate	• Dragonboard Code Malfunction • Inadequate Power to motor • Arrangement of stepper motor wiring	• Download provided code to Dragonboard • Ensure power supply is connected securely • See stepper motor specifications for wiring arrangement
Stepper motor overshoots/undershoots	• Stepper motor has not been calibrated for movement	• Change number of steps in code – decrease or increase depending on over/under-shooting
Z-Sensor not detecting rod	• Data cable not connected • Sensor is malfunctioning • Both dummy sensor and z-sensor require displacement measurements	• Securely connect cable • Test a different sensor ring to ensure sensor is not broken • Titanium rod using on the Z-Platform is to be replaced with a bar that will cover both dummy and z-sensor.
X and Y Sensor not detecting shaft	• Data cable not connected • Sensor is malfunctioning • Target sleeve on shaft is not of appropriate material	• Securely connect cable • Test a different sensor ring to ensure sensor is not broken • Replace target sleeve with either Titanium or Stainless Steel

Table 5

Maintenance

The majority of the test rig cannot be replaced, due to the fact that the rig is assembled so that every surface is perpendicular or parallel to each other. Because of this if a component were to be removed and replaced the misalignment that it would cause would have a serious effect on the testing of the test rig. With that said the components that do require maintenance are the LVDTs, guide rods, and the springs.

LVDT

Over time the LVDTs begin to lose accuracy, because of this they have to be tested to ensure that they are recording precise and accurate measurements. Twice a year, about every six months, the LVDTs are to be removed and verified that they are acceptable. In order to do this they are to be compared in measured to a micrometer. The appropriate deviation from the micrometer head is to be less than ± 3 micrometers. Any error greater than that will exponentially decrease any reliability the system has and the LVDT is to be replaced.

Guide Rods

The stainless steel guide rods ensure that there is smooth movement of the sensor ring table. Any debris or anything that would cause unnecessary friction between the rod and bearings can affect the movement of the table. The guide rods should be wiped down and polished to a near mirror like finish as needed. That is when there is any visible deterioration of the guide rods. Using some kind of lubrication, such as oil, on the guide rails will also aid the bearings to ensure that the friction is kept to a minimum.

Springs

The springs in the system allow for minimal backlash while it is in motion. It is critical that they retain their stiffness and are always straight. If one set of springs is not straight and parallel with the other, it will cause jerkiness of the system and also variable movement on both sides of the table. In order to prevent this, visual inspection of the springs is to be done every time the test rig is used. If a spring appears to be tangled/uncoiled/wearing/uneven then it is to be replaced with a new one.

Future Repair

To maintain a properly functioning production test fixture, several of the moving parts need to be considered for replacing after an extended period of use. When working on the scale of microns, every little discrepancy in machining and simple wear and tear may have a devastating result. The main moving piece is the test stage.

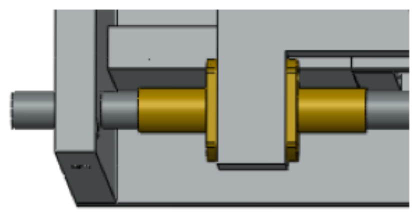

Figure 6- Linear Bearings coupled to Shaft

Besides regular maintenance, calling for lubrication of the linear bearings every so often, the overall smoothness of the motion needs to be maintained. Because of the microscopic nature of the testing process, the linear bearings aren't required to handle a significant load. Thus, the lifetime of the bearings should be sufficient and not require replacing except if failure occurs.

Another key component to consider for lifetime management is the step motor used as the driver for the test stage. The step motor assembly includes the motor, coupler shaft, bellows coupler, and drive screw. After extended periods of testing, some of these parts may lose some of their machined precision required for the rig. The step motor, inside coupler, and bellows coupler should all maintain a high level of precision after use. However the drive screw may require some inspection to ensure the threads

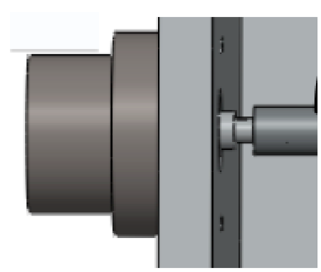

Figure 7- Step Motor coupled with Drive Screw

haven't lost any shape. Regular lubrication is recommended, but in the case of failure, a spare drive screw would be a simple fix.

This brings us to the testing stage and drive screw connection. In order to ensure the connection retains its smoothness over extended period of usage, the materials that were chosen were aluminum and aluminum. Although the aluminum-aluminum connection exposes some vulnerability to the smoothness of the movement the eight linear bearings will work in synch to ensure the test stage is moving in the correct direction. This material of choice makes the replacement of the drive screw a simple fix and the ability to quickly machine a new test stage more simple, being made out of aluminum.

The other major created displacement is the test for the axial or Z direction sensor. Since there is an entirely separate movement mechanism for this sensor, the movement does not rely on the linear bearings or the guide rails, but instead press-in brass sleeve bearings. The brass bearings are again not required to bear a significantly large load, and therefore are expected to maintain a smooth contact surface with the shoulder bolts that hold up the axial sensor tester, for extended periods of usage. The micrometer that is located on top of the test stage is used for the movement in the axial sensors direction. Because of the precision of the micrometer, there might be a need to inspect the accuracy aver extended usage, and possibly replace the micrometer all together.

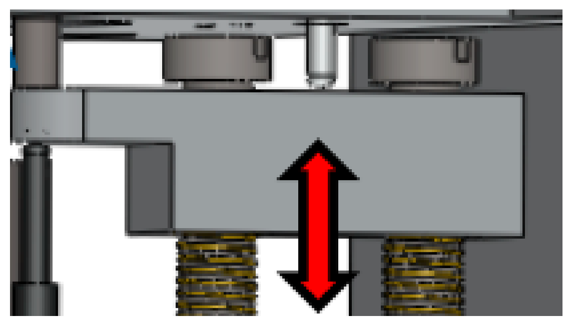
Figure 8- Z Bracket coupled to Micrometer

Because of the rigidity of the test fixtures structure, there are only two major displacement areas that require constant maintenance or inspection. The main testing stage, held by linear bearings and guiderails, as well as the axial sensor test mechanism which is held by two shoulder bolts pressfitted with two brass sleeve bearings. As stated before, due to the microscopic nature of this testing fixture, the loads on these bearings are not significant and therefore do not pose any immediate threat to the high precision required for the test rig.

Spare Parts

In the event that a test fixture failure occurs and the specific part that caused the failure can be determined, a list of essential spare parts was developed to give the user the ability to avoid long periods of downtime. It would be especially advantageous to have all of the parts of the test fixture on hand at all time, however it might be unrealistic to assume that. The parts that require the most machining are never subjected to any significant load, so the user has to reason to keep extras of these. These parts include:

- Test Stage
- Base Plate
- Side Walls (2 large & 2 small)
- Test Platform (or any of the braces)
- Test Shaft
- Linear Bearings (incl. Sleeve bearings)
- Step Motor
- LVDT's
- Micrometer
- Guide Rails

On the other hand there are main movement creating parts that the user is recommended to have spares of on hand at all times in the event of a failure. Some of the parts that are in constant contact with other aluminum parts will be part of that list. Although regular upkeep and lubrication can prevent failure, there will be some instance where wear and tear will cause failure. These parts include:

- Drive Screw
- Z mechanism bracket
- Compression Springs