Restated Project Definition and Project Plan

Group 4: Back EMF Test Fixture

Group Members:

Thomas Razabdouski - Team Leader

Russell Hamerski - Secretary

Timothy Romano - Treasurer

Andrew Panek - Lead Mechanical Engineer

Andre Steimer - Webmaster

Sponsored By:

Danfoss Turbocor

Sponsor: Brandon Pritchard

Advisor: Dr. Cattafesta

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1.0 Problem Statement

Danfoss Turbocor plans to launch a new compressor model before the end of 2014. Current production plans call for the use of a rotor that will be manufactured by a third party company. There needs to be a way to quality check these rotors to ensure they are up to Turbocor standards prior to installing them in the compressor. To test these rotors, Danfoss Turbocor must measure the back electromagnetic force delivered by the electric motor when the rotor is being rotated inside of the stator. Electromotive force, or EMF, typically refers to voltage generated when a motor is spun. Measuring this voltage can be used as a method to determine the rotational speed of the motor, which is called back EMF. The reason it is referred to as a back EMF force is because the voltage pushes against the current that induces it.3 By measuring this back EMF force, Danfoss Turbocor will be able to verify the quality of the rotors being supplied by a third party manufacturer. Eventually, Turbocor plans to manufacture these rotors in-house, but until they switch over to manufacturing these themselves, they require this method of quality assurance.

2.0 Justification/Background

The focus of the team is not on the function of the overall compressor but rather the performance of the third-party rotor. Turbocor has already created a test fixture for their smaller compressor, which has served as a guide for the new design that can accommodate a larger rotor. However, this smaller test fixture cannot be modified to test the new rotor due to an increase in size, electromagnetic force and a need for a more reliable unit as discussed previously. The overall setup of this previously developed test fixture does give this senior design group an opportunity to view the essential features of the test fixture. A picture of the previously utilized back EMF test fixture can be seen below in Figure 1.

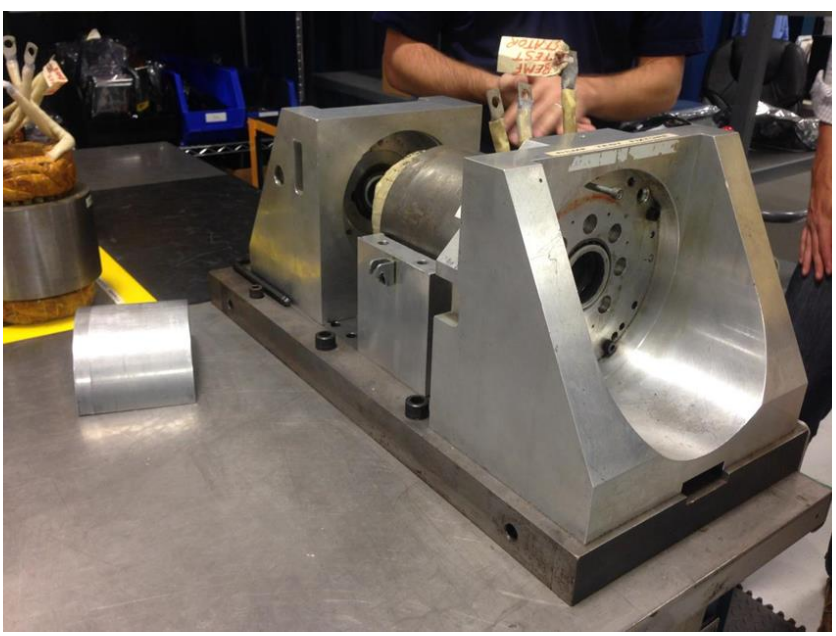

Figure 1: Old Back EMF Test Fixture for smaller rotor model

To review the fall 2014 semester, Team 4 focused on the older test fixture and came up with several prospective designs for the project accordingly. In the test fixture for the smaller compressor model, there is a locking feature that locks the stator into place and can be unlocked, should the stator need to be replaced. This is an essential feature of the new design. The old design utilizes a bearing to ensure the centering of the rotor within the stator. This is an effective way to ensure that the rotor is centered; however, there is a high cost associated with the replacement of bearings over the life cycle of the test fixture, and thus an alternative method of centering was developed. One key feature of the larger rotor is a key-like-hole centered on the end of the rotor. A live center was chosen to center the rotor based on this hole, as it allows for high-speed rotation while handling heavy loads.

A stator will be provided by Turbocor that will reside within a custom-made stator housing. This stator will be used to get the back EMF readings. When the stator is pushed over the magnetic portion of the rotor, there will be a resistive force of approximately 70 pounds. The force will then reverse itself and become an attractive force once the stator is halfway over the magnetic section of the rotor. This is crucial, as this magnetic force will then act to align the stator and the magnetic portion of the rotor horizontally. Linear guides were chosen to allow the stator on the test fixture to move over the rotor, as well as moving the live center into place on the rotor. The linear guide consists of a carriage riding on a track, usually through the use of bearings. Linear guides significantly reduce friction, and thus, ensure that a heavy part can be easily pushed or pulled. A total of two linear guides will be used, and each linear guide will have two carriages, one for the stator and the other for the live center.

The base plate and mounting point for all of the other components will be comprised of extruded aluminum. Extruded aluminum was chosen for its high rigidity and low deflection properties, which is crucial for this project, as a lack of concentricity between the stator and rotor will yield unusable test results. To move the different components, a ball screw will be employed as ball screws have low wear properties and provide the operator with the mechanical advantage needed to move the stator into the working position by transferring rotary motion into linear motion. To spin the rotor, a motor and motor drive were chosen from Marathon Electric. The motor will have the capability of spinning the rotor at up to 1800 rpm. The purpose of the drive is so that the operator may slowly ramp up the angular velocity of the motor during operation.

The final design has been reviewed by Danfoss Turbocor, and barring minor changes, will be manufactured and implemented this coming spring semester. It is shown in Figure 2. The majority of the components of the final design will be off-the-shelf items that will be purchased through the parts retailer Misumi. The only parts that will not be purchased from Misumi will be the live center housing, stator housing, and motor support. Having fewer custom parts is beneficial as it reduces the overall cost of the project. Should parts need to be replaced, there is no necessity for drawings or access to a machine shop because the parts can be ordered and assembled. One of the more unique parts will be the 3D printed nylon motor connection, which will be responsible for transferring torque from the motor to the rotor. This 3D printed part will be ordered through the company FineLine, and is critical because it must be soft enough to not damage the rotor, yet strong enough to handle the 24.5 foot pounds of startup torque of the motor. The live center adaptor is another part that simplifies the design as it allows the hole in the live center housing to be drilled with a constant diameter instead of a tapered one, thus making the machine work for the live center housing considerably less expensive.

3.0 Construction Process

The group will begin construction of the test fixture once all the parts have been obtained. Instead of assembling the entire test fixture one part at a time, the team will assemble the test fixture in subassemblies. This will keep productivity up by always having a subassembly to work on until they are all assembled, as opposed to waiting on a single piece that may be in the machine shop, to continue assembly of the entire test fixture. Constructing subassemblies will also help with any issues in fitment that may occur, because it will allow the group to review the subassembly to make sure everything fits well before completely assembling the test fixture. The subassembly breakdown can be seen in Figure 2 below and Figure 3 shows our final assembly.

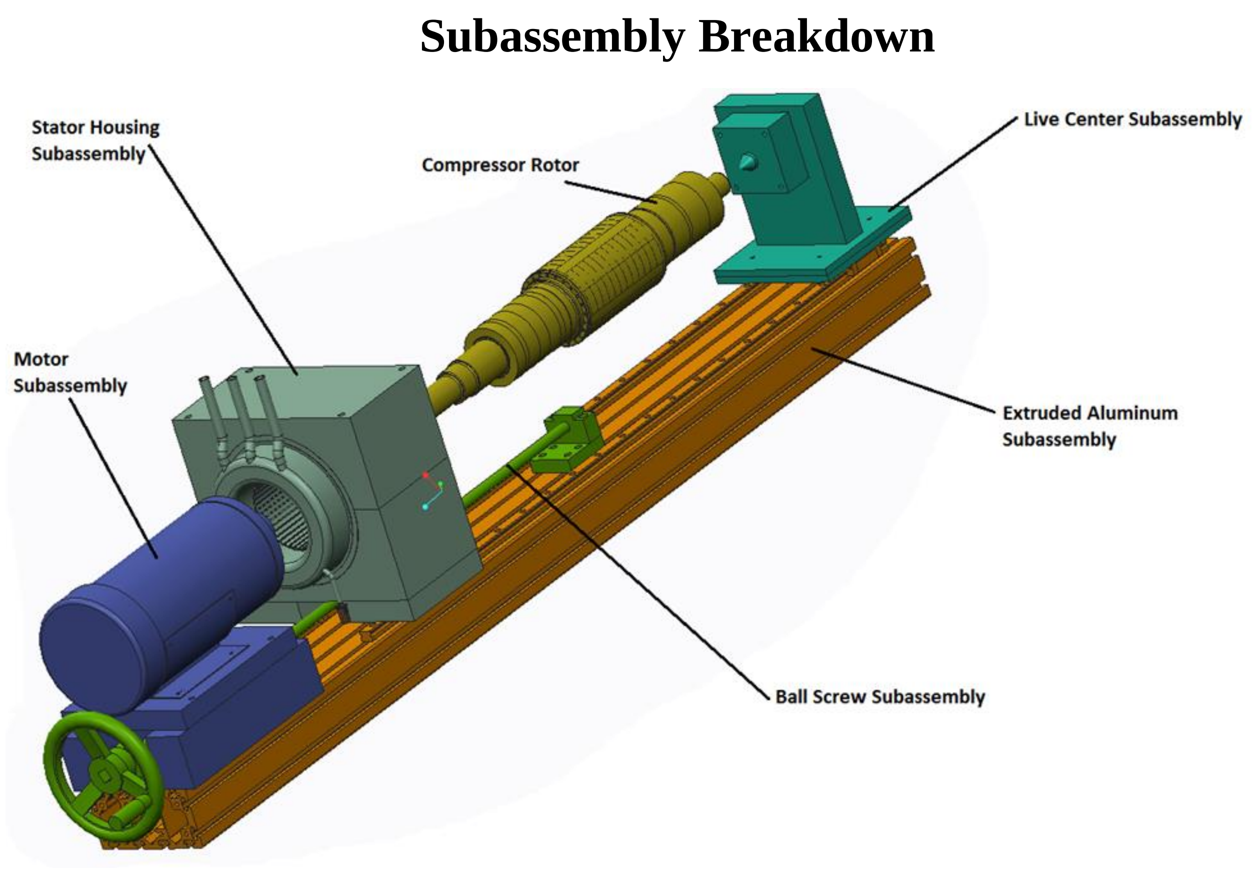

Figure 2: Final model of test fixture showing various subassemblies

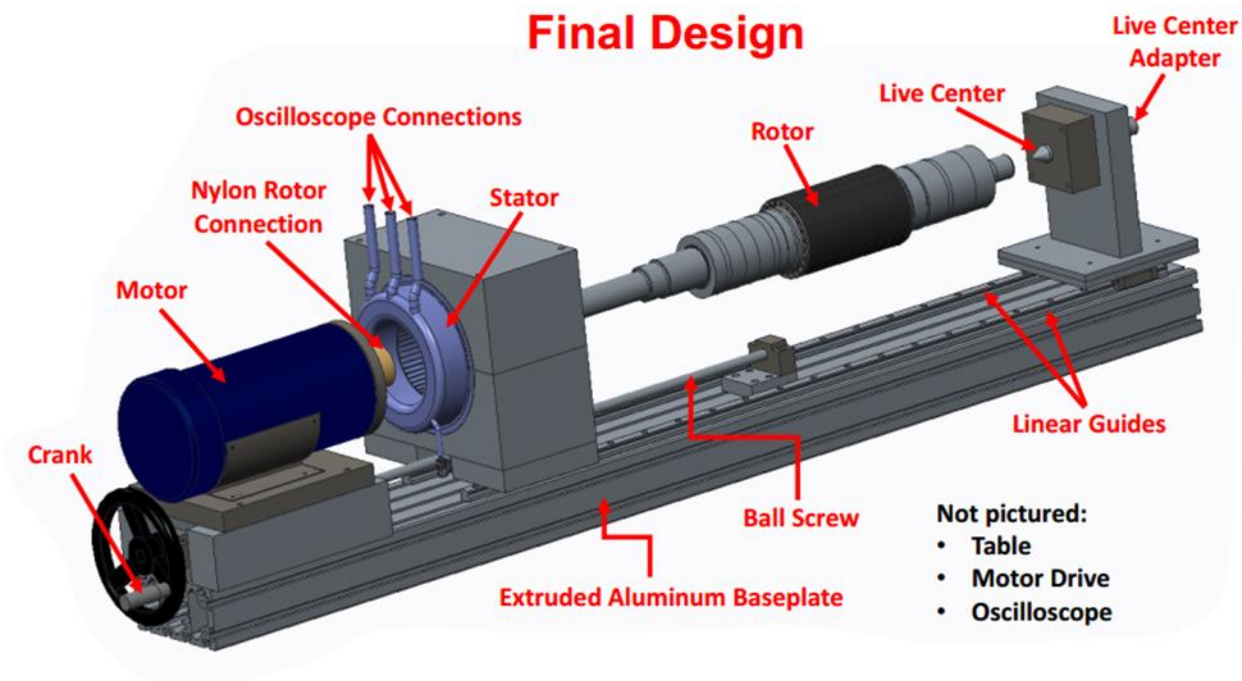

Figure 3: Final design showing various components of test fixture

4.0 Objective

The main objective for this semester is to build a back-EMF test fixture to measure the current and voltage generated when a rotor from Turbocor is spun within one of their stators at a minimum of 1000 RPM. This information will then be compared to that back-EMF required by Turbocor in order to determine whether a rotor passes or fails the quality check. This test fixture will be completely built and tested by April 14, 2015, after which it will be delivered to Turbocor to be implemented into the assembly line.

5.0 Methodology

In order to stay on track and finish by April 14, 2015, the project has been split into milestones. The first milestone is the Parts Ordering process, which consists mainly of finishing the drawings for the custom parts as well as ordering the material and machining these parts. During this process, the team will be split into two groups: one group to complete the classwork, the other group tasked to complete the drawings for each custom made part. This ensures that the team does not fall behind either in the course work or on the project itself.

The second milestone is that of the Assembly process. Once the parts have been received, this stage can commence. As all of the parts will not be received at the same time, the assembly process has been split into subassemblies. Therefore, should a few parts come in late, most of the assembly can be completed without delay. Should it be deemed necessary, the team will split into two groups again in order to complete both the deliverables for the course as well as the assembly of the project.

The third milestone is the Testing and Presentation milestone. This includes testing every part of the fixture and troubleshooting any problems if necessary. This milestone concludes with the final presentation and the final test at Turbocor.

6.0 Expected Results

The expected results of this semester is the success of the Back EMF test fixture. Group 4 hopes to meet or exceed the objectives set by our sponsor, Brandon Pritchard, as well as the expectations set by Dr. Gupta. The biggest success of this project would be full time implementation of the successful test fixture and the construction of additional test fixtures.

7.0 Constraints

As with any project there are expected constraints that must be worked around. This spring semester will provide old obstacles as well as new ones, some of the constraints were implemented by our sponsor and some are put in place by group members. The design that has been developed has many custom parts that will require time in the machine shop which must be accounted for when setting time aside to construct the subassemblies, as well the final assembly. Budget is always a major constraint and this project is no exception, the project was allotted $4,000 and the final cost was $3,600, well within our budget. Due to the nature of the test fixture and the requirement for as little fluctuation as possible in parts dimensions, the machining for the custom parts will be handled by the experienced machinists at the Turbocor machine shop.

8.0 Updates

There are a few minor updates to the design to insure that everything will fit together smoothly. For the custom parts, the counter bore depth of certain mounting holes was adjusted to provide accurate fitment during construction. Another minor update will be stops that will be responsible for locking the live center housing in position along with the stator housing assembly.

9.0 Work Breakdown Structure

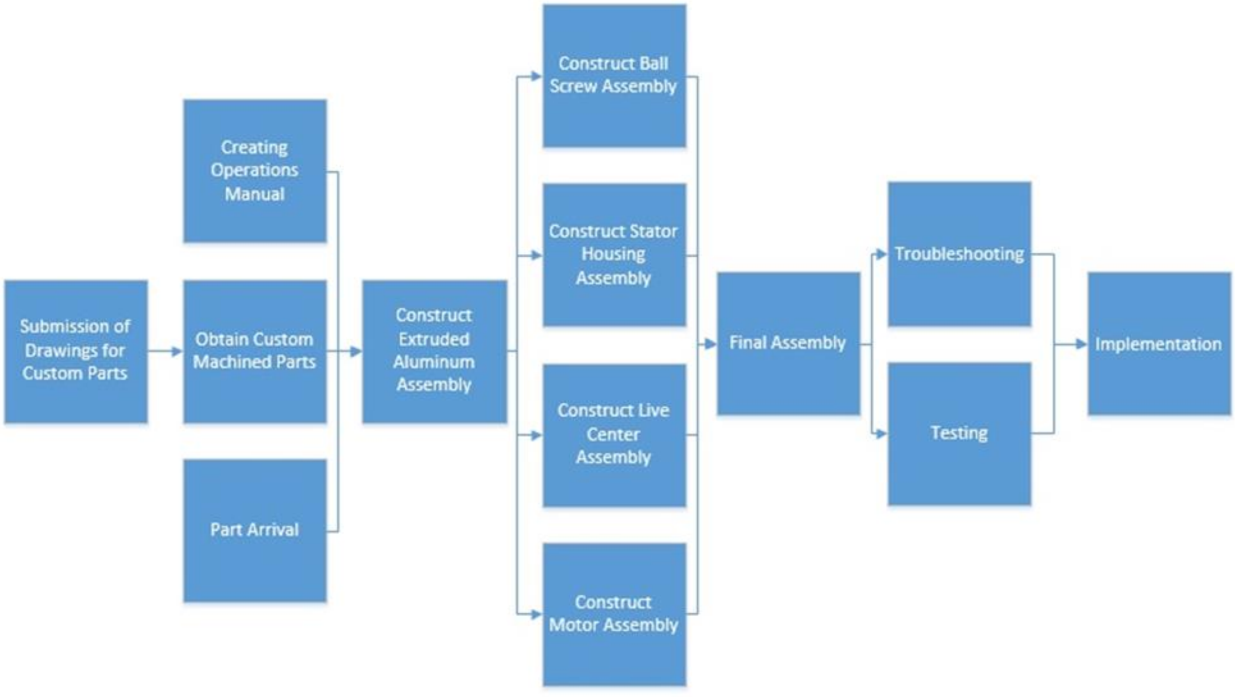

Figure 4: Visual showing work breakdown structure for spring semester

The Work Breakdown Structure (WBS) for the spring semester can be seen in Figure 4 above. The WBS is a visual breakdown of the tasks that must be completed in order to implement the VTT Rotor Back EMF Test Fixture. During the fall semester, many parts such as the motor, ball screw assembly, and extruded aluminum baseplate were ordered. These parts, along with the parts that need to be custom machined at Turbocor will make up the entire assembly. The first task that needs to be completed is the final submission of drawings for the custom parts. This can be completed as the off the shelf parts are arriving. Once all parts have arrived and the custom machined parts are obtained from Turbocor's machine shop, the assembly may begin. The first step in the assembly is to construct the extruded aluminum subassembly which involves setting up the extruded aluminum on the table and getting all connector nuts in place. Once this has been completed, there are several subassemblies that may be worked on simultaneously, this includes the ball screw, stator housing, live center, and motor subassemblies. The final assembly may be done once all subassemblies are completed. The final assembly will involve connecting the individual subassemblies to the extruded aluminum baseplate.

Once the test fixture has been assembled, several tests must be completed before the test fixture may be implemented at Turbocor. The rotor placement and alignment need to be verified, the motor needs to be controlled, an emergency stop needs to be implemented and tested, and the stator needs to be configured properly with the oscilloscope. After all of these initial tests are completed, the complete prototype can be tested with a full run-through mock test. While these tests are taking place, issues may come up and troubleshooting may need to be performed. This can occur simultaneously with the other tests that need to be completed. The final step is implementation of the test fixture on Turbocor's assembly line which will be able to occur once all testing and troubleshooting has been completed to the satisfaction of Turbocor.

10.0 Gantt Chart

The Gantt chart is broken down into three stages and can be seen below in Figure 5: the parts ordering stage, the assembly stage, and the testing and presentation stage. It is very important that the tasks are completed on time to deliver a successful, working prototype to Turbocor. The parts ordering stage consists of submission of drawings for custom parts, creation of the test fixture operations manual, and part procurement. The task of obtaining custom machined parts is 15 days of the 23 day parts ordering stage. This is necessary because of the lead time when waiting on parts to be delivered after being machined, also considering backup time for parts currently being manufactured. The assembly stage will begin with the construction of the extruded aluminum subassembly which must be finished first. All the remaining subassemblies will be constructed after the extruded aluminum and will be attached to the extruded aluminum assembly as they are completed until the entire prototype has been assembled. The final stage on the Gantt chart is the testing and presentation stage, which is critical to insure the prototype will work as it is intended. The most important test is the rotor fitment and alignment test because of the sensitivity of the deviation of the alignment of the rotor within the stator. Once all the testing and the troubleshooting has been successfully completed, the final presentation to Turbocor will take place on Friday, April 17, 2015.

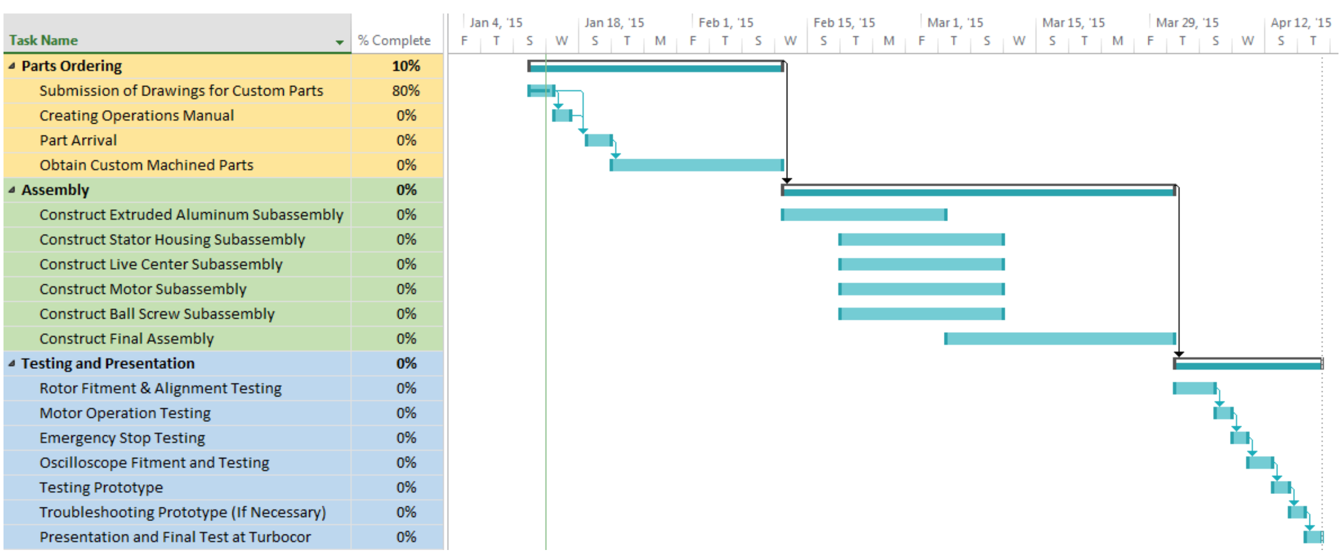

Figure 5: Spring 2015 Gantt Chart

11.0 Conclusion

This report has provided an update to the progress of the Back EMF Test Fixture. The design has been finalized and approved by Turbocor. All of the off the shelf parts have been ordered and will be arriving at Turbocor over the course of the next month. The finalized drawings for the custom made parts are currently being worked on and will be submitted at the first meeting of the semester with the sponsor. Once the custom made parts have been machined, assembly will begin. Several tests need to be performed prior to implementation to ensure everything is working properly. In order to stay on schedule and ensure all tasks are completed, several organization tools are used by the group which include a Gantt Chart and Work Breakdown Structure. Tasks are divided between the group members to ensure the manufacturing semester is successful and all requirements for the class are satisfactorily met.

12.0 References

[1] "Electromotive Force." Princeton University. N.p., n.d. Web. 12 Jan. 2015