11/3/2017

Team 05: High Speed Motor Test Stand

David Balbuena, McLaren Beckwith, Charles Daher, Jacob Quigley, Emily Simmons

FAMU-FSU College of Engineering 2525 Pottsdamer St. Tallahassee, FL. 32310

Table of Contents

List of Tables

Chapter One: EML 4551C

1.1 Project Scope

Danfoss is tasking Team 05 with designing a system that can measure motor efficiency at standard operating speeds for motors inside various Danfoss Turbocor compressors. Team 05 will determine the best way to measure output power for efficiency calculations and the best way to couple the motor shafts for operation at high speeds. They will design and implement a safety shield in order to maintain safe operating conditions while testing the system

Only the Danfoss facility will use the motor testing system. The assembly line will not use the system to test each compressor; instead, the research and development team will utilize it. The stakeholders include Danfoss, research, and product development.

1.2 Customer Needs

Danfoss Turbocor research and development team requires a high-speed motor testing system capable of measuring the power output and efficiency of the Turbocor compressors. The system will operate at a range of 13,000 to 40,000 rpm. Improvements are to be made to the existing system based off need when testing. The system will have a stand since the current motor testing system sits on the floor. It will also need some sort of structure surrounding the entire system for safety purposes. Finally, the team will select and add a torque transducer to the test stand to accurately measure the efficiency of the compressor.

1.3 Functional Decomposition

From the project scope and customer needs, the Danfoss High Speed Motor Test Stand Team can determine the functions of the stand. The team decides on four main functions. The high speed motor test stand will measure motor efficiency, hold the weight of the motor testing system, and protect the operator from harm while testing is in progress. Each of these main functions will also have subfunctions, which will be discussed below.

A subfunction is what needs to be done in order for the main function to take place. For the test stand to be able to measure motor efficiency, it will first need to be able to operate at standard motor speeds. For the motors used in this project, standard motor speed is between 13,000 to 40,000 rpm. Then, it will have to measure torque with a torque transducer.

To hold the weight of the motor testing system, the stand will need to be built with a suitable material. It will also maintain stability.

A safety shield will attach to the motor test stand to protect the operator during testing. The safety shield will be built with a suitable material. After the safety shield is built, the stand will have easily accessible E-stops added to it.

1.4 Target Summary

After defining our functions and their subfunctions, the Danfoss High Speed Motor Test Stand team can now establish the targets for each subfunction. By establishing targets for the project, it will help the team in the further stages of the design process because they will have clear goals to aim for, and it will help eliminate concepts. Each subfunction discussed in the previous section will have a target that the design must satisfy.

The first main function for the high speed motor test stand, as discussed above, is to measure motor efficiency. This function has two subfunctions: operate at standard operating speeds and measure torque with a torque transducer. The standard operating speeds of a Danfoss compressor can range from 13,000 to 40,000 rpm; however, the target for this subfunction is 7,000 to 40,000 rpm. This is because the previous Senior Design Team that worked on this project only achieved 7,000 rpm, and one of the goals set by our sponsor is to achieve a speed higher than the previous team (Aponinuola, De La Rose, Jurko, & Pullo, 2017). To measure torque, the torque transducer must be able to measure a torque of up to 100 newton meters and be able to operate at 40,000 rpm.

From the Functional Decomposition, the second main function is to hold the weight of the motor testing system. This function also has two subfunctions. To be able to hold the weight of the motor testing system, the stand must be built with a suitable material and be able to maintain stability. The material used for the test stand must be able to withstand the weight of two Danfoss compressors, which total 272 kilograms. The stand must also maintain stability while operating underneath the weight of the system. If the system is unstable, the two compressor motor shafts become misaligned, and when the misalignment is too great the compressors completely shut down and stop running. This shutdown occurs when the radial force exceeds 890 newtons.

Safety of the operator using the high speed motor test stand is one of the main concerns of this design project; therefore, the third main function is to protect the operator while testing is in progress. To protect the operator, the system will have a safety shield which must be at least 0.61 meters long, 0.61 meters wide, and 0.5 meters in depth in order to cover all moving parts of

the high speed motor testing system. The safety shield will need to be built with a suitable material that can handle the impact energy of a projectile hitting it. Team 05 calculates this energy using the equation below.

$$E = \frac{1}{2}mv^2$$

The variable ‘m’ represents the mass of the projectile, and ‘v’ represents the velocity of the projectile. For the worst-case scenario, the team uses the coupler, with an outer diameter of 0.08128 meters and a mass of 0.907 kg, as a possible projectile and 40,000 rpm to calculate the velocity. By converting the revolutions per minute to radians per second and then multiplying it by the radius of the coupler, the velocity is 170 meters per second. From the energy equation above, the impact energy of the coupler is 13 kilojoules. The material used must be able absorb an impact energy of 13 kJ. The stand will also need accessible E-stop buttons. An E-stop is defined as “a function that is intended to invert harm or to reduce existing hazards to persons, machinery, or work in progress” (Nix, 2017). For each operator station that can produce mechanical motion, there must be one emergency stop function (Nix, 2017). Finally, for the testing system to be safe to operate, it must prevent the operator from handling the tester while testing. OSHA standards state that rotating parts cannot come into contact with any part of the body. The target set for this subfunction is 0.172 meters because that is the average size of a woman’s hand. Team 05 uses this metric because a woman’s hand on average is smaller than a man’s, and a hand is the most likely body part to come into contact with the tester. The safety shield must be designed so that no operator can come within 0.172 meters of the motor shaft.

The Target Catalog, Table 2 shown in Appendix C, shows all the metrics discussed above. The table also contains the relating subfunctions and main functions.

Appendices

Appendix A: Code of Conduct

Mission Statement

The Danfoss High Speed Motor Test Stand Team is dedicated to work together in a positive environment through the entirety of this project. Each team member will always be respectful and professional with other team members. Each member will utilize his or her strengths in order to contribute as much as possible to this project.

Team Member Roles

Team Manager – Emily Simmons

The Team Manager will ensure that each team member is aware of his or her responsibilities through every stage of the design project. She will also make sure that all members are completing assigned tasks in a timely manner. The Team Manager is responsible for editing each deliverable before the submission deadlines. This includes all reports, presentations, and any other documents required by the project. Once the Team Manager has edited a deliverable, she will be in charge of submitting it on time. Lastly, the Team Manager will always inform the other team members of the project's progress.

Lead ME – David Balbuena

The Lead ME will be in charge of the technical part of the project. This includes data analysis, programming, and any calculations that need to be done. The Lead ME will be held responsible for these tasks even when the work is done by another team member. In the event that another team member does any calculations, the Lead ME will thoroughly check their work for correctness.

Design Lead & Communication Liaison – Jacob Quigley

The Communication Liaison will be the main contact between the senior design team and the sponsor. The responsibilities of the Communication Liaison are but not limited to ensuring that the wants and needs of the customer are well understood, ensuring that the sponsor is aware of the current state of the project, and providing the sponsor with feedback and answering/ finding the answers to any questions that may come up.

The Design Lead will be tasked with creatively designing a mounting stand for the torque transducer and its connections. The Design Lead will also ensure that the safety of the test stand is improved. All parts will be made by the Design Lead taking into account the machinability and cost of the process. All part drawings will be done by the Design Lead, and he will schedule drawing reviews with all team members before any submissions or purchases.

Financial Planner – McLaren Beckwith

The Financial Planner will be responsible for the supervision of the project's budget as well as maintaining a record of all of the relevant team purchases. All expenditures must be reviewed by the financial planner for approval. Pending approval, the planner is responsible for analyzing alternative products and verifying that the order is satisfactory. Once the transaction is complete, a record of the purchase must be created and maintained by the planner.

Web Designer – Charles Daher

The Web Designer will be in charge of creating the template for the 2017 High Speed Motor Test Rig website. He will update the website as necessary with information describing the project, project deliverables, and sponsor and team member information. He will make sure that

the website is easy to navigate, esthetically pleasing, and always up to date with the project's progress.

Organizational Chart

Team Member Names	Team Member Roles					
	Team Manager	Lead ME	Design Lead	Communication Liaison	Financial Planner	Web Designer
David Balbuena		✓				
McLaren Beckwith					✓	
Charles Daher						✓
Jacob Quigley			✓	✓		
Emily Simmons	✓					

All Team Members:

- Contribute equally
- Listen and be open-minded to others' ideas
- Provide constructive feedback
- Deliver on commitments

Communication

Communication between team members will be done in person on Tuesdays and Thursdays in class, through a group messaging app called GroupMe, and on Google Drive when preparing presentations and papers that we will all collectively be collaborating on. If a member of the team is having difficulty with communication, (i.e. not responding to messages/ not doing

their part) Jacob and/or Emily will be tasked with trying to effectively communicate the task at hand. If this is a continuous problem, it will be addressed with Dr. McConomy.

Communication between the senior design team and the sponsor at Danfoss will be done mostly through the Communication Liaison, Jacob. Verbal communications between Jacob and the sponsor pertaining to the project will be relayed to the team members using GroupMe. The Communications Liaison will also handle all emails and will be responsible for sharing the information to all group members.

Team Dynamics

Each team member will have their own responsibilities during the project. They are in charge of making sure their portion of the project is progressing in a timely manner and are ultimately responsible for making sure it is completed by the specified deadline. One of the most important things is that a team member should communicate with the team if they are having difficulty completing a task.

Ethics

The team will be adhering to the National Society of Professional Engineers' Code of Ethics. Team members are required to model their behavior to the highest standard of honesty and integrity for the benefit of the client, the team and the profession.

Dress Code

During presentations, team members will be expected to dress in business formal attire. Client meetings will be held in business casual attire. There will be no required dress code for routine team meetings. All dress code expectations are subject to change with a unanimous team decision.

Weekly and Biweekly Tasks

Weekly meetings will be held between team members during class time. In these meetings, the group will make sure all the team members are up to date on the progress of the project. Project updates and any new information will be discussed here. At least one meeting per week with all team members will be expected with strict attendance. The team will communicate with the sponsor biweekly, either in person or through Jacob Quigley. If needed the team will plan for more meetings depending on the project direction.

Decision Making

All decisions will be made together as a team. Ideally, in the event that two group members disagree, an intelligent conversation would be had including all team members, leading to a resolution. If there is still a disagreement, a vote would be taken amongst team members. We have an odd number of group members so this should solve the issue. In the unlikely event that only a certain amount of team members could vote and it resulted in a tie, the tiebreaker would go to whoever is leading that discipline. For example, if it were a discrepancy on the background color of the webpage, Charles would have final say since he is the Web Designer.

Conflict Resolution

If the team members have any discord, the following steps will be employed:

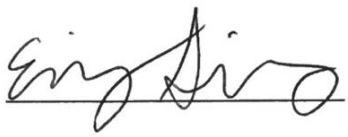
- Ideas will be discussed with all members to analyze the pros and cons.
- The leader of each department will decide what the final result will be.
- If needed, the team manager will intervene.
- Instructor will facilitate the resolution of conflicts.

Amendment Process

This code of conduct can be amended only if all team members sign off on the amendment.

Statement of Understanding

By signing this document, the members of the Danfoss High Speed Motor Test Stand Team agree to the code of conducts and understand its principles.

Name	Signature	Date
Emily Simmons		09/21/17
David Balbuena		09/21/17
McLaren Beckwith		09/21/17
Jacob Quigley		9/21/17
Charles Dahm		9/21/17

Appendix B: Functional Decomposition

Table 1
Functional Decomposition

		Main Functions		
		Measure Motor Efficiency	Hold the Weight of Motor Testing System	Protect Operator while Testing
Sub-Functions	Operate at standard motor speeds	●		
	Attach a safety shield			●
	Measures torque with a torque transducer	●		
	Build with appropriate material		●	●
	Add accessible E-stops			●
	Maintain stability		●	
	Prevents operator from handling tester while testing			●

Appendix C: Target Catalog

Table 2
Target Catalog

Main Function	Sub-Functions	Type of Target	Target
Measure motor efficiency	Operate at standard motor speeds	Speed	7,000 - 40,000 rpm
	Measures torque with a torque transducer	Speed, Torque	40,000 rpm, 100 Nm
Hold the weight of motor testing system	Build with appropriate material	Mass	272 kg
	Maintain stability	Radial Force	890 N
Protect operator while testing	Attach a safety shield	Length	0.61 m x 0.61 m x 0.5 m
	Build with appropriate material	Impact Energy	13 kJ
	Add accessible E-stops	Number of E-stops	1 E-Stop
	Prevents operator from handling tester while testing	Length	0.172 m

References

Aponinuola, F., De La Rosa, J., Jurko, A., Pullo, J. (2017, April 21). *Final Report Team 05 Motor Test Rig.* [PDF document]. Retrieved from https://www.eng.famu.fsu.edu/me/senior_design/2017/team05/deliverables/Final%20Report%20Spring%202017.pdf

Nix, D. (2017, July). *Emergency Stops – What's so Confusing About That?* Retrieved from http://machinerysafety101.com/2009/03/06/emergency-stop-whats-so-confusing-about-that/

Occupational Safety & Health Administration. *Chapter 1 – Basics of Machine Guarding.* Retrieved from https://www.osha.gov/Publications/Mach_SafeGuard/chapt1.html