

ECE443: Engineering Design Project

AEMD Project Closeout

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Introduction

Our project partners at AquaHarmonics require a dynamometer to determine, with certainty, the motors capabilities and efficiency at performing the required tasks, being that manufacturers specifications are notoriously poor when it comes to DC motors. The Automated Electric Motor Dynamometer (AEMD) is aimed to design a device to measure real-time motor performance and display multiple characteristics such as torque, speed and efficiency across a broad spectrum of motor, drive, and feedback sensor configurations. On a broader level, the AEMD will be integrated into the R&D of Wave Energy Converters (WECs), which are an integral part of harnessing the ocean's energy potential to transition our world into a greener, sustainable future. That said, the importance of delivering the AEMD as a quality product to our project partners carries significant weight in their ability to make the best motor design choices, whose impacts could be drastic and wide in scope.

AEMD Design Impact Statement

Public Health, Safety, and Welfare Impacts

In regards to public health, safety, and welfare impacts, the AEMD presents a concern due to the high speeds the AEMD could potentially reach during its motor testing. To integrate safety into the AEMD design, a shield is in place to physically protect those observing the AEMD from potential flying parts in a worst-case scenario [1]. This enables observers to take note of the process while being safely protected by a strong, deflective piece of plexiglass should a piece of the AEMD ever choose to fly off unexpectedly. Without such precautions, this poses a dangerous risk in potential injury and damage to nearby equipment within the vicinity. On a global scale, a shield implementation would only be paramount to the level of safety that manufacturing/motor companies emphasize on a constant basis. Overall, without any considerations for public health, safety, and welfare, the world would be in a horrible position as a lot of individual's lives safety and welfare would be put in danger simply because safety mechanisms weren't considered in the overall design of a product.

Cultural and Social Impacts

With a focus on renewable energy, this provides the US with energy independence and ongoing efforts to reduce carbon footprint. AEMD's focus on improving wave energy converters (WECs) would create jobs and a new industry centered around these devices. Since 2010, solar industry employment has grown by 167 percent [2]. Although solar and wave energy are two different industries, the comparison is still helpful. We could estimate that a similar number of jobs would be created to integrate wave energy equally as solar. Culturally, the AEMD serves as a strong symbol towards global transition towards renewables and clean energy technology.

Environmental Impacts

The environmental threat posed by climate change makes advancements in clean energy solutions imperative. WEC technology is at the forefront of trying to solve this problem and maintains several distinct advantages over other forms of sustainable energy. With the ocean always capable of producing energy, it carries 1000x the kinetic energy of wind and is extremely consistent across time. [3]. A possible drawback are the effects electro-magnetic fields (EMF) have on marine life. Studies have shown that EMF can disrupt migratory patterns of fish and potentially increase aggression in marine predators [4]. However, steps are being taken to mitigate or remove these effects by advancements and studies in materials and their effects.

Economic Factors

Should the AEMD gain traction for motor performance and testing, this would present job opportunities and business ideas to improve WECs in the future. Thus, the AEMD would serve as a prototype for improved motor testing and enhancement. The AEMD will enable more motor R&D for documenting and observing the performance of motors under certain conditions. Being that around 45% of the global electricity is estimated to be used for electric motors, it is definitely an economic opportunity for jobs and to explore new ventures within the motor-testing industry [5]. Explicitly, a whole new niche of jobs would be created for motors and motor-testing tools thus pushing our technology towards improved design and performance of motors.

Project Timeline

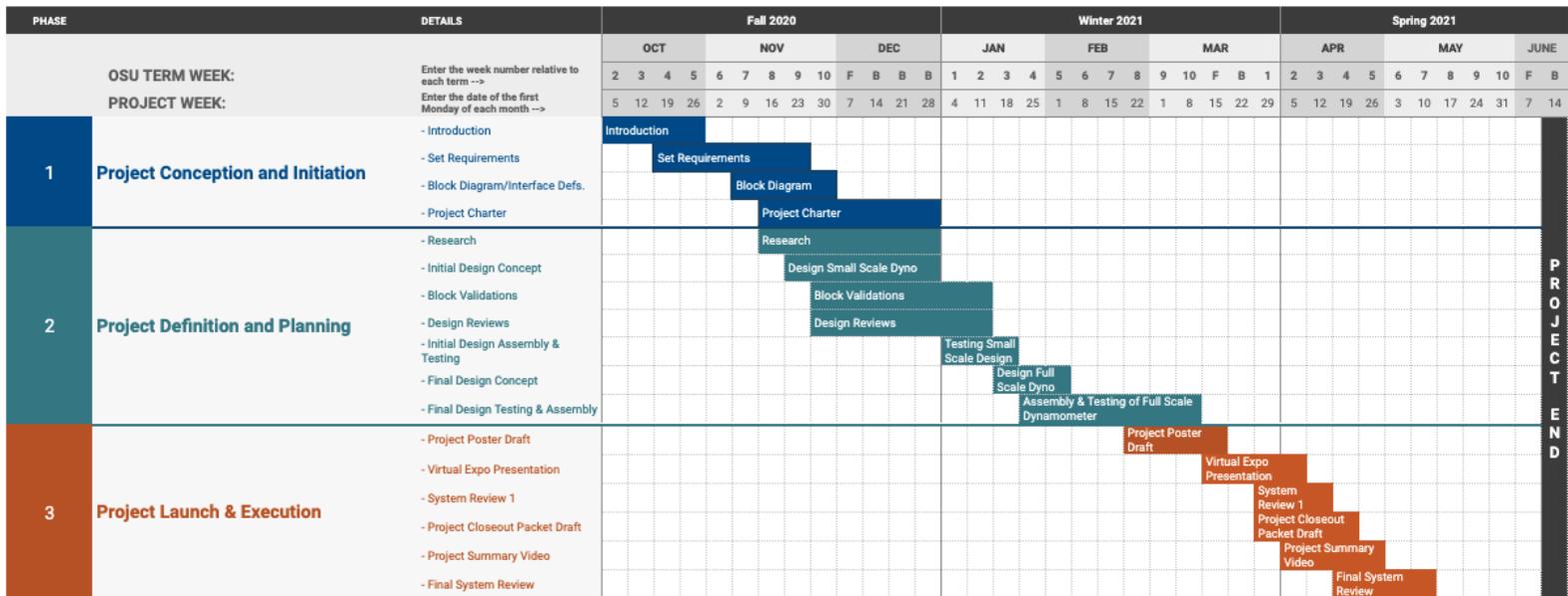
The AEMD has been held to a general project timeline for expected project completion by Spring 2021. Thus, we developed a Gantt Chart in Fall 2020 outlining the general project progression which displays expected progress starting from October 2020 to May 2021. As you'll see, our Gantt chart included general project goals, and each block's end represented the deadline for that block (either a course deadline or an agreed upon deadline for our group), and what is expected for each block. Moreover, we have generalized our project in three different phases:

- 1) Project Conception and Initiation
- 2) Project Definition and Planning
- 3) Project Launch & Execution

That said, the main stakeholders and AEMD team are listed and have initially developed this Gantt chart displayed below to facilitate the progression our team followed throughout the project.

AEMD PROJECT TIMELINE

PROJECT TITLE	Automated Electric Motor Dynamometer (AEMD)	COMPANY NAME	AquaHarmonics
PROJECT MANAGER	Alex Hagmüller, Max Ginsburg	DATE	11/7/20
TEAM MEMBERS	Ben Carlson, Jordan Brown, Ian Brysen Pagatpatan		

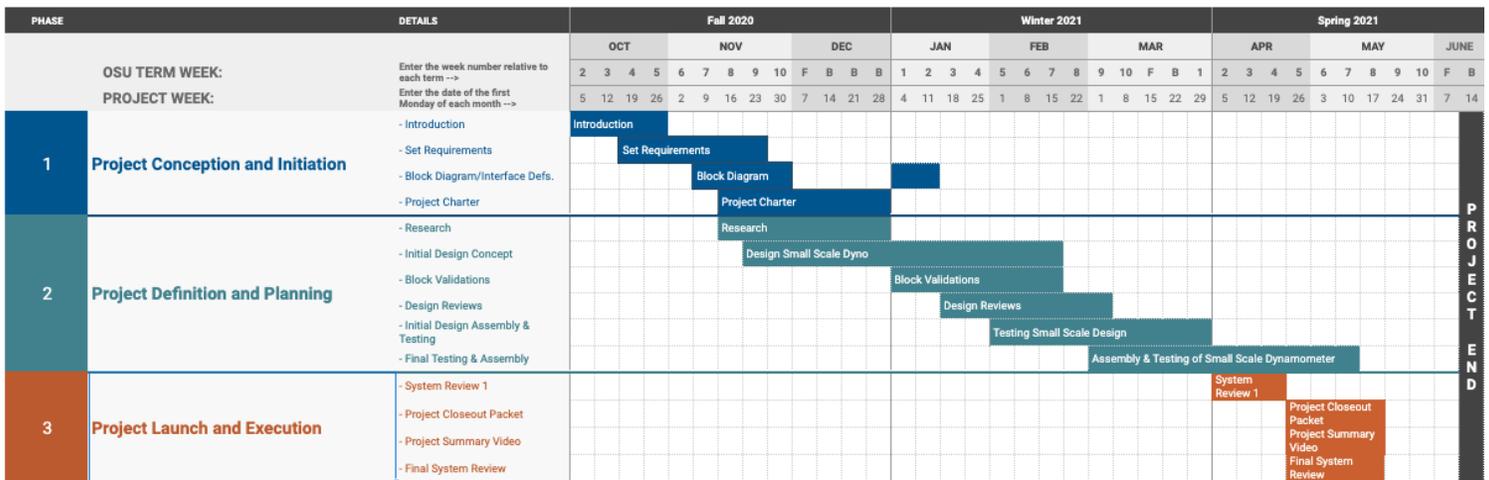


Reflection of Project Timeline

As the AEMD Project comes to a close, our group devoted time to reflect on the progression of our project and observed any deviations and achievements that were attained throughout the AEMD’s development. We organized weekly AEMD Team Meetings on Mondays at 12PM and Fridays for Team Meetings with our project partners for major project updates throughout this project. In the image below, this displays the actual project timeline that played out through the course of this project from Fall 2020 to Spring 2020.

AEMD ACTUAL PROJECT TIMELINE

PROJECT TITLE	Automated Electric Motor Dynamometer (AEMD)	COMPANY NAME	AquaHarmonics
PROJECT MANAGER	Alex Hagmüller, Max Ginsburg	DATE	5/16/21
TEAM MEMBERS	Ben Carlson, Jordan Brown, Ian Brysen Pagatpatan		



Now, comparing our initial timeline with our actual project timeline, it is evident that our project progression wasn’t as linear as we were expecting. Throughout the duration of our project, we’ve observed that a lot of project definition and planning were extended a significant amount, which resulted in a lot of revised project timeline goals. After great deliberation, we can attribute these deviations in our timeline due to lack of experience and a steep learning curve of the equipment and software that were required of us during the development of the AEMD. However, this will be elaborated on within the “Future Recommendations” section. As a result of this, our group had to work through to the final deadline of Final System Reviews to achieve an AEMD that met most of the engineering requirements and completed it to the best of our ability.

Scope and Engineering Requirements Summary

The AEMD team has continued to refine our understanding of the scope and implied engineering requirements to successfully develop the AEMD. In a general sense, the project scope is centralized around developing a tool that is able to characterize motors of varying sizes using sensors and software to output a report displaying the motor's actual performance and thus validating the motor's overall compatibility for ongoing projects at AquaHarmonics. That said, we have curated eight engineering requirements:

1. **Accuracy**

The system torque and speed output will be within 10% of their respective target values.

2. **Adaptability**

The system will be designed to fit 3 different combinations of motors and drives.

3. **Automation**

The system will be able to perform tests with speed ranging from 100 - 3000 RPM.

4. **Cooling**

Temperature is maintained to within ± 15 degrees of room temperature and temperature safety shutoff will end testing if the motor becomes too hot.

5. **Dynamometer Report**

At the completion of the motor test, a post-report containing collected data that is created that will be printable and easily shared.

6. **Motor Characteristics**

System must display data: Torque, RPM, and power in/out should be displayed to the user through a graphical display.

7. **Portability**

Entire system will weigh less than 75 lbs assembled (or disassembled with a weight summing to 75lbs) and utilize a manual for assembly/disassembly instructions.

8. **Test Configuration**

The system will provide the user with the choice between predetermined tests. The user should be able to select from a variety of tests and ways to stress the motor and test performance.

Updated Risk Register

At the start of the project development of the AEMD, our team curated a list of ten potential risks we anticipated to encounter throughout the project (displayed below). We've updated our risk register to include a column to address if the risk was encountered and the actual impact it had on our project on a scale from Low (L), Medium (M), or High (H) impact on our project timeline.

Risk ID	Description	Category	Prob	Risk Encountered (Y/N)	Actual Impact	Anticipated Impact	Performance Indicator	Responsible Party	Risk Action Plan
1.1	Team member scheduling conflicts	Timeline	50%	Y	L	M	Not meeting agreed upon deadlines.	Entire group will attempt to attend every group meeting	Avoid
2.1	Expensive Equipment	Inventory	50%	Y	M	H	High-cost and possibly very effective that could compromise budget	Jordan Brown	Transfer
3.1	Inability to secure proper software licensing	Design	50%	Y	H	L	Awaiting feedback from MATLAB regarding temporary product licensing.	Ben Carlson will pursue alternative software in the event that Simulink Real-Time is unavailable.	Avoid
4.1	Interrupted supply chain and shipping delays	Timeline/ Inventory	20%	N	L	L	Monitoring package tracking	Jordan	Reduce
5.1	Learning Curve for New Skills/Programs	Skillset	70%	Y	M	M	Longer than expected time to become proficient in skill/program	Ben, Ian, and Jordan	Retain
6.1	Lack of familiarity with motor drives - introducing encoder	Technical	25%	Y	H	M	Ability to drive motor in correct sequence	Ben, Ian, and Jordan	Reduce
7.1	Accidental damage to system during testing	Technical	30%	Y	H	H	Previous mishaps during testing, uncertainty of design.	All team members will consult with other members before pursuing any uncertain tests.	Avoid

8.1	Understanding variables associated with electric motors, and applying in Simulink.	Technical	60%	Y	L	M	Low-cost yet effective for project implementation	Jordan Brown	Retain
9.1	Inability to secure lab space	Timeline	20%	N	L	L	Lab seats are filling up, especially during approaching deadlines.	Ian will check the Doodle page for Dearborne lab space and make appointments as needed.	Reduce
10.1	Difficulty creating an enclosure to contain the system.	Technical	10%	N	L	L	Success with fabrication	Ben	Reduce

Avoid — change your project so the risk becomes obsolete

Retain — decide the risk is reasonable to proceed with your project

Reduce — decrease the likelihood of the risk occurring without changing the project

Transfer — delegate responsibility for that particular risk area to a stakeholder or someone outside the team

Legend:

- Yellow: Low impact
- Orange: Medium impact
- Red: High impact

Lessons Learned in the AEMD

With the project timeline of the AEMD coming to an end, we have experienced a handful of lessons learned in each phase of the project: Project Conception and Initiation, Project Definition and Planning, Project Launch and Execution. In our project conception and initiation phase, an important lesson learned was the importance of developing a relationship within our team as the project began to unfold. Our team established a great foundation for communication and a collaborative/supportive environment, which ultimately led to constant project progress and updates throughout the development of the AEMD. In our second phase of project definition and planning, we understood the value in devoting time and energy in the design process and the documents associated with the AEMD such as the block diagram, the design of each individual block, and the implementation of these blocks. With a lack of experience in the equipment being used, we had a conceptual understanding of implementation thus proving our design documents useful but then faced the battle of how to properly implement our blocks in the AEMD. In our last phase of project launch and execution, the team environment we developed really facilitated the collaboration and willingness to meet project deadlines in a timely manner. Although our project didn't necessarily follow our project timeline, we were able

to communicate what needed to be done and when we would be able to do that either as a group or individually thus never leaving room for uncertainty about our project. All in all, these lessons proved invaluable when working on an engineering group project and exemplified the ideal environment within a group really holds a key towards a project's success and the relationships within the group to achieve the goals and objectives along the way.

Unanticipated Risks

Many of the unforeseen issues we encountered were a result of difficulties in setting up the hardware we were working with. The PD4 drive and motor combination was especially difficult to set up because it communicated through the CANOpen protocol which had to be interfaced with proprietary hardware that operated on the Ethercat. It's challenging to find documentation for this process and even people who have experience with Ethercat find this extremely challenging. The other drive had issues detecting an encoder which prevented it from functioning properly. This wasn't able to be resolved through adjustments to the firmware or settings of the drive. Additionally, once the VESC drive was working we had issues with the input for the throttle of the motor. After reading through forum posts we learned that this was a symptom of a broken ADC and it could be fixed with custom firmware for the drive. Thankfully this is very easy due to the open source code for the VESC. Some aspects of data collection through Simulink Real-Time are also confusing and becoming familiar with the system was more time consuming than expected. Altogether, although these risks were unanticipated, our team worked diligently to address these risks and reacted appropriately to progress the AEMD's development further towards completion.

Future Recommendations

With the trials, tribulations, and multitude of experiences with the development of the Automated Electric Motor Dynamometer (AEMD), there are a lot of factors that contribute to the following recommendations and improvements of the AEMD. These factors range from lack of experience/steep learning curve of equipment and software to managing a workload between school, work, and other items that life has to offer. That said, the list below displays key future recommendations that would further improve the AEMD in regards to usability, convenience, and team management:

I. Compactness

Throughout the development of the AEMD, our current product has resulted in a bunch of components such as: a motor rig, a battery pack, a target machine, monitor, and PC. In regards to future recommendations, designing the AEMD to create an enclosure that houses these several moving parts would greatly increase the mobility and overall aesthetic of the AEMD. With an improved enclosure, the previously mentioned major components of the AEMD will be tucked away thus allowing the user to focus on the user interface to configure the motor test as well as observing the motor during testing.

Essentially, this “black box” will simply ask for test inputs and provide an output report that the user can utilize to determine motor performance. A drawback to this recommendation would be accessibility to these major components but can be resolved with an easy-to-remove enclosure with a simple latch that would cover these components. All in all, as technology continues to advance and become smaller, creating a compact design of the AEMD would make it a much more desirable option for motor testing.

2. Consolidation of Software

The development of the AEMD resulted in a variety of software being utilized to develop a dynamometer to conduct motor testing. These software programs included: MATLAB's App Designer, MATLAB, Simulink, Simulink Real-Time, TwinCAT software, and VESC software. Considering the wide spread of software programs that were used, developing a consolidated software program specializing in Dynamometer motor testing would greatly benefit the AEMD by allowing for all configuring, calculations, and communication between the motors, drives, and target machines to be done in one centralized piece of software. Overall, consolidating the AEMD's software would provide faster results and time to set up the AEMD to begin testing motors.

3. Extensive research, prior experience of utilized software

Should the previous future recommendation be not reasonable, we would advise a great amount of time and effort be put towards learning the software utilized to develop this AEMD. A bunch of our time within the AEMD group was spent learning the Simulink Real-Time program and implementing TwinCAT communication and software properly to ensure proper signal communication between our PC and the drives/motors. This resulted in a bit of delay in our project timeline but was a valuable step in the process. That said, becoming familiar with the AEMD software would tremendously increase improvements to AEMD in overall system design and effectiveness.

4. Additional Motor Performance Metrics

With the current model of the AEMD, it is able to configure a certain Drive Cycle Test that then measures the phase voltages, current in and out, as well as the torque and RPM of a motor. A future recommendation to improve the AEMD is to integrate other values and graphs that would provide the user with more motor characteristic values that were obtained during the actual motor test. This would provide added insight of the motor performance and further validate the manufacturer's datasheet. Overall, this will require further design considerations on future versions of the AEMD but will result in a clearer understanding of the motor's capabilities during different circumstances.

5. Improved Motor Test Customizability

In regards to the user interface, the AEMD allows the user to select a predefined Drive Cycle that tests the motor in ramping up between certain speeds over a certain amount of time. To improve on this, the user interface would be able to allow the user to fully customize the drive cycle data to speeds of their liking or different additional modes that would focus on maximum/minimum limits of torque, RPM, current, voltage, and other characteristics. This customizability essentially allows for a dynamometer test that is able to provide insight into nearly and all performance capabilities of the motor at hand. That said, an improved user interface redesigned for complete customizability would allow the user for endless combinations to test their motors of interest.

6. Smart AEMD Emergency Shut-Off System

With any sort of testing, it is important to consider the worst case scenario and the systems put in place to reduce any consequential events that could place people and/or the system at harm. To improve the AEMD, a variety of sensors can be integrated to observe values such as temperature, voltage, current, and EMF levels to ensure a test doesn't go as planned. By programming the AEMD to safely execute a series of protocols, it would quickly yet effectively cancel the current test to prevent the system from breaking and harm nearby users and bystanders.

7. Automated Calibration System

With devices involved with collecting data and measuring specific values, a key part in developing a piece of equipment is ensuring the collected set of data is accurate to a certain degree. Thus, to ensure accuracy of the AEMD, a calibration system can be implemented to periodically reset the system and ensure the precision at which values are collected and are done so on a consistent basis. The automated calibration system would be executed at the beginning of each test to ensure accurate data collection and provide the user with reliable information to determine a motor's true performance.

8. Improved AEMD Cooling System

Considering the AEMD involves high speed spinning motors and metal, design considerations for a cooling system are integral for keeping the AEMD cool and ensure its components to melt or overloaded due to excess in temperature. That said, improving the AEMD's heatsink or implementation of a air/water cooling system would serve as a key safety feature when executing motor tests. Should a motor exceed a certain threshold temperature, the system should be able to execute the necessary protocols to either safely shut down the AEMD or regulate the temperature to ensure a safe AEMD testing environment. Overall, safety is a huge design consideration in the AEMD and an improved cooling system would ensure optimal motor test outcomes.

References

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