Strain Gauge Project

Postmortem Analysis

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INTRODUCTION

This report is the postmortem analysis of the Strain Gauge Team for its project of developing a laboratory strain measurement device. Throughout the ME-476C course over the summer, the team has gone halfway through the project and built a preliminary prototype. Heading into the later stages of the project, the team would have a brief review of how it performed and gained in the past, which is the main purpose of this report.

CONTRIBUTORS TO PROJECT SUCCESS

In general, the team had a lot of success in several areas. Following are the detailed descriptions.

The team followed almost all the ground rules as stated in the team charter. Most team meetings were carried out and executed as planned. Virtual meetings took up the majority of the team's time with some strict procedures: Before the meeting, the team would always decide in advance on the meeting topic and things that members needed to prepare for. During the meeting, all members held in-depth discussions, where they all showed great professionalism, including good work ethic, willingness to communicate, and respecting each other's ideas in decision-making occasions. At the end of each meeting, there would be a short evaluation on how the meeting goes, as well as planning for the next. Apart from virtual meetings, the team was able to carry out in-person "workshop sections" when members could have more detailed discussions as well as actually working on the product. Based on the effectiveness of the meetings and feedback from members, the team also made some adjustments. One example is giving up the rule of meeting three times a week and extending the time duration for every single meeting instead. It proved that this adjustment could get the team more concentrated on specific topics and therefore increasing the efficiency of those meetings. The success in meetings also made huge benefits to the team's time management, which resulted in the project timeline being pushed forward continuously. This is specifically manifested in that a lot of team assignments were completed not only on time but ahead of schedule.

The team also did a solid job making the most of the resources both on and off the campus. With Dr. Trevas being both the course instructor and the client, the team took advantage of the opportunity to keep in contact with each other. During client meetings, the team reported the progress of the project with everybody involved. Dr. Trevas not only gave feedback on the team's outcome but provided a lot of valuable suggestions, including the use of HX711. It turned out that the Analog-Digital Converter became one of the key components of the device. The team might not have the same achievement without his instructions. Under the pandemic situation, the team also tried its best to access online resources, such as academic journals, youtube tutorials, professional websites and forums. Although those resources might not cover all grounds, they still provided the team with a lot of useful information.

As a formal project, it is necessary for the team to apply engineering techniques and methodologies into it. Following the instructions, the team completed the Quality Functional Decomposition (QFD), Black Box and Functional models, Failure Mode and Effect Analysis (FMEA), Gantt Chart and Peer Evaluation. The team created the QFD chart to map customer requirements to engineering requirements by evaluating and scoring. The Black Box Model visualizes the overall function of the device, which is to measure the strain under different load types. The functional model of the device is divided into three sections in an order of material, energy, and signal. At the same time, the model goes through a complete working process of the device and splits the device into different subsystems. In the risk analysis and FMEA section, this team listed ten potential sub-risks, and analyzed their causes and possible problems. The team ranked the risk by the RPN point. The RPN is equal to $S \times O \times D$. Higher RPN numbers signify more risks. Moreover, for each risk, the team proposed test methods and solutions. And the Peer Evaluation makes sure all the team members can find out the pros and cons as soon as possible. The use of engineering tools was where the team showed some creativity, a typical example was the development environment of Processing. Instead of displaying all the results on the Arduino-based serial monitor, Processing enables the team to create an interface with some artistic effects while retaining serial communication. The team will continue its development on Processing along with the product.

When it comes to the work accomplished by the team, the major achievement would be putting strain measurement theory into practice, which led to the building of a prototype. Regarding the work quality, there are a few upsides as well. First, the prototype was able to realize strain measurements with almost all the core components included, and could establish stable and effective connections with PC through serial communication. The team also had some success programming for the device. All the codes have passed the tests and could run without error, which contributed to the functioning of the device with immediate effect. With the basic structures of those programs built, they would also lay a solid foundation for further development. In addition, the building of the prototype only took a small portion of the budget, which not only allows the team to have more flexibility to manage costs but encourages it to carry on with the path as planned.

OPPORTUNITIES/AREA FOR IMPROVEMENT

Despite the success the team had in realizing the project's goal and purposes, the team still has a long way to go to get all the design ideas materialized and finish the product, and there is also a lot of room to modify and improve the device.

The first important aspect is to complete the missing functions on the prototype. Currently, the prototype is only capable of measuring the strain from bending, making the realization of the other three functions an uncertainty to the team. That also leads to another problem: Although the team spent a lot of time modeling and conducting mathematical calculations, there is a lack of advanced analyzing techniques (such as finite element analysis) on load cells, which could help the team simulate the metal condition and deformation in a way closer to the reality prior to testing. Indeed, pure maths is an effective way to give the team an idea of how the device works out, as it could calculate the maximum weight and strain value on each load cell. However, it is too vague to visualize and fails to meet with more complex conditions in real life, a typical indication is the difficulty to predict the effects of material fatigue and deformation. But through finite element analysis, the team could use graphics to observe and analyze the feasibility of the results obtained on paper, and therefore finding ways for improvement.

Another topic is to achieve full adaptation of materials and components on BOM, which the team did not quite make it over the summer. For example, the clamps for metal bars. On Amazon, the team can only find some common clamps for daily fixing. However, some special metal rods which for measuring torque and internal pressure, their cross-sectional area is very large, ordinary clamps can not be well fixed and installed on the base. The team needs to consider more suitable methods such as 3D printing or laser cutting to create a new clamp in this semester to solve this problem. In terms of the choice of the base, the team's original plan was to use the 3D printing of the school library. But the disadvantage is that the solidity and accuracy of the 3D printed model are not very reliable. Also, the expensive cost will greatly use the team. In the face of this problem, the team plans to buy metal or engineering plastic plates as the base and perform laser cutting. But the problem still faced is that the team does not know the use of cutting machines very well, which takes a lot of time to learn. At the same time, since the team are all mechanical engineering students and are not very familiar with Arduino, website design and other programming, when the team encounters technical difficulties, we need to spend more time to solve them.

As mentioned in the previous category, the resources that the team has accessed are still relatively limited. Despite that the team made a lot of effort searching for them, the effects of the pandemic and not taking the course in a regular semester could not be fully erased. Without a workshop, the team had some struggles in some areas while building the prototype. As mentioned above, the metal rod that the team intended to use was purchased online. However, it proved not to be fit for the prototype demonstration for its dimensions. In the end, the team used a plastic ruler as a replacement. Although it did end up with some strain readings, it did not give the team enough room to prove it due to the irregularity of its shape and the uncertainty of its Young's modulus. Additionally, the building of the entire prototype (especially the gluing of strain gauges) was hand-crafted, which might have some negative effects on the accuracy of the system.

The team will continue to put effort into the building of organization to maximize the effectiveness of teamwork. Based on the existing team rules, the team will evaluate what worked and what did not. For those which did not reach satisfactory outcomes, the team will make reasonable adjustments through discussion while making sure that every team member is comfortable with. When it comes to execution, the team would again clarify everyone's responsibilities, and establish an appropriate punishment mechanism for some violations of team rules. The group has at least two group meetings a week (maybe we will choose to meet online). During meetings, all members are encouraged to express their thoughts, and various resolutions will be passed by voting to ensure that the opinions of each member can be accepted by the team. In addition, we increase the cohesion and sense of honor of the team through extracurricular activities outside of the curriculum. Let each member establish good communication and friendship.

Through the project, the team applied the knowledge of strain measurement into the device, which provides all members with a deeper understanding of engineering concepts and a valuable opportunity to put them into practice. Also, with the use of electronic components such as HX711 load cell amplifier and Arduino board, the team gained some knowledge and experience in electric circuit basics, signal transformation, and programming. In completing the coursework, the team also solidified basic engineering techniques and skills of SolidWorks modeling, technical writing, and documentation.

In conclusion, looking back on the team's results and outcomes over the ME-476C course, the team is on the right path. Since this prototype is still very rudimentary, the next focus would be improving its accuracy and completing its functions. With more time and effort put into the following months, the team is expecting a great product to finish up the capstone project.