UM–SJTU Joint Institute

Major Design Experience (MDE)
(ECE/ME/MSE4500J)

Analysis of Vibration-Induced Measurement Inaccuracies in Riveting Processes

Design Review # 1

Sponsored by
Shanghai Systence Electronics Co.,Ltd

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Figure 1: Riveting Machine [1]

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1 Abstract

This project is sponsored by *Shanghai Systence*. During their manufacturing process, inaccuracies caused by rivet vibrations have prevented their products from meeting client requirements. Therefore, this project aims to assist the company by develop a system comprising a sensor and a software interface, where the sensor will capture vibration data during the riveting process and the software will visualize the vibration patterns as well as identifying anomalies. Ultimately, the project will provide recommendations to mitigate these vibrations. While commercial products exist that achieve similar goals, they are often expensive, do not meet the company's specific requirements, or are too large to be easily placed around the small rivets of interest to the company. Through discussions with the company, we have identified ten customer requirements, ranked by their importance: accurate vibration capture, ease of use, stability after long-distance transportation, accurate vibration analysis, fast, portability, ease of installation, cheap, compactness, and appealing design. The company prioritized accuracy and usability over cost and aesthetics, though we still aim to meet our budget and create an attractive final product for presentation to their customers. Based on these customer requirements, we have established several engineering specifications, categorized into data collection components, data analysis (user interface, software), and overall product attributes. For the overall product, we focused on mass, volume, and price. For the software, we prioritized processing time, ensuring the system can quickly visualize vibration patterns, identify types of vibrations, and provide solutions. For data collection, the key parameters are sensor characteristics, including resolution, repeatability, response time, frequency response range, error range, and success rate. The team will adhere to the timeline for the three design reviews. With our diverse background, the tasks are divided into two major areas: vibration analysis and software development. We hope that the final product will enable the company to better control the riveting process, saving time and energy, and boosting confidence in attracting potential customers.

Key Words: vibration analysis, rivet accuracy, data visualization

Contents

2 Introduction

2.1 Project Background

Shanghai Systence Co. is a prominent entity in the assembly line industry, specializing in the production of three primary product categories: electro-mechanical assembly presses, riveting machines, and the comprehensive design and construction of assembly line systems for various factories. Team 24 will focus on the optimization of riveting technology, specifically targeting the identification and mitigation of vibration-related issues inherent in the riveting process. The aim is to provide *Shanghai Systence Co.* with actionable insights and recommendations to enhance the efficiency and reliability of their riveting operations. Team 24's investigation is specifically concentrated on radial riveting technology, a widely utilized technique in the assembly of mechanical components. Despite its prevalent use, *Shanghai Systence Co.* faces challenges in quantitatively analyzing the riveting process. The existing methodology predominantly relies on experiential knowledge and qualitative assessments of the rivet's behavior. While this traditional approach has its merits, it often falls short in addressing the nuanced complexities of the riveting process, leading to sub-optimal solutions that result in financial losses, wasted time, and diminished confidence in the company's problem-solving capabilities.

2.2 Problem

A thorough literature search on the impact of vibrations during the riveting process on rivet accuracy yielded no substantial results from academic search engines. Consequently, the nature of this problem is primarily based on descriptions provided by *Shanghai Systence Co.* and an example of a previously encountered issue. *Shanghai Systence*, along with their partner *FMW Friedrich*, an industry pioneer in data-driven riveting, report that vibrations are a significant cause of inaccuracies in the riveting process, sometimes failing to meet customer specifications. The riveting process at *Shanghai Systence* involves the machine initially determining the rivet's height before proceeding with the riveting operation until the required height is achieved. However, rivets' vibrating during this process compromise the accuracy of height measurements, resulting in inconsistent output parameters. A notable instance illustrating this issue involved a complex U-shaped riveting part, where additional bending occurred due to momentum. This complication led to significant time and financial investments as parts were sent to Germany for testing, in-house experiments were conducted, and repeated consultations with the multinational client were necessary. This iterative and inefficient problem-solving approach highlights the urgent need for a quantifiable solution to address the vibration-induced inaccuracies in the riveting process. Therefore, group 24 aims to address this critical issue by developing a system to quantify and visualize vibrations during the riveting process. The primary objectives include:

- Data Collection: Finding robust sensors to gather real-time data on vibrations occurring during the riveting process.
- Data Visualization: Creating visualization tools to identify anomalies and patterns in the vibration data, providing insights into the correlation between vibrations and rivet accuracy.
- Problem Mitigation: Offering actionable recommendations to eliminate or minimize the impact of vibrations on the riveting process.

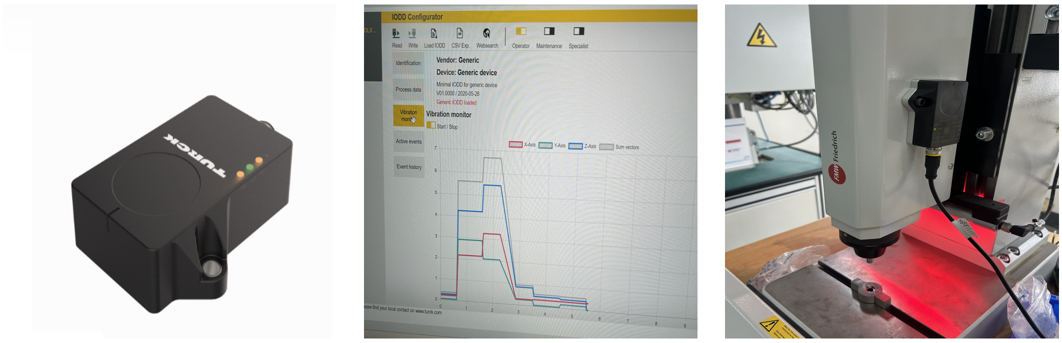
By quantifying the impact of vibrations and visualizing the data, Group 24 intends to facilitate a deeper understanding of the riveting process anomalies. This approach aims to significantly expedite and economize the problem-solving process for future riveting challenges, thereby enhancing the operational efficiency and product quality for *Shanghai Systence Co.* and its partners.

3 Literature Review

3.1 Benchmarks

3.1.1 TURCK - Model: CMVT-QR20-IOLX3-H1141

This vibration and temperature sensor (Figure 2(a)) is used mainly for the condition monitoring of the equipment. The device features a magnetic surface, which simplifies the attachment process to any metal equipment. Once attached, it is linked with the software that collects the data and can either visualize it for the manual check or automatically notify the responsible engineer if anomalies are detected. One key parameter tracked is the sensor's displacement to monitor vibration states. weighing 85 grams [2], the sensor is considered relatively lightweight. However, while its size is suitable to put on the riveting machine, it's too large for precise placement on the riveting parts, which are our group's primary interest as in the riveting process, inaccuracies mainly stem from the mechanics of this part rather than the machine failure. Additionally,



(a) Sensor (b) Software (c) Equipment Setup

Figure 2: TURCK - Vibrations and Temperature Control System. (a) Sensor - a device that measures the connected item's temperature, acceleration, and velocity. (b) shows the software interface that is used for data visualization. It allows manual analysis of the operation state and can automatically notify the responsible person about the anomalies. (c) is how this equipment is set up on the riveting machine using a magnetic surface.

the product is relatively expensive at 3700 RMB, considering its limitation to equipment monitoring. Nevertheless, the concept of this product is similar to the final outcome that group 24 wants to achieve, though it cannot directly and accurately solve the company's problem.

3.1.2 FLUKE 820-2 LED Stroboscope

This product (Figure 3(a)), developed by *Fluke*, is designed to detect the running speed of rotating equipment. It can diagnose parasitic oscillations, slippage, or unwanted distortions without being physically attached to the measured part. Although lightweight at 0.24kg, its size (5.71cm $\times$6.09cm $\times$19.05cm) make it difficult to place around the rivet. Additionally, it costs $1,923.99 [3], which exceeds our budget. Furthermore, it is not easy to be accustomed or adapted to *Shanghai Systene*'s riveting machine, since its hardware and software are already integrated. However, it has several useful features that our group can learn from, including digital pulse width modulation for exceptionally shart images at high speeds and a quartz-accuracy control system for high precision (0.02% $\pm$ 0.001).

(a) FLUKE 820-2 LED Stroboscope

(b) enDAQ sensor

(c) enDAQ Lab

Figure 3: (a) Fluke vibration sensor. It can quickly record the vibration object and finish analysis on multiple aspects.(b) enDAQ System. The sensor can continuously catch fatal vibration parameters with outside environment conditions for more than 13 hours at a time without charging. (c) The enDAQ analyzing software. It can be imported with data gathered from the sensor and perform corresponding analysis.

3.1.3 enDAQ S3 Vibration Sensor

enDAQ is a professional company specializing in vibration analysis. It provides paid services for hardware configuration (Figure 3(b)) and free software analysis (Figure 3(c)). The enDAQ S3 Vibration Sensor can function as a general-purpose vibration recordeer, with additional environmental sensors. The compact product measures 76.2mm $\times$29.8mm $\times$15.0mm and weighs only 40g, and it comes with dust protection. It can operate continuously for 13 hours at its highest sample rate (3200Hz), incorporating many additional embedded sensors into a single system. Its bandwidth ranges from 0 to 300 Hz with $\pm$5% accuracy. It costs over $1299 with free and customizable software solutions like *enDAQ LAB* and *enDAQ Cloud*, which support both simple real-time response and complex post analysis [4].

Similar to TRUCK and FLUKE, this system is well-developed and could potentially achieve Team 24's objectives. However, since we have not yet determined the type of vibration occurring on the rivet during the riveting process, it's possible that the vibration may exceed the sensor's bandwidth. Additionally, the enDAQ sensor is quite expensive.

3.2 Literature on Specific fields of Interest

In addition to analyzing competitor products, we reviewed literature related to the three main steps of our project: gathering vibration data through sensors, conducting theoretical vibration analysis, and performing data analysis using software.

3.2.1 Sensors: Data Collection

In recent years, significant advancements have been made in the field of vibration data collection through the development of innovative sensor technologies and methodologies. Works by Garcia et al. [5], Liu et al. [6], and Weng et al. [7] focus on *Fiber-Optic-Based Vibration Sensors*. These studies explore various applications of fiber-optic technology in vibration measurement, emphasizing its high sensitivity, immunity to electromagnetic interference, and suitability for long-distance monitoring. On the other hand, works by Shukla et al. [8] and Guo et al. [9] focus on *Smart and Non-Contact Vibration Sensors*. These studies introduce innovative approaches using smart sensors and non-contact methods, leveraging advanced data analysis techniques and deep learning to enhance the efficiency and applicability of vibration measurement systems.

Shukla et al. [8] introduce a smart sensor-based monitoring system for real-time vibration measurement and bearing fault detection, employing advanced sensors and data analysis to prevent machinery breakdowns and reduce maintenance costs. Liu et al. [6] explore distributed fiber-optic sensors for high-resolution, long-distance vibration detection, enhancing structural health monitoring for large structures like bridges and pipelines by detecting even minor vibrations. Guo et al. [9] propose a non-contact vibration sensor using deep learning and image processing, utilizing optical flow for signal extraction and addressing the deployment challenges of traditional sensors, making it suitable for inaccessible or hazardous areas.

Despite their innovative approaches, these papers have certain limitations. The smart sensor-based system, while highly effective for bearing fault detection, is somewhat limited to specific types of machinery and relies on predefined fault patterns, reducing its adaptability to new or unforeseen types of faults. The distributed fiber-optic sensors, though excellent for large-scale applications, face challenges in terms of installation complexity and cost, and their performance can be affected by environmental conditions such as temperature variations and physical damages to the fiber. The non-contact vibration sensor, despite its advanced capabilities, is susceptible to variations in lighting conditions and background features, which can affect its accuracy, and the need for high computational power for deep learning algorithms might limit its real-time application in certain scenarios. Our data collection efforts will aim to overcome these limitations by focusing on adaptable, cost-effective, and robust solutions for a variety of environmental conditions and applications.

3.2.2 Vibration Theory

In Krodkiewski [10]'s book, vibration is defined as the oscillatory motion of a mechanical system about its equilibrium position. Mechanical vibrations can be categorized in various ways. In our project, we aim to discover methods to mitigate vibrations. Therefore, we will classify vibrations based on their causes, which include free vibration, forced vibration, self-excited vibration, and parametric vibration.

Free vibration refers to the vibration that occurs near the equilibrium position after the initial disturbance and no other excitation.The period and frequency of free vibration are determined by the characteristics of the system itself. When considering the effects of resistance, free vibration can be further categorized into underdamped vibration, overdamped vibration, and critically damped vibration, which implies that the period and amplitude of free vibration will be influenced by the magnitude of damping.

Forced vibration occurs when a system is subjected to periodic external forces. It initially manifests as a combination of two vibration states: one determined by the system's natural frequency and the other by the frequency of the driving force. When the driving force is small, the attenuation of free vibration is gradual. Conversely, when the driving force is large, the free vibration decays rapidly. If the frequency of the driving force is close to the natural frequency, the system will exhibit a resonance phenomenon, resulting in larger amplitude vibrations.

Self-excited vibration refers to the phenomenon where a system, after experiencing an initial accidental disturbance, continues to vibrate without the need for external excitation. This sustained vibration occurs at or near the system's natural frequency and does not attenuate over time. Unlike the previous two types of vibration, the study of self-excited vibration does not focus on the magnitude or form of the disturbance. Instead, it emphasizes the inherent instability of the system itself.

Parametric vibration refers to the phenomenon where the parameters of a vibration system vary periodically due to external forces. Taking the swing as an example, if you want to swing up, people should periodically apply force, swing amplitude, frequency should also change accordingly, the mathematical model describing the parameter vibration is the ordinary differential equation with periodic variable coefficient.

The above analysis provides an overview of the four vibration modes without delving into specific modeling derivations. Once we have identified the vibration type in our project, we can proceed with a more detailed analysis by employing specific research methods that are relevant to that particular type of vibration. This will allow us to gain a deeper understanding of the phenomenon and make informed decisions based on our findings.

3.2.3 Data Analysis

The field of vibration data analysis has seen significant advancements, with numerous studies exploring various methods to improve machine monitoring and fault diagnosis. Mohd Ghazali [11] provides a systematic review and general overview of vibration analysis techniques. Yan and Gao [12], Staszewski [13], and Saruhan [14] focus on specific techniques for vibration analysis. Amihai [15] and Zhao [16] explore the application of machine learning and artificial intelligence in vibration analysis. Prudhom [17] and Jung [18] present case studies and practical implementations. Trendafilova [19] and Grasso [20] introduce innovative methods and frameworks.

Yan and Gao [12] proposed the use of the Hilbert-Huang Transform (HHT) for vibration signal analysis, which effectively decomposes nonlinear and non-stationary signals into intrinsic mode functions. This method addresses the limitation of traditional Fourier-based methods in handling non-stationary signals. Staszewski [13] introduced a wavelet-based approach for compressing and selecting features from vibration signals. The wavelet transform allows for multi-resolution analysis, making it suitable for detecting transient features. Amihai et al. [15] conducted an industrial case study using machine learning to predict asset health based on vibration data. The study employed Random Forest algorithms to predict failures up to seven days in advance, outperforming traditional persistence techniques. Trendafilova et al. [19] developed a method combining Principal Component Analysis (PCA) and pattern recognition for damage detection in an aircraft wing model. This approach reduces the dimensionality of vibration data and enhances damage feature extraction.

While significant advancements have been made in vibration analysis for machine monitoring and diagnosis, several limitations remain. These include computational complexity, sensitivity to noise, dependency on data quality, and the need for extensive historical data. Addressing these limitations is essential for improving the robustness and applicability of these methods in real-world scenarios. Our work will focus on developing robust, scalable methods to collect data related to vibrations during the riveting process, create algorithms that identify anomaly patterns, and suggest solutions. This research aims to enhance the accuracy and reliability of vibration-based fault detection systems, making them more applicable to diverse industrial environments.

4 Quality Function Development (QFD)

As stated in previous section, the goal for this project is to develop a system that can detect, visualize, analyze the vibrations of rivets during the riveting process and suggest potential solutions for managing these vibrations. We collaborated with the company to identify the top 10 customer requirements. We then determined the engineering specifications for the entire product, which we categorized into three major parts: data collection, data analysis, and overall appearance.

4.1 Customer Requirements

Our sponsored company, *Shanghai Systence* is the primary customer for this project, as they will be the main users of the product. The customer requirements, summarized in Table 1, were established based on their input and prioritized according to their weighted importance.

Table 1: Customer's requirements with weighted importance

Requirements	Weight (1-10)
Accurate vibration capture	10
Easy-to-use	9
Stable (long-distance transport)	9
Accurate vibration analysis	8
Fast	8
Portable	8
Easy-to-install	4
Cheap	3
Less parts needed	2
Appealing design	2

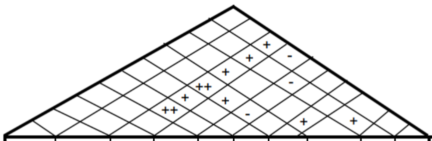
Through discussions with the company, we found that they prioritized accuracy and ease of use over cost and aesthetics of the final product. The highest priority was **accurate vibration capture**, as the company was aware of the existence and impacts of vibrations but needed a way to visualize and categorize them. Therefore, our primary goal was to first obtain the correct vibrations so as to provide further accurate analysis. **"Ease-of-use"** followed, as the product interface needs to be intuitive for engineers. **Stability** refers to the product's durability during long-distance transportation; the final product should maintain good functionality after being transported, as it will be used in various factories and client locations. **Accurate vibration analysis** and **speed (fast)** in both data capture and software processing were also crucial. Additionally, **Portability** and **"Less parts needed"** both means the product should be a compact design that ensures the ease of transport and assembly. **Easy installation** of both software and sensors, though less critical, was still a consideration. The least important factors were **cheap** and **design appeal**, but the company expressed their wish for a good-looking product so that they can also present it in front of their clients.

4.2 Engineering Specifications

Based on customer requirements, we established corresponding engineering specifications, summarized in the QFD chart in Figure 4.

We categorized the engineering specifications into three main areas: data collection components, data analysis (user interface, software), and overall product attributes. Each category aligns with specific customer requirements. For the overall product, we focused on **mass**, **volume**, and **price**, which correspond to requirements for stability, portability, ease of installation, and minimal components. In terms of the software, we prioritized **processing time**, ensuring the system can quickly visualize vibration patterns, identify types of vibrations, and provide solutions. For data collection, the key parameters were sensor characteristics, such as **resolution**, **repeatability**, **response time**, **frequency response range**, **error range**, and **success rate**. These specifications were obtained by evaluating parameters for commercial sensors and are relevant for the identified customer requirements, such as capturing accurate and reliable vibration data.

- Resolution: The smallest detectable change in the measured variable by the sensor.
- Repeatability: The sensor's ability to provide the same output for repeated



	Weight (1-10)	mass	volume	price	system's processing time	sensor's resolution	sensor's Repeatability	sensor's response time	sensor's frequency response range	sensor's error range	sensor's success rate	m+p Analyzer	VibrationData Toolbox enDAQ	Dplot
Accurate vibration capture	10			1		9	9		9	9	9	5	5	/
Easy-to-use	9				9		1	3			1	5	2	3
Stable (long-distance transport)	9	3	3	3								5	4	5
Accurate vibration analysis	8				3	3	3		9	3	3	5	5	4
Fast	8			1	9			9				5	4	4
Portable	8	9	9									1	2	/
Easy-to-install	4	3	3	3								5	2	1
Cheap	3	3	3	9		3	1	9	3	3	1	1	3	5
Less parts needed	2	3	3	1								4	2	/
Appealing design	2	1	1									3	3	4
Measurement Unit		g	cm^3	RMB	ms	um	um	ms	Hz	%	%			
Target Value		1000	8000	4000	2000	1	±1	10	0-1000	±1	70			
Total		128	128	86	177	123	126	126	171	123	126			
Normalized		0.10	0.10	0.07	0.13	0.09	0.10	0.10	0.13	0.09	0.10			

Benchmarks: m+p Analyzer, VibrationData Toolbox enDAQ, Dplot

Figure 4: Quality Function Development chart for the project. Engineering specifications highlighted in yellow are the most important ones, followed by those highlighted in green.

measurements under unchanged conditions, crucial for accurate vibration capture.

- Response Time: The time the sensor takes to respond to a change in the measured variable, impacting the speed of data capture.
- Frequency Response Range: The range of frequencies over which the sensor can accurately measure the variable, ensuring all relevant vibrations are detected.
- Error Range: The range within which the true value lies considering all potential sources of error, essential for accuracy.
- Success Rate: A parameter specific to our vibration detection, comparing the performance of our chosen sensor with a high-accuracy laser vibration sensor used as a benchmark (JI has the laser sensor that professor Huang said we could borrow).

After normalizing the scores, we found that the system's processing time and the sensor's frequency response range received the highest scores, followed by the mass and volume of the overall product, as well as the sensor's repeatability, response time, and success rate. These are highlighted in yellow and green in Figure 5. This prioritization aligns well with the customer requirements and we will focus on these specifications during our project development. For each customer requirement, we identified at least one engineering specification with a strong correlation (9 points), except for ”Stability”, “Easy Installation”, ”Less parts needed”, and ”Appealing Design”, which had lower weighted importance or were inherently addressed by the overall product design.

Target values for these specifications were agreed upon with the company and bench-marked against commercial products. Specifications like mass, volume, processing time, and sensor success rate were directly provided by the company based on their machinery and needs. The project budget guided the target price, set at 4000 RMB. Sensor specifications were derived from averages of commercial sensors available on Amazon. We will try to meet the target values when deciding the types of sensors we will use in the project.

5 Project Plan

Team 24 will adhere to the schedule set by the Design Reviews. The specific tasks to be completed during each period after DR1 are outlined as follows. Figure 5 visualizes the tasks in a Gantt chart. Budget will mostly be spent on purchasing sensors, and transporting to the company.

- Design Review 2
  - June 18: Concept Generation for Sensors
    Come up with potential approaches to perform data gathering. Yujia will study laser sensor; Yiming and Mansur will focus on accelerometer; Jingtian and heng will search for other potential sensors that meet the engineering specifications.
  - June 24: Concept Generation for Vibration theories
    Yujia, Jingtian and heng will focus on finding the appropriate software for visualization; Yiming and Mansur will study the vibration analysis theory.
  - June 27: Concept evaluation and final decision
    All group member will evaluate every scheme and score it. The one scored highest will be the final decision without altering again.
  - **July 1: Design Review 2 Presentation**

- Design Review 3
  - July 6: Build Data Collection System
    Place the sensor on the desired place and obtain vibration data. Yiming and Mansur will mainly be responsible for this part.
  - July 9: Software Development
    Jingtian, Heng and Yujia will focus on building the software that can visualize the vibration data, and detect the places where the pattern looks wrong.
  - July 12: Vibration Test and Classifications (Until Jul 12)
    Yiming and Mansur will mainly be responsible for this part.
  - July 15: Animation&Videoprototype
    All group members participate in shooting clips for the final video.
  - **July 17: Design Review e Presentation**
- Final Design Export
  - July 22: Material Preparation Video
    Shooting and editing the presentation video. All group members participate.
  - August 1: Vibration Classification and Elimination
    Yiming and Mansur will continue working on improving the vibration analysis and offering suggestions.
  - August 1: Software Development and UI Automated Algorithm
    Yujia, Heng and Jingtian will work on the software part synchronously.
  - **August 2: Presentation to sponsor**
  - **August 7: Design Expo and Oral Defense**

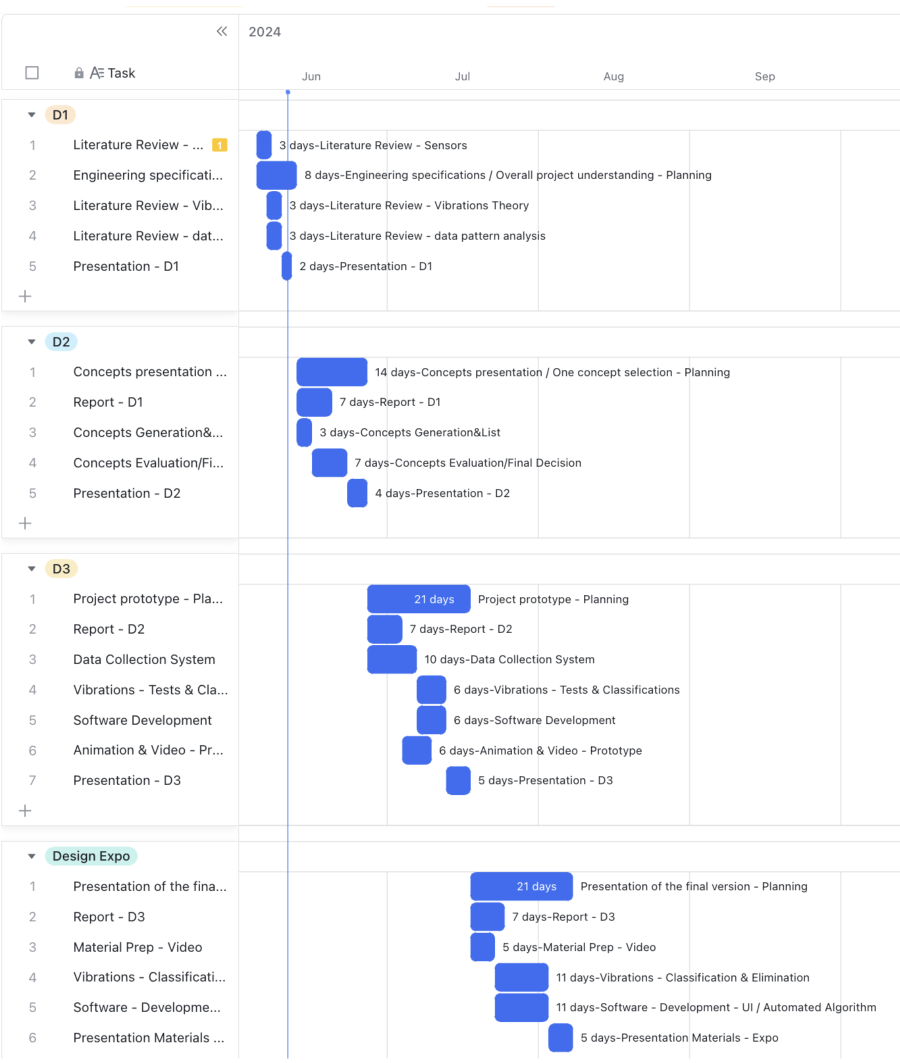


Figure 5: Gantt Chart regarding tasks management for Group 24 Project

6 Conclusion

The report introduces vibration-related challenges encountered by Shanghai Systence Company during the riveting process, and provides proposed solutions. Currently, the existing methods heavily rely on empirical knowledge and qualitative assessment, rather than quantitative analysis. Our objective is to develop a system that would enable the quantification and visualization of vibrations during riveting, while also suggesting appropriate remedies. The primary goals encompassed data collection, data visualization, and problem mitigation. To achieve this, we consulted relevant literature on vibration sensors, vibration theory, and data analysis, and conducted a classification analysis.

Additionally, we delves into the customer requirements and engineering specifications. The customer requirements encompass accurate vibration capture, ease of use, stability, and more. Engineering specifications address aspects such as data collection, data analysis, and overall product attributes. In the project plan section, we list specific tasks that will be completed during each design review phase, including concept generation, construction of a data collection system, vibration testing and classification, software development, and so forth.

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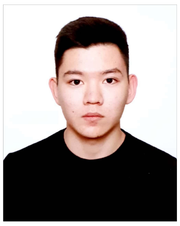
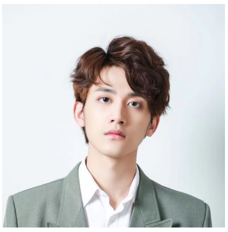
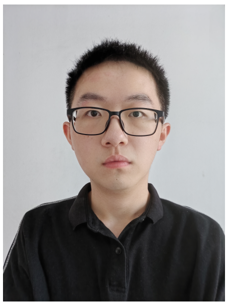
7 Bios



Mansur Ayazbayev - senior student at UMSJTUJI studying Mechanical Engineering. Passionate about connecting engineering knowledge with business best practices. Has a strong belief that it is important to know how to create a product and identify a group of people for whom this product could be useful and helpful. Did several internships in both engineering and business development roles at the projects including wind farm planning and construction, venture capital analysis, business development for a green tech startup, and e-commerce analytics. After graduation has a plan to start a career journey in a technological company based in Shanghai because of the love of Chinese food, the incredible pace of the economic development of this region, and desire to learn from the best. In free time hobbies include training, running, playing the guitar, singing, exploring bars in Shanghai, and going to KTV with friends. Likes working on projects that can have an actual impact and understands how actions lead to the development of the product, department, or the whole company. Not sure of the exact industry would like to spend the next 10 years in but trials and making a difference in real projects should be helpful to define what would be the best personally and for society. Again, learning and understanding the way Shanghai and China in general made this incredible economic jump in such a short time period is another goal that could also help shape Kazakhstan's economic path in the future.



Jingtian Zhu is a senior student majoring in Electronic and Computer Engineering. He has planned to work in financial area after graduation. When entering the college, He was ambitious about my following study life. But it struck me when the epidemic, physical and mental distort came together, He failed to follow up the majority. Thanks to the help and guidance from many people, I struggled to the end of the undergraduate term. He had made some academic research with the guidance of Prof. Qiao Heng in convex optimization algorithm and successfully reproducted some newly designed methods. In this project, He will make market research to offer suggestions on specific problem solving and help develop the analysis software and UI interface. It is supposed that he will have a deep experience in entire process of engineering problem solving and apply it in the future career.



Yiming Wang is a senior student majoring in Material Science and Engineering. He has received the Freshman Merit Scholarship and Academic Progress Scholarship. During the first two years of his undergraduate study, he faced difficulties in his academics, partly due to personal reasons and the impact of the epidemic. Nevertheless, with the guidance of others and his own self-reflection, Wang managed to overcome these challenges and invested more effort into his academic pursuits. He had engaged in research projects involving Fourier spectrum analysis of polymers and Differential Scanning Calorimetry of metals, allowing him to accumulate valuable research experience. Through his participation in these projects, he has gained in-depth knowledge and practical skills in conducting research within the field. Upon graduation, he decides to pursue a master's degree in materials science. And in this project, he plans to initially research on the study of vibration theory, broadening his understanding of the subject matter. Subsequently, he will utilize his expertise to assist his teammates in sensor selection and modeling.

Heng Zhao is a senior student majoring in Electronic and Computer Engineering. He has received Fuda, Huatai Securities Research Scholarship. He has been admitted to the JI Computer Science and Technology master's program under the guidance of Professor Zhu Yifei. He has accumulated extensive research experience in various cutting-edge technological domains. From February to May 2022, he worked under Professor Zhang Quanshi on a project titled "Batch Normalization Is Blind to the First and Second Derivatives of the Loss." Following this, from May to October 2022, he collaborated with Professor Jin Haiming on ego-motion estimation for mobile platforms. His research journey continued from October 2022 to March 2023, where he worked with Professor Tang Aimin on joint communications and indoor localization via UWB. Since April 2023, he has been conducting research under Professor Zhu Yifei on a project titled "The Space above the Sky: Uniting Global-Scale Ground Station as a Service for Efficient Orbital Data Processing," with his first-author paper currently under review.

Yujia Gao is a senior student majoring in Electronic and Computer Engineering. She has been participating in the Graduate Degree Program, a collaboration between Shanghai Jiao Tong University-University of Michigan Joint Institute (SJTU-UM JI) and the University of Michigan. Through this program, she discovered her passion for Data Science and decided to shift her academic focus in that direction. Throughout her four years at JI, Yujia has concentrated on Electronic Engineering, engaging deeply in both coursework and research. One notable project she contributed to was under the guidance of Professor Yuljae Cho, where she worked on developing a piezoelectric sensor designed to measure human body pulses. This research experience fueled her interest in applying engineering principles to practical, real-world problems. After graduation, she plans to continue her master's degree, and explore opportunities in Data Analysis and Business Analysis, as she is enthusiastic in working with numbers and communicating with people. As she prepares for this next chapter, Yujia is committed to leveraging her education and experiences to make meaningful contributions to this project.