MERIT-WINGS Entrepreneurship Challenge Report

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I developed a spectroscopy method in my research that extracts magnetization fluctuations from the amplitude and phase information of magnetization. By applying the insights gained from the spectroscopy to eddy current testing, I will achieve high-precision flaw detection. Based on the achievement, I formulated a business plan to establish a startup.

1. Overview of the Seed Research

In my research activities, I proposed and implemented a novel method to perform time-resolved measurements of magnetization fluctuations in phase space [1]. Traditionally, studies on magnetic dynamics have been grounded in frequency spectrum analysis. However, it is well-known that in nonlinear dynamics resulting in non-Gaussian behavior, frequency spectra alone do not provide sufficient information. The lack of methods to investigate higher-order fluctuations in magnetic dynamics has been one of the bottlenecks in spintronics research.

The information discarded by conventional power spectrum measurements lies in the correlation between the amplitude and phase of magnetization. This correlation can be observed by converting the fluctuations in magnetization dynamics into electrical signals via AC spin pumping. By combining this technique with a microwave homodyne method and performing real-time statistical processing, I established an experimental approach to obtain the probability distribution of magnetization fluctuations.

The resulting probability distribution is equivalent to a density matrix, encompassing all information about the system. By applying this method to a nonlinear excitation process, specifically parametric excitation, I successfully detected distortions in magnetization fluctuations caused by nonlinear effects for the first time.

2. Eddy Current Testing

The spectroscopy method I developed acquires and analyzes amplitude and phase fluctuations of AC signals. By combining these insights with machine learning and applying them to eddy current testing—a type of non-destructive inspection—I aim to achieve high-precision flaw detection.

Non-destructive testing is a method used to detect defects or damage in mechanical components or structures without causing any destruction to the target. Infrastructures like gas plants and manufacturing processes for products rely on early detection of defects and damages through non-destructive testing, which is essential for reducing costs and promoting sustainability by minimizing large-scale repairs and replacements. The market for non-destructive testing is expected to grow at a CAGR of 10.1% from 2023 to 2030.

Eddy current testing, one of the primary methods of non-destructive testing, involves bringing a coil carrying high-frequency current close to the surface of the object under inspection, thereby inducing eddy currents on the surface. If there are defects on the surface, the eddy currents become disrupted, and these disruptions can be detected through changes in the magnitude and phase of the eddy currents. However, due to the skin effect, the penetration depth of the eddy currents is limited, which restricts detection capabilities in the depth direction.

To address this limitation, I propose a high-precision eddy current inspection system that detects fluctuations in the amplitude and phase of the magnetic flux generated by eddy currents, coupled with machine learning.

3. Entrepreneurship Challenge Activity

As part of my entrepreneurial activities, I formulated a business plan by conducting interviews based on the concept of lean startup. Lean startup, one of the most widely recognized methodologies in modern entrepreneurship, was proposed by Eric Ries, who drew on his own entrepreneurial experience to present an approach for clarifying value-generating activities and enabling efficient startup operations.

Traditional entrepreneurial approaches often involved creating detailed business plans before launching activities. However, unlike established businesses, startups often lack clarity about the value their customers seek, leading to inefficiencies and wasted efforts. The lean startup methodology addresses this by adopting a "Build-Measure-Learn" cycle, which emphasizes feedback on hypotheses about value, thereby minimizing waste and enabling efficient entrepreneurial efforts.

In the first stage, Build, the hypothesis to be tested is used to create a product or service with minimal resources. This stage involves developing a Minimum Viable Product (MVP), a version of the product that includes only the essential features needed to validate the hypothesis and elicit customer responses. For example, when testing a new app idea, instead of incorporating all potential features, only the aspects whose value to customers is uncertain are implemented in a simplified version. Early adopters, a crucial group of enthusiastic initial users, play a key role in this stage by providing swift feedback to help evaluate the validity of the hypothesis.

The second stage, Measure, involves collecting feedback and data from actual customers using the MVP in the market. This stage assesses how well the product addresses customer challenges and how customers use the product, based on specific data. The goal is to derive insights not only from customer opinions but also from their actual behavioral data. Feedback from early adopters remains highly valuable here, as their experiences and requests provide

benchmarks for gauging market-wide receptivity.
In the final stage, Learn, the collected data is analyzed to evaluate the validity of the hypothesis and identify areas for improvement. For example, if certain features are well-received by customers, they are enhanced, while less effective elements are considered for removal or redirection. These insights are reflected in the next iteration of the Build stage, leading to incremental improvements in the product and business model. Insights from early adopters deepen understanding and form the foundation for strategies targeting broader markets.
By repeating the "Build-Measure-Learn" cycle, entrepreneurs can quickly adapt to customer needs, minimize resource waste, and efficiently advance their business. The involvement of early adopters exemplifies the lean startup approach's focus on flexibility and efficiency. This methodology has been widely adopted as a guideline for creating continuous value through practical processes.
In this entrepreneurship challenge activities, I applied the lean startup methodology to clarify the value of high-precision eddy current inspection based on amplitude and phase fluctuation data through interviews, which informed the development of a business plan. Experimental researchers conducting highly sensitive experiments were identified as early adopters, as minor defects can significantly affect the precision of their measurements. Issues such as the vacuum quality in vacuum systems or the performance of dilution refrigerators could also be impacted by such defects. By identifying the value of eddy current inspection through interviews, I developed a business plan that positions experimental researchers as early adopters.

4. Business Plan

4-1. Vision and Problem Definition

Eddy current testing is currently widely utilized in industries such as manufacturing, aerospace, railways, and automotive. In recent years, the field of non-destructive testing has seen increasing demand for improved inspection efficiency and accuracy, along with growing awareness of sustainability. Specifically, in eddy current testing, accurately detecting fine defects and material changes has become a critical challenge across many industries.
To address this issue, I aim to enhance the precision of eddy current testing by combining data on amplitude and phase fluctuations with machine learning. This approach enables the detection of subtle anomalies that are often overlooked by conventional technologies, while also improving the efficiency of the inspection process. Moreover, by increasing the accuracy of inspections, defects can be detected at an earlier stage, extending the lifespan of components and equipment. This not only reduces resource waste but also offers a sustainable solution by lowering environmental impact.

4-2. Initial Business Development

In the initial stage, the primary target customers will be research institutions and equipment manufacturers operating precision experimental devices. The focus will be on addressing specific challenges faced by these customer segments, such as the detection of minute defects or deterioration that conventional non-destructive testing methods may fail to identify.

To meet these needs, I will develop a system that analyzes amplitude and phase fluctuation data obtained from eddy current testing equipment using AI. This system will be introduced as a prototype equipped with a user-friendly interface designed for quick and easy deployment in operational settings.

Following deployment, I will conduct pilot testing in collaboration with early customers to enhance the system's practicality and value. This process will involve validating the system in real-world environments using experimental devices owned by the customers. Specifically, the AI analysis model will be evaluated for its ability to adapt to complex operational conditions and specialized environments, ensuring the reliable detection of subtle anomalies. Feedback from these pilot tests will directly inform system improvements and clarify directions for functionality and customization tailored to specific customer needs. Key performance metrics such as inspection accuracy, false detection rates, and usability will be monitored, with algorithm refinements and interface adjustments made as needed.

At this stage, delivering the product's value proposition to customers will be the top priority. The developed eddy current testing system aims to extend the lifespan of equipment and enable stable operations by rapidly and accurately detecting minute anomalies. Additionally, early detection of issues will reduce equipment downtime, emphasizing the system's sustainable aspects by minimizing resource waste and environmental impact. This will allow customers to lower their operational costs while improving the reliability of quality control processes.

The revenue model will initially rely on sales revenue from the introduction of the prototype. Post-launch, the focus will shift to expanding revenue through subscription-based software licensing agreements. Additionally, customized solutions tailored to niche customer needs and ongoing maintenance contracts will secure stable revenue streams. By diversifying the revenue structure in this way, the business will achieve both sustainability and growth potential.

Customer engagement will begin with direct sales to research institutions and equipment manufacturers to identify challenges and provide solutions. Concurrently, participation in specialized exhibitions and academic conferences will raise product awareness and expand connections with potential customers. Online marketing will also be leveraged to disseminate product information to target researchers and engineers, further advancing market

development.
To establish a competitive advantage, I will continue developing proprietary algorithms based on AI analysis technology. Building analytical models tailored to the characteristics of precision experimental devices will differentiate the system from competitors. Furthermore, market data and operational expertise accumulated through early customer collaborations will be utilized to expand into other customer segments, strengthening the competitive edge necessary to support business growth.

4-3. Business Expansion Plan

After demonstrating the effectiveness of the developed eddy current testing system in the field of precision experimental devices, the next step is to expand the business model by leveraging this success to penetrate other niche markets. This phase will focus on providing solutions tailored to specific challenges in different industries, utilizing the technical achievements and operational expertise gained from the precision experimental devices sector to attract new customer segments.

First, industries requiring advanced non-destructive testing similar to that for precision experimental devices will be identified. Potential targets include manufacturing, energy, aerospace, and medical device production. In these sectors, ensuring the quality of equipment and components is critical, and conventional inspection methods often struggle to detect subtle abnormalities. For example, components exposed to high-temperature and high-pressure environments, such as turbine blades in aircraft or piping in energy plants, require improved inspection accuracy to prevent minor deterioration from escalating into serious accidents.

Understanding the common needs across these fields, the eddy current testing system will be customized for each application. For manufacturing, automated solutions enabling rapid inspection on production lines will be developed. For the energy sector, portable systems tailored for periodic inspections of large-scale equipment will be introduced, prioritizing ease of use in field operations. In medical device manufacturing, where extremely high precision and reproducibility are essential, the system will be designed with a strong emphasis on the reliability of data analysis.

During this market expansion, compliance with industry-specific regulations and standards will be essential. Therefore, the necessary certifications and adherence to applicable standards for each target market will be swiftly achieved to establish customer trust and confidence.

To maintain competitive advantage in the expanded market, continuous advancements in AI analysis technology will be pursued. Data collected across industries will be used to train AI models, achieving higher accuracy and versatility in analytics. This data-driven approach will not only optimize product performance for industry-specific challenges but also serve as a

foundation for entering new markets.
The revenue model will also expand in line with market penetration. In addition to product sales and subscription models, comprehensive service contracts will be offered to large-scale customers. These contracts will include customized development, operational training, regular model updates, and analytical reporting services, fostering long-term relationships with clients and ensuring a stable revenue base.
The marketing strategy will leverage early success stories to accelerate the approach to new markets. Demonstrated performance in research institutions and precision equipment sectors will be actively promoted through exhibitions, academic conferences, and industry journals to highlight the reliability and value of the product.
Ultimately, the expertise in technology and customer engagement cultivated in the field of precision experimental devices will form the foundation for delivering customizable non-destructive testing solutions to a variety of niche markets. By continuing to address specific challenges with a focused approach, the business aims to maintain its competitive edge while establishing a sustainable business model.