CHAPTER 1

INTRODUCTION

A. Background

To deal with a microcantilever, we must comprehend the micro-electromechanical system (MEMS). MEMS is a tiny device that combines mechanical and electrical components. MEMS work at the microscopic level, sensing, controlling, and regulating various functions such as temperature, pressure, and motion. They can convert mechanical energy into electricity and vice versa, using techniques like piezoelectricity and microfabrication. MEMS can also integrate the device from the microscopic level to the macroscopic level. What this means is that MEMS can create a bridge from a microscopic level to a macroscopic level. This allows people to see the microscopic world at a macroscopic level. and the The reason why MEMS can do this is that it contains a micrometer-scaled precision device that can accomplish tasks that are usually carried out in the macroscopic system and vice versa. (Chircov & Grumezescu, 2022).

MEMS can also be applied in physics and other fields; for instance, it can be applied in fields of the food and process industry, environmental monitoring, healthcare, microfluidics, and others. This shows a small quantity of a variety of MEMS that can be applied to(Mouro et al., 2021). However, in this research study, the MEMS that will be used is much more towards the physics side. More specifically, on the resonance side, resonance in the frequency of our surroundings can be detected and data extracted from it; this is possible using a microcantilever. A microcantilever is a suspended micro-scale beam structure supported at one end that can bend and vibrate when subjected to a load. (Mouro et al., 2021). Think of it like a plank in a swimming pool that is used to jump and create a swimming pose in the air and a huge splash when a person hits the water. If we remember, when someone jumps off that plank, it creates this up-and-down motion, and that motion creates a frequency that usually can be heard by sound. So, the idea of a microcantilever is to use that swimming pool plank method on a microscopic scale therefore the frequency is on a small scale, that it can be used as data and the resonance of that frequency can be found**.** Microcantilever also have a way to costumized its material, the method its called doping. Doping is the process of incorporating impure particles into a pristine semiconductor material. Doping enables researchers to control the conductance of a semiconductor by exploiting the properties of a class of elements known as dopants. Example of this is Silicon doped microcantilever,gold doped microcantilever, and ZNO doped microcantilever(Fletcher et al., 2011; Nuryadi et al., 2020; Steffens et al., 2014).

Many research facilities have tried to research this study case. However, a lot of it has some issues with how the microcantilever turns out; for example, a case study conducted at the Department of Chemical & Biological Engineering, the University at Buffalo to review the microcantilever, they test the microcantilever on reaction-based sensing. In short, they tested multiple chemical reactions to see how well the microcantilever performed in that scenario. So, they decided to modify the surface of the microcantilever with a coating to increase the sensing of it. The result is that they found some excellent points about microcantilever and some bad points about microcantilever. The good points are that it is easy to operate a chemistry lab and very uniform layer-wise, reliable, and reproducible. The bad point about the microcantilever is that, because of the vast and widespread uses of microcantilevers and many possible options for modification. In that paper, they indicate that even though it is modified, it is still not suitable for reaction-based sensing; the reason for that, based on the paper, is that "Sensor efficiency comparisons are necessary since various modification methods influence MCL(microcantilever) performance."(Lam et al., 2023).

Because of this and many other problems that can occur, there are two possible ways to solve this problem. The first one is to buy the microcantilever and use a trial-and-error method. If something goes wrong, buying a microcantilever and using a trial-and-error method will cost a significant budget. The second way of doing this is to simulate it first on software, the problem of it happening in real life will be reduced to zero since the trial and error process can be done in a simulation world where it will not affect the budget of the research facility. *Badan Riset Innovasi Nasional*(BRIN) chose the second path, the simulation route. They think this is the best because it is more effective and less reliant on money. Also, the trial and error method can be done within the simulation without any consequences in real life rather than spending considerable money to have it broken or encountering an error to repurchase it**.**

However, problems will still arise when using the simulation method. Three things about simulation have to be looked at or paid attention to:

1. Time is essential because it can affect how the simulation will be shown. The reason for this case study is to show what a fully working microcantilever is. If that fails to show, then the whole process is entirely useless.
2. How the simulation will work, adding the concept of time can be detrimental because most physics formulas interact with time. If the concept of time is wrong, then all physics will not work, and the data will be wrong and unusable.
3. How it will affect the simulation performance, Because of a missed timing, some physics might collide, creating a bug that might cause problems for the microcantilever showcase.

The second one is quality. The best quality of a simulation is showcase and performance. Suppose the simulation shows the product without any problems with the performance. In that case, that simulation is good quality, if it is terrible quality, it usually means that it failed to showcase the product and has a bug or an error. The third one is to improve learning. Improved learning means that the showcase of that product can show how it Works, how it is built, and how it performs. This another essential part that must also be looked at because the purpose of this case study is to show how microcantilever work and how it can be built by using simulation it can be built in real life without any problem(Pariafsai, 2016). Furthermore, these are significant simulation problems, therefore knowledge of Resonance MEMS is required to approach them.

Lastly, the simulation will be simulated using ANSYS. ANSYS, in short, is a software that can simulate physics in multiple ways. One example of ANSYS work is that it can simulate a Heat Exchanger, a tool to help exchange heat and fluid(Muzaki & Anggara, 2022). ANSYS also provide one of the simulation method that helps solving the problem when its come to simulating an time-course data. Time-course data is a data that is recoreded over consistent amount of time, usually this type of data is used to solve an diffential equation or an equation that requires time, the result can be used as a new parameter for the data. The problem is that it requires a lot of computational demands of numerical integration this sometimes can create a noise within the data(Wong et al., 2023).

There is a method that can solve this issue called the finite element method. The finite element method can approximate the solution of differential equations and analyze their stability and the accuracy of the approximation. The finite element method will make the differential equation easy to differentiate and integrate(Pasteur & Koch, 2020). The noise that was created by the error of simulation also got reduced significantly, allowing for a reduction in the computational cost of numerical integration. the idea is to use this method to help solve and approximate the differential equation that is going to be used to help simulate the microcantilever. Another technique that is very detrimental to this simulation is the harmonic response analysis method. In simpler terms, this method takes the result of modal analysis, which is the analysis the modal state of the microcantilever. The maximum deformation value from the modal analysis was determined for each natural frequency. Harmonic response analysis uses this result from modal analysis to create data on natural frequency and maximum deformation that can be shown in the graph.

The main goal of this research is to simulate a microcantilever with ANSYS and can be applied to use a finite element method to create the mesh of the microcantilever. This can be applied to the modal analysis to find the natural frequency of the simulated microcantilever, and that frequency can be applied to the harmonic response analysis method, and the result will create data that can be used to determine the Q-factor of the microcantilever with FWHM. This method will be applied to the L300 and L400 to see the difference between the two microcantilevers. (Wong et al., 2021).

B. Research Question

Based on background the research problem of this study are:

1. How modal analysis obtain natural frequency?
2. How finite element method help the other method?
3. What other Method that help to simulate Microcantilever?
4. What makes L300 and L400 microcantilever different than each other?
5. Why modal analysis method is the important one out of other method?

C. Research Aim

The objective of this study is as follow:

1. To learn the functionality of each method that are used for the simulation.
2. To explore what other data that can be obtain from this methods.
3. To understand more how finite element method purpose on harmonic response analysis.
4. To understand more how frequency can be used as sensor.
5. To understand more about Q-Factor.

D. Research Benefits

Based on the research objectives, the benefits of this study are:

1. Able to understand the method that are used for the simulation.
2. Able to understand the role of natural frequency
3. Able to understand the usage of finite element method
4. Able to understand the importance of Q-Factor
5. Able to understand more about microcantilever

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