Development of Elekctric Digital Musschenbroek Long Expansion Experiment Tools

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Abstract. The aims of this research is to develop a musschenbroek long expansion device digitally by using electic heaters from solder elements and LM35 temperature sensors based on Atmega 16. This research starts from the potential to develop a manual musschenbroek long expansion experiment tools. In the second stage, collect information about digital products that can support the development this tools. In the third stage, carry out the planning of the design and manufacturing of tools. In the next stage, try out the tools dan repairment. The final results of the test obtained the value of the length of the expansion coefficient of eachmetal has approached the theoretical value that has been previously known. Brass expansion coefficient $2{,}04x10^{-5}/^{o}C$; Iron expansion coefficient $1{,}31x10^{-5}/^{o}C$; Aluminium expansion coefficient $2{,}72x10^{-5}/^{o}C$. Due to the simplicity of the experiment tools, it can be used to introduce the concept of metal long expansion in the learning process to high schools students.

Keywords: musschenbroek experiment tools, LM35 sensors temperature, Atmega16

1 Introduction

The world has entered a change called industrial revolution 4.0 or the fourth world revolution where information technology is the basis of human life[1]. All areas of life have been influenced by the industrial revolution 4.0 including the education sector. In the face of industrial revolution 4.0, it is necessary to prepare for the implementation of education that links and matches between human resources and the needs of the era in the era of the industrial revolution [2]. Educational innovation is needed, espercially in learning process. Innovative learning is oriented to the competence of students in the 21st century characterized by 4Cs: creativity and innovation, critical thinking and problem solving, communication skills, and collaboration [3].

One part that has a great influence from the 4.0 industrial revolution in the field of education is the learning process in the classroom. The 4.0 industrial revolution not only gives influence in terms of the models and learning methods used in the classroom, but also the learning media used. Learning media have an important role in the learning process. One of the fundamental things played by learning media is as a means to make abstract concepts that are difficult to explain directly into concrete so that they can be seen even directly felt by students. Therefore, Educators are required to be creative in creating and developing learning

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media so that students can be interested in learning physics and the material delivered can be truly understood by students [4].

Basically, technology is created to further facilitate human affairs to be more effective and efficient. Increasingly sophisticated technological developments contribute to the development of learning media. The practicum tool is one of the learning media that has a significant influence on technological sophistication. Experiment tools have been developed using digital systems. Making digital practicum tools is intended to streamline time and minimize the level of errors in data collection so that the end result is in accordance with the theory of reference that has been studied before [5].

Experiment has an important role in learning science, especially physics. Through practical activities, psychomotor, affective, and cognitive aspects of students can be improved. In the affective domain, students are trained to plan activities independently. Psychomotor aspects of students are also trained in using certain instruments to complete an activity. Whereas for the cognitive domain, high-level thinking skills or better known as high order thinking skills (HOTS) students are also involved in solving the problems faced. High-level thinking skills (HOTS) is one of the skills that must be possessed by students in the era of industrial revolution 4.0. The use of experiment tools in learning physics that has developed successfully in HOTS of students, in particular, the ability to think critically [6].

Long expansion is one of the properties of metal materials when experiencing heat gain. The utilization of expansion properties of materials has been widely used in daily life, especially in the construction field. One example that is often used in explaining the concept of expansion in students is the installation of railroad tracks. In addition to using examples in everyday life, the concept of expansion should also be explained using practicum because there is a long expansion practicum, namely musschenbroek. However, these tools are rarely used because most of those found in schools are still conventional. The need for the development of a digital expansion tool so that students can have a direct experience in obtaining their own knowledge in the concept of expansion.

This study aims to develop a digitally musschenbroek long expansion experiment tool using an electric heater derived from soldering elements and atmega16 based LM35 temperature sensors. With the existence of a digital-based digital expansion tool, it is expected to facilitate the learning process. Students become easier to understand the concept of expansion. On the other hand, writing this article is expected to be one of the references in the development of practicum tools, especially the concept of expansion.

2 Methods

This research type is Research and Development (R & D). The aims of R&D is to producing certain products and testing the effectiveness of these products [7]. The produced product in this study is digitally musschenbroek experiment tool. This tool is used to determine the value of the metallong expansion coefficient. This research was conducted at the Physics Workshop Laboratory, FMIPA UNNES, Building D9 1st Floor.

The step of using the R & D method used in this study starts from seeing the potential to develop a musschenbroek long expansion practicing tool that still uses heaters and manual indicators. In the second stage, information was collected about digital products that could support the development of musschenbroek long expansion practicum tools. In the third stage, the design and manufacture of tools are carried out. In the next stage, a tool test was conducted, but it turned out that the data obtained from the trial results were not in accordance with what was expected so further analysis was needed to improve the tool. After the revision was carried out, a device trial was conducted again.

The tools and materials used in the development of this tool are a set of musschenbreuk experimental devices including metal test materials including aluminum, copper, and iron, electric heaters derived from soldering elements, cables connected to LM35 temperature sensors, LCD circuits as temperature and time viewers , acrylic as an expansion indicator viewer, power supply, ac adapter and ruler.

3. Result and Discussion

The Musschenbroek long expansion experiment tool was developed using LM35 sensors temperature based on atmega 16 and the electric thermal by solder elements. The design of this experiment tool is shown clearly in Figure 1.

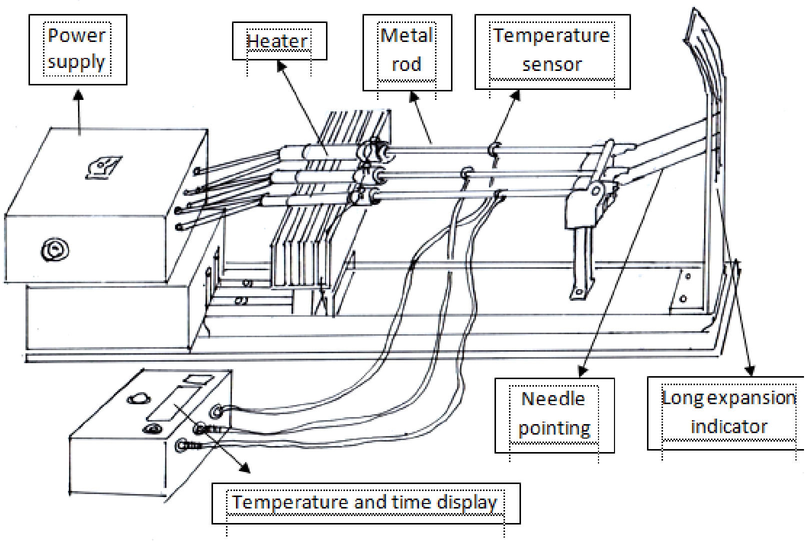

Figure 1. *Musschenbroek* long expansion experiment tools design

The working principle of the tool is when a metal rod is heated, metal objects will experience a long increase so that the needle position shifts upwards. The greater the temperature, the metal rod will increase in length so that the needle moves more upwards. Changes in temperature caused by electric heaters detected by LM35 sensors are placed at three points, namely the tip of the rod near the heater, the center of the rod, and the end of the rod away from the heater.

Based on the results of the first phase of testing, this tool still needs improvement. The first improvement is to place the sensors temperature on the metal rod. At the initial stage, only one temperature sensor is used on each bar placed in the middle. It turns out that the data obtained shows a mismatch between the value of the metal expansion coefficient as a result of the test and the value of the theory. The temperature range that can be measured by the LM35 sensor only reaches 150OC [8] making measurements less effective because the length increment that occurs is less visible. So that repairs are made in the form of adding the number of temperature sensors used on metal rods to three pieces placed at the end of the rod near the heater, the center of the stem, and the far end of the rod, as shown in figure 2.

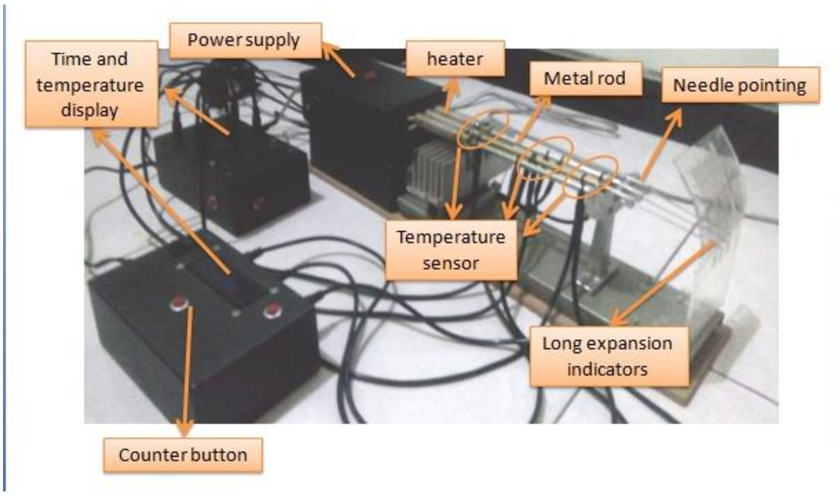

Figure 2. *Musschenbroek* long expansion experiment tools

The second improvement is in the long expansion indicator. The long increments that occur in the metal rod due to heating cause the pointer to move upwards. At first, the scale shown by the needle on the long expansion indicator was considered as a long increment that occurred in the metal. But after analyzing the data, the long expansion coefficient values obtained were not in accordance with the value of the theory. After further analysis, the improvements made are the conversion of calculation of length increments. The third improvement is the provision of a thin metal rod as a buffer. This is done so as to minimize the heat flowing on the supporting rod and the pointer.

The results of the final stage trial are presented in table 1.

Table 1. Data Result

Metal Rod	ΔT (ºC)	ΔL (mm)	α (ºC^{-1})	$\bar{\alpha}$ (ºC^{-1})
	84.15	0.5	2.93 x 10^{-5}	
	81.75	0.4	2.41 x 10^{-5}	
Aluminium	81.05	0.4	2.43 x 10^{-5}	2.72 x 10^{-5}
	84.3	0.5	2.92 x 10^{-5}	
	85.3	0.5	2.89 x 10^{-5}	
	76.45	0.3	1.93 x 10^{-5}	
	72.15	0.3	2,05 x 10^{-5}	
Brass	72.9	0.3	2,03 x 10^{-5}	2.04 x 10^{-5}
	70.85	0.3	2,09 x 10^{-5}	
	70.55	0.3	2,09 x 10^{-5}	
	72.7	0.2	1.36 x 10^{-5}	
	68.4	0.2	1.44 x 10^{-5}	
Iron	68.85	0.2	1.43 x 10^{-5}	1,31 x 10^{-5}
	62.83	0.15	1.18 x 10^{-5}	
	64.23	0.15	1.15 x 10^{-5}	

This experiment tool is intended to calculate the value of the long expansion coefficient of a metal. When a metal is heated, the metal will experience expansion. When a metal rod with Lo length is heated until the temperature changes by ΔT, the metal rod will experience a length increase of ΔL. Mathematically it can be written as equation (1).

$$\Delta L = L_0 \, \Delta T \, \alpha \qquad (1)$$

The metals used in this lab are aluminum, brass, and iron. The length of each metal rod is fixed and equal, which is 203 mm. The data obtained in this practicum are temperature changes as independent variables and length increments as dependent variables. The data is then used to determine the value of the metal expansion coefficient at equation (2).

$$\alpha = \frac{\Delta L}{\Delta T \, L_0} \qquad (2)$$

Based on the results of the trial data in table 1, it was found that the greater the temperature change, the greater the length of the metal rod. This is in accordance with the theory used. Although the error factor of the tool has been minimized, the results obtained are not exactly in accordance with the value of the theory. The results of the analysis obtained error values for each metal tested, namely Aluminum 6.25%; Brass 6.86%; and Iron 8.4%. Direct contact between the device and free air is one factor in the emergence of error values in the data obtained. A little heat energy produced from solder elements is irradiated to free air.

The length expansion coefficient can also be determined using a single slit diffraction experiment using aluminum [9]. Long expansion coefficient of Aluminium is obtained by using two analytical methods, namely the linear regression method and the graph method. Based on the analysis using linear regression method, the obtained value of aluminum expansion coefficient is (2.72 ± 2.26) x 10-5/oC, and the value of the long expansion coefficient based on the graph method is 2.74 x 10-5/oC. This value is not much different from the results obtained by using digital electric Musschenbroek is 2.72 x 10-5/oC.

The use of electrical digital-based tools minimizes human error and makes the experiments more effective so that errors are smaller than traditional methods [10]. The existence of a digital-based musschenboek long expansion tool is expected to facilitate the learning process. Students become easier to understand the concept of expansion. On the other hand, this article is expected to be a reference material for students and teachers to develop long expansion experiment tools.

4. Conclusion

Based on the research and development conducted, it can be concluded that the electrically-based digital Musschenbroek long expansion practicum is suitable for use in physics learning.The musschenbroek digital electric expansion instrument is developed in accordance with the concept of expansion, namely the greater the change in the temperature of the object, the greater the length of the metal rod.The test length expansion coefficient value which is Aluminium = 2.55 x 10^{-5} /ºC; Iron = 1.31 x 10^{-5} /ºC ; dan Brass= 2.04 x 10^{-5} /ºC.

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