

Physic Laboratory by Video Tracker and Visual Basic for Application at Home During Covid-19 Pandemic: Material Elasticity Measurement

Rahmawati Munir^{1,a)}, Nadya Amalia^{2,b)} and Rahmiati Munir^{3,b)}

^{1,a)} Physics Department, Faculty of Mathematics and Natural Sciences, Mulawarman University, Jalan Barong Tongkok No.4, Samarinda 75123, Indonesia

^{2,b)} Research Center of Metallurgy and Materials, Indonesian Institute of Sciences, Puspitek Area, Building 470, South Tangerang, 15314, Indonesia

^{3,b)} Geophysics Department, Faculty of Mathematics and Natural Sciences, Mulawarman University, Jalan Barong Tongkok No.4, Samarinda 75123, Indonesia

^{a)}rahma.mipaunmul@gmail.com

^{b)}amalianadd@gmail.com

^{b)}rahmiatimunir@gmail.com

Abstract. There are many applications that can be used to support physics laboratory today during Covid-19 pandemic. Video tracker and Visual Basic for Application are the simplest application nowadays. In this work, we present the implementation of Video Tracker and Visual Basic for Application at home to measure elasticity modulus of Sheet-Shaped Material in physics Laboratory. There were two stages performed to obtain elasticity modulus of sheet-shaped material. Firstly, the sample was placed in a curved position (curvature angle variation) then the image was recorded. The result of these photo recording was processed using video tracker software. The data obtained were coordinates point mass of each sheet-shaped material curvature. These coordinate point mass used to calculate elasticity modulus using cantilever beam elasticity equation. Finally, to confirm these results, we also measured directly on the material using a tensile test equipment. The computed results showed that elasticity modulus value closed to value obtained by direct measurement using a tensile strength device. Hence, this method is very potential to develop new ways of practice in physics laboratory.

INTRODUCTION

At present, digital technology development of has provided several benefits in physics laboratory during Covid-19 pandemic. Many applications have been developed to support learning in the laboratory to make more interesting and enjoyable for students. The teaching and learning process is the most important activity of all teaching activities from home. The material used in learning must contain facts, concepts and procedures which relevant in accordance with indicators and competencies to be achieved [1]. Physics laboratory in a scientist research class is one of those activities according to reality situations [2]. The situation of general learning activities must be limited by memorizing scientific facts, because students must be able to explore deeper concept understanding through modeling and modeling skills for students from environment exploration [3].

One of the popular applications that can be utilized to support students in learning physics phenomenon in daily lives is tracker video analysis. This application was developed by Java Source Physics (OSP) and has ability to do tracking an object and can analyze the information that we need of motion analysis in two dimensions [4].

The use of video analysis in learning will change teacher practices in teaching students. These changes occur because of several things, namely focus on the analysis, see their teaching from a new perspective, feel accountable to change the practice, remember to implement change and see their progress [6]. Rohman et al, 2018 and Nurmayanti et al, 2019 have also made a video tracker as a tool for learning and practicing activities in schools. This proves that the video tracker can be a reference for teachers in developing physics learning methods in the schools [7,8,9].

Video tracker and Visual Basic for Application are the simplest application nowadays. This research proposes the use of a video tracker to support physics laboratory, especially in measurement and analyzing the materials properties. In this work, we present the implementation of Video Tracker and Visual Basic for Application at home to measure elasticity modulus of sheet-shaped material in physics laboratory. One of the important material properties should be to know is the elasticity modulus.

Observation for materials elasticity in this study using sheet-shaped material. Previous studies examining the elasticity modulus of sheet-shaped materials have existed [10,11]. The proposed method is to combine the basic formula of cantilever beam equation and results of tracking curvature angles data. We also measured directly on the material using a tensile test equipment. The computed results showed that elasticity modulus value closed to value obtained by direct measurement using a tensile strength device. Hence, this method is very potential to develop new ways of practice in physics laboratory.

Research Method

In this work, a simple method was developed to calculate modulus elastic of a sheet-shaped material. There were four stages of the procedure carried out to estimate the elasticity modulus. Firstly, recorded sample images formed sheet using a digital camera then save the image file in jpeg or png format. We prepared samples with a size 16 x 5 cm (see **FIGURE 1**) were placed on experimental table then clamped at one end and the other end was left free so that formed bending curves. The curvature angle controlled at 0° , 45° and 90° .

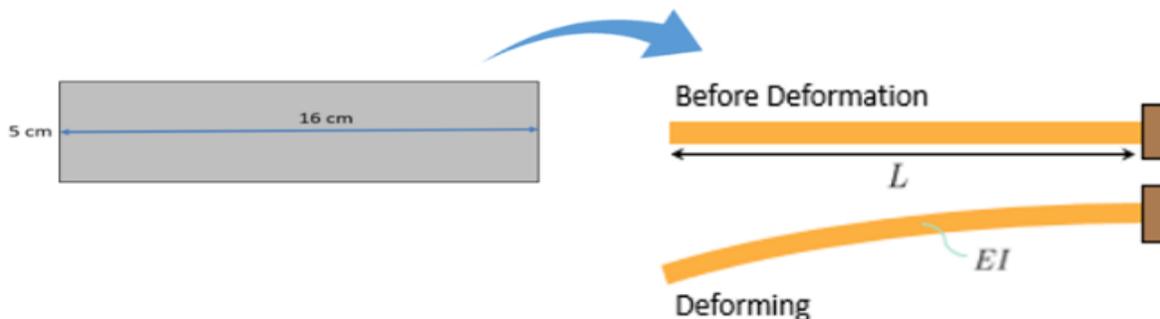


FIGURE 1. Sample preparation of sheet-shaped material using 100 gsm copy paper

Second, we performed tracking samples image using video tracker application. Opened the tracker program by double click on tracker shortcut in computer to show tracker program windows and selected picture frame. Furthermore, we calibrated sticks and tapes to determine xy axes and made points mass. Calibration tape made into 16 to divide sample image segments, then track 2 mass points at each length of calibration tape till resulted 32 xy coordinate points. The procedure for calculating elasticity modulus of sheet-shaped material is shown in **FIGURE 2**.

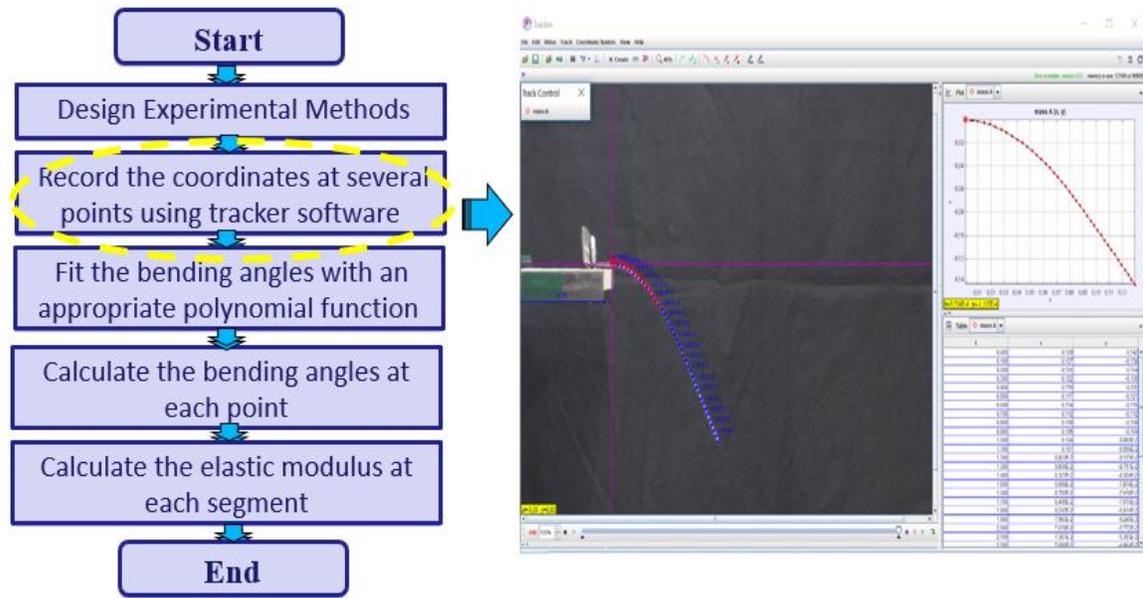


FIGURE 2. Procedure for estimating the elastic modulus of the beam

Third stage, the xy coordinate data from the tracker screen is the coordinate angle of the sample curvature transferred to the excel program for further processing. Then, using the cantilever beam equation to calculate the elastic modulus such equation has the simple form

$$Y_j \approx -\frac{a^3 g}{I_j(\theta_j - \theta_{j-1})} \sum_{i=1}^j (\sum_{k=1}^i \lambda_k) \cos \theta_i \quad (1)$$

The accuracy of elasticity modulus for calculation used equation (1) to fit bending angles with an initial estimate by corresponding polynomial. The fitting process will smooth changes in angle along for sample curve and subtle changes in bending angle which were representative of actual conditions. The last stage, we also measured directly using a tensile strength equipment to compare the calculations results.

Calculation Stages

Before we continue with the discussion, there are a few limitations to note. Cantilever beam analysis uses the following assumptions

1. The material of the cantilever beam is linearly elastic, homogeneous, and isotropic.
2. The bending of the beam does not change its length.
3. Although the bending of the cantilever beam is essentially a three-dimensional problem where elastic stretching in one direction is followed by compression in the other two perpendicular directions due to the Poisson effect, this effect can be neglected because the length of the cantilever beam is much greater than the thickness of the perpendicular section.
4. The beam does not elongate or is inextensible, the strain remains small within the elastic limit.
5. The cross-sectional plane normal to the neutral axis remains in the form of a plane and is perpendicular to the neutral axis before and after deformation.

When the force acting on the beam is only due to its own load, the angle of bending in the j -th segment, i.e., $\theta(j)$, satisfies the following recursive equation

$$\theta_j = \theta_{j-1} - \frac{a^3 g}{E_j I_j} \sum_{i=1}^{j-1} (\sum_{k=1}^i \cos \theta_k) \quad (2)$$

Where I_j is the second area moment, E_j is the elastic modulus, λ_j is the mass density per unit length of the j -th segment, and g is the acceleration of gravity.

The second broad moment is a cross-sectional property that can be used to predict the resistance of the beam to bending and deflection. The bending of a beam when it receives a load depends not only on the magnitude of the load, but also on the geometry of the cross section of the beam. A beam with a large second area moment is more resistant to bending, in other words it is stiffer, than a beam with a small second area moment. In this case, the cross-sectional shape of the sample used was rectangular.

Based on the equation (2), it can be understood that the calculation must be carried out from the first segment, namely the segment located at the free end. Having determined the angle formed by the free end, the angles of the next segment can be calculated sequentially up to the last angle at the fixed end. The problem is that the boundary conditions are at the fixed end instead of the first segment. Therefore, after calculating the angle of all segments, the calculated angle at the end segment may still not meet the proper boundary conditions. If this is the case, then the initial angle used in the first segment is incorrect. Then another angle is used as the first segment until the calculated angle from the last segment is the same as the boundary condition. This approach may seem cumbersome, but it can be accomplished by an iterative process

The angle formed by the first segment has values in the range of $-\pi/2$ (free end pointing vertically up) and $+\pi/2$ (free angle pointing vertically down). Thus, the possible angle formed by the first segment is in the range of π radian. Since the bending direction has been assumed to be counterclockwise, then for all j , $\theta_{j+1} < \theta_j$. To determine the true angle of the first segment, the small angle range is divided into $N1$ increments of value, where the angle increment is $\Delta\theta1 = \pi/N1$. Then the value of the angle that will be used as the first angle will be tested from $-\pi/2$, $-\pi/2 + \Delta\theta1$, $-\pi/2 + 2\Delta\theta1$, $-\pi/2 + 3\Delta\theta1$, ..., $+\pi/2$. From each choice, calculations are made for all $\theta2$, $\theta3$, $\theta4$, ..., θ_{N1} and the value of θ_{N1} is checked whether it has met the boundary conditions or not. If θ_{N1} does not meet the boundary conditions, the calculation process will be repeated from the beginning with the addition of the angle used as the free end. If $N1$ has met the boundary conditions, the iteration is stopped. The condition for stopping the iteration is where is a very small number and depends on the desired accuracy.

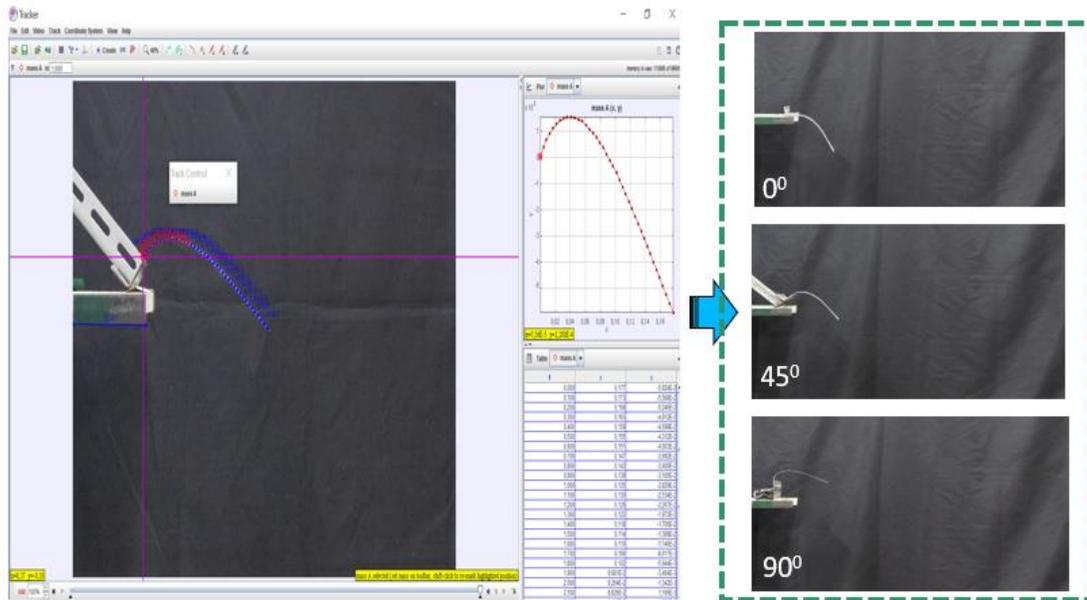
After the actual series of angles $\{\theta1, \theta2, \theta3, \dots, \theta_{N2}\}$ are obtained, followed by determining the coordinates of each segment. We assume that the free end has coordinates $(0,0)$. The coordinates of the first segment and so on can be calculated as

$$x_j = x_{j-1} + a \cos \theta_j \quad \text{and} \quad y_j = y_{j-1} + a \sin \theta_j \quad (3)$$

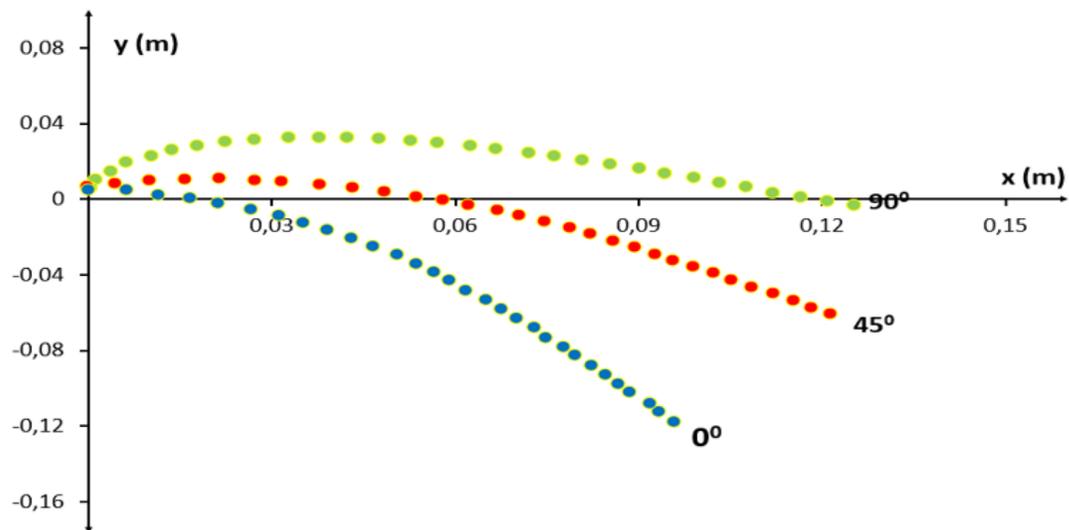
Finally, the curve of the calculated beam can be plotted based on the above two equations.

Results and Discussion

The display of video tracker software when tracking sheet-shaped samples (**FIGURE 3 (a)**) and xy coordinate tracking results for each curvature angle in sheet-shaped samples using video tracker software are shown in **FIGURE 3 (b)**



(a)



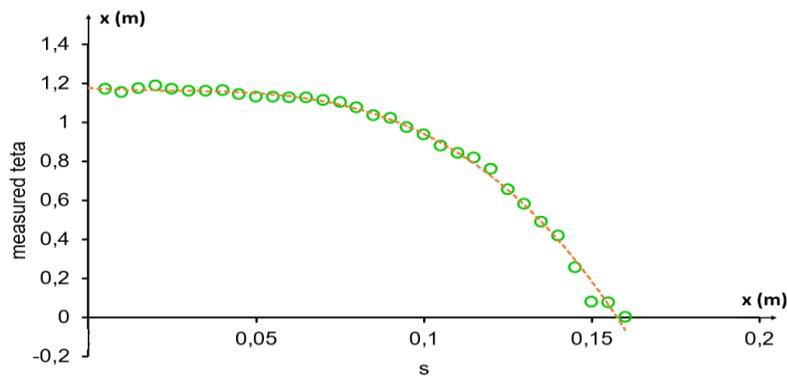
(b)

FIGURE 3. (a) Display video tracker when tracking mass points for the sample. (b) The deflection profile of the results of the image through image tracking using a video tracker for sheet-shaped samples for curvature angle 0°, 45° dan 90°.

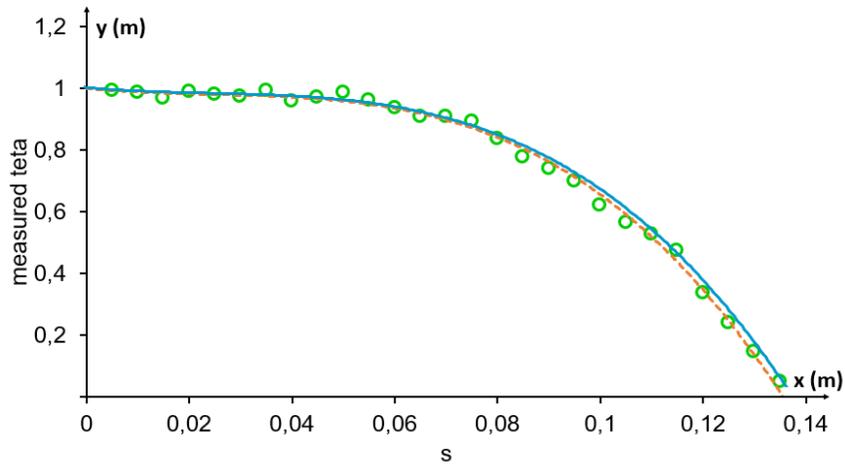
The coordinate of track results from copy paper 100 gsm image, which fixed end (the far-left end) was controled at various angles of curvature (00, 450 and 900). From these tracking coordinates, the bending angle can be calculated using equation (4)

$$\theta_{\alpha} = \tan^{-1}[f'(x_{\alpha})] \tag{4}$$

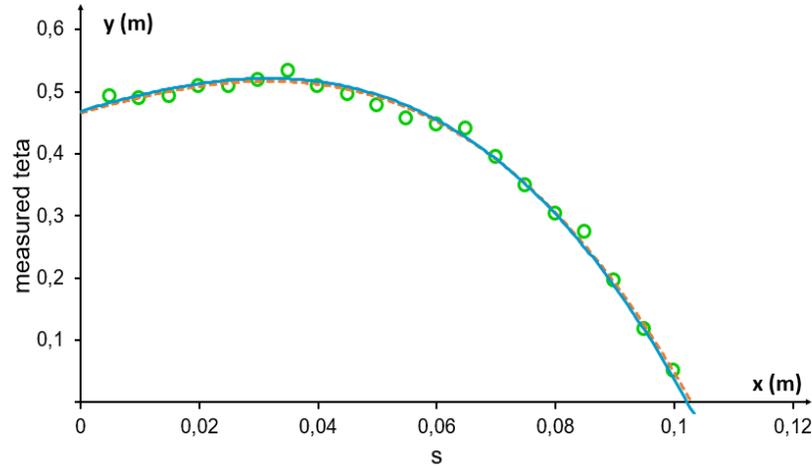
Initial estimation of bending angle, sample image was divided into 16 segments whose calculation results were represented by symbol in **FIGURE 3**. These angles were then fitted with polynomial order 3 to obtain fitting curve that useful for decreased inaccuracies of coordinates tracking data from experimental results. The fitting curve, curvature angles for each of more numerous segments can be recalculated. The angular data was used to estimate elastic modulus in each segment using equation (1). The sample fitting curves measured with curvature angles 0° 45° and 90° are shown in **FIGURE 4**



(a)



(b)



(c)

FIGURE 4. Experimental data fitting graph (green colored round shape), theory (orange dashed line) on rectangular sample for Curvature angle 0^0 (a), 45^0 (b) and 90^0 (c).

Polynomial order 3 fittings to the tracking data of experimental results at an angle of 0^0 , shown in the form of a dashed line (orange). The polynomial order 3 equation is shown in equation 5

$$y = -485.8x^3 + 36.412x^2 - 1.141x + 1.1755 \quad (5)$$

More bending angle data obtained through the fitting curve was calculated based on equation (1) so that the modulus value of Young = $2.42 \times 10^9 = 2.42$ GPa was obtained. The order 3 polynomial equation for the 45^0 curvature angle is expressed with

$$y = -686.23x^3 + 50.606x^2 - 1.6501x + 1.0008 \quad (6)$$

Based on equation (6), the bending angle data obtained were used to calculate elastic modulus using equation (1). The calculation results obtained modulus of elasticity of $2.18 \times 10^9 = 2.18$ GPa. Finally, the curvature angle of 90^0 with the fitting curve (see **FIGURE 4** (c)) was obtained in order 3 polynomial equations

$$y = -490.35x^3 - 20.042x^2 + 2.7403x + 0.4656 \quad (7)$$

In the same way as before, the elasticity modulus was calculated using equation (1), the modulus of elasticity obtained was $2.32 \times 10^9 = 2.32$ GPa.

Elasticity modulus calculation results (angular variations) obtained values with the same order and values closed to the data measurement. This shows that estimation provides accurate modulus elasticity information using cantilever beam (see: equation (1)).

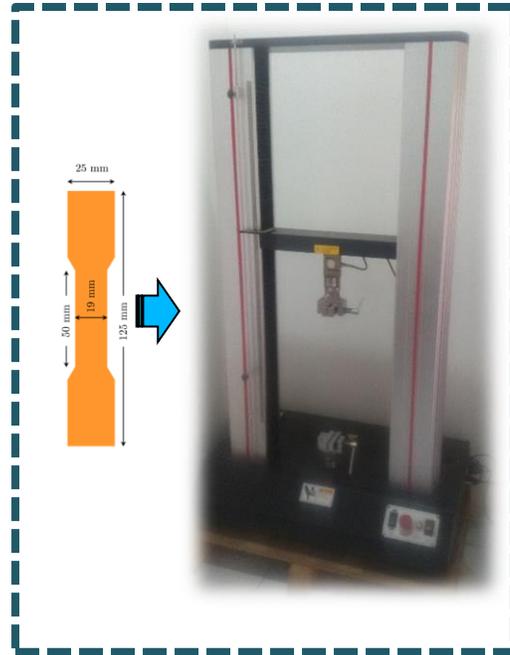


FIGURE 5. Tensile testing equipment to measure the modulus of elasticity of a material

To further assure the results of direct measurements by performing a tensile equipment (**FIGURE 5**) and provide results that can be compared with the results of calculations as shown in **TABLE 1**.

TABLE 1. The average values of elastic modulus obtained from calculation and direct measurement for sheet-shaped material (copy paper 100 gsm)

Angle	Sheet-shaped material (Copy paper 100 gsm)	Elasticity Modulus (GPa)	
		Averaged Calculated	Averaged Measurement
0 ⁰		2.42	1.4-2.1
45 ⁰		2.18	1.4-2.1
90 ⁰		2.32	1.4-2.1

We only show 3 data because these data represent a lot of previous data that had been tested for various angles. Testing the sample using a tensile test equipment resulted elasticity modulus values at range 1.4 - 2.1 GPa. This value does not differ greatly from the results of calculations on samples that are tracked with a curvature angle of 45⁰ which is 2.18 GPa. Based on the calculation and measurement results using a tensile test equipment, the accuracy or error obtained from Young Modulus calculated for the 0⁰ 45⁰ and 90⁰ curvature angle using Eq. (8) as shown in **TABLE 2**.

$$E = \frac{Y_u - Y_h}{Y_u} \times 100\% \quad (8)$$

with Y_u : Modulus Young calculation results
 Y_h : Modulus Young measurement results

TABLE 2. The calculation and measurement results using a tensile test equipment as well as the accuracy or error

Angle	Y_u	Y_h	Error (%)
0 ⁰	2.42	2.1	13.2
45 ⁰	2.18	2.1	3.6
90 ⁰	2.32	2.2	9.4

The best calculation results are at a 45 degree curvature angle. The error from the calculated elasticity modulus estimate is 3.6%. This means that the procedure has been able to estimate elastic modulus with deviations from the measurement results of less than 5%. The smaller value of deviation compared to the results obtained by Amalia et al, 2018 is a range of 16% [10].

Conclusion

We have shown video tracker and VBA for elasticity modulus measurement of sheet-shaped in material (copy paper 100 gsm). This method a series of procedures: Tracking images using Video Tracker Software, Calculating bending angles using cantilever beam equation. These procedures can be conducted at home. We can accurately estimate modulus material elasticity without tensile strength equipment.

References

1. PERMENDIKBUD. 2016. *Standards for the Process of Primary and Secondary Education*. Retrieved from <http://www.bsnp-indonesia.org/id/wp-content/uploads/2012/04/Laporan-BSNP-2010.pdf>, (Date: 26-09-2019)
2. Kang Wee, L., & Kwang Leong, T. (2015). Video Analysis and Modeling Performance Task to Promote Becoming Like Scientists in Classrooms. *American Journal of Educational Research*, 3(2), 197–207
3. Enyedy, N., Danish, JA, Delacruz, G., & Kumar, M. (2012). Learning physics through play in an augmented reality environment. *International Journal of Computer-Supported Collaborative Learning*, 7(3), 347–378
4. Wee, L.K., dan Lee, T.L. (2011). Video Analysis and Modeling Tool for Physics Education: A workshop for Redesigning Pedagogy. *Workshop at the 4th Redesigning Pedagogy International Conference June 2011, Singapore*
5. Bryan, J. (2004). Video analysis software and the investigation of the conservation of mechanical energy. *Contemporary Issues in Technology and Teacher Education*, 4(3), 284-298
6. Trip, T.R. (2010). *The Influence of Video Analysis on Teaching*. A dissertation submitted to the faculty of Brigham Young University
7. Rohman, F., & Fauzan, A. (2019, April). Integration of technology in projec based learning with tracker on practicum activities. In *Journal of Physics: Conference Series* (Vol. 1185, No. 1, p. 012036). IOP Publishing
8. Nurmayanti, D., Jumadi, J., Wilujeng, I., & Kuswanto, H. (2019, June). Developing of Learning Instruments based on Software Tracker in Measuring Cognitive Learning Outcomes. In *Journal of Physics: Conference Series* (Vol. 1233, No. 1, p. 012047). IOP Publishing
9. Rahmayanti, H. D., Margareta, D., Amalia, N., Utami, F. D., Yuliza, E., Munir, R., ... & Abdullah, M. (2018). How a Snake Can Raise its Neck High although its Body is Very Soft. Similarity with a Thin Plastic Tube Filled with Air. *arXiv preprint arXiv:1812.02348*
10. Amalia, N., Yuliza, E., Margareta, D. O., Utami, F. D., Surtiyeni, N., Viridi, S., & Abdullah, M. (2018). A novel method for characterizing temperature-dependent elastic modulus and glass transition temperature by processing the images of bending cantilever slender beams at different temperatures. *AIP Advances*, 8(11), 115201
11. Munir, R., Rahmayanti, H. D., Amalia, N., Viridi, S., & Abdullah, M. (2019). Penggunaan Image Tracking untuk Pengukuran Sifat Mekanik pada Kertas. *Jurnal Fisika*, 9(1)