Low-cost bending test laboratory kit

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Abstract. The big dimension and higher price of conventional bending test machine is making the school and start-up company hard to fulfilled. This study aims to demonstrate a new design of a low-cost and portable laboratory kit that is prospective for bending test. The kit is using hydraulic pressure tools with maximal capacity is about 6 tons. Economic analysis and smaller dimension of this kit (length x width x height of 700x100x750 mm) Showed that this kit is a low-cost and adaptable to classroom and easy to assemble for school. The different between another modification before bending test kit is on the pedestal and the suppressor of the kit is the which is allowing the machine to test materials with Thicker dimensions. The test result Obtained by calculating the maximum compressive force, moment of cross section inneria, flexural strength and elastic modulus of specimen. The result Also Compared with another test material from bending test machine with the American society of testing and materials (ASTM) standard and Showed that there is not much different in the test result for both. Further development of this kit is Potentially implemented an as an experimental tool for the student.

1. Introduction
Bending test is one form of testing materials in the production of machinery. The engineer currently requires testing of materials easy and simple yet given satisfactory results because of the quality of the material depends on the results of the test run [1,2]. For testing a material of industrial products usually require cost is not cheap, so not all the materials testing company products [3]. The number of products on the market that do not pass the test may not even be tested, sometimes if you buy an unknown product strength and will be used to create an object or device that requires a certain force the tools or objects made in vain for a tool created be easily damaged and can be harmful to the construction nor to the use [4-6]. This of course would be detrimental to consumers. In addition, in the learning of school often cannot provide material testing tools to test equipment such as in factories or conventional. Costly apparatus as mentioned previously, the dimensions of the tool is so great is another problem in the effort to equip a learning medium. In the last decade, virtual and remote laboratory continue to experience growth, the use of low-cost platform also can improve the methodology in education [7,8]. Changes in engineering design of an impact on the process, machine, material, labor, operating time and costs [9]. Another emerging concern in an engine development laboratory is the difference in size and usability of efficiency and costs compared with commercial industrial machinery [10]. Therefore, the value of a product development can be analyzed in advance of the big whether charges will be used [11].
addition, low-cost laboratory should be made in accordance with the purpose of the experiment and the availability workbench or place [12].

Previous research shows a low-cost learning with media laboratory able to meet the learning needs of students [13,14]. Another study found also argued that the use of platform a low-cost laboratory can run effectively and accurately [15]. This of course shows that the development and renewal of technology in learning needs to be done to follow the increasingly rapid changes in technology as well as considering the development of increasingly complex technology [16]. A few years suggests that the development of low-cost laboratory and similar concepts for learning [17-19]. Simple materials testing tool previously developed to meet the learning needs of learning materials testing. However, there are still some shortcomings in its design. Tool bending test previously developed only for testing materials with the dimensions of the material is very small (brass, glass, composites) and simply calculate the influence of the compressive force that is, the test results were not compared with the tools bending test existing conventional so that the accuracy of testing and efficiency results test tool developed by unknown [20]. So that learning materials testing with a larger material and thickness (metal plate) this tool cannot be used.

Cases like the one above was the inspiration for modifying the test equipment that is making it both simple and easy to operate, the study was modified tool bending test with dimensions smaller organs (700x100x750 mm) of the test equipment conventionally exist that make this tool better used in the learning process in schools and certainly cheaper. The research purposed to show that this bending low-cost bending laboratory kit is easy to use for learning media. In addition, the difference tool bending test previously created by means of this modification results contained in the pedestal and a pressure test object so that this material test equipment capable of testing the material with dimensions that are thicker than in previous studies.

2. Method
The technique used to obtain data on test results modification tools bending test is to see and count the maximum compressive force, moment of inertia of the cross section, the flexural strength of the material and calculate the elastic modulus of the material. At the end of the test, a material with the same composition tested by means of existing conventional bending tests a second comparison test equipment to see large deviation occurs in the test results with the results of bending test equipment modifications. Observations were also performed on the performance of the tool is made, if as expected, or is there a component or mechanism should be enhanced. So expect the bend test tool (bending) can be used to test materials even if only with simple tools.

3. Results and discussion

3.1. Low-cost design laboratory test equipment bending kit
Figure 1 and 2 following the layout of the low-cost laboratory bending test tool kit. This bending test equipment using a hydraulic jack with a maximum capacity of 6 ton presses the test specimen actuated manually using a lever. Test equipment is also made using iron U is used as a framework. As the steering pedestal jig jack onto the runway, used as stainless steel diameter 24 cm by 46 cm as well as the size of the iron box with a size of 50x50 cm each 2 pieces.
3.2. **Draft analysis and economic analysis tools and materials used**

3.2.1. **Economic analysis.** Table 1 is a list of tools and materials used in the construction of this simple bending test. Tools and materials used are materials and components that are easily available in the market. In addition, the construction of simple tools developed and implemented by local workshops and more profitable economically around Rp. 4,000,000 to Rp. 5,000,000 compared to a conventional bending test machine factory with larger dimensions with max capacity <1000 kN can be seen in figure 3, the price of these machines sold in the range of US $ 10,000-1,000,000 / Piece or approximately Rp. 140.03 million up to Rp. 14.001 billion [21].
Table 1. Equipment and materials engineering bending test equipment.

| No. | Name of Material | Size            | Total Material | Price   |
|-----|------------------|-----------------|----------------|---------|
| 1.  | U channel iron (UNP) | 3m×10cm×5cm | 1 stick       | Rp 500,000,- |
| 2.  | Strip steel plate | 10x10x5 cm    | 1 stick       | Rp 400,000,- |
| 3.  | Iron as stainless round | 160x2,4 cm | 1 stick | Rp 200,000,- |
| 4.  | Strip steel plate | 10x10x2 cm    | 1 stick       | Rp 250,000,- |
| 5.  | Manometer / pressure gauge | - | 2 pieces | Rp 450,000,- |
| 6.  | Hose / Elbo       | -               | 1 piece       | Rp 30,000,-   |
| 7.  | hydraulic jack    | 5 ton           | 1 piece       | Rp 500,000,- |
| 8.  | Nuts and bolts    | 12 mm           | 4 pieces      | Rp 25,000,-   |
| 9.  | Welding wire      | -               | 1 pc          | Rp 100,000,- |
| 10. | eye gurinda       | -               | 1 piece       | Rp 20,000,-   |
| 11. | Paint             | -               | 1 tin         | Rp 25,000,-   |
| 12. | Thinner           | -               | 1 liter       | Rp 10,000,-   |
| 13. | Brush             | -               | 2 pieces      | Rp 10,000,-   |
| 14. | Cost cutting plate | - | - | Rp 500,000,- |
| 15. | Cost of labor     | -               | -             | Rp 1,500,000,- |
| 16. | Unforeseen expenses | Repair and transport | - | Rp 200,000,- |

3.2.2. Draft analysis. In designing this tool, please note the area of the base cross section of the holder jig with a large power capacity of the jack to know how big the moment pedestal that can be provided between the jack with a foundation that can be received by the specimen as well as the power of the framework instrument bending test this by performing a tensile test on the canal iron U (UNP). Area of the base used to calculate the formula \( A = P \times L \) where \( A \) is the cross-sectional area, \( P = L = \) length and width thus obtained the following results [23]:

\[
A = P \times L = 40 \times 10 = 400 \text{ so } xcm^2 \sigma = \frac{F}{A} = \frac{6000}{400} = 15 \text{ kg/cm}^2
\]

Next calculate the strength of the framework design tool to perform tensile tests on iron U. Maximum load that is given (Fmaks) of 17200 N to the specimen width (b) of 12.5 mm. The test results before and after the drop can be seen in table 2 below:

Table 2. Results of testing pull frame bending test equipment.

| Before Testing | After Testing |
|----------------|--------------|
| Initial length (Lo) = 60 mm | Long after the test (Li) = 63 mm |
| Specimen Thickness (t) = 3mm | Thick specimen after testing (t1) = 2.8 mm |

From the results of this test it can be seen that the tensile stress is generated by calculating using the formula \( \sigma = \frac{F}{A} \) where to get the value of \( A = BXT \) thus obtained tensile stress is:

\[
\sigma = \frac{17200}{37.5} = 458.666 \text{ kg/mm}^2, \sigma = \frac{458.666}{9.81} = 45,8 \text{ kg/mm}^2
\]

Furthermore, the strain obtained after in drag [24,25]:

\[
\varepsilon = \frac{X}{L} = 100\% = 100\% = \frac{L_l - L_o}{L_o} \times 63 - 60 \times 60
\]

3.3. Low-cost testing laboratory test equipment bending kit

Specimens tested were strips of steel plate ST-37 as much as 6 pieces with a size of 20×3 cm with two dimensions of different thickness is 6 mm 3 pieces and 10 mm 3 pieces. The test results with small scale bending test apparatus is then compared with the results of the test strip steel plate ST-37 with the same dimensions of the test materials on the ASTM standard machine. Figure 4 and 5 the following is the result of tests performed on a simple bending test equipment modification results.
The technique used to obtain data on test results modification tools bending test is to see and count the maximum compressive force, moment of inertia cross-section, the bending strength and deflection of the material. The initial step after the testing is to calculate the compressive force is given to the specimen with a thickness of 6 mm and 10 mm by first calculating Apiston = πr², Asaluran = πr² subsequently resolved by counting F = \( \frac{A_{\text{piston}}}{A_{\text{saluran}}} \) \( P_1 \) [26]. The entire test results obtained vary according to the amount of pressure that is obtained for each specimen during the test. The overall results of the test can be seen in Table 3 and 4 below:

**Table 3. Calculation results at the maximum compressive force with a thickness of 6 mm specimen.**

| Long specimen (l) | The width of the specimen (b) | Thick specimen (h) | Distance pedestal | Diameter leverage | The maximum load (P) |
|------------------|-----------------------------|-------------------|------------------|------------------|---------------------|
| 200 mm           | 45 mm                       | 6 mm              | 110 mm           | 24 mm            | 6349 N              |
| 200 mm           | 45 mm                       | 6 mm              | 110 mm           | 24 mm            | 4530 N              |
| 200 mm           | 45 mm                       | 6 mm              | 110 mm           | 24 mm            | 3628 N              |

**Table 4. Maximum press force calculation results in specimens with a thickness of 10 mm.**

| Long specimen (l) | The width of the specimen (b) | Thick specimen (h) | Distance pedestal | Diameter leverage | The maximum load (P) |
|------------------|-----------------------------|-------------------|------------------|------------------|---------------------|
| 200 mm           | 45 mm                       | 10 mm             | 110 mm           | 24 mm            | 10884 N             |
| 200 mm           | 45 mm                       | 10 mm             | 110 mm           | 24 mm            | 9977 N              |
| 200 mm           | 45 mm                       | 10 mm             | 110 mm           | 24 mm            | 9070 N              |

The test results are then processed to obtain cross-sectional moment of inertia, the bending strength and deflection of steel plate strip material ST 37. The moment of inertia (1), flexural strength (2) and the deflection of the material (3) is calculated using the following formula [27-29]:

\[ I = \frac{1}{12}bh^3 \]  

(1)
\[
\sigma = \frac{M_c}{I} = \frac{PLh}{b h^3} \frac{4}{T^2} \\
\delta = \frac{PL^3}{4EI}
\]

(2)

(3)

Results obtained by using a differential equation modulus of elasticity is 210 GPa literature. Because the testing lists different types of 3-point bending test, which tested deflection point is not necessarily the point where the maximum moment. The calculation result of testing specimens can be seen in Table 5 below:

**Table 5.** Results of testing specimens with a thickness dimension of 6 mm and 10 mm.

| h (mm) | Load (N) | \(\sigma\) (N/mm²) | \(\delta\) (mm) | I (MM4) |
|--------|----------|--------------------|----------------|---------|
| 6      | 6349     | 646.65             | 1.3049         | 810     |
|        | 4530     | 461.38             | 0.73847        | 3628    |
|        | 3628     | 369.51             | 0.59143        | 10884   |
|        | 10884    | 399.08             | 0.09323        | 399.08  |
| 10     | 9977     | 365.82             | 0.35131        | 3340    |
|        | 9070     | 332.56             | 0.31937        | 3340    |

**Figure 6.** Final results of bending test equipment design.

Figure 6 is a bending test tool has been created. After the test, the specimen bent (plastically deformed) without any cracks and fractures. Thick after the bend experiencing differences, where thick in bending (pressure area) to be more obese than thick outside seam. The phenomenon is caused by the centroid of specimens down to the point of loading. Thus, it can be concluded that the test specimens are resilient. The results are consistent with the results of research conducted using standard bending test machine in Lab Department of Civil Engineering and Designing for comparison. For the bending strength, moment of inertia and the differential is obtained using the same formula in its calculations with the data and the results of the calculation as follows:

**Table 6.** Results of bending test machines using ASTM standards.

| h (mm) | Load (N) | \(\sigma\) (N/mm²) | \(\delta\) (mm) | I (MM4) |
|--------|----------|--------------------|----------------|---------|
| 6      | 6349     | 646.65             | 1.3049         | 810     |
|        | 6900     | 776.25             | 1.87132        | 900     |
| 10     | 10884    | 399.08             | 0.09323        | 3750    |
|        | 3340     | 811.62             | 1.95659        | 4166.66 |
4. Conclusion
The main advantage of the 3-point bending is the ease of specimen preparation and testing. These methods also have adequate shortfall where the principle of three-point bending test point deflection is not necessarily the point where the maximum moment. This study shows a method for developing a bending test tools that are simple, inexpensive and easy to use as the basis of learning media for testing materials. The analysis showed that this bending test machine can be categorized as a low-cost laboratory kit. To demonstrate the efficiency of the tools, testing the use of the tool has done and compare the test results with the standards of ASTM bending test machine and does not show a significant difference.

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