DESIGN OF BUCKLING AND BENDING TESTING MACHINE USING SYSTEMATIC METHOD

Pham Hoang Nam[1], Hendri Syamsudin[1],
Tatacipta Dirgantara[1], IchsanSetya Putra[*],Le Xuan Truong[2]

[1]Faculty of Mechanical &Aerospace Engineering, InstitutTeknologi Bandung
JL.Ganesha 10, Bandung 40132, Indonesia
[2]School of Transportation Engineering, Hanoi University of Science and Technology
No. 1 Dai Co Viet str., Hanoi 10000, Vietnam
[*]Corresponding author: isp@aero.pauir.itb.ac.id

Abstract

In this work, a new testing machine is designed with two main functions, i.e., buckling experiment and bending experiment. This machine is designed for classroom demonstrations, or students working in pairs or small groups. The buckling experiment is used to show the buckling phenomenon and to determine critical buckling load for struts with pinned and clamped ends for various strut lengths. The bending experiment can carry out testing to find the flexural rigidity of struts. The supports of strut in bending test can be changed to fixed, pinned, and rolled supports. The struts for buckling test are made from aluminum alloys with section 2 mm × 20 mm and lengths 300 mm, 350mm, 400mm, 450mm, 500mm. Maximum buckling load is 500 N. The struts of bending test are made from aluminum alloys and common steel with section 3 mm × 20 mm and length 600 mm. Maximum bending load is 20 N. Using a systematic method, the development of the machine is developed in 3 stages. The first step of the systematic process is to define the specification based on requirements and objectives. Secondly, the conceptual design stage. The evaluationof the function to find advantages and disadvantages of the components based on the design requirements setup earlier. The comparison of the design concepts against several existing machines was made. Based on this evaluation, the final design is selected for the detail design stage. Thirdly, is the detail design process. In this stage, each component is designed and analysed in detail. The result shows a new design that meets the requirements.

Keywords: Buckling experiment, bending experiment, design of machine

1. INTRODUCTION

The buckling and bending machine was designed for classroom demonstration. Since the cost of the buckling and bending test machine in the market is very expensive, so this work was developed the new machine with lower cost. This design was developed through a systematic method.This method has a wide application in industry, research and education. The systematic method concentrates does the concept selection process [1] [2] [3].The conceptual phase concerns the problem of coming up with new ideas or new solutions to older problems [4]. Pahl and Beitz, the authors of “A Systematic Approach to Engineering Design” (1988), have divided the design process into the following four distinct phases: clarification of the task and development of the design specifications, conceptual design, embodiment design, and detail design. The concept variants of Pahl and Beitz corresponds to the functional variants presented by Hundal [5]. Hundal advocates the use of a functional description and functional decomposition for the conceptual design phase. Finger and Rinderle have developed systematic method for transforming a "specification graph" into components and possible configurations [6].

Buckling is primarily a stability problem. Buckling plays an important role in almost every field of technology. The shape of the rod is the factor determines which of the two cases of failure will occur. A slender, thin rod is more likely to buckle than a thick, stout rod.

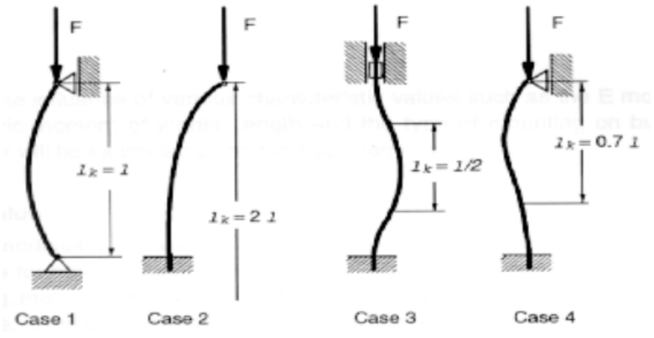


Figure 1: Euler cases of buckling

The objectives of the buckling experiment are to determine critical buckling loads for struts and to examination the Euler theory of buckling as can be seen in Figure 1.

The objectives of the bending experiment (as can be seen in Figure 2) are to examination general bending formula and to determine Young's modulus for material.

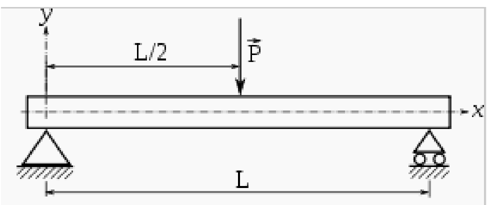


Figure 2: Simply supported beam with central point load

2. SYSTEMATIC METHOD

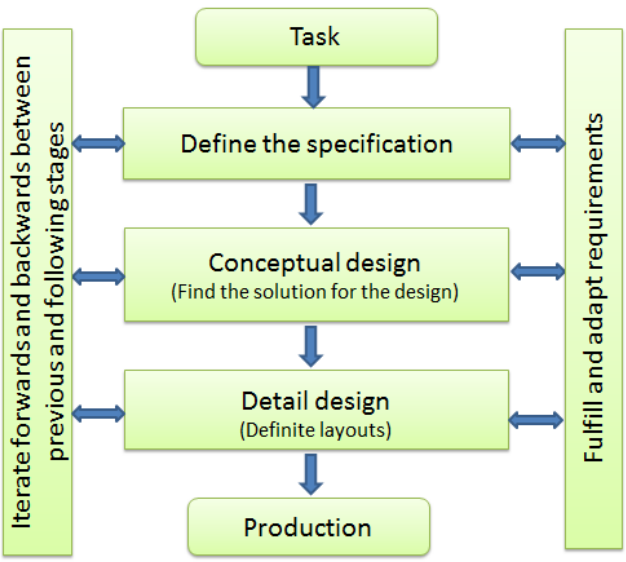


Figure 3. Systematic design method.

Systematic method contains three stages i.e. specification definition stage, conceptual design stage and detail design stage as can be seen in Figure 3.

2.1 Determine requirements and specification of the machine

The main requirement of the design is possible to do bending test and buckling test on one machine. Another important requirement is to make the machine has the good viewing for demonstration. Besides that, the machine must be easy to set up, operate and ease to change between two testing type. In addition, the support of buckling experiment can be interchangable between fixed, pinned support. While for the bending experiment the same support will be used with an additional possibility of using roller support. The next requirement of the design is ease for production and maintenance, so the cost of machine will be low. The last one is to make the machine with minimum size.

Specimens of buckling test are made from steel and aluminum with dimension 2×20×300, 350, 400, 450, 500 mm. Specimens of bending test are made from steel and aluminum with dimension 3×20×600 mm.Hand operated loading mechanism by using power screw system, digital load cell with capacity 1000 N.

2.2 Conceptual design stage

The first step of this stage is to find design concept for important components of the machine to satisfy the requirement. There are two design options considered for the frame i.e. vertical frame and table. The most important consideration for the selection of the frame design is good view of a group of students performing the experiment. For the support of the specimen some design alternatives are considered. An important consideration to be considered is the flexibility in changing between the two test set-up. For loading system of the machine, the consideration of the simplicity leads to power screw system. To measure the load in buckling experiment a digital load cell will be used, while for the bending experiment dead weight will be used for simplicity.

Some conceptual design solutions, the results of this stage, can be found based on combination of solutions of all components. After that, the evaluation of the function to find advantages and disadvantages of the components based on the design requirements setup earlier. The last step of this stage is to find the best conceptual design, the final result of conceptual design step, based on above evaluation of components .These results and evaluation of components will be shown in section 3 of this paper.

2.3 Detail design stage

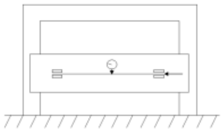
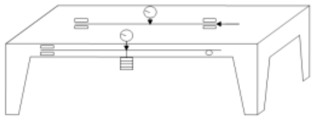
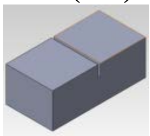
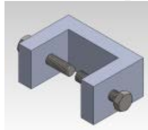
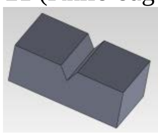
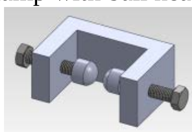
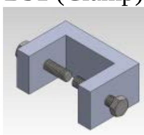
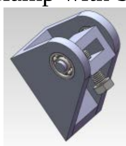
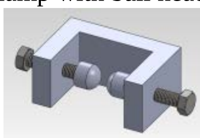
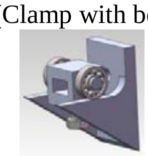
After the best conceptual design is found, the next stage is to design the detail layouts of the machine. The first step of this stage is dividing the machine in to realisable modules. After that, module structures are designed. The next step is to develop layout of key modules. After this step, preliminary layouts are constructed. The final step is to complete overall layout. The result of detail design stage is definite layouts of the machine. This result will be shown in section 3.

3. RESULTS AND DISCUSSION

There are two results in this present work, the first result is conceptual design solution and the second result is the detail design.

3.1 The result of the conceptual design stage

Table 1. Solutions of components.

Component	Solution	
A (Frame)	A1 (Vertical frame) 	A2 (Table) 
B1(Fixed support of buckling test)	B11 (Slot) 	B12 (Clamp) 
B2 (Pined support of buckling test)	B21 (Knife-edge) 	B22 (Clamp with ball head screw) 
B3(Fixed support of bending test)	B31 (Clamp) 	
B4(Pined support of bending test)	B41 (Clamp with bearing) 	B42 (Clamp with ball head screw) 
B5(Roller support of bending test)	B51 (Clamp with bearing) 	

Conceptual design solutions can be found based on combination of various solutions of all components as shown in Table 1. There are four results of this step.

Conceptual design 1, the vertical frame type machine as can be seen in Figure 4, is based on solutions A1 – B12 - B21 - B31 - B41 - B51 - C1 - D1 - E1 - F1 - G1. In this type, buckling test and bending test can operate on one plate, this plate fixed on one rigid frame. The fixed and pinned supports of buckling test are provided by clamp type and knife edge type. The pinned support of bending test is clamp with a bearing mechanism attached to the frame.

Conceptual design 2 has the same vertical frame type with conceptual design 1 as can be seen in Figure 4. The difference is on the support types. This design is based on solutions A1 – B11 - B22 - B31 - B42 - B51 - C1 - D1 - E1 - F1 - G1. The fixed and pinned supports of buckling test are provided by the slot type and clamp type with ball head screw. The pinned support of bending test is a clamp type with ball head screw.

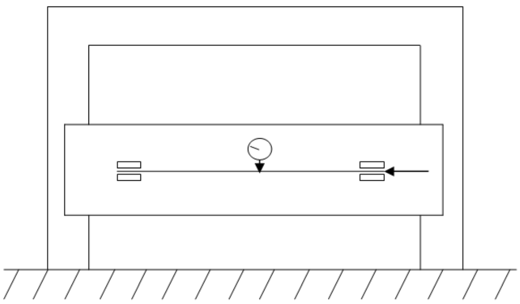


Figure 4. Conceptual design of vertical frame type machine.

Conceptual design 3, the table type machine as can be seen in Figure 5, is based on solutions A2 – B12 - B22 - B31 - B41 - B51 - C1- D1 - E1 - F1 - G1. The buckling test can be performed on the surface of table, whilst the bending test is on the side of table. The fixed and pinned supports of buckling test are provided by clamp type and clamp type with ball head screw. The pinned support of bending test is a clamp with bearing.

Conceptual design 4 has same table type with conceptual design 3 as can be seen in Figure 5, but the supports are different. This design is based on solutions A2 – B12 - B22 - B31 - B42 - B51 - C1- D1 - E1 - F1 - G1. The fixed and pinned supports of buckling test are provided by slot type and clamp with ball head screw. The pinned support of bending test is clamp with ball head screw.

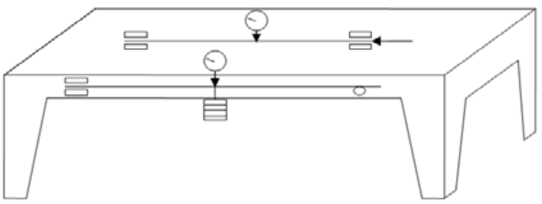


Figure 5. Conceptual design of table type machine.

Having designed few combinations to find some conceptual designs, the next step is the evaluation of the function to find advantages and disadvantages of the components based on the design requirements.

The first step is the evaluation between two types of frame, vertical frame and table. The advantage of vertical frame type is the good viewing because of students can see from side of machine. The good viewing is very important requirement, so vertical frame type has a big advantage. Another advantage of vertical frame type is easy to manufacture because of it can be made from some steel column with rectangular cross section which is widely available in the market. Besides that, this vertical frame type is using less material than table type, so the cost to buy material will be lower. However, with vertical frame, two experiments are done on the same mid-plate, so it requires some changing between two experiment to replace components such as power screw, load cell and the supports. With the table type, the advantage is possible to do two experiments on two different position, buckling experiment on the surface of table and bending test on the side of table as can be seen in Figure 5. But a big disadvantage is on bad viewing of buckling experiment. The student must see from the top of machine. In addition, this table type using more material than the vertical frame type and some profile of the table need some machining process during manufacturing.

The second evaluation is about the supports. There are two fixed support types for buckling test i.e. the slot type and the clamp with a screw. With the slot type, dimension of slot is same with thickness of specimen (2 mm), one end of the specimen will be put in the slot. This support type cannot be used for the table type because of the specimen will drop. So it is impossible to make a feasible design from this combination. The slot type is simple to set up and to manufacture, but it will be less flexible various thickness of specimen. With clamp type, it can be used for different thickness of specimens.

The next is the evaluation of pinned supports for buckling test. The knife-edge is simple solution for manufacturing and setting up but it cannot be use for the table type machine because the specimen will fall. The clamp with ball head screw is used to constrain horizontal movement of specimen, while the specimen can still rotate. This support will become a fixed support when replacing the ball head screw with the normal screw, so the experiment is very easy to change between fixed and pinned support. But this type has big disadvantage, it is only pinned support when the contact point between ball head and specimen is very small, so the accuracy of experiment will be lower when using this support type.

Clamp with bearing is one type of pinned support for bending test. It consist of one clamp that can rotate using one bearing on the side. This type has better accuracy than clamp with ball head but it is more difficult to manufacture.

Based on above evaluations, weighting factor based evaluation for the various conceptual designs was performed as shown in table 2.

Table 2. Weighting-factor based evaluation table of conceptual designs against the set of requirements.

Weight factor	Requirements List	Design 1	Design 2	Design 3	Design 4	Explain
20 %	View of buckling experiment	5	5	3	3	Table type: see from top Vertical frame type: see from side
20 %	View of bending experiment	5	5	5	5	Same (see from side)
10%	Change between two experiments	4	4	5	5	Table type: don't need change Vertical frame type: changed supports
10%	Easy to set up	4	5	5	5	Clamp with ball head is easy to set up
10%	Accuracy	5	3	3	3	Accuracy of ball head screw support is lower than other types
10%	Manufacture ability	4	4	3	3	Difficult to make some profile of table type Slot type and knife-edge are easier Clamp with bearing is more difficult
10%	Price of material	5	5	4	4	Table type need more material
10%	Size of machine	4	4	5	5	Vertical frame is higher
Total		**4,6**	**4,5**	**4,1**	**4,1**	

The scrore for each design features is using the scale 5, 4, 3, 2, 1 with respect to very good, good, barely acceptable, poor, very poor, subsequently.

The total value of each conceptual design is obtained by taking the total of score point multiplied with weighting factor.

As can be seen, the conceptual design 1 is chosen for the design as it has the highest score. This is the final result of conceptual design stage.

3.2 The result of the detail design stage

Buckling testing machine

Figure 6 shows the CAD drawing of designed frame type machine.

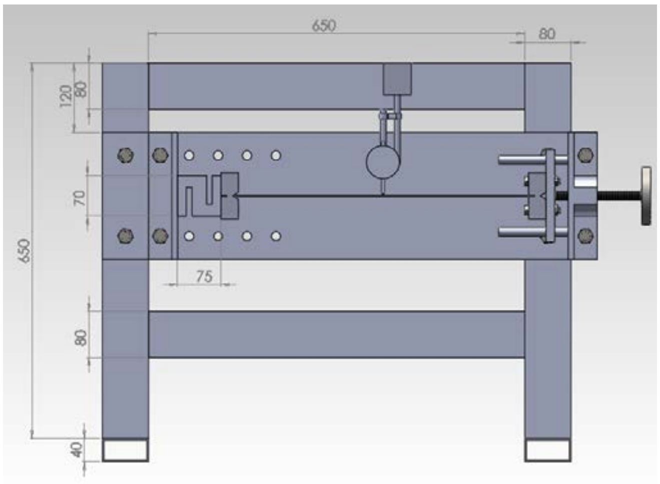


Figure 6: Design of buckling test machine

The main part of the machine is a precision rigid At one end is the loading device which uses a screw to apply loads to the struts. The power screw is in fixing blocks to give precise and easy load application. At the opposite end is the load measuring device. This is a precision mechanism that resists the bending moments produced by the struts as they deflect, and transmits thepure axial force to an electronic load cell (capacity of the load cell is 1 kN). This gives an accurate measurement of buckling load. An indicator fixed to the upper frame by using a magnetic base (the capacity of the indicator is 10 mm). This gives an accurate measurement of deflection.

Students may move the load-measuring device along the base to work with struts of different lengths and fixing conditions.

Bending machine

The arrangement of bending testing machine is shown in the Figure 7. There are three available types of support in bending machine i.e. fixed, pinned and roller. The weight is hanging on the struts which gives load application. An indicator is fixed to the upper frame to measure the lateral deflection of strut.

To change the setup of testing machine from buckling test to bending test and vice versa is simply by removing the power screw and the digital load cell and replacing them with the supporting components of bending test.

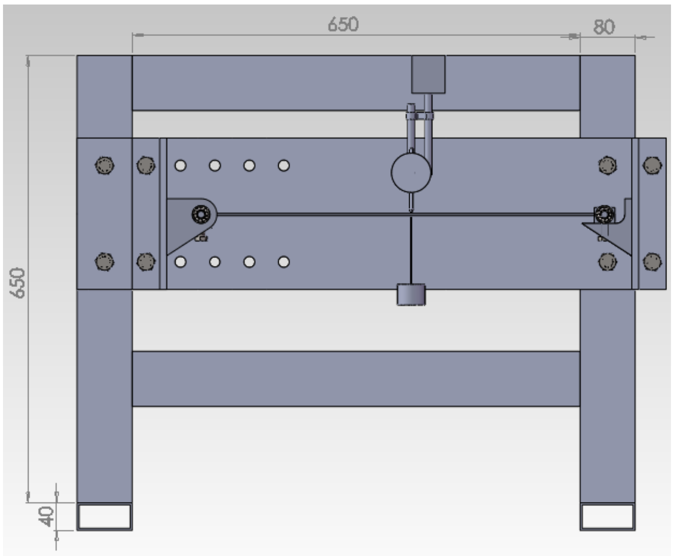


Figure 7: Design of bending test

4. CONCLUSION

The proposed design has been shown to fulfill the given set of requirements. The machine can carry out two testing functions, interchangeable between all support type, easy to set up and shows ease for production.

ACKNOWLEDGMENT

This research was supported by Light Weight Structure Research Group and the KNB Scholarship (Developing Countries Partnership program on Scholarship) of the Indonesian Government.

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