Calculation and Design of a Combined Buckling and Bending Testing Equipment

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Abstract

In this study, a new combined buckling and bending testing equipment is calclated and designed to perform both tests in a single apparatus. Buckling testing is carried out on various length struts which are pinned and clamped ends. Buckling loading is determined by the test with the maximum range of 500 N. Struts using for buckling test are aluminum alloy with 2 mm x 20 mm cross section in various lengths of 300 mm, 350 mm, 400 mm, 450 mm and 500 mm. Bending testing is carried out to examine the flexural rigidity of the struts. In bending test, the changeable supports are designed which can be fixed, pinned and rolled. Struts using for bending test are aluminum and steel alloys with 3 mm x 20 mm cross section in length of 600 mm. Bending load is in a range of 20 N. The whole equipment was then simulated in commercial software to investigate the designed structure. The obtained results show that the designed structure is met requirements for working load conditions.

Keywords: Bending test, Buckling test, Combined bending & buckling test

1. Introduction

Buckling and bending phenomena are common in mechanical engineering, civil engineering and manufacturing. Understanding on such phenomena can prevent unstability, damage or fatality to structures. Hence, studying and testing these phenomena in universities play an important role in most areas of construction, design as well as manufacturing industries. Currently, there are quite a number of companies and factories have designed and manufactured bending and buckling testing equipments. Figure 1 shows an example of a buckling testing equipment on the market [1]. However, the price of such testing machine is quite expensive especially compared to university budget. Beside of that, testing machine for buckling and bending is normallly separated into two individual equipments. It raises a need to calculate and design a combined equipment to test buckling and bending in a single apparatus with low cost which may orientate to apply to university laboratories.

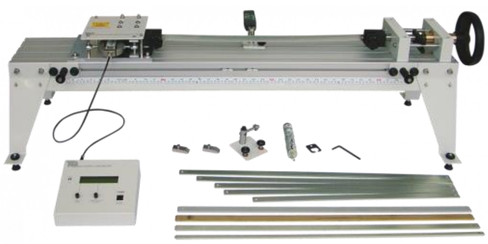

Fig. 1. Euler buckling apparatus of Tecquipment [1]

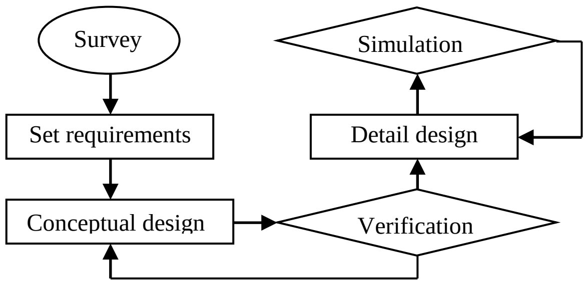

Fig. 2. Design layout

2. Conceptual design

In order to design an equipment for laboratory testing, the equipment must be easy to observe, to operate, and to change the configuration for both tests with reasonable equipment size [2]. Figure 2 shows the design layout.

Table 1. Functions of the combined testing equipment

Functions		
Buckling test	Bending test	Easy to change between 2 tests
Easy to test & observe buckling phenomena	Easy to test & observe bending phenomena	Easy to set up and operate
Compact size	Low material cost	Low manufacture cost
Low maintenance cost		

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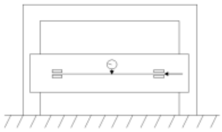
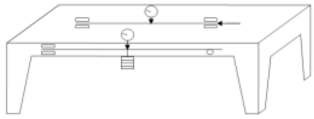
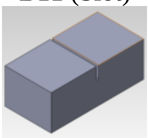
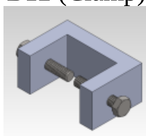
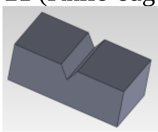
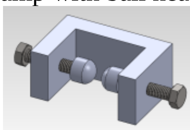
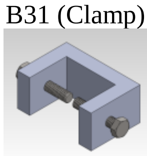
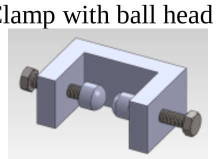
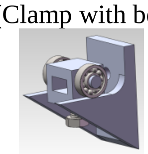
Table 2. Component options

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) 	

With the need of test in laboratory, struts using for buckling testing suggested with size: 2 mm x 20 mm in cross section and with various lengths of 300, 350, 400, 450, 500 mm. And the struts using for bending with 3 mm x 20 mm of cross section and 600 mm long. Applied load is adjusted by screw and using loadcell to measure testing load with maximum scale of 1000 N. Table 1 shows the expected testing equipment with all characteristics [2,3].

3. Component seclection

Based on the survey of available products on market, some main components of the equipment is summed up in Table 2 [4-6].

From the combination of the whole component options, the first proposed design selection, called D1 bases on the frame type is vertical as shown in Fig. 3.

In this selection, the testing equipment is the solution of A1 - B12 - B21 - B31 - B41 - B51 in Table 2 in which buckling and bending tests can carry out one plate. The plate is fixed on a rigid frame. In buckling test, the fixed and pinned supports are provided by clamp and knife edge types. In bending test, the pinned support is clamped with a bearing mechanism attached to the frame.

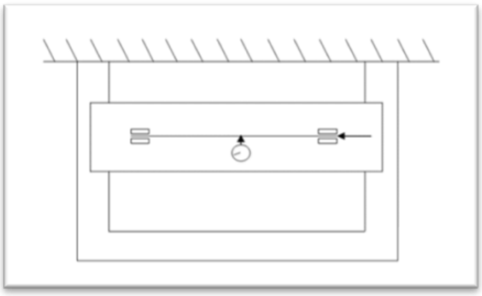


Fig. 3. Selected design D1

The second proposed design selection, called D2, is a combination of A1 - B11 - B22 - B31 - B42 - B51 with similar vertical frame type as in D1. It is shown in Fig. 4.

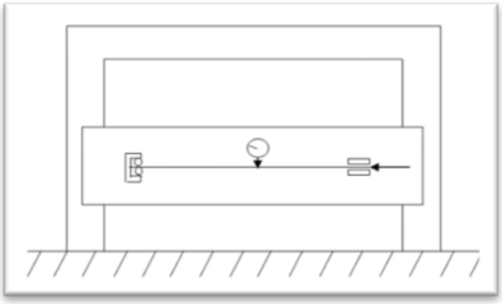


Fig. 4. Selected design D2

For buckling test, the fixed and pinned supports are provided by the slot and clamp types with ball head screw. For bending test, the pinned support is a clamp type with ball head screw.

The third proposed design selection, called D3 as in Fig. 5, is a combination of A2 - B12 - B22 - B31 - B41 - B51 in a table platform. In this arrangement, the buckling test can be performed on the surface of table, whilst the bending test is on the side of table. For buckling test, the fixed and pinned supports are provided by both clamp types with ball head screw. For bending test, the pinned support of is a clamp with bearing.

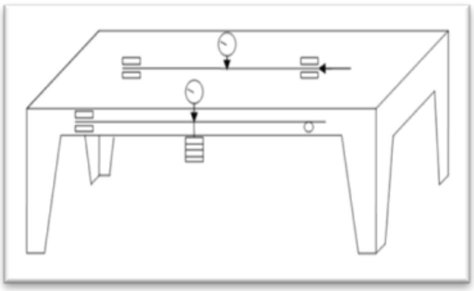


Fig. 5. Selected design D3

The fourth proposed design selection, called D4 as in Fig. 6, is also in a table platform but in different supports by a combination of A2 - B12 - B22 - B31 - B42 - B51.

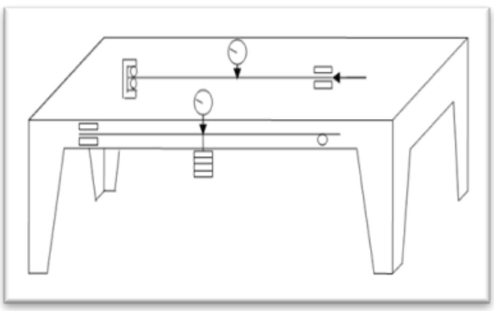


Fig. 6. Selected design D4

For buckling test, the fixed and pinned supports are provided by slot type and clamp with ball head screw. For bending test, the pinned support is clamp with ball head screw.

From the above selections, the next step is to evaluate advantages and disadvantages of the components following the design requirements. Firstly, evaluation for the frame between two types: vertical frame and table. The vertical frame type shows its advantage of good viewing because of students can see from side of machine, easy to observe buckling phenomena. This point is a very important requirement, so vertical frame type has a big advantage. Vertical frame type also has another advantage of easy to manufacture because 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, it means that 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 tests at two different positions, buckling experiment on the surface of table and bending test on the side of table, as shown in Fig. 5 or Fig. 6. But a big disadvantage is on bad viewing of buckling experiment. When observing, student must see from the top of machine.

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 into the slot. This support type cannot be used for the table type because 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 for various thickness of specimens. With clamp type, it can be used for different thickness of specimens.

The third is the evaluation of pinned supports for buckling test. The knife-edge is simple solution for manufacturing and setting up but it cannot be used for the table type 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 supports. 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 consists 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 for the various conceptual designs was performed as shown in Table 3.The scrore for each design features is using the scale 5, 4, 3, 2 and 1 with respect to very good, good, barely acceptable, poor, very poor. 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 D1 is chosen for the design as it has the highest score. This is the final result of conceptual design stage.

4. Detailed design

4.1 Material selection

There are two common materials on the market can be selected for the frame, those are aluminum alloy and steel. The price of both material is almost similar however the strength of steel is higher than aluminum alloy. Beside of that, steel is heavier so that the structure will be more stable and steel is easier for welding. For all of those reasons, steel is selected for the frame structure in this work. The material properties of steel are: specific density: 7870 kg/m^3, and ultimate strength: 420 N/mm^2.

4.2 Structure for buckling test

Main part of testing equipment is the frame. The buckling load is given by screw on the right. The buckling load will act indirectl to attached loadcell. By setting up for calibration, the display will show the loading value. By using dial gauge, the displacemnt will be measured on each testing models.

Figure 7 shows the technical drawing of the apparatus in the mode of buckling test.

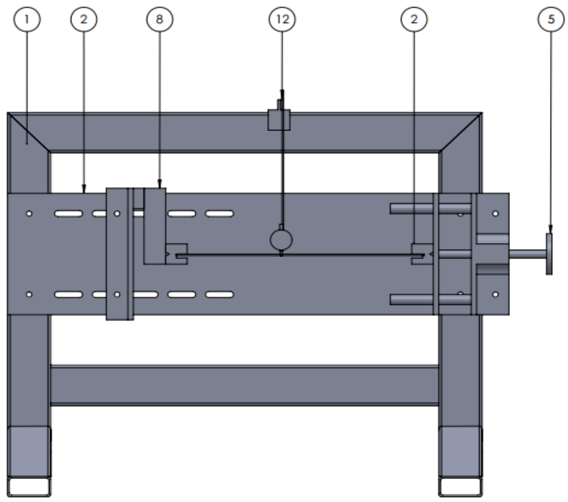


Fig. 7. Technical drawing of the buckling test mode

Table 3. Weight factor

Weight factor	Requirements	D1	D2	D3	D4	Descriptions
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	Similar (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**	

4.3 Structure for bending test

By the changing configuration, the bending test mode can be set-up as shown in Fig. 8. The load is hang up at the middle point of the specimen and the dial gauge is fixed on the upper of the frame. The change between two test configurations is quite simple by changing the screw pack and loadcell

5. Structural Simulation

The whole structure is modeled and simulated in Static structure module of ANSYS, a commercial software to investigate mechanical behaviour.

Based on the set-up input, the maximum buckling loading is 500 N and bending load is 13 N. The safety factor is taken as 1.5 to ensure the safety work for any test conditions. Figure 9 shows the input load applied in the equipment.

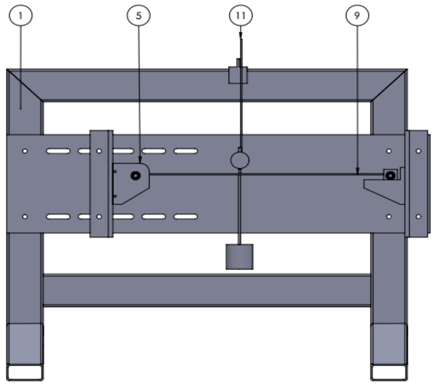


Fig. 8. Technical drawing of the bending test mode

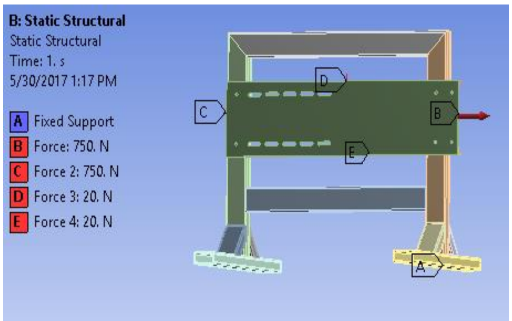


Fig. 9. Boundary condition applied in ANSYS

The simulation results are shown in Fig. 10 for total deformation.

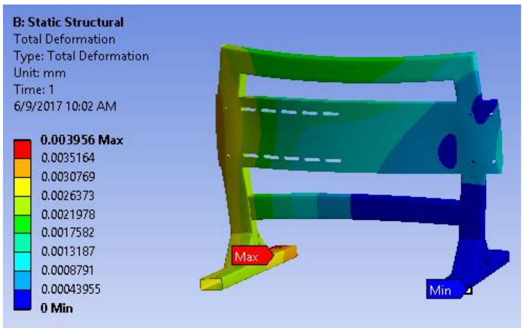


Fig. 10. Total deformation of structure

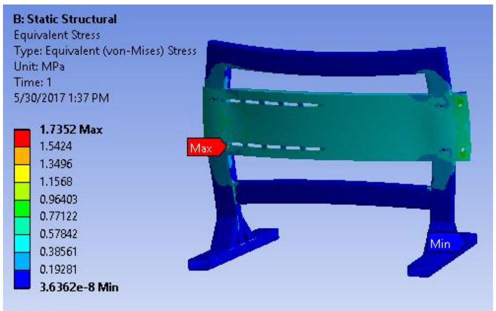


Fig. 11. Equivalent Stress of structure

The results show that, the maximum total deformation is approximate 0.003956 mm. This deformation is much smaller than the length 930 mm of the equipment and equal to 0.7 % of its length at the thinnest of the plate with 5 mm.

The investigation on stress is shown in Fig. 11, in which the maximum stress is 1.74 MPa. That stress is equal to approximate 0.413 % of maximum strength of the material of 420 MPa.

6. Conclusions

The research was carried out fully from conceptual design to the investigation of structure under simulation software for the combined buckling and bending test equipment. By the investigation of the need and availability of components, a combination for the equipment is created to satisfy most of requirements as it can be suitable for both tests with easy to change configurations, low price, easy to observe for people to carry out the test. Simulation results also show that the structure is strong enough to carry out all the tests with a safety factor.

Acknowledgments

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