

# Experimental Teaching Reform of the Measurement of Normal Stress in Pure Bending within Mechanics of Materials

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## Abstract

The material mechanics experiment is an indispensable part of the material mechanics course, and the normal stress measurement experiment of the pure curved beam constitutes the highlight of the material mechanics experiment. Aiming at the problems such as large differences in students' learning basis, single experimental teaching method, incomplete assessment and evaluation model, and imperfect construction of teachers, this paper carries on the teaching reform of the pure bending beam normal stress measurement experiment. Effective measures such as enriching experimental teaching methods, introducing virtual simulation technology, establishing practical operation skill evaluation scale and updating experimental equipment are adopted. Our students' experimental participation, practical ability and innovative thinking have been improved, and their ability to solve practical engineering problems has been improved.

## Keywords

Pure Bending Normal Stress Measurement, Experimental Teaching Reform, Virtual Simulation, Evaluation Scale

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## 1. Introduction

Colleges and universities play an extremely important role in the training of high-level applied talents and are an important force for the realization of Chinese-style modernization (Li & Ma, 2023: pp. 81-84). The material mechanics experiment course is an important part of the material mechanics course and plays a vital role in the cultivation of students' comprehensive quality (Zhou et al., 2023: pp. 186-188). The predecessors have carried out a series of teaching reforms on the main

experimental content of material mechanics and achieved some results. Li Wen integrated and optimized different experimental items in material mechanics experiments, and designed comprehensive experimental items that met the development requirements of students (Li, 2020: pp. 195-196). Wang Yunyang reformed the experimental teaching of mechanical properties of mild steel tensile, integrating ideological and political elements into the course during the experiment to cultivate students' comprehensive literacy (Wang et al., 2020: pp: 111-114). Lin Peng et al. reformed the experiment of mechanics of materials and achieved expected results by studying the mixed experimental teaching mode of online and offline (Lin et al., 2023: pp. 141-145). In this paper, the teaching reform of the normal stress measurement experiment of pure curved beam is carried out in the aspects of learning method and assessment model, which is of great significance for students to understand the bending theory of beam and master the stress analysis method.

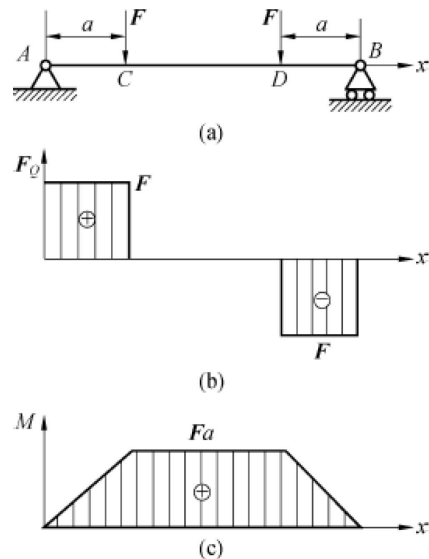
## **2. Traditional Normal Stress Measurement Experiment Teaching Problems**

### **2.1. Students Have Great Differences in Learning Basis**

Taking Xinjiang Institute of Technology as an example, the student groups of material mechanics experiment include the Chinese class, the civilian class, the bilingual class, the helicopter class and the 3 + 2 class. The pure bending beam normal stress measurement experiment is started on the basis of the completion of the theoretical knowledge of material mechanics. However, through the way of asking questions before class, to understand the students in different classes to grasp the theoretical knowledge of bending strength, it was found that some students could answer the questions raised by the teacher, but most of the students could not tell the basic knowledge of the calculation of bending internal force, the basic concept of pure curved beam and how to calculate the normal stress size formula of any point on the cross-section of pure curved beam. As shown in **Figure 1**, the CD segment is a pure bending segment. Compared with other classes, Chinese students have a better grasp of theoretical knowledge. Students are not proficient in theoretical knowledge, which will have a great impact on the smooth development of pure bending normal stress measurement experiment, resulting in theoretical knowledge can not solve practical problems.

### **2.2. Imperfect Experimental Teaching Equipment**

There are 15 equipments in the mechanical engineering Laboratory of Xinjiang Institute of Technology, which cannot meet the requirement of one person using one equipment. Experimental projects are carried out according to the class, with about 45 people in each experiment, and students usually need to be divided into groups of 3 - 4 people to carry out experiments. During the experimental operation, students watch beside the instrument, but do not operate by themselves. At the same time, the aging and damage of some experimental equipment, including



**Figure 1.** Stress and internal force diagram of simply supported beam.

the sensors and display screens for measuring force, will also affect the normal conduct of experimental teaching. Since there is no multimedia equipment such as nano blackboard or projector in the laboratory, the explanation of the normal stress measurement experiment content of pure curved beam is still based on blackboard writing. It is necessary to write the main content of the experiment topic, experiment purpose, experiment equipment, experiment principle, measurement data and result processing on the blackboard in advance, so that students can learn in the class. Since the material mechanics combination test bench is placed on the experimental table, it will affect the students behind the test bench to watch the blackboard.

### 2.3. The Experimental Teaching Method is Relatively Simple

The teaching method of normal stress measurement of pure bending beam is mainly explained and demonstrated by teachers. Firstly, the purpose of normal stress measurement experiment is introduced. The content includes measuring strain with electric strain measurement method, obtaining normal stress and verifying the calculation formula of pure bending normal stress according to the relationship between stress and normal stress. Secondly, the experimental equipment, including resistance strain gauge and material mechanics test bench, is introduced. Then, the experimental principle is introduced, how to design the pure bending section, select five measuring points in the pure bending section, stick strain gauge on the surface of the measuring point, and measure the strain of the measured point with resistance strain gauge. According to the relationship between stress and strain, the normal stress corresponding to the five measuring points is calculated. Before the students operate the experiment, the teacher first demonstrates how to patch, the size of the loading force, and how to use the resistance strain gauge correctly. In the whole teaching process, teachers mainly

explain and demonstrate. After the content is explained, students are asked questions, such as calculating the normal stress of the measured point according to the experiment of electrical measurement method. It is found that only some students can answer it, and this teaching method lacks the interaction between experimental teachers and students.

#### 2.4. Unreasonable Assessment Methods

The test result of normal stress measurement of pure bending beam is composed of two parts, including the usual attendance and the experiment report, the experiment report accounts for 70%, and the attendance accounts for 30%. Before the start of each experiment, a roll call is required, and if there are students who are late or absent, the attendance section will deduct the corresponding points. The experimental report gives students' scores according to certain scoring standards. As shown in **Table 1**, the results of the report are divided into 5 grades and specific scores are given according to completeness. At present, the experimental assessment is mainly based on the experimental report. As long as the content of the report is complete and standardized, and the experimental results and analysis process are accurate, a high score can be obtained. The whole evaluation of experimental results does not pay attention to the procedural evaluation, and the normative assessment of students' theoretical knowledge learning and experimental operation process is not comprehensive enough. This kind of assessment method that only focuses on the results of the experiment report is easy to cause students to pay more attention to the results than the process, and it is easy to ignore the standardization and accuracy of the experiment operation, which is unfavorable for students to learn the experimental course of material mechanics.

**Table 1.** Evaluation criteria for mechanical experiment reports.

Serial number	Comprehensive evaluation content	Score
1	The content of the experimental report is complete and substantial, complete specifications are written, experimental results, analysis and conclusions are accurate, and formulae are accurate	90 - 100
2	The content of the experimental report is complete, the writing is standardized, and the experimental results, analysis and conclusions are correct	80 - 89
3	The content of the experimental report is basically complete, the writing is relatively standardized, and the experimental results, analysis and conclusions are basically correct	70 - 79
4	The content of the experimental report is basically complete, and there are obvious problems in the experimental results, analysis and conclusions	60 - 69
5	The content of the experimental report is incomplete, there are serious errors in the experimental results, analysis and conclusions, or the full report is plagiarized	<60

## 2.5. The Construction of Experimental Teachers Is Not Perfect

There are 9 teachers in the teaching and research Department of Mechanics of Xinjiang Institute of Technology, including 1 professor, 1 associate professor, 5 lecturers, 1 experimentalist and 1 teaching assistant. There are 2 teachers with working experience in enterprises and 5 teachers with dual teachers. Most of the teachers are basically directly graduated from universities to join the teaching of mechanics courses, and have no relevant experience in enterprise work. And there was only one full-time experimenter. With the expansion of the school scale, the number of experimental teachers can hardly meet the teaching demand of nearly 4000 students doing experiments every year. Moreover, most of the substitute experiment teachers lack systematic training of professional knowledge of mechanics, and have insufficient grasp of advanced instrument using technology and operation methods. The knowledge reserve between different professional disciplines is insufficient, and it is difficult to meet the requirements of comprehensive experimental teaching.

## 3. Reform Measures of Normal Stress Measurement Experiment Teaching

In order to solve the problems of different students' foundation and incomplete assessment model in the current normal stress measurement experiment teaching, the mechanical engineering laboratory has carried out a student-centered teaching reform of normal stress measurement. The use of multimedia and virtual simulation combined with traditional teaching pure bending beam normal stress experiment teaching, as far as possible to achieve the combination of traditional experiment and simulation, so that students are mastering the content.

### 3.1. Enrich Experimental Teaching Methods

Before the normal stress measurement experiment on the pure curved beam, the students were assigned a preview task. It is required to master the bending strength content, including the geometric quantity of the section figure related to stress analysis -- moment of inertia  $I_z$ , the basic knowledge points such as the normal stress analysis on the cross-section of the beam when it is pure bending, the normal stress calculation formula on the cross-section, and the meaning of each parameter in the formula. In addition, the video of normal stress experiment of pure curved beam was released on the learning platform in advance, so that students could understand the experiment content in advance and have a clear idea. Before the experiment began, guided roll call questions were adopted. The questions raised were about the contents that had been previewed by students, and the situation of students' preview was understood by asking questions, and then the experiment contents were explained in a targeted way. After class, the teacher will explain and demonstrate the content of normal stress measurement experiment. During the lecture, the teacher can ask questions to let students think about it. When talking about the key content, the students can discuss with each other.

Students are actively encouraged to express their views, communicate with each other, complement each other, and finally fully grasp the content of the experiment.

For the introduction of the use of resistance strain gauge, the traditional teaching method is to demonstrate step by step to the students, the whole process takes a long time, and the teaching effect is not ideal. In order to solve the existing problems, the operation procedure of the strain gauge has been printed on A4 paper. Electrical test method TZT3822EN test analyzer operation process is as follows: The first step: open the “ON” key, touch the screen click - enter the system; Step 2: Touch the screen and click “Channel Settings”; Step 3: Touch the screen to click “Bridge Settings”, then click CH1, select 1/4 bridge, click back. CH2, CH3, CH4, and CH5 select 1/4 bridge and click to return. Step 4: Touch the screen to click “bridge mode”, then click CH1, select mode 2, click back. CH2, CH3, CH4, and CH5 Click Return and then click Return again. Step 5: Touch the screen and click “Channel Balance”, click “OK”, and click “OK” again; Step 6: Touch the screen to click “test point monitoring”, then click “Start”, clockwise load 500 N, 1000 N, 1500 N, 2000 N, 2500 N, 3000 N, and record the test data in the table. Students conducted experiments according to the operation process, as shown in **Figure 2**. Students are using resistance strain gauges, which can improve students’ problem-solving and hands-on skills.



**Figure 2.** Students conduct normal stress measurement experiment.

### 3.2. Introduction of Virtual Experiment Teaching

The traditional pure bending normal stress measurement experiment needs to use the material mechanics combination test bench, resistance strain gauge, resistance strain gauge and other instruments and equipment, the price ranges from several thousand to ten thousand yuan. And the equipment occupies the experimental site, the class number is too large, it is difficult to meet the teaching requirements. Because the instrument needs to be connected to the power supply, there are also certain safety problems during the experimental operation. Virtual simulation is composed of advanced technologies such as computer, simulation, artificial intelligence and human-machine interface, which can simulate the normal stress measurement experiment of pure curved beam (Zhao, 2021: pp. 165-168). Virtual simulation can solve the problems existing in traditional mechanical experiments.

At present, the mechanical engineering laboratory has not developed virtual simulation software, so the virtual experimental software of pure bending beam normal stress measurement simulation software tested by the Mechanical Experiment Center of Tong ji University is used. The virtual simulation interface is simple to operate and has a good agreement with the actual normal stress measurement experiment. Before the start of each experiment, students are allowed to log in to the simulation platform in their spare time and conduct the simulation experiment in advance according to the simulation operation steps, so as to obtain the ideal simulation results, which can lay a good learning foundation for the experimental class.

### 3.3. Adopt Diversified Assessment Methods

It is necessary to establish a diversified examination system for the normal stress test of pure curved beams. The test should not only include attendance and test report, but also include test process and test operation skills. The experimental process assessment mainly examines the students' participation degree, experimental attitude, teamwork and problem-solving ability; The test of experimental operation mainly examines the standardization and accuracy of students' experimental operation. In order to accurately evaluate students' experimental operation skills, it is necessary to carry out quantitative assessment and evaluate them through different standards. Now we have made an evaluation scale of operation skills, as shown in **Table 2**. According to the table, it can be seen that the degree of each student's mastery of experimental operation can be comprehensively and accurately evaluated by quantifying the assessment criteria such as the completion of experimental tasks, the degree of assistance required and the application of safety practices.

**Table 2.** Practical skill evaluation scale.

mark	4	3	2	1	mark
Standard	As good as gold	good	poor	Very bad	
Complete the experiment task	Complete the task according to the standard time and the specified task	The task is complete, but minor modifications are required	The task is complete, but a few minor modifications are required	The job was done, but several major changes were needed	
The ability to follow directions	Follow instructions highly effectively	Follow directions	General instruction	Follow instructions, but with limited success	
Degree of need	Students can complete the task without help	The students complete the task with little help	Students complete the task with moderate help	The students complete the task with more help	
Application of security practices	Students follow all safety rules	Students follow most safety rules	Students obey the most important safety rules	Students need to be reminded to follow safety rules	

### 3.4. Update and Management of Experimental Teaching Equipment

At present, the experimental bench of material mechanics used in the normal stress measurement experiment of pure bending beam is aging and damaged, and the experimental equipment needs to be replaced in time. The Mechanical Engineering Laboratory has purchased 5 new materials mechanics combination test stands and resistance strain gauges respectively, as shown in **Figure 3**. Two different test stands can meet the needs of experimental teaching at this stage. Since there are only two blackboards in the lab and no multimedia equipment, it is planned to install a projector to replace the blackboard, which can better stimulate students' learning interest and class participation.



**Figure 3.** Multi-functional composite test bench of material mechanics.

### 3.5. Improve the Team of Experimental Teachers

In the teaching staff of colleges and universities, experimental technicians are an important part. If colleges and universities want to become high-level application-oriented first-class universities, they should not only have a good teaching environment and experimental conditions, but more importantly, have a first-class teaching team (Ding et al., 2021: pp. 1038-1040). Li et al. (2024: pp. 7-10) The knowledge level of experimental technicians will not only affect the quality of experiments, but also hinder the training of innovative talents in colleges and universities, so it is necessary to strengthen the construction and training of experimental technical teams (Xiao & He, 2012: pp. 418-419). According to the content of normal stress measurement experiment of pure bending beam, the experiment teacher has mastered the operation steps of TZT3822EN resistance strain gauge and material mechanics combination test bench in advance, and found that the problem can be solved in time. The working principle, precautions and maintenance of the instrument are matters that the experimentals must master, and it is recommended that the experimental teachers learn through different channels, and go to the production enterprise for training and learning if conditions permit. Experiment teachers use vacation time to study in construction enterprises to understand the production process of construction enterprises. With the work experience of enterprises, they can better guide students to experiment.

## 4. Conclusion

The student-centered experimental teaching reform on the measurement of normal stress of pure curved beam is an important way to improve the quality of experimental teaching and train high quality engineering and technical personnel. By enriching experimental teaching methods, introducing virtual simulation experiments, diversified assessment models, improving the construction of teachers and updating experimental equipment, students really like the pure bending beam normal stress experiment. In the future experimental teaching, we should continue to explore and innovate, and add AI technology to make the content of experimental courses more rich and diverse. Through the student-centered teaching reform method of pure bending beam normal stress experiment, we can make a greater contribution to training high-quality applied engineering and technical talents to meet the needs of social development.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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