CHAPTER 12

Use of Mixed Reality in Engineering Laboratory Applications: Flexural Strength Test

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Introduction

High-cost laboratory equipment and limited accessibility often result in undergraduate students being deprived of laboratory experiences. This problem is generally seen more frequently in newly established or rapidly developing educational institutions. Especially for engineering students, laboratory experiences are critically important for their professional lives. Students who graduate without laboratory experience start behind compared to their colleagues. Engineering students' completion of laboratory experiences greatly improves their jobs and professional careers. The practical knowledge and skills provided by laboratory experiences increase students' success. Additionally, laboratory experiences provide students with the opportunity to gain more in-depth knowledge and positively impact their engineering careers.

Considering the purchase of costly testing equipment and the cost of materials required for each experiment, the importance of laboratory experiences becomes clear. Additionally, material costs are incurred for each repeated experiment.

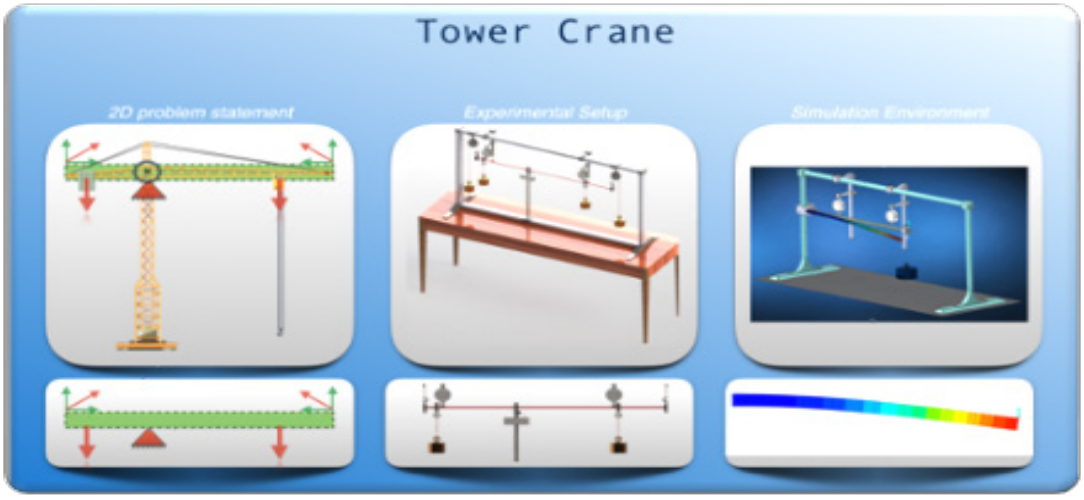
In today's rapidly developing digital world, augmented reality (AR) technology stands out by offering a unique interaction and learning experience with traditional knowledge. While AR provides users with a deeper understanding by combining the real world with virtual elements, it also has various applications in many fields, from education to virtual commerce. This technology has the potential to transform both the learning processes and the efficiency of the education world (Lyrath & et al. 2023; Alvarez & Velazquez, 20217; Chu, 2022.

In the studies conducted; Augmented Reality (AR) is seen to offer students a simple way to provide students with illustrative resources for learning, including videos and virtual 3D items from a first-person perspective (GUNT Inc., n.d.; Microsoft, n.d.; Fang, 2009).

Mechanical engineering is an application-based engineering field. Therefore, establishing a laboratory infrastructure for each of these applications creates very serious costs. To avoid costs, augmented reality applications have come to the fore by taking advantage of today's technology (Silva & et al., 2013; Kaplan & et al., 2021; Kaur & et al., 2021).

This study includes an augmented reality application performed with a flexural Strength test device used in the mechanical engineering mechanics laboratory. This application demonstrates the potential of augmented reality in the use of a flexural Strength testing machine and provides an example of real engineering applications and illustrative representation of the project is given in Figure 1.

Figure 1.
Illustrative Representation of the Project



1. Flexural Strength Test

Beams play a pivotal role in both mechanical engineering and construction. These structural components, characterized by their elongated, bar-like shape with relatively small cross-sectional dimensions compared to their length, experience loads along and perpendicular to their longitudinal axis. Such perpendicular loading results in the bending or deformation of the beam. In terms of modeling, beams are typically treated as one-dimensional entities due to their characteristic size and behavior.

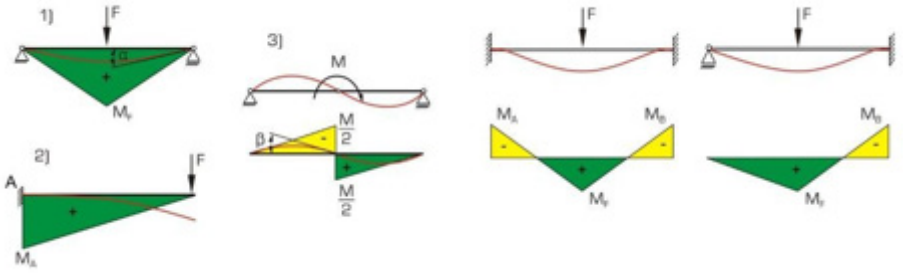
The field of strength of materials is concerned with understanding the stresses and strains that arise when forces are applied to structural components. A straight beam serves as an excellent practical example to illustrate fundamental principles in this field. The SE 110.47 experimental setup investigates a specific beam, exploring its behavior under different bearing methods. This beam can be supported in distinct ways, enabling the realization of statically determinate and indeterminate systems. The setup provides two supports with clamp fixings, equipped with dial gauges, which can also function as articulated supports. These dial gauges serve the purpose of determining the beam's angle of inclination at the support. Additionally, a third dial gauge is dedicated to recording the deflection of the beam at a chosen point.

The experimentation further incorporates a device designed to introduce a bending moment at an arbitrary location on the beam. A fourth dial gauge is employed to monitor the angle of inclination of this device. To apply loads to the beam, weights are used, including point loads and coupled forces to induce the bending moment. The clamping moment on the supports can be accurately determined by adjusting the weights.

This experiment delves into beam behavior, offering insights into different methods for determining the elastic line and the response of statically determinate and indeterminate beams under various support conditions. The setup comprises essential components, including supports with clamp fixing that can also function as articulated supports, an articulated support with a force gauge, a device for generating bending

moments, dial gauges for measuring inclination angles and beam deformations, as well as weights for applying point loads and assessing clamping moments (Figure 2).

Figure 2.
The diagram shows the bending moment characteristics (green/yellow) and elastic line (red) for statically determinate beams, including a single-span beam with a mid-point load, a cantilever beam with a point load, and a single-span beam with a bending moment as the load, while referencing "MA" as the bending moment on support A, "MF" as the bending moment from force F, and "M" as the overall bending moment, along with "α" and "β" representing the angles of inclination. B) Bending moment characteristic (green/yellow) and elastic line (red) for statically indeterminate beams with centralized point load (Gunt Inc.n.d.).



2. Mixed Reality (MR) Technology

Mixed Reality (MR) is a wearable computing device that uses augmented reality (AR) technology. MR combines virtual objects and information with the real world while the user interacts with the real world. Its main features include holographic imaging, holographic audio, cameras, and sensors, as well as wireless connectivity. This technology is used in a few industries such as education, healthcare, industrial design, and military applications. For example, educational institutions use MR to provide students with visual and interactive learning experiences, while the healthcare industry uses this technology for surgical planning and patient care. It is also used in industrial design and military applications. MR combines the real and virtual worlds, giving users access to richer and more interactive experiences.

3. A Holographic Processing Unit: HoloLens

In this book chapter, we took a practical approach by deploying our application on the Microsoft HoloLens Developer Edition (1st Gen.), a device introduced by Microsoft in 2016. HoloLens is essentially a mobile holographic computer that lets you work with digital objects while staying aware of your surroundings. It uses laser-based cameras to map the space around you. You can control it using hand gestures and voice commands. HoloLens is designed to be wireless and offers a whole new way of computing with 3D holograms that interact with the real world. It relies on gaze tracking, gestures, and voice commands to understand what you want to do and uses features like spatial sound, various cameras, an inertial measurement unit (IMU), and microphones to adapt to your environment effectively Figure 3 (Microsoft, n.d.).

Figure 3.
This Figure Shows Lenses On The Visor Of Hololens (Microsoft, n.d.)



4. Flexural Testing Setup: Building a Digital Twin Simulation

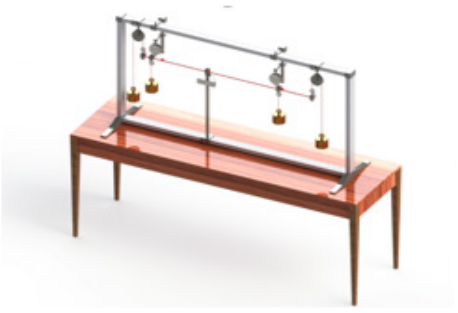
The process of creating 3D models and assembling them using SolidWorks is straightforward and commonly employed in academic and industrial settings. This practical approach involves generating detailed 3D models of individual components. SolidWorks Pro, known for its precision, simplifies this task by enabling the creation of virtual replicas that accurately resemble real-world parts.

Once these individual 3D models are ready, they are assembled to form a complete digital representation of the flexure strength testing instrument. The assembly process carried out with SolidWorks Pro, aims to mimic physical assembly, ensuring a seamless fit between the components without the need for elaborate constraints and relationships.

After successful assembly, the next step involves converting the entire assembly into a usable file format, typically an STL file. This format is essential for various applications, such as 3D printing and simulations, facilitating practical testing and analysis.

In summary, the process of creating 3D models and assembling them using SolidWorks is a concrete and systematic approach, allowing for the development of a digital twin for a flexure strength testing instrument with precision and efficiency. SolidWorks Pro serves as a practical tool, essential for a wide range of applications, from academic research to practical design.

Figure 4.
3D Models of Experimental Set Up (Gunt Inc.n.d.)





2.4.1. Importing models into the UNITY 3D game engine and adding “textures”

Following the assembly of the 3D models in SolidWorks, the next step involves importing

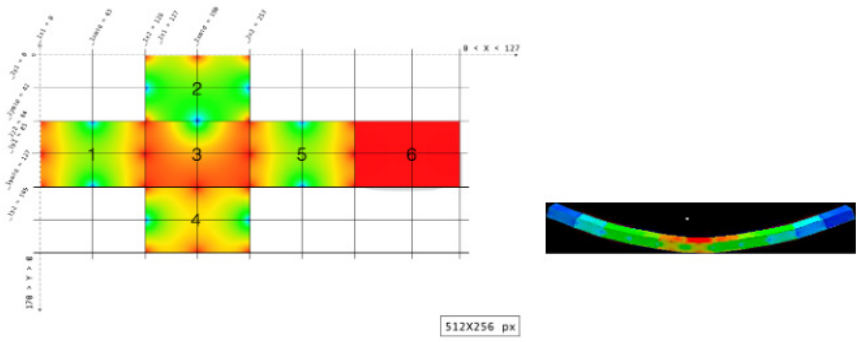
the resulting STL files into the Unity3D game engine. Within Unity, constraints and textures can be added to enhance the visual and interactive aspects of the digital twin. Additionally, user interactions are programmed into the digital twin, allowing users to engage with the virtual representation of the flexure strength testing instrument. These interactions include features zooming, rotating, or manipulating different components, making the experience more engaging and informative.

2.4.2. Performing mathematical calculations

To simulate the flexure response of the chosen material, a solver is programmed within Unity3D. This solver calculates the material's instantaneous flexure response, providing valuable insights into how the instrument would perform under various conditions.

This comprehensive process, from 3D modeling and assembly in SolidWorks to the integration with Unity3D and the addition of user interactions and a flexure response solver, offers a practical and interactive approach to studying and analyzing the flexure strength testing instrument. In a virtual environment formulation (Figure 6).

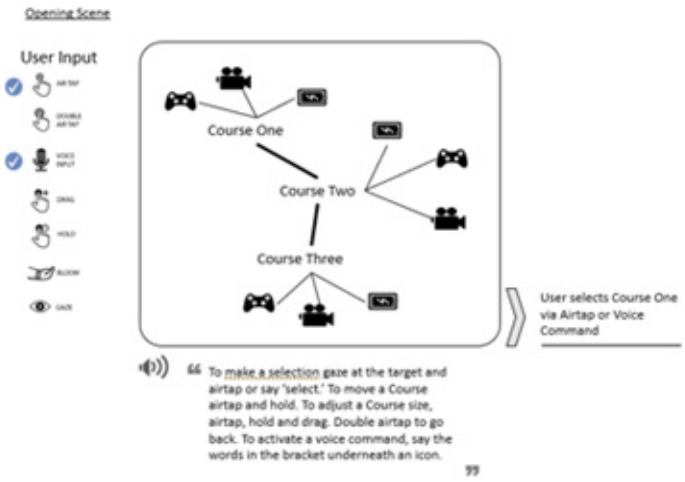
Figure 6.
Texture Creation Process in Unity 3D Results Data is Readily Available for Immersive Experience. (Gunt Inc.n.d.)



2.4.3. Creation of the user interface

Since Microsoft HoloLens is a headset that provides an augmented reality (AR) experience, the creation of the user interface is an important element that allows users to interact with virtual objects or information in the real world. Creating the user interface enables developers to integrate interactive and informative 3D visuals on the HoloLens device as shown in Fig.7. These interfaces enable users to interact using HoloLens' motion tracking, voice recognition, and gesture detection capabilities. The HoloLens Development Kit (HoloLens SDK), Microsoft's HoloLens development platform, is typically used to create a user interface. These development kits provide developers with the tools necessary to create customized holograms, menus, buttons, and other interaction elements on the HoloLens device. Developers can design unique user interfaces for HoloLens using game engines such as Unity or Unreal Engine and 3D modeling tools. In this way, users can interact seamlessly between the real world and the virtual world. Creating the user interface is a critical step in enriching the user experience of HoloLens apps.

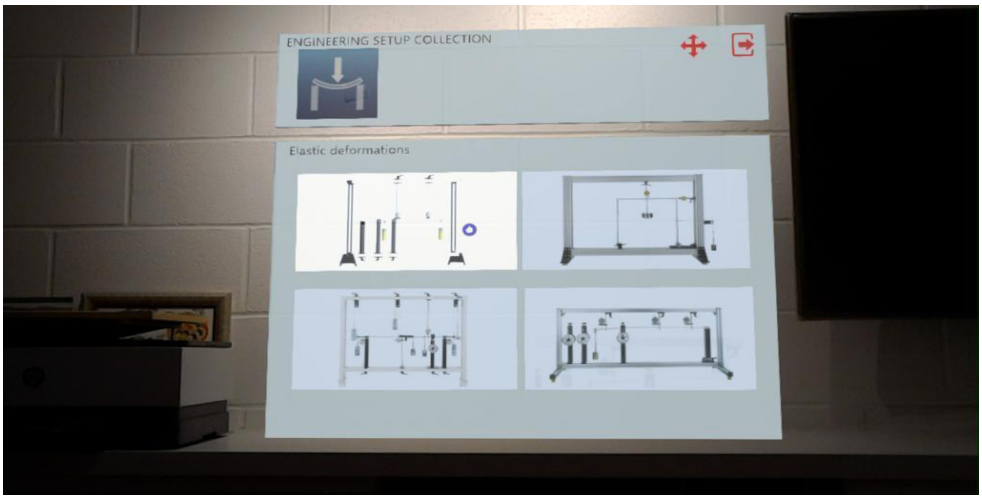
Figure 7.
User Interface



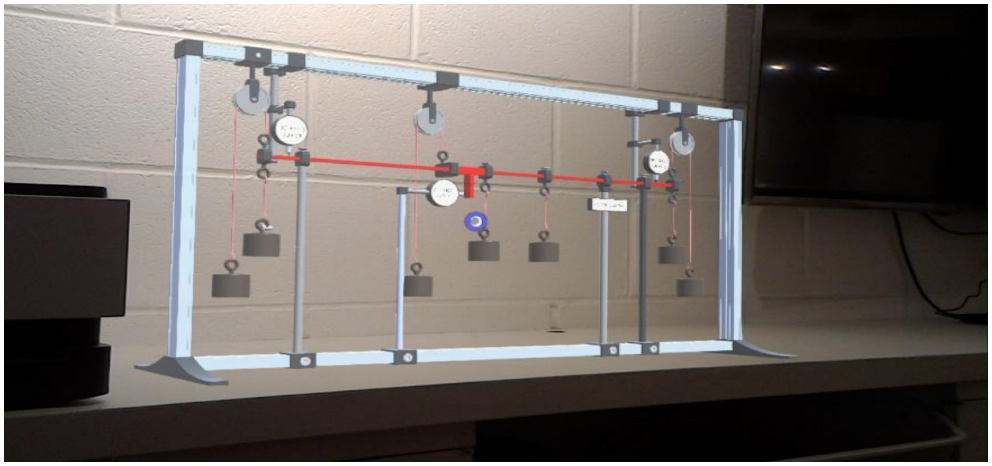
3. Demo application of flexural testing setup

A comprehensive demonstration of a flexure test setup, in which we will explore the practical aspects and procedures involved in performing flexure tests on various materials and forces, is given in Fig. 8a, b, c, d, e & f). This demo application aims to provide a hands-on understanding of how flexural testing works and its importance in assessing the mechanical properties of materials.

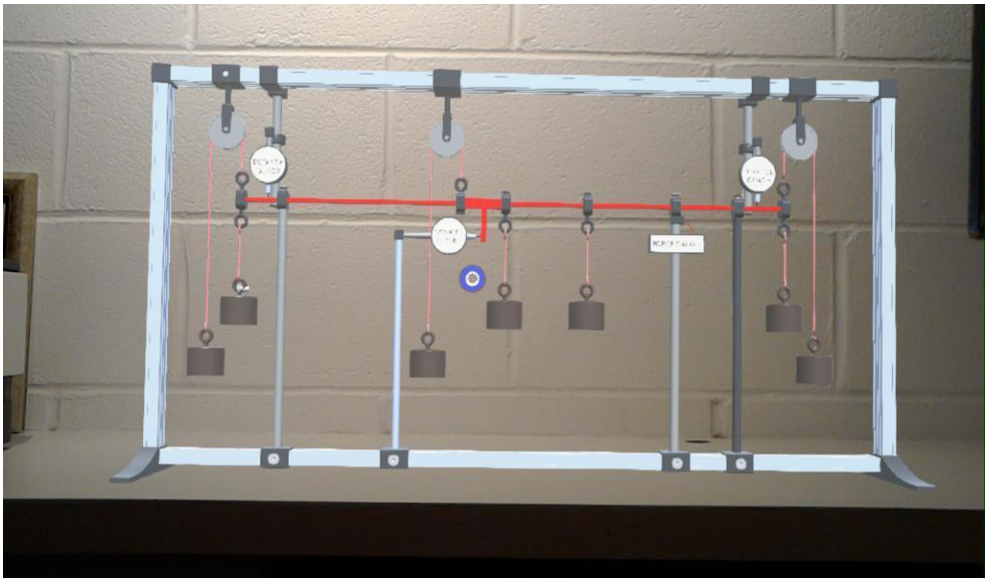
Figure 8.
a, b, c, d, & e *Comprehensive Demonstrations of a Flexure Test Setup In MR*



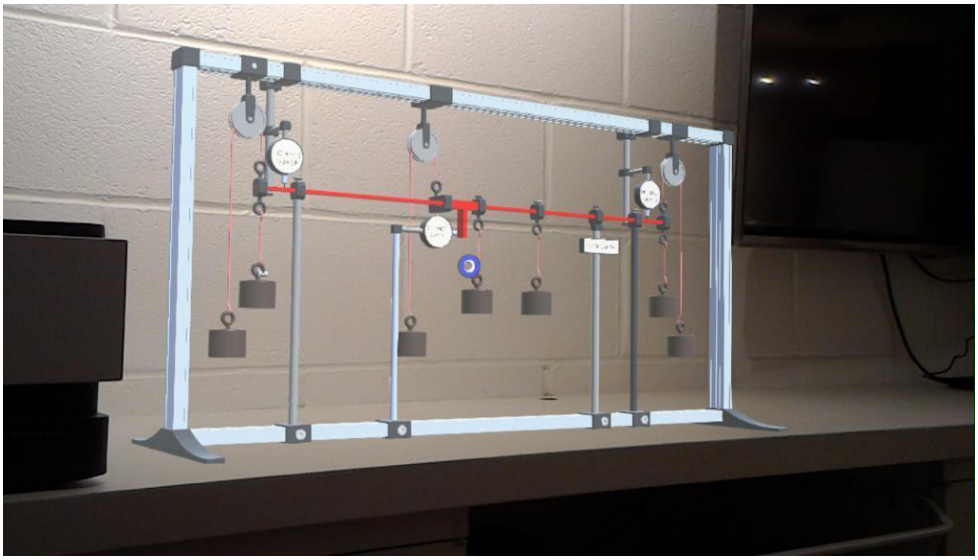
a)



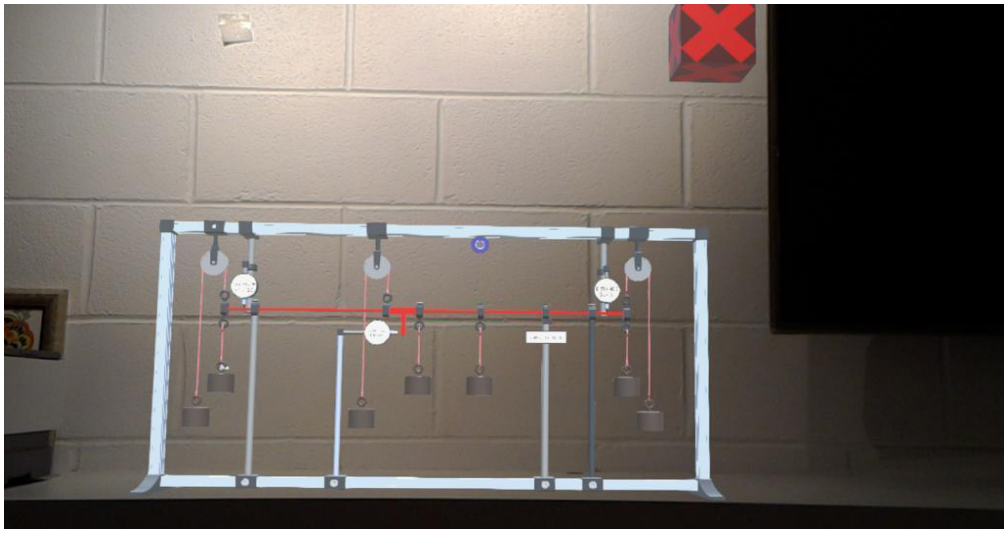
b)



c)



d)



e)

In this section, we focused on the importance of engineering students' lab experiences on their job prospects and careers. Situations, where laboratory experiences are not available to some students due to costly equipment and access difficulties, are a problem faced by educational institutions. However, these experiences are critical for engineering students because they enhance student achievement by imparting practical knowledge and skills, positively impacting engineering careers.

Mixed Reality (MR) technology has the potential to transform learning processes and efficiency in the world of education. The ability to offer an interactive learning experience with traditional knowledge is one of the great advantages of MR in this field. In addition, as an example of the use of MR technology in engineering laboratory applications, the flexural strength test was examined.

MR applications for flexural strength testing provide students with better explanatory resources and can reduce the installation costs of laboratory infrastructure. The process of creating a 3D model and developing this digital twin using SolidWorks Pro provides a concrete and systematic approach to improving the precision and efficiency of flexure testers. In conclusion, MR technology has the potential to make engineering students' lab experiences more accessible and effective.

This technology offers a huge opportunity to make engineering education more efficient and effective.

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