Design 3
Final Report

Group 36

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Section 1: Selection & evaluation process

Section 1.1: Selection Matrix

	Weighting 1-5	Jiacheng Design 1		Kexun Design 2		Shengyuan Design 3		Zhanyu Design 4		Zhenyu Design 5	
		PF	Score	PF	Score	PF	Score	PF	Score	PF	Score
Selection criteria											
1. Ability of the device to fit to the Zwick/Roell Z250 SN/SW (Type 2) testing machine without requiring any modifications to the testing machine. [0/5]	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**20**	**5**	**20**
2. Ability of the device to test the specified cruciform specimens.	**5**	**5**	**25**	**5**	**25**	**5**	**25**	**5**	**25**	**5**	**25**
3. Ability of the device to perform tension-tension, compression-compression, and tension-compression tests under the following loading ratios: ±0.5 and ±1. The loads must be provided by the testing machine only (extra actuators are not allowed).	**5**	**3**	**15**	**3**	**15**	**3**	**15**	**3**	**15**	**4**	**20**
4. Ability of the fixture to measure the applied loads along each axis (maximum applied load in each axis: 100kN) as well as the deformation of the specimen (maximum displacement in each axis: 10mm).	**5**	**4**	**20**	**3**	**15**	**4**	**20**	**4**	**20**	**4**	**20**
5. Alignment ability of the fixture for not creating any bending moments or shear forces on the specimen being tested.	**4**	**4**	**16**	**4**	**16**	**4**	**16**	**2**	**8**	**4**	**16**
6. Ability of the fixture for keeping the centre of the test specimen in its original position during the testing.	**4**	**5**	**20**	**5**	**20**	**5**	**20**	**5**	**20**	**5**	**20**
7. The design of the specimen clamps must be compatible with the testing machine.	**3**	**5**	**15**	**5**	**15**	**5**	**15**	**5**	**15**	**5**	**15**
8. A maximum of two people (skilled and trained mechanical/electrical	**3**	**5**	**15**	**4**	**12**	**5**	**15**	**4**	**12**	**2**	**6**

engineer) must be able to set-up the fixture.											
9. Maximum time for the reconfiguration of the device must be less than 30 minutes.	**3**	**3**	**9**	**4**	**12**	**4**	**12**	**4**	**12**	**2**	**6**
10. The device must not require servicing more than once every six months.	**3**	**2**	**6**	**3**	**9**	**3**	**9**	**3**	**9**	**2**	**6**
11. The fixture must comply with selected relevant health and safety regulations.	**5**	**4**	**20**	**4**	**20**	**4**	**20**	**4**	**20**	**2**	**10**
12. The design of the fixture must exhibit some degree of compliance with appropriate Ecodesign principles.	**3**	**2**	**6**	**2**	**6**	**3**	**9**	**3**	**9**	**2**	**6**
	Total score	**167**		**165**		**176**		**185**		**170**	

Section 1.2: Comments on the selections

The following criteria are significant and weighted 4-5 due to their importance for this bi-axial loading fixture. Compatibility with the testing machine is fundamental to the success of the design and is therefore heavily weighted. The scores reflect how well each component integrates with the Zwick/Roell Z250 SN/SW (Type 2) testing machine. If the design cannot fit into the machine, the score will be zero. Testing specified cruciform specimens is weighted 5 due to its high importance as the primary purpose is to test these specific specimens. It is essential that the design is capable of effectively testing the specimen. Moreover, loading ratios and actuator limitations are of high importance due to the need for testing versatility. The scores reflect the ability of each concept to perform tension-tension, compression-compression, and tension-compression tests within the specified loading ratios. It is critical to have accurate load and deformation measurement for reliable data collection. The scores indicate the ability of each concept to accurately measure applied loads and specimen deformation. During testing, it is crucial to align and apply forces to the specimen to prevent any unnecessary forces or moments. Maintaining the specimen position is another crucial aspect for consistency in test conditions and accurate data interpretation. The scoring criteria apply only as long as the design is symmetrical. Due to the critical importance of safety in materials testing, Health and Safety Compliance was assigned the highest weight. The scores reflect the degree to which each concept complies with relevant health and safety regulations.

The remaining criteria are given a weight of three in comparison to the significant criteria, as they are considered reasonably important. For instance, while simplicity of setup is crucial for efficiency, it is not as vital as other functional features. Similarly, compatibility of Specimen Clamps is regarded as relatively important to provide a secure grip without compromising the integrity of the specimen. Reconfiguration Time is important for minimizing downtime but may be considered less critical than ensuring accurate testing. Although service intervals are crucial for maintenance and long-term usage, they might not be as significant as immediate functionality. Although the significance of eco-design principles varies according to the objectives of a project, they are essential for sustainability and environmental responsibility.

Design 4（Zhanyu) is the recommended option for further development as it achieved the highest overall score in the weighted evaluation. It combines strong performance across multiple criteria, including specimen testing, alignment, and health and safety regulations. It is recommended to conduct more comprehensive design and testing to confirm its overall viability and functionality.

Section 2: Comprehensive overview of the selected final design

Section 2.1 Overviews of the biaxial loading fixture

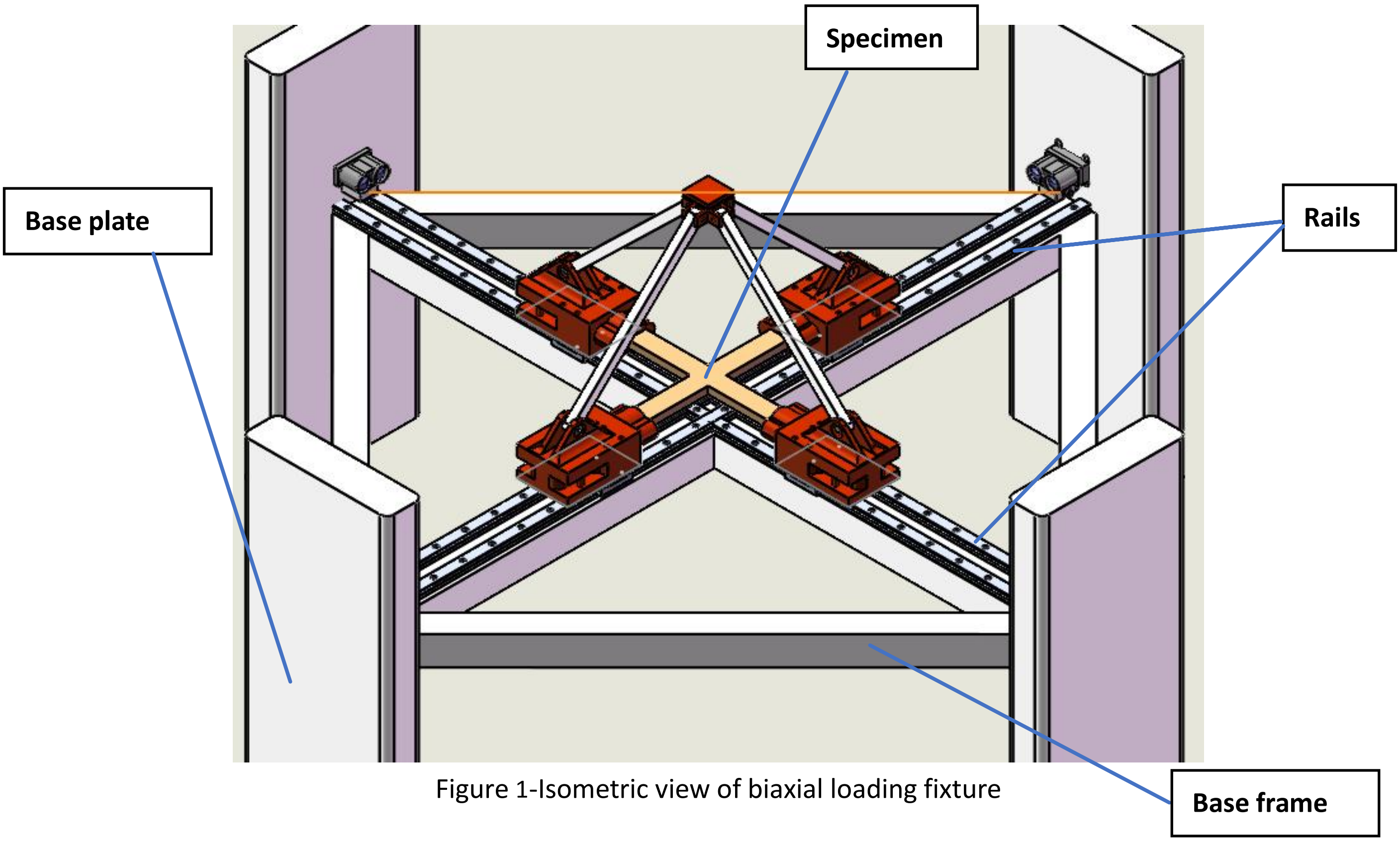


Figure 1-Isometric view of biaxial loading fixture

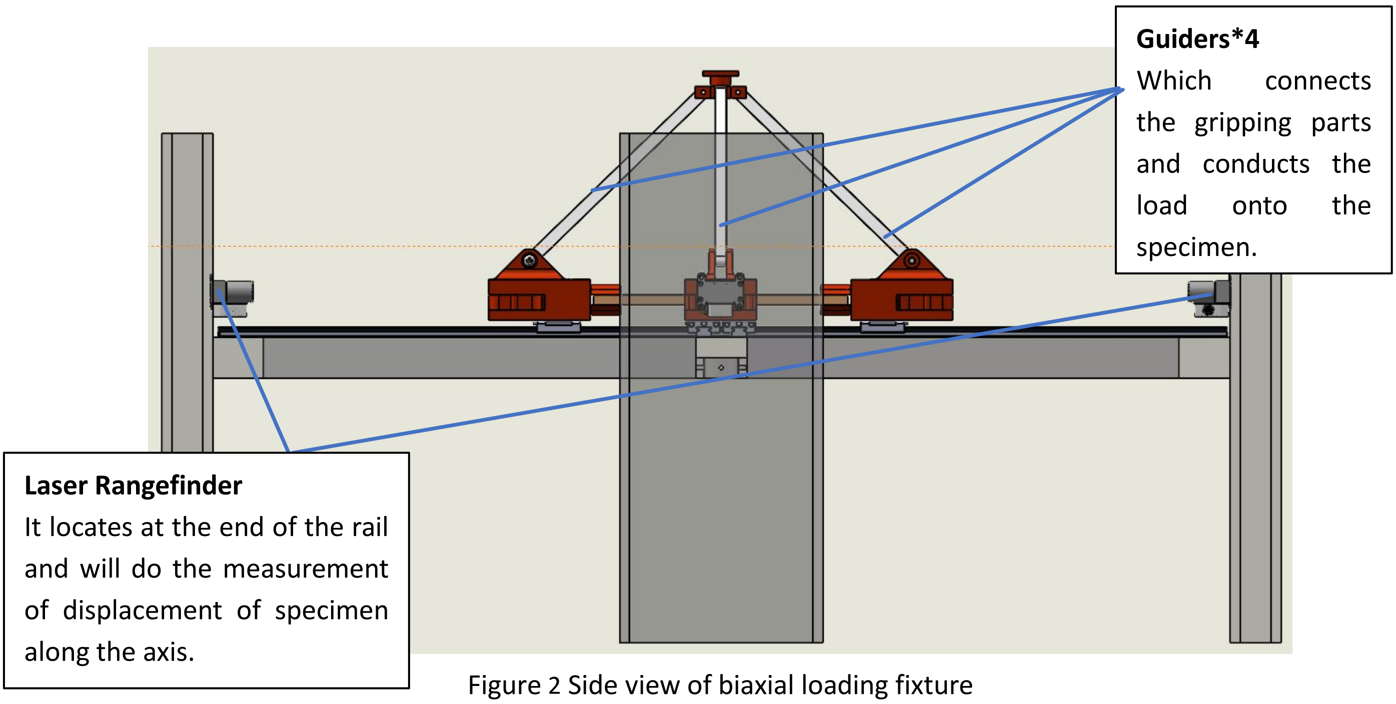


Figure 2 Side view of biaxial loading fixture

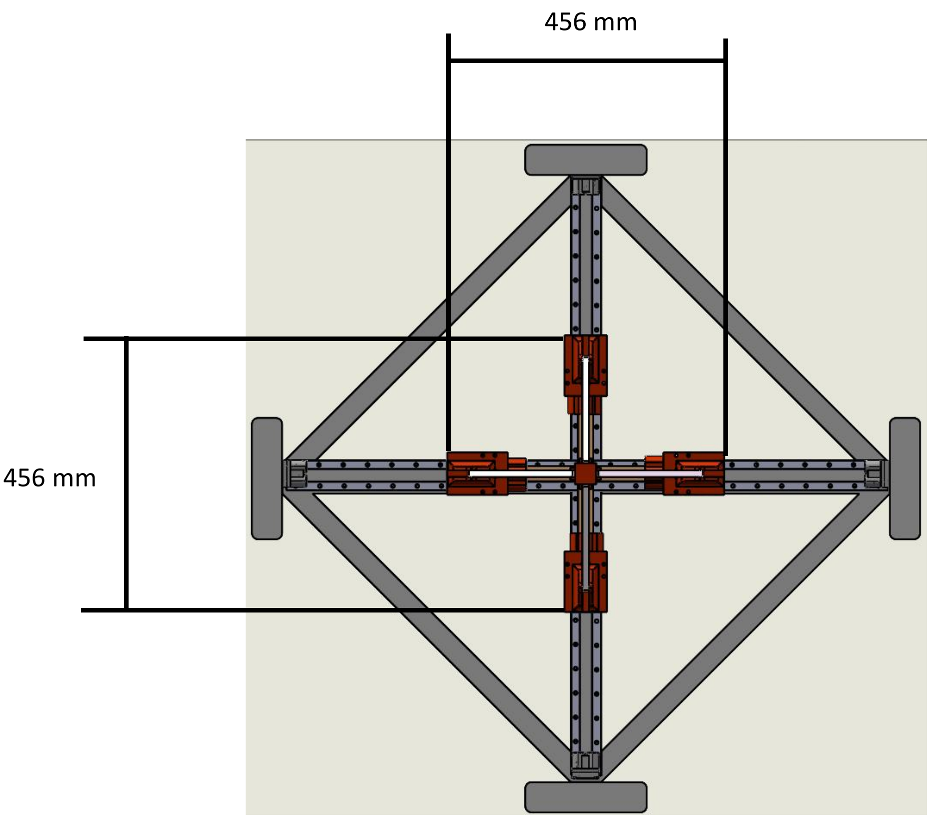


Figure 3 Top view of biaxial loading fixture

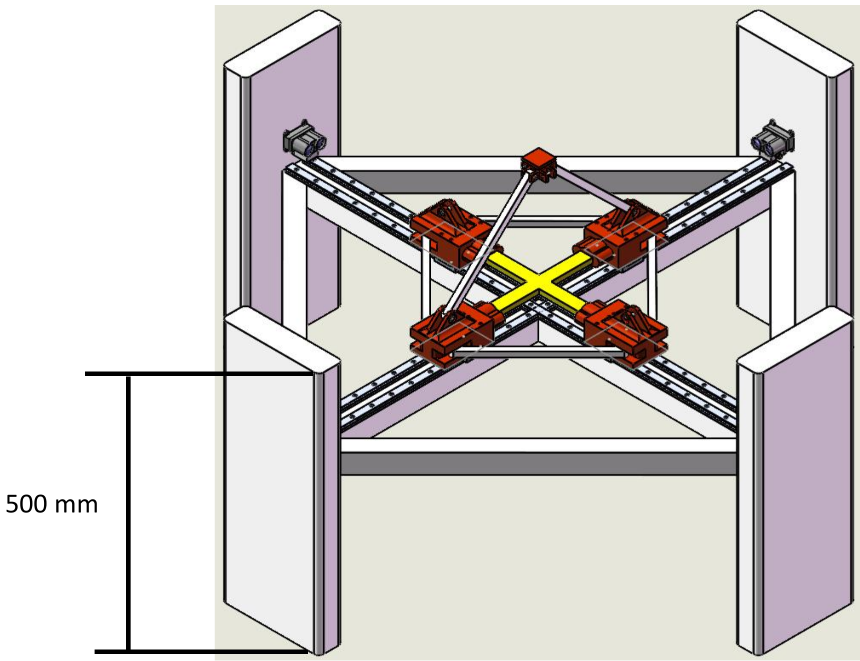


Figure 4 Isometric view of biaxial loading fixture after reconfiguration

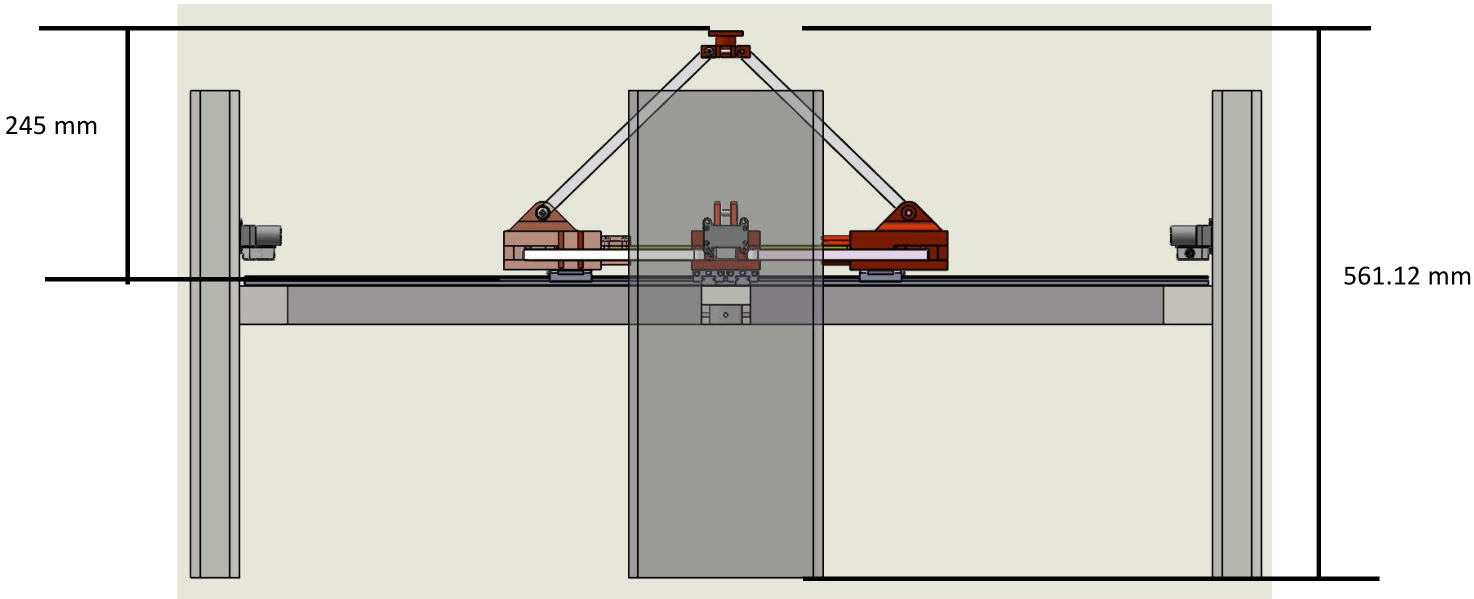


Figure 5 Side view of biaxial loading fixture after reconfiguration

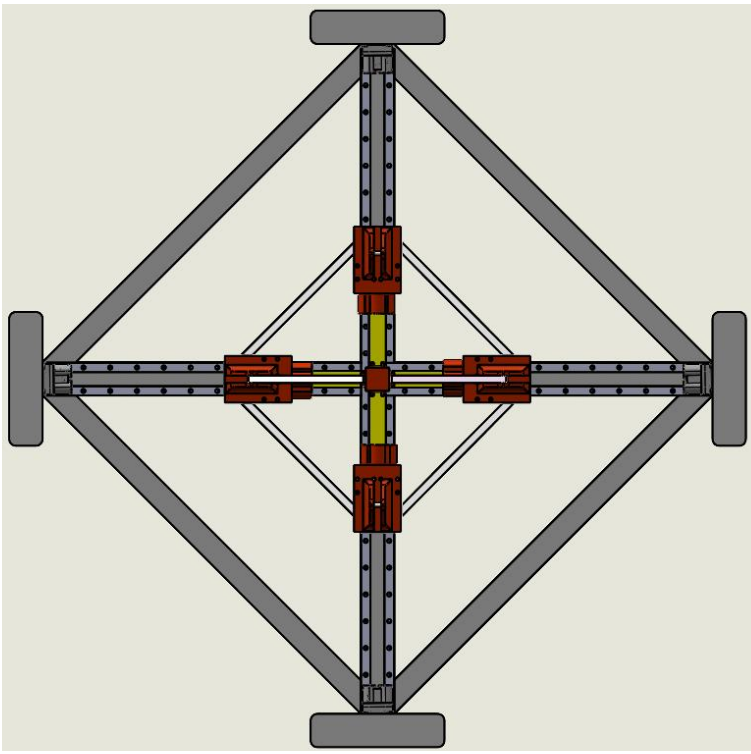


Figure 6 Top view of biaxial loading fixture after reconfiguration

Section 2.2 Force diagrams of the biaxial loading fixture

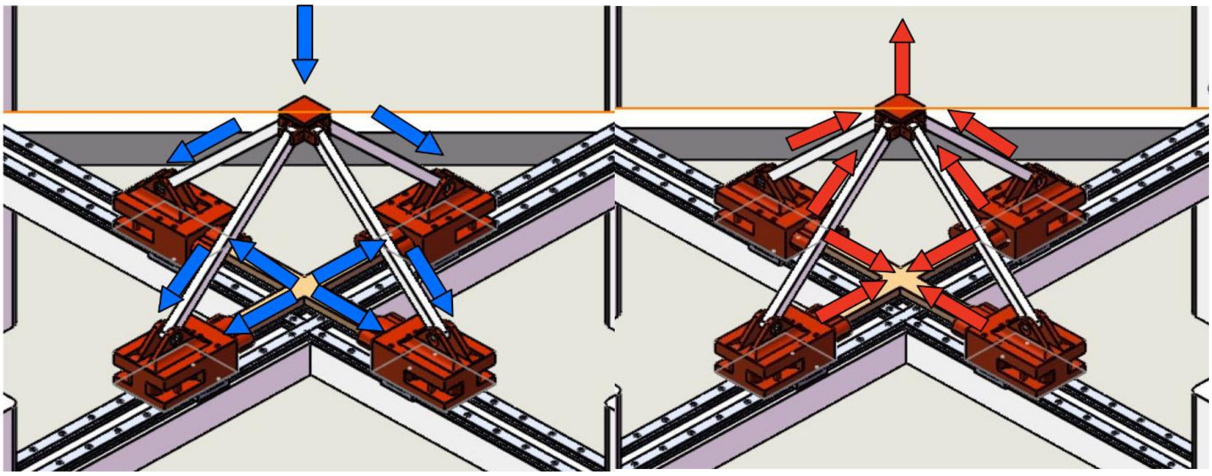


Figure 7 Tension-Tension and Compression-Compression movements

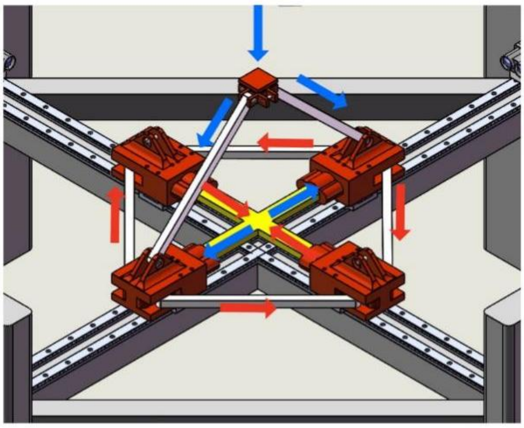
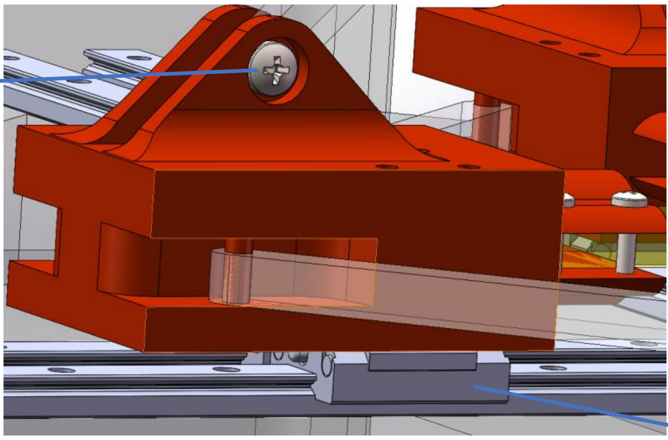


Figure 8 Tension-Compression movements

Section 2.3 Details diagrams of the biaxial loading fixture

Screw
ISO 7045-M6x16



Carriages
Allows the gripping parts to slide on the rails.

Figure 9 Detailed diagram of gripping part

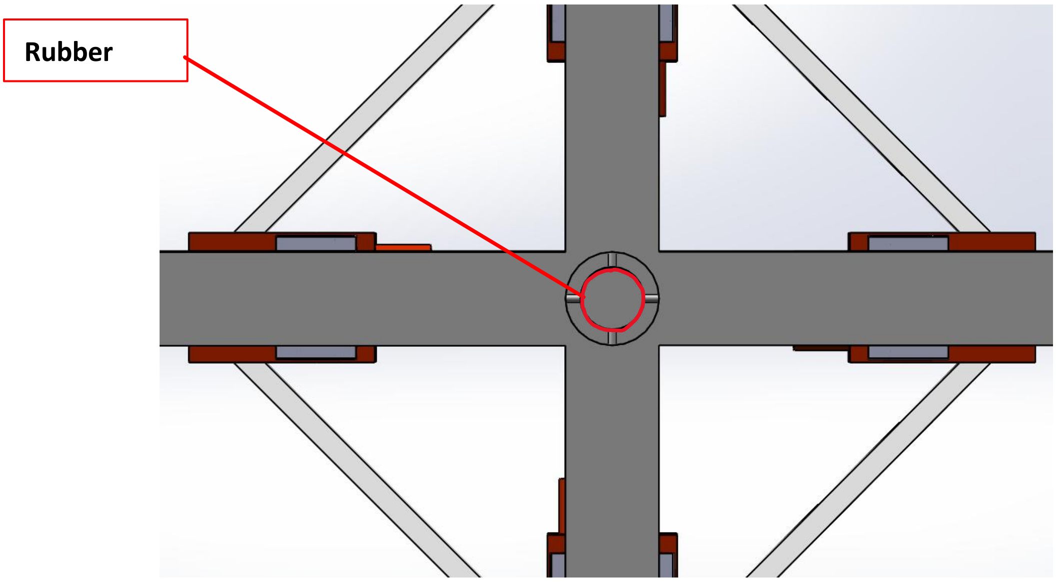


Figure 10 Fixing design under the base plate

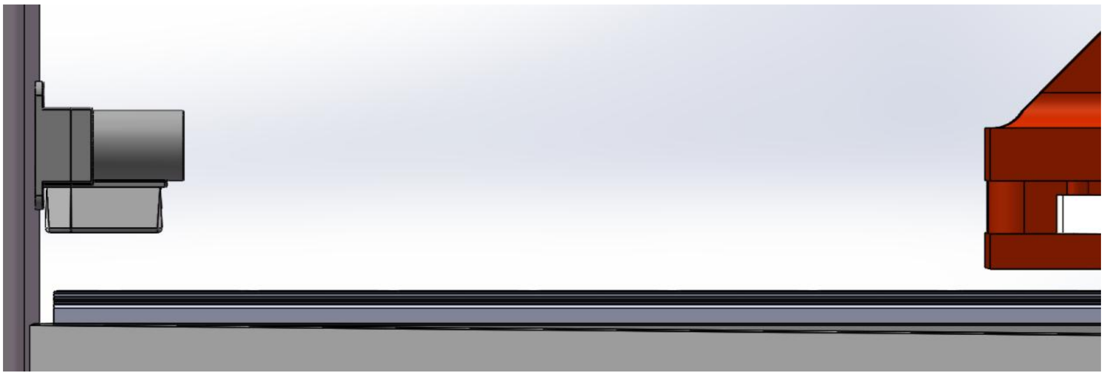


Figure 11 Side view of laser rangefinder

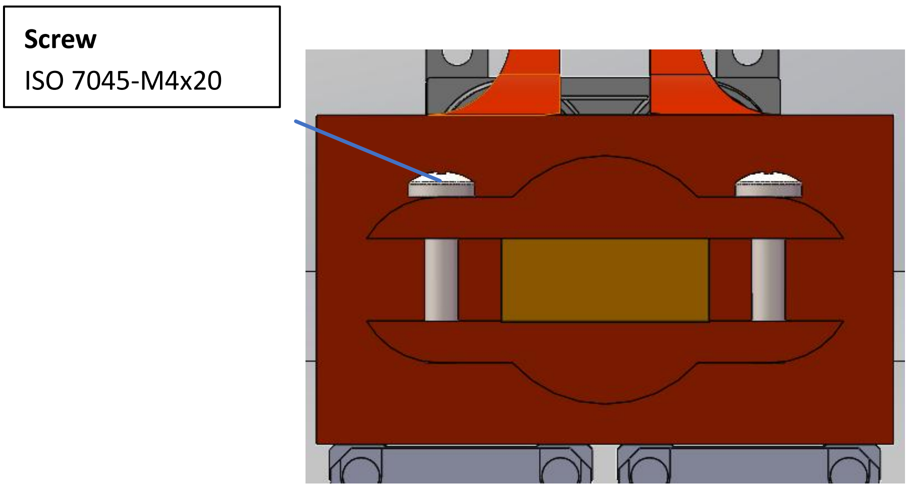


Figure 12 The insertion of specimen

Section 3: An explanation of how the design works

Section 3.1: Basic design scheme

The main dimensions of this biaxial test fixture are shown in **Figure 3**. The length and width of the rails are both 990mm. There's also a square frame to reinforce the whole structure and also to protect all the core components. 4 identical 500mm base plates are fitted to all 4 corners of the frame, which are in direct contact with the test machine, providing primary fixation. These parts, with reasonable dimensions, have been successfully assembled into the testing machine [Zwick/Roell Z250 SN/SW (Type 2)]. As shown in the isometric view: **Figure 1**. As the upper and lower load application probes could be freely manipulated by digital systems, it was possible to move the lower probe platform from below to a certain height on the machine. In this way, the platform could act as a stable plate and exert a very strong supporting force on the test fixture. In addition, a small circular hole is cut in the centre of the fixture's base frame so that the probe and fixture can be easily fixed. A rubber ring is glued in place to protect the fixture and probe. As shown in **Figure 10**. This support and connection structure provides stability to the underside of the fixture. It won't change position when the load is applied, ensuring that the centre of the specimen remains in its original position during testing.

The 4 identical clamps are specially designed for the specimen. As shown in **Figures 9 & 12**. Each specimen is divided into 2 sections: top and bottom. In addition, the specimen could be fixed by tightening the screw connections, it could produce absolute tightness. The specimen is stable enough to avoid the occurrence of bending moments or shear forces.

Taking into account the tensile or compressive movement of the specimen, rails were designed to provide moving tracks for the clamps. In addition, carriages are mounted between the clamps and the rails. These carriages contain ball bearings to make the movement smooth and keep the movement speed constant, as shown in **Figures 1 & 9**.

The laser rangefinders are installed at the end of all four tracks. As shown in **Figure 11**. These could measure the displacement for all 4 clamps when the biaxial test is running. Specific computer programs are nested within the detectors to manipulate the control system so that the maximum displacement can be controlled within a specific limit (10mm). The load range could also be set by the digital control system using only the testing machine. The square structure with equal side lengths and suitable dimensions also ensures the desired load ratios. The design parameters and configurations for all 4 lines are 100% consistent.

The guiders are the components that connect the top （the bearing area of the load around the testing machine） and the clamps. and the clamps. As shown in **Figure 2**. These guiders could transfer the load of the machine to the clamps and activate the movement to achieve the experimental function. At the same time, the shapes of the guider assembly could be changed at will depending on the experimental types. **Figures 7 and 8** illustrate this process, showing how the guiders can be adjusted to achieve the desired tension and compression configurations.

The reconfiguration process is very simple due to the flexible design of clamps. Firstly, the guiders are very easy to detach and reassemble. Secondly, the bolted joints of the clamps could be loosen easily by using standard screwdrivers, allowing the tightness of these clamps to be changed. Thirdly, the position of the clamps could be reset by hand thanks to the ball bearings inside the carriages. Thus, the reconfiguration time is significantly reduced.

The design of the model incorporates a safe and efficient set up process. This configuration, crafted for ease of use, allows for effortless setup by a maximum of two skilled and trained mechanical engineers. There's no harmful element in this fixture. High quality materials are used to construct this equipment, resulting in high durability.

Section 3.2: Tension – Tension

To execute this test, four guides have been set up as shown in **Figure 7**. The machine's upper probe is lowered, exerting a downward pressure force on the top of the fixture at the intersection of all four connection rods. This causes the four guiders to move away from the center of the machine, and the four clamps secure the specimen away from the center. This setup indicates a tension-tension condition in this scenario.

Section 3.3: Compression – Compression

To perform this test, follow the same setup as the tension-tension condition illustrated in **Figure 7**. Raising the upper probe shifts the testing condition to compression-compression. This alters the dynamics and exerts an upward force on the top of the fixture, specifically at the intersection of all four connection rods. As a result, the four guiders move towards the center of the machine, causing the four clamps to secure the specimen closer to the center. This statement clearly indicates a compression-compression condition in this testing scenario.

Section 3.4: Tension – Compression

Executing this test involves a setup modification, particularly adjusting two guiders connected with the top fixture and four rods linking all four clamps to achieve a tension-compression configuration illustrated in **Figure 8**. Lowering the upper probe causes distinct movements: the two sides connected with the top guiders move away from the machine's center, causing two clamps to secure the specimen outward, establishing a tension condition. Simultaneously, the four connection rods linked to all four clamps push the remaining two clamps toward the machine's center, securing the specimen closer to the center, indicating a compression condition. This adjustment underscores the fixture's versatility, effortlessly transitioning between tension and compression configurations by manipulating the position of the upper probe.

Section 4: A demonstration of alignment with Sustainable Development Goals (SDGs)

Generally speaking, the design project that we have dedicated ourselves in this term basically increases the availability of biaxial testing machines, by doing so, more companies in various industries from developing countries can have access to the originally expensive technique. This could have several impacts in terms of the sustainable development goals (SDGs).

One of the results is that companies in infrastructure will benefit as the quality of the built infrastructure would increase with higher quality material. This corresponds to sustainable development goal (SDG) 9, particularly 9.1[1], which is to develop quality and reliable infrastructure.

Furthermore, increasing availability of biaxial testing machines could potentially be beneficial to research and development in developing countries. For example, one private research institute studying material science and engineering in Malaysia may be struggled to the cost of biaxial testing machines, but with our designed module, they are able to modify the axial testing machine into simple biaxial test machine with a much lower cost. This aligns with SDG target 9.5[1], which is to enhance scientific research and encourage innovation.

Another advantageous consequence of increasing availability of biaxial testing is sustainable process of production, as the cost of the technique decreases, more manufacturing companies would have access to biaxial testing. This gives more information on the mechanical properties of the material they used; thus, the material usage would be optimized, leading to a more efficient and more sustainable manufacturing process. With a more efficient material usage, companies from various manufacturing sectors could be assisted to reach the SDG target 12.2[2], which is to achieve the sustainable management and efficient use of natural resources by 2030. The improved knowledge of the mechanical properties could also lead to less waste generation. For example, a manufacturing company producing large food containers may suffer from quality control and be required by customers to replace containers too often due to lack of knowledge on mechanical properties of material they used for walls of the container, while the cost of purchasing a biaxial testing machine is over the budget. With the designed biaxial testing module, the quality of the manufactured containers would be increased by getting more knowledge on the material the company used, thus increasing the lifespan of the containers and decreasing the need for replacements. As a result, the company has helped to meet the SDG target 12.5[2], as waste generation has been reduced substantially through reduction.

Increasing access to biaxial testing machines could also lead to improvements in the energy sector. With more knowledge on the mechanical properties of materials used, the efficiency and durability of the components in energy production system could be enhanced, which further leads to an increase in the overall efficiency and a decrease in cost of energy production. This aligns with the SDG target 7.1[3], as it promotes universal access to affordable and reliable energy services. Furthermore, the improved component could also contribute to an increase in efficiency in renewable energy sources such as solar panels or wind turbines. This intersects with SDG target 7.2[3], which is to increase substantially the share of renewable energy in global energy mix.

Section 5: List of references

1. Goal 9 | Department of Economic and Social Affairs (no date). https://sdgs.un.org/goals/goal9#targets_and_indicators.
2. Goal 12 | Department of Economic and Social Affairs (no date). https://sdgs.un.org/goals/goal12.
3. Goal 7 | Department of Economic and Social Affairs (no date). https://sdgs.un.org/goals/goal7#targets_and_indicators.