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Pengembangan Sistem Akuisisi Data pada Mesin Uji Tarik berbasis Arduino untuk Material Komposit

Development of Data Acquisition System on an Arduino-Based Tensile Test Machine for Composite Materials

Dede Lia Zariatin*, Yani Kurniawan dan N.A Reza Afika
Department of Mechanical Engineering, Faculty of Engineering, Universitas Pancasila, Jl. Raya Lenteng Agung, Serengseng Sawah, Jagakarsa, Jakarta Selatan 12640, Indonesia

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Abstract

A tensile testing machine with a lower load capacity is needed to identify the mechanical properties of composite materials. Tensile testing machines for composite materials are available in the market but at high prices. Previously, using a pneumatic system, a tensile testing machine for composite materials with a maximum load of 2000N was developed. However, this tensile test machine still needs improvement because the display of eventuating forces is only in numbers, not yet including a test graph. Therefore, this study developed a prototype data acquisition system for a tensile test machine to record the test results in more detail, both numbers and graphs. This data acquisition system uses the Arduino Uno Microcontroller, which processes data from the load cell through the HX711 module intermediary. A tensile test was carried out using a bamboo fiber composite material to validate the results of testing the prototype of this data acquisition system. Furthermore, the test results data are compared with the results on the indicators of the existing tensile test machine. The test was carried out nine times with an average tensile force of 1.66 N/mm², while the average tensile force on the tool indicator was 2.02 N/mm². There is a difference in the average test results equal to 12%. This difference is a systematic error because nine experiments have shown the same trend, with standard error and standard deviation of 0.3368 and 0.1123, respectively. The systematic error is compensated through calibration between the load cell of the tensile test machine and a series of data acquisition systems based on Arduino Uno.

Keywords: *load cell, logging time, bamboo composite, data acquisition, tensile test machine.*

***SDGs*:**

Abstrak

Untuk mengidentifikasi sifat mekanik material komposit dibutuhkan mesin uji tarik dengan kapasitas beban yang lebih rendah dibandingkan mesin uji tarik logam. Mesin uji Tarik untuk material komposit telah tersedia di pasaran namun dengan harga yang kompetitif. Sebelumnya telah dikembangkan sebuah mesin uji tarik material komposit dengan beban maksimal 2kN menggunakan tenaga penggerak pneumatika. Namun, alat uji tarik tersebut masih perlu dikembangkan karena tampilan gaya yang terjadi selama pengujian hanya dalam bentuk angka, belum menghasilkan suatu grafik pengujian. Oleh karena itu, pada penelitian ini dikembangkan sebuah prototipe sistem akuisisi data alat uji tarik agar hasil pengujian dapat terekam lebih detail dalam bentuk angka dan grafik. Sistem akuisisi data ini menggunakan mikrokontroler Arduino Uno yang mengolah data dari *loadcell* melalui perantara modul HX711. Untuk memvalidasi hasil pengujian prototipe sistem akuisisi data ini, maka dilakukan pengujian Tarik menggunakan material komposit serat bambu. Selanjutnya, data hasil pengujian dibandingkan dengan hasil pada indikator alat uji tarik yang sudah ada. Pengujian dilakukan sebanyak sembilan kali dengan gaya tarik rata-rata sebesar 1,66 N/mm. sedangkan gaya tarik rata-rata pada indikator alat adalah 2,02 N/mm2. Terdapat perbedaan rata-rata hasil pengujian yaitu sebesar 12%. Perbedaan tersebut merupakan kesalahan sistematik karena dari sembilan percobaan yang sudah dilakukan menunjukkan tren yang sama, dengan standar deviasi dan standar *error* sebesar 0.3368 and 0.1123. Kesalahan sistematik tersebut di kompensasi dengan cara kalibrasi antara *loadcell* alat uji tarik dengan rangkaian sistem akuisisi data berbasis Arduino Uno.

Kata Kunci: *load cell*, *logging time*, komposit bambu, akuisisi data, mesin uji tarik.

*Correspondence Author
email : dedeliazariatin@univpancasila.ac.id

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1. INTRODUCTION

A tensile test is one of the most widely used material tests in industries. It is used to determine mechanical properties, especially in manufacturing. In addition to the industrial world, tensile testing is also a part of educational laboratory facilities, which are very important in supporting the teaching and learning process in higher education, especially in mechanical engineering major. This tensile test is arguably an easy test to do, and many data can be obtained from it, including tensile strength, yield strength, elongation, elasticity, and area reduction (Elanchezhian *et al.*, 2018).

A tensile test is a method used to test the strength of a material by providing an axial force load (Arrizabalaga, Simmons and Nollert, 2017; Zheng *et al.*, 2020). The results obtained from tensile testing can be used to select materials, develop alloy materials, and design processes under various conditions. At first, many industries needed raw materials to make a product. To ensure the quality of the required raw materials and to determine whether the existing raw materials are suitable or not, a tensile test is carried out (Truong and Kim, 2021).

Tensile test machines can perform tests not only on metal but also on non-metallic materials (Zariatin, Kurniawan and Ikhsan, 2021; Singh *et al.*, 2014). Currently, material technology development is more focused on developing lighter non-metallic materials or composite materials, with maximum strength and good performance (Khalil *et al.*, 2012; Abedom *et al.*, 2021; Adriant *et al.*, 2019; Gellert, 2010; Getu *et al.*, 2021). Therefore, the development of these materials requires a test machine that is by the material's properties to be tested. Commercially, a tensile test machine is available for composite materials with low tensile loads, but the price is relatively high. To overcome this problem, a tensile test device with a load capacity of 2 kN used for testing composite materials has been developed (Kurniawan and Zariatin, 2019; Zariatin, Kurniawan and Ikhsan, 2021)., as shown in Figure 1.

The working principle of tensile test machines for composite materials is similar to those of tensile test machines in general, namely by applying a tensile force to the test material that has been gripped on the tool. In most of the commercial tensile test machines produce stress-strain graphs for prominent analysis and to understand the mechanical behavior of the material. However, the existing composite material tensile test machine has some shortcomings, such as the fact that the results only display the number of forces that occur during material testing. Therefore, it is necessary to develop a tensile test machine for the composite material so that the forces that occur when performing tensile testing can be recorded in more detail in the form of graphs and numbers, which in turn will make it possible for the results of material testing to be analyzed more accurate than the previous indicator.

Figure 1. Tensile test machine up to 2 kN capacity (Zariatin, Kurniawan and Ikhsan, 2021)

It is necessary to add an electronic device, including a microcontroller, to enable a graphical display to the tensile test machine. The microcontroller itself processes, communicates, and translates the data resulting from the tensile test machine (Pandiatmi *et al.*, 2017; Wiranata *et al.*, 2022). The microcontroller used is Arduino Uno, which will be connected to the load cell sensor on the tensile test machine and a computer as the output display of the test results.

This study aims to develop a prototype data acquisition system of a composite material tensile testing machine whose measurement results are displayed in the form of numbers and graphs to improve and simplify the data analysis.

2. METHODOLOGY

In developing the data acquisition system, there were research steps performed in the research. Figure 2 shows the flow chart of the research process.

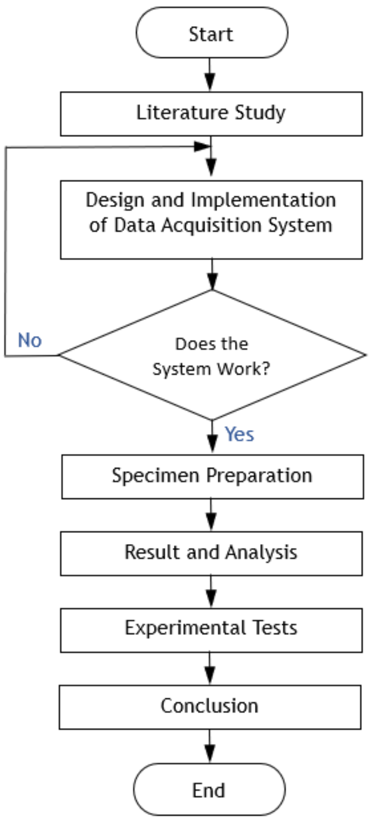

Figure 2. Research methodology

This research was started by collecting data for a literature study. The literature study aimed to identify the design requirement, problem, design limitation, and bench marking, as well as to prepare a research plan to be carried out. The first research plan was to collect existing research data. The data of this study was used as a comparison to the results of the tests to be carried out. The data observed included the development of the data acquisition system on the existing tensile testing machine and the materials to be tested.

The second research plan was to conduct a field survey to examine the fiber materials that would be used as tensile test specimens. The third research plan was to carry out the work processes, starting from developing the tensile test machine to making specimens from predetermined materials. The fourth research plan was to assess the test material and process the data. The fifth research plan was to draw the conclusions and suggestions of the research.

3. RESULTS AND DISCUSSION

3.1. The Design of Data Acquisition

The schematic diagram of data acquisition is shown in Figure 3, which consists of RTC module, Signal process and data logger, and a microSD card to store the data that connect to a PC. The PC monitor shows the data and the graphics of the test. Meanwhile, Figure 4 shows the circuit of Data Acquisition Control System implemented in the Developed Tensile Test Machine.

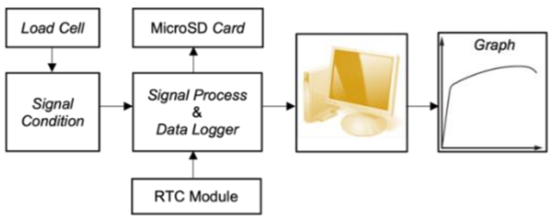

Figure 3. The schematic diagram of data acquisition

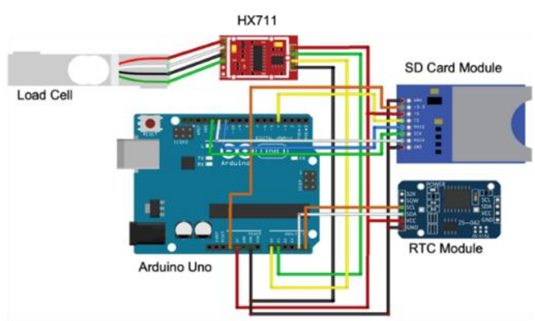

Figure 4. The circuit of data acquisition control system

The output signal generated in the load cell, which functions as a sensor to measure the force that occurs during tensile testing. The load cell used in this tensile test is type S with a maximum capacity of 2 kN. The result of the force measurement from the load cell is then sent into a signal condition through an ADC (Analog to Digital Converter) device, which functions to convert the measurement from analogue to digital so that it can be processed by a data processor. The type of ADC used is the Load Cell Amplifier HX711 module. The output of the signal condition then enters the signal process and the data logger in the form of an Arduino microcontroller which functions as a processor and translator of the data from the tensile test results into a computer device (see Figure 5). An SD card data logging module is also added to store the results of data processing. Then the data of the test results received by the computer is processed again so that the output is obtained in the form of a graph. Microsoft Excel and PLX - DAQ software are used in processing the tensile test data. PLX-DAQ or Parallax Data Acquisition software is a data logger or data acquisition add-on in Excel developed by Parallax.

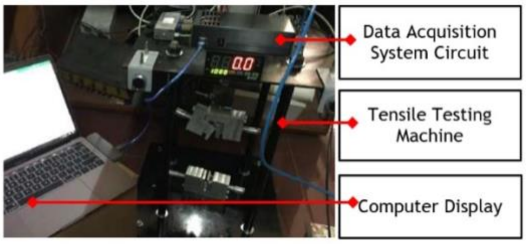

Figure 5. Developed data acquisition

3.2. Experiment Results

After the assembly of circuit data acquisition systems, further testing was carried out to determine whether the system could receive the data from the tensile test machine. The first step was to make a tensile test specimen using bamboo fiber composite material. The manufacture of tensile test specimens began with the preparation of the required materials and tools such as resins, catalysts, bamboo fibers, molds and cutting tools. The composition for the manufacture of this composite material is 10% bamboo fiber and 90% resin. The composite material was molded to a size of 200mm × 100mm × 2 mm. The finished bamboo fiber composite material was then cut to form a tensile test specimen according to the ASTM D638 standard size (ASTM, 2010) as shown in Figure 6 and Table 1.

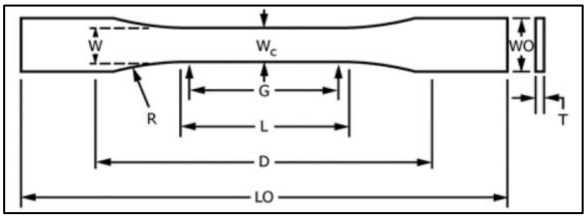

Figure 6. Tensile test specimen ASTM D638 (ASTM, 2010)

Table 1. The standard sizes for tensile test specimen ASTM D638 (ASTM, 2010)

Dimension	Size (mm)
W	13
L	57
WO	19
LO	165
G	50
D	115
R	76

Nine specimens were produced and tested using the tensile test machine. The data obtained from this tensile test acquisition system were Date, Time, Logging time, and Cell Load. The parameters that could be read by this circuit of data acquisition systems were the amount of load received during the tensile test (kg) and the test time (seconds). Data reading in this circuit was carried out approximately once every 0.4 seconds. Furthermore, the data was received by the Microsoft Excel program and processed so that a graph of the tensile test results was obtained.

The load data was generated from the loadcell. Then the data acquisition system calculated it into force value using the formula of $F = m \times g$ in which F is the force (N), m is the load received (kg), and g is the acceleration of gravity with a value of 9.81 (m/s^2). Then, the force value was converted to a tensile strength value using the formula $\sigma = F/A_0$ where σ is the value of the tensile strength (N/mm^2), F is the force (N), and A_0 is the initial cross-sectional area of the tensile test specimen (mm^2). The cross-sectional area itself was calculated using the formula $A_0 = l \times t$, where l is the width of the specimen (mm) and t is the thickness of the specimen (mm).

In this study, the value of $A_0 = 13\,mm\,x\,2\,mm =$ 26 mm^2. The conversion of the values on existing tool indicators used the formula $\sigma = F/A_0$ because the results obtained on the tool indicators were already in the force value (N).

The measurement and data calculation of the experiment are shown in Table 2, meanwhile Figure 7, Figure 8 and Figure 9 shows examples of the graphical display of testing result.

Table 2. The measurement and calculation result

Specimen	Data Acquisition System			Tool Indicators	
	Load (kg)	F (N)	σ (N/mm²)	F (N)	σ (N/mm2)
1	3.4	33.35	1.28	47.5	1.83
2	5.8	56.90	2.19	63.7	2.45
3	3.4	33.35	1.28	53.0	2.04
4	5.1	50.03	1.92	57.7	2.22
5	4.1	40.22	1.54	49.2	1.89
6	3.8	37.28	1.43	42.4	1.63
7	3.9	38.26	1.47	45.1	1.73
8	5.4	52.97	2.04	59.7	2.30
9	4.8	47.09	1.81	53.3	2.05
Avg		43.27	1.66	52.40	2.02

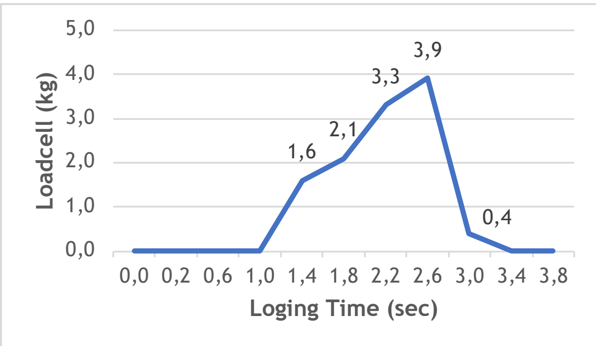

Figure 7. Graphical display of the 1st specimen

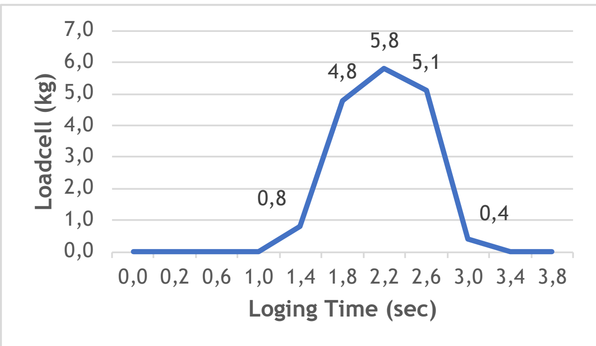

Figure 8. Graphical display of the 2nd specimen

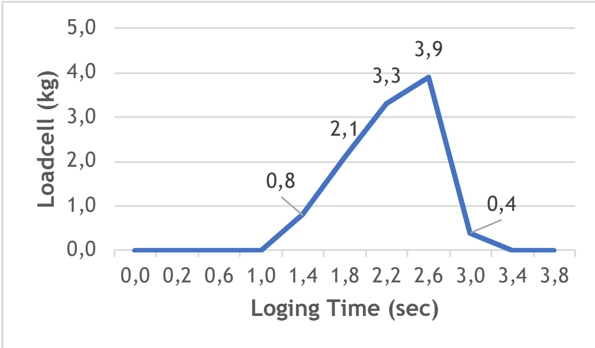

Figure 9. Graphical display of the 7th specimen

Table 2 shows two different data of tensile strength (σ, N/mm^2). The first tensile strength is calculated in the Data Acquisition System developed in this research, meanwhile the second tensile strength is obtained from the display indicator. In comparison of between tensile strength of Data Acquisition System and Indicator, the standard deviation value and the standard error was determined using the following equation (1) and (2) (Montgomery, 2019):

$$s = \sqrt{\frac{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_1)^2}{n(n-1)}} \quad (1)$$

$$SE = \frac{s}{\sqrt{n}} \quad (2)$$

s = Standard deviation
SE = Standard error
n = Sample
x_i = Value x to i

By calculating data of Table 3 using Eq 1 and Eq 2, the result of standard deviation and standard error for the Data Acquisition System is 0.3368 and 0.1123, respectively. Meanwhile, the standard deviation and standard error for Tool Indicator is 0.2724 and 0.0908, respectively.

From the results above, the percentage of the largest difference in tensile strength is on the third test, which is 37.25%, while the smallest difference is on the second test, which is 10.61%. The standard deviation value for the data acquisition system is 0.3368 and the standard error is 0.1123.

Table 3. Calculation of standard deviation and standard error

Specimen	Data Acquisition System		Tool Indicators	
	σ (N/mm²) x_i	x_i^2	σ (N/mm²) x_i	x_i^2
1	1.28	1.64	1.83	3.35
2	2.19	4.80	2.45	6.00
3	1.28	1.64	2.04	4.16
4	1.92	3.69	2.22	4.93
5	1.54	2.37	1.89	3.57
6	1.43	2.04	1.63	2.66
7	1.47	2.16	1.73	2.99
8	2.04	4.16	2.30	5.29
9	1.81	3.28	2.05	4.20
Sum Σ	14.96	25.77	18.14	37.16
s	0.3368		0.2724	
SE	0.1123		0.0908	

The indicators deviation value for the instrument indicator is 0.2724 and the standard error is 0.0908. This is a systematic error because from the three experiments that have been carried out above, the results obtained from the data acquisition system and the indicators on the tool are the same. The way to overcome this is by calibrating the load cell of the tensile test machine with a series of data acquisition systems that are compensated on the Arduino. Calibration was also carried out to determine the accuracy of the load cell itself. Calibration can be done by placing some load on the load cell and checking the amount of voltage (volts) received, so that a graph between load and voltage (volts) is obtained. From the graph, the trend line, and the confider value (R2) will be obtained to determine the accuracy of the load cell.

As for the calibration between the load cell and the program, it is necessary to find the calibration factor value which is then entered into the Arduino IDE program. The calibration factor is found by placing a load on the load cell and observing whether the given load and the results displayed are the same or not. If they are not the same, then it is necessary to change the value of the calibration factor by adding or subtracting it - depending on the reading results - until the weight value given is the same as that displayed.

The results obtained from the data acquisition system and the indicators on the trend tool are the same because the data acquisition system will read the received voltage and convert it into weight, like in the indicator. In addition, by using an Arduino-based data acquisition system, we can record the results of testing numerical and graphic data, so that a data acquisition system using an Arduino base for tensile test machine can be used.

4. CONCLUSION

The prototype of the data acquisition system of the tensile test machine for composite materials developed using the Arduino Uno microcontroller by adding the HX711 module to convert the load cell results from analogue signals to digital signals so that the data can be processed in the form of numbers and graphs using Microsoft Excel and PLX-DAQ software.

There are still some differences found between the prototype of the data acquisition system and the indicators of the existing tools. The biggest difference is 37.25% and the smallest one is 10.65%. The standard deviation and standard error for the Data Acquisition System is 0.3368 and 0.1123, respectively. Meanwhile, the standard deviation and standard error for Tool Indicator is 0.2724 and 0.0908, respectively. These differences indicate that it is still necessary to calibrate the load cell with a series of data acquisition systems to determine the accuracy of the load cell and the calibration factor used in the Arduino IDE program.

The analysis of the graph of the results from the data acquisition system test can still be developed because the graph displayed is still in the form of voltage per time. This provides further research opportunities.

REFERENCES

Abedom, F. *et al.* (2021) 'Development of Natural Fiber Hybrid Composites Using Sugarcane Bagasse and Bamboo Charcoal for Automotive Thermal Insulation Materials', *Advances in Materials Science and Engineering*, 2021, p. e2508840.

Adriant, Z. *et al*. (2019) 'The Effect of Mesh Size on Mechanical and Thermal Properties of Bamboo Composites', *JEMMME (Journal of Energy, Mechanical, Material, and Manufacturing Engineering)*, 4(2), pp. 63–72.

Arrizabalaga, J.H., Simmons, A.D. and Nollert, M.U. (2017) 'Fabrication of an Economical Arduino-Based Uniaxial Tensile Tester', *Journal of Chemical Education*, 94(4), pp. 530–533.

ASTM (2010) 'Standard Test Method for Tensile Properties of Plastics'. ASTM International [Print].

Elanchezhian, C. *et al*. (2018) 'Review on mechanical properties of natural fiber composites.', in *Materials Today: Proceedings. International Conference on Processing of Materials, Minerals and Energy*, India: Elsevier, pp. 1785–1790.

Gellert, R. (2010) '8 - Inorganic mineral materials for insulation in buildings', in M.R. Hall (ed.) *Materials for Energy Efficiency and Thermal Comfort in Buildings*. Woodhead Publishing (Woodhead Publishing Series in Energy), pp. 193–228.

Getu, D. *et al*. (2021) 'Production and characterization of bamboo and sisal fiber reinforced hybrid composite for interior automotive body application', in *Materials Today: Proceedings. International Conference & Exposition on Mechanical, Material and Manufacturing Technology (ICE3MT)*, India: Elsevier, pp. 2853–2860.

Khalil, H.P.S.A. *et al*. (2012) 'Bamboo fibre reinforced biocomposites: A review', *Materials & Design*, 42, pp. 353–368.

Kurniawan, R.M. and Zariatin, D.L. (2019) 'Perancangan Alat Uji Tarik Dengan Beban 2000 N Untuk Pengujian Material Komposit Alami', in *Prosiding Seminar Rekayasa Teknologi (SemResTek) 2019. Seminar Rekayasa Teknologi (SemResTek) 2019*, Indonesia: Fakultas Teknik Universitas Pancasila, pp. 351–360.

Montgomery, D.C. (2019) *Design and Analysis of Experiments*. 10th edn. USA: John Wiley & Sons Inc. [Print].

Pandiatmi, P. *et al*. (2017) 'Pembuatan mesin uji tarik kapasitas kecil: bagian data akuisisi', *Dinamika Teknik Mesin*, 7(1), pp. 45–49.

Singh, S. *et al*. (2014) 'Tensile and Flexural Behavior of Hemp Fiber Reinforced Virgin-recycled HDPE Matrix Composites', in *Procedia Materials Science. 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014)*, India: Elsevier, pp. 1696–1702.

Truong, V.D. and Kim, D.J. (2021) 'A review paper on direct tensile behavior and test methods of textile reinforced cementitious composites', *Composite Structures*, 263, p. 113661.

Wiranata, A. *et al*. (2022) 'Electromechanical tensile test equipment for stretchable conductive materials', *HardwareX*, 11, p. e00287.

Zariatin, D.L., Kurniawan, R.M. and Ikhsan, N. (2021) 'Pengembangan alat uji tarik dengan beban maksimal 2 kN', *Dinamika Teknik Mesin*, 11(2), pp. 96–106.

Zheng, P. *et al*. (2020) 'On the standards and practices for miniaturized tensile test – A review', *Fusion Engineering and Design*, 161, p. 112006.