KONGSBERG

Tensile test report of polylactic acid (PLA)

Kromium

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Campus Kongsberg

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Testers::

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Abbreviations

PLA Polylactic acid. 8, 10

UTS Ultimate tensile strength. 10, 13, 17, 19

Description of Terms

3D printer A machine where a thread of plastic is moved through and heated up by a nozzle that melts and places it layer by layer to create a part. 10

ultimate tensile strength The end of plastic deformation region and the maximum stress a material can take. 8

yield strength The point where a material goes from elastic to plastic deformation. 8

Young's modulus Also known as E-modulus or E-module, is the measurement of the stiffness of a material when a tensile or compressive force is applied lengthwise. 8

Introduction

This test is performed as part of the 2024 bachelor project Kromium[1]. This test aims to extract necessary material data for use in custom material in SolidWorks for the project. The material in question is the Polylactic acid (PLA) supplied by the company Clas Ohlson. This material has a good shelf life even if stored exposed to open air, and becomes good quality prints with little effort. The material has no datasheet containing information regarding yield strength, Young's modulus and ultimate tensile strength which is what we need to gather from this test.

1 Standards

These are the standards we have followed when performing the tests. In the second test the there is a deviation from the test specimen specified in ISO-527-2-2012

ISO-5425-2023: Specifications for use of poly(lactic acid) based filament in additive manufacturing applications[2]

ISO-527-1-2012: Determination of tensile properties Part 1:General principles[3]

ISO-527-2-2012: Determination of tensile properties Part 2:Test conditions for moulding and extrusion plastics[4]

2 Test equipment

The equipment used in this test:

- 3D-printer: Ender-3 v2
- Tensile test machine: LLOYD LR 10K
- Computer with test-software

2.1 Ender-3 v2 **HB** | *AEH*

The Ender-3 v2 is a 3D printer that has an exposed printing surface. This means that the environment of the print is the same as in the room the printer is placed in. This can affect the print, if the printer is placed in a poor environment. Fortunately, normal room temperature (around 20 degrees Celsius) and normal indoor air moisture are good enough for simple prints, with a simple filament type such as PLA.

2.2 LLOYD LR 10K **HB** | *AEH*

The LLOYD LR 10K is a tensile testing machine with a maximum load capacity of 10.0 kN and a speed range of 0.1 to 500 mm per minute. [5] The machine is fitted with wedge grippers to fasten the test piece, increasing clamping force as more force is applied in the stretching direction. The disadvantage with the wedge grippers is at the start of the tensile test, the test piece can slip if it is not fitted correctly and/or the test piece consists of a material that has a low friction coefficient. To increase the friction between the test piece and the wedge grip, the surface of the jaw insert of the wedge grips has a serrated surface.

2.3 Computer with test-software **HB** | *AEH*

The LLOYD LR 10K is operated using software from an external computer. This program is by the time of this test newly developed by one of the students at the university. Although faults may lie in the program, it has been approved by the professors and the results gathered seem logical.
Before a test can be carried out, some steps must be completed. The first step is to link the test file to a folder on the computer. Then some information needs to be put into the software. These values are the length between the crossheads, the thickness, and the width of the test specimen.

While the test is carried out the software plots the stress-strain curve in real time. This is great for monitoring for faults during the test. After a test has been carried out, some more steps need to be completed. These steps are to double-check that the automatically generated points, such as Ultimate tensile strength (UTS), fracture, and the proportional limit are correct. In addition, you have to choose if some of the test data needs to be adjusted. These adjustments are in cases where the start point is wrong and the machine moves a distance before putting a load on the specimen. In these cases, the zero point can be moved so that the elongation is correct.
After the adjustments are made the calculate button can be pushed and the results will be displayed. If you want to keep the results, press save. Now the data will be transferred

to an Excel document, and the raw file itself will also be saved inside the folder to which you assigned the test file.

3 Tensile test T1

3.1 Preparations

AEH | *HB*

Following ISO standard 527-1 section 7.1, the mean value should be calculated from at least five test specimens and the results should not differ from the mean value by more than 20%. We produced seven test pieces to have extra in case we encountered problems during the test. The dimensions of the test pieces can be found in appendix A.1. The Test pieces were 3D-printed with the following settings:

Settings	Used
Orientation	Flat
Nozzle	0.4 mm brass
Layer height	0.2 mm
Walls	3
Infill	100 %
Nozzle temperature	220°C
Bed temperature	60°C
Printing speed	60 mm/s

Table 3.1: Test T1 specimen manufacturing settings for Ender-3 V2.

Figure 3.1: Test specimen

3.2 Test

HB | *AEH*

The tests were performed in a room at 24 degrees Celsius.
We started by turning on the tensile testing machine and the computer connected to the machine. Then we had to find out how to use the program, due to new software on the computer with a completely different interface, than the program that we learned to use this machine on. Luckily the person who made the software had made a couple of video tutorials, but it still took some time to understand everything. So we ended up watching the tutorial and doing the first test together, step by step.

Before we started the tests, we made a new folder on the computer. This was to keep track of our test results, and easier to transfer the data to our storage device, for later review of the test results. Then we assigned the first test file to this folder and filled in the different required data for executing the test. Then we inserted the first test piece into the tensile testing machine and started the test. Because this was the first test piece, we struggled a bit to make the test piece attach itself properly. The machine moved almost 4mm before the clamps started to get a grip on the test piece. Then we selected the data we wanted and saved the results into the folder. The same happened to many of the other pieces as well, the worst one was test piece T1-4 where we failed to get a grip, and the test had to be restarted.

The test consisted of seven seemingly equal test pieces. This is also visible on the stress-strain curve, where the point of UTS and the fracture were very similar in every test. The biggest difference in the tests was the start. On several of the tests, it is visible on the stress-strain curve that the tensile testing machine was struggling to get a proper grip on the test pieces. There were only two exceptions, test pieces T1-2 and T1-7. These test pieces got a grip almost instantly.

We tested them one by one and the test program then logged the results automatically into the program. Then we adjusted some of the automatically generated points and discarded some of the start on the stress-strain curve. The amount discarded was very varying, due to some human errors during the testing. The different errors and other things that may have affected the result of the tests are written about in the Deviations chapter.

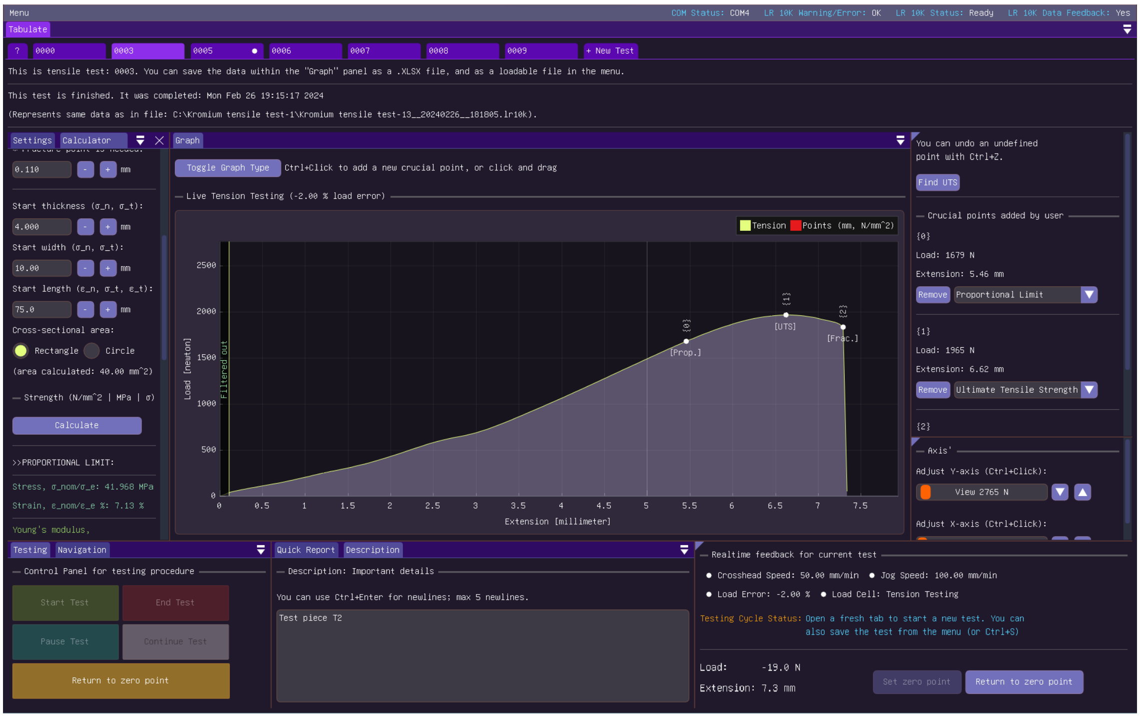


Figure 3.2: Screenshot of the software interface after a test

3.3 Results **HB** | *AEH*

In the picture below is the fractured test specimen. Below the test specimen is a table containing the main relevant values from each test. The rest of the test data can be found in appendix B. If you look closely at the fracture points of the test specimen and compare them to the test values below, there is a pattern. Test specimens T1-2 and T1-7 are the only ones that had a straight fracture point, these were the only two test pieces that did not slip during the testing. It is also visible on Young's modulus which specimen slipped, these values are higher than the ones that did not slip. The more the pieces slipped, the higher the Young's modulus became. It is important to note that Young's modulus for the test specimen is only an approximation because polymers do not have one consistent Young's modulus like metals. Instead, the module changes depending on where you look at it. This is because the thermoplastic polymer chains don't behave the same way as atoms in metal. When the thermoplastics are exposed to forces still in the stress-strain curve's elastic region, the polymer chains untangle themselves stretch parallel to the applied force and become anisotropic.

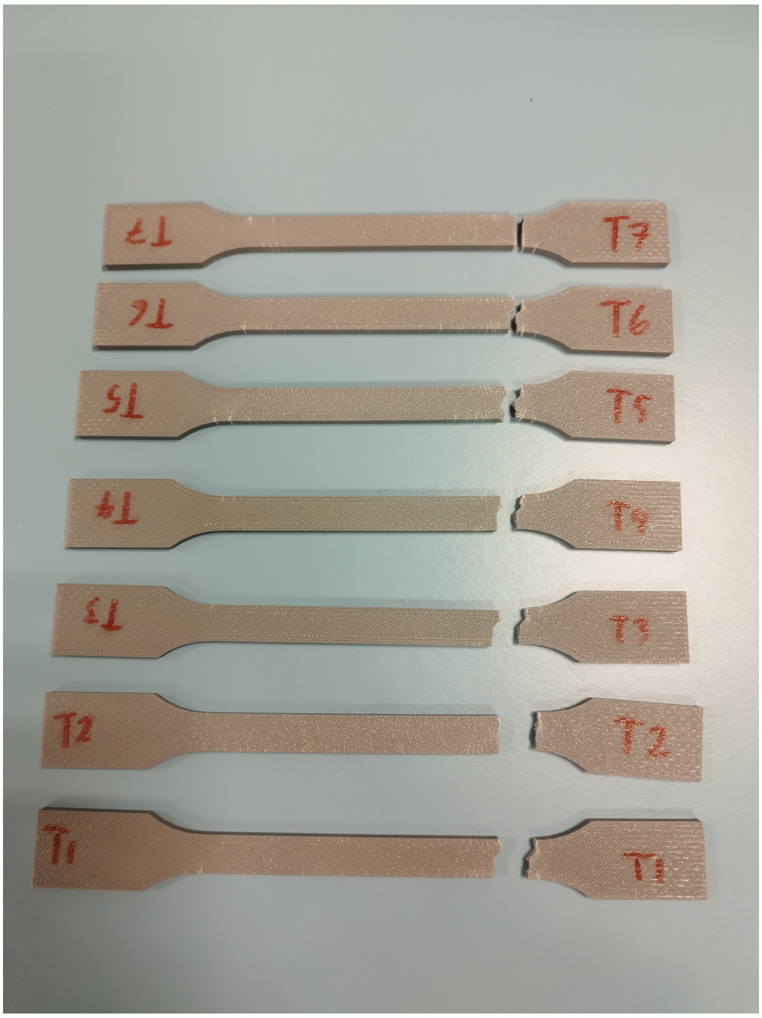


Figure 3.3: The fractured test specimens

Tensile test T1 (true stress) (MPa [N/mm^2])									
Test:	**T1-1**	**T1-2**	**T1-3**	**T1-4**	**T1-5**	**T1-6**	**T1-7**	**Median**	**Mean**
Ultimate tensile strength	50,401	53,390	50,214	49,704	49,860	50,373	49,960	**50,214**	**50,557**
Fracture:	47,337	50,203	48,363	47,928	46,764	47,170	47,447	**47,447**	**47,887**
Young's modulus:	696,489	588,563	684,626	737,726	879,383	923,334	572,496	**696,489**	**726,088**

Table 3.2: The tensile testing results of PLA. Colour-coded if the test is valid or if it failed.

3.4 Deviations **AEH** | *HB*

From the results we found that five out of seven test pieces were invalid, however, some of the results are. The valid results are the UTS and fracture values, while the invalid results are Young's modulus. The reason the UTS and fracture values are valid results is that these values are calculated from the amount of applied stress (Newton) over the cross-section area (millimetres). Young's modulus results are not valid because these are calculated with the use of elongation in the direction of applied force. The invalid test pieces were slipping during the testing, which led to an inaccurate elongation reading, this can be observed on the stress-strain curve shown below.

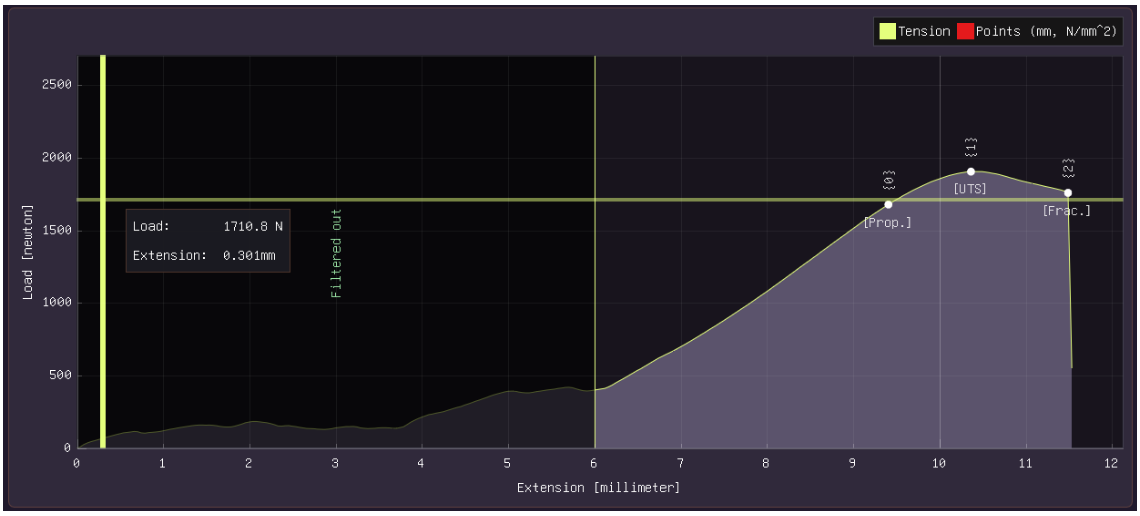


Figure 3.4: An inaccurate test result, due to improper attachment

As seen on the graph, there is a lot of movement (6mm) before the load increases with a significant value. And the Young's modulus for this test piece is becoming very inaccurate. Evidence of this is the failed first try of test T1-4 as well as the lines on five out of seven test pieces. These lines as shown below are a result of the grip slipping before getting a hold.

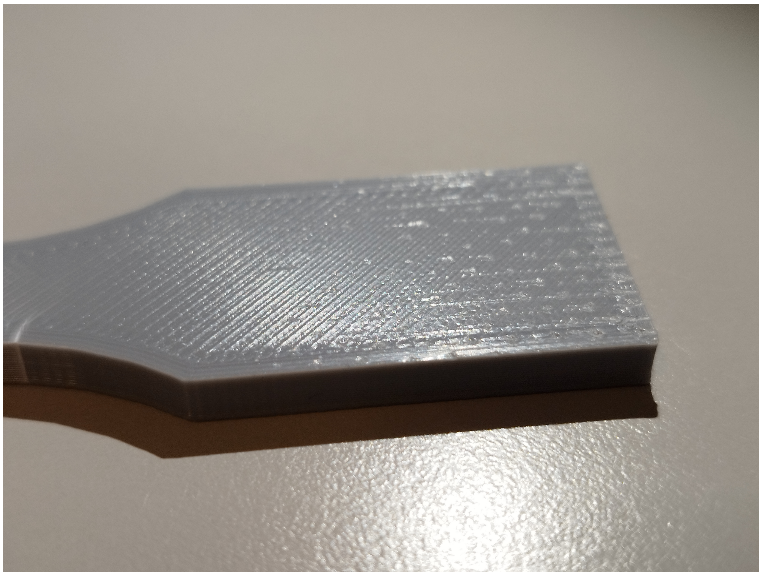


Figure 3.5: Evidence of scraping

All the test pieces broke outside the gauge length area. The reason for this is likely because of the production method, all the pieces break in the same area which is the start of the radius where the width expands. As we can see in the picture the radius is made up of many straight lines that create edges where the tension will accumulate.

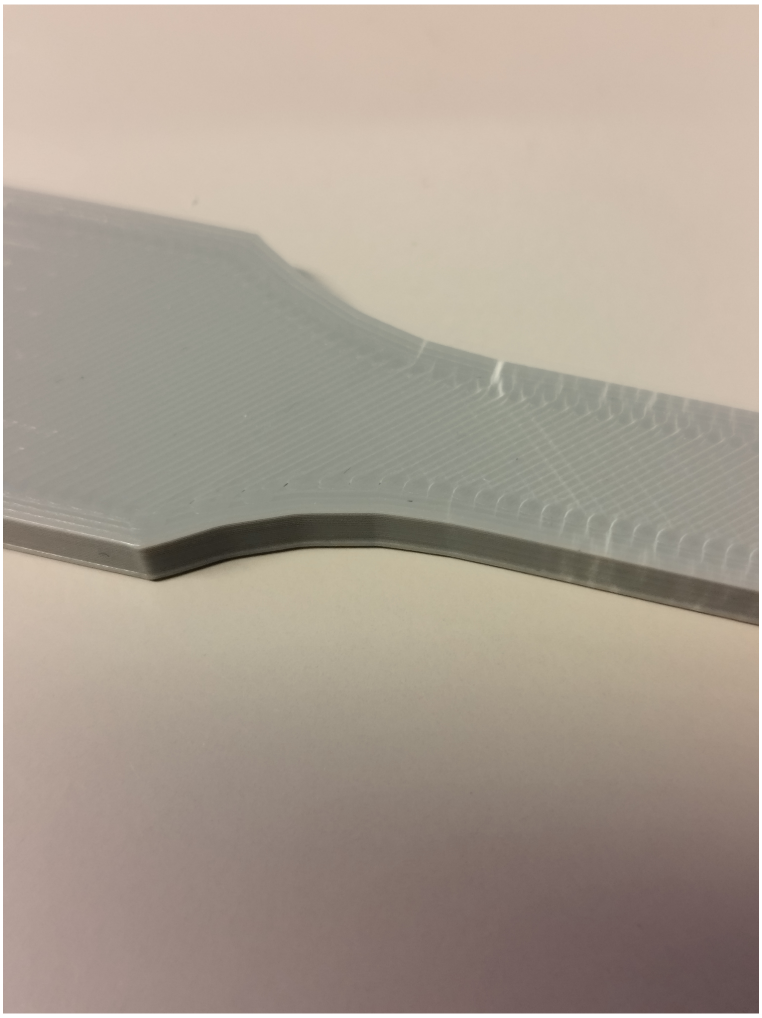


Figure 3.6: Corners on the radius

3.5 Conclusion **HB** | *AEH*

The reason we choose to believe that the UTS and fracture values are somewhat correct, is because the values from test T1-2 are at the higher end of the results, while the values from test T1-7 are at the lower end of the scale. This indicates that the values for UTS and fracture for the other test pieces are within range of what they would be if they didn't slip during the testing.

Because only two of the tests can be defined as valid tests due to slipping, we will not be able to use the values we got for a material specification in Solid Works. However, the test results that are categorized as valid give us a good indication of an approximate value. But our team want to have as accurate values as possible, so a new test will be carried out later on.

4 Tensile test T2

4.1 Preparations

AEH | *HB*

Since the deviations from the first test showed an indication of scraping, we chose to go for the university's test specimen design which can be found in appendix A.2. These test specimens are designed so that the ends can be secured properly within a holder. For this test, we produced eight test specimens. The settings for manufacturing the test specimen can be found in the table below.

Settings	Used
Orientation	Flat
Nozzle	0.4 mm brass
Layer height	0.2 mm
Walls	3
Infill	100 %
Nozzle temperature	220°C
Bed temperature	60°C
Printing speed	60 mm/s

Table 4.1: Test T2 specimen manufacturing settings for Ender-3 V2.

4.2 Test

AEH | *HB*

Each specimen test was performed following the same steps as discussed in 3.2 except the way that they were fastened. For this test, the specimens were secured by putting the holders shown below, on both ends and then placing them in the test machine.

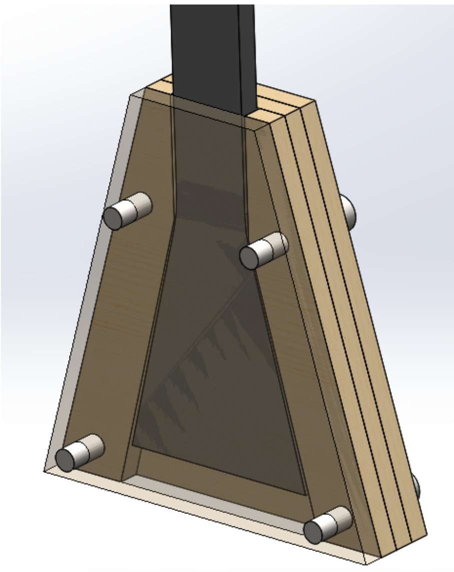


Figure 4.1: The test specimen put into a holder

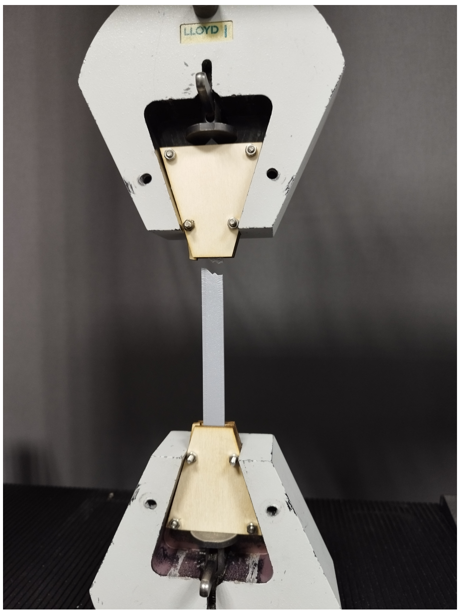


Figure 4.2: Test specimen placed in test machine

4.3 Results

AEH | *HB*

The tables below contain the main interest data. The rest of the collected data can be found in appendix C.

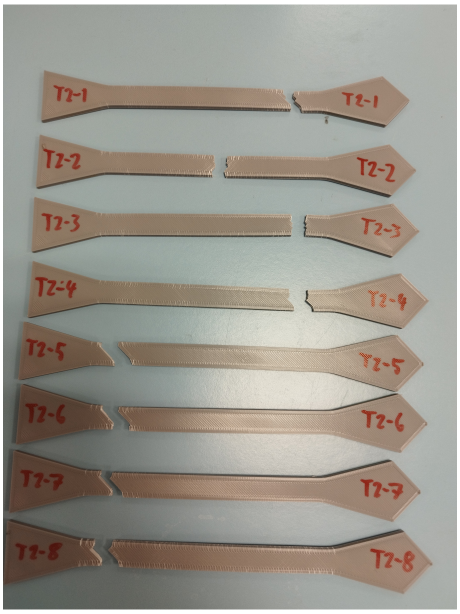


Figure 4.3: The test specimen after the test

Tensile test T2 (true stress) (MPa [N/mm^2])										
Test:	**T2-1**	**T2-2**	**T2-3**	**T2-4**	**T2-5**	**T2-6**	**T2-7**	**T2-8**	**Median**	**Mean**
Young's modulus	646,790	594,052	660,158	866,162	668,935	762,796	597,099	632,418	**653,474**	**678,551**
Yielding (lower)	35,004	32,884	40,930	35,658	30,983	31,205	35,576	42,666	**35,290**	**35,613**
Ultimate tensile strength	51,077	48,858	50,606	45,951	46,864	47,387	46,912	50,307	**48,123**	**48,495**
Fracture	47,800	45,736	47,806	43,176	43,711	42,506	45,370	45,646	**45,508**	**45,219**

Table 4.2: Table containing results of true stress from all tests as well as median and mean values. Red values deviate from the mean value by more than 20%.

Tensile test T2 (true stress) (MPa [N/mm^2])									
Test:	**T2-1**	**T2-2**	**T2-3**	**T2-5**	**T2-6**	**T2-7**	**T2-8**	**Median**	**Mean**
Young's modulus	646,790	594,052	660,158	668,935	762,796	597,099	632,418	**646,790**	**651,750**
Yielding (lower)	35,004	32,884	40,930	30,983	31,205	35,576	42,666	**35,004**	**35,607**
Ultimate tensile strength	51,077	48,858	50,606	46,864	47,387	46,912	50,307	**48,858**	**48,859**
Fracture	47,800	45,736	47,806	43,711	42,506	45,370	45,646	**45,646**	**45,511**

Table 4.3: Table containing results of true stress from the valid tests as well as median and mean values.

4.4 Deviations **AEH** | *HB*

Small defects and deviations will occur during manufacturing and because of this, we can see that the test pieces break at different areas of the cross-section and different loads.
The test T2-4 has Young's modulus over 20% higher than the mean of the tests and is therefore excluded from the final calculation.
Other possible deviations may come from variations in the zero point, proportional limit and yield strength points, and wrong readings from the machine sensors.

4.5 Conclusion **AEH** | *HB*

There were performed eight tests this time with a new design that properly secured the ends and prevented slipping. As a result, seven out of the eight tests were usable and gave us a proper estimate of the material strength properties.

5 References

[1] Kromium. Kromium website. [Online]. Available: https://itfag.usn.no/grupper/D03-24/

[2] International Organization for Standardization. ISO 5425:2023. [Online]. Available: https://www.iso.org/standard/81238.html

[3] ——. ISO 527-1:2019. [Online]. Available: https://www.iso.org/standard/75824.html

[4] ——. ISO 527-2:2012. [Online]. Available: https://www.iso.org/standard/56046.html

[5] Lloyd LR10k tensile machine. [Online]. Available: https://www.tts-ltd.co.uk/lloyd-lr10k-tensile-machine

A Technical drawings

A.1 Tensile test piece ISO 527

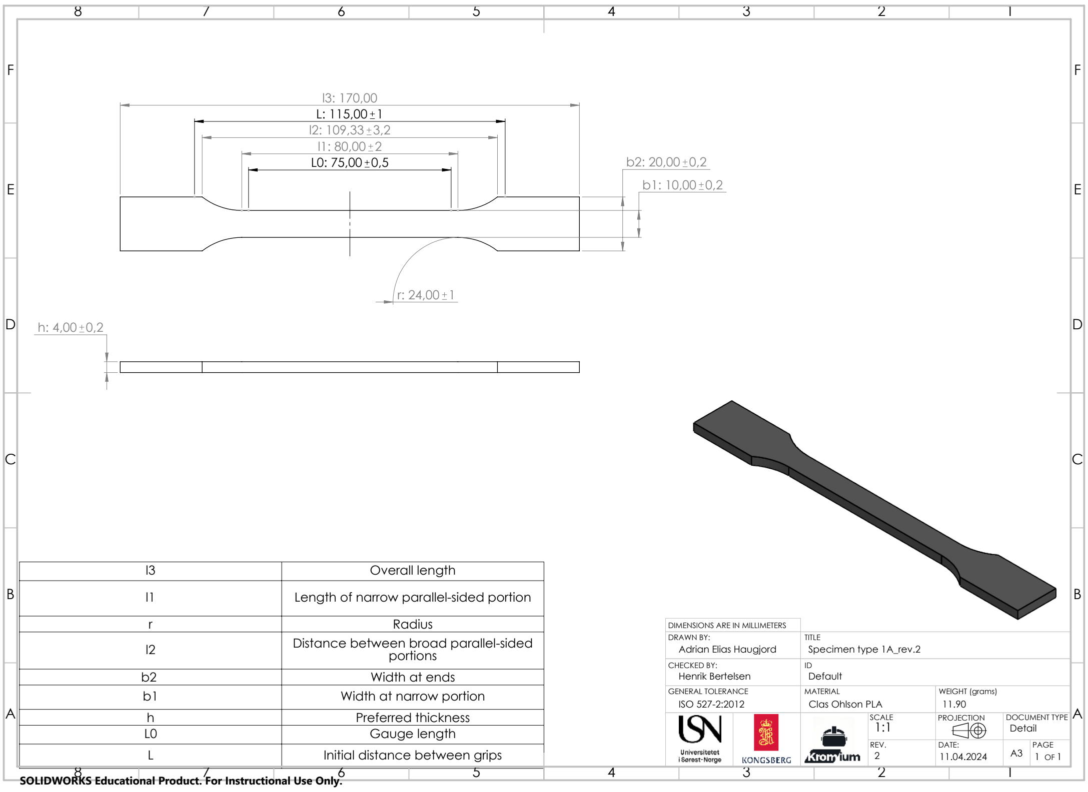


Figure A.1: Tensile test specimen type A dimensions technical drawing

A.2 Tensile test piece USN Kongsberg

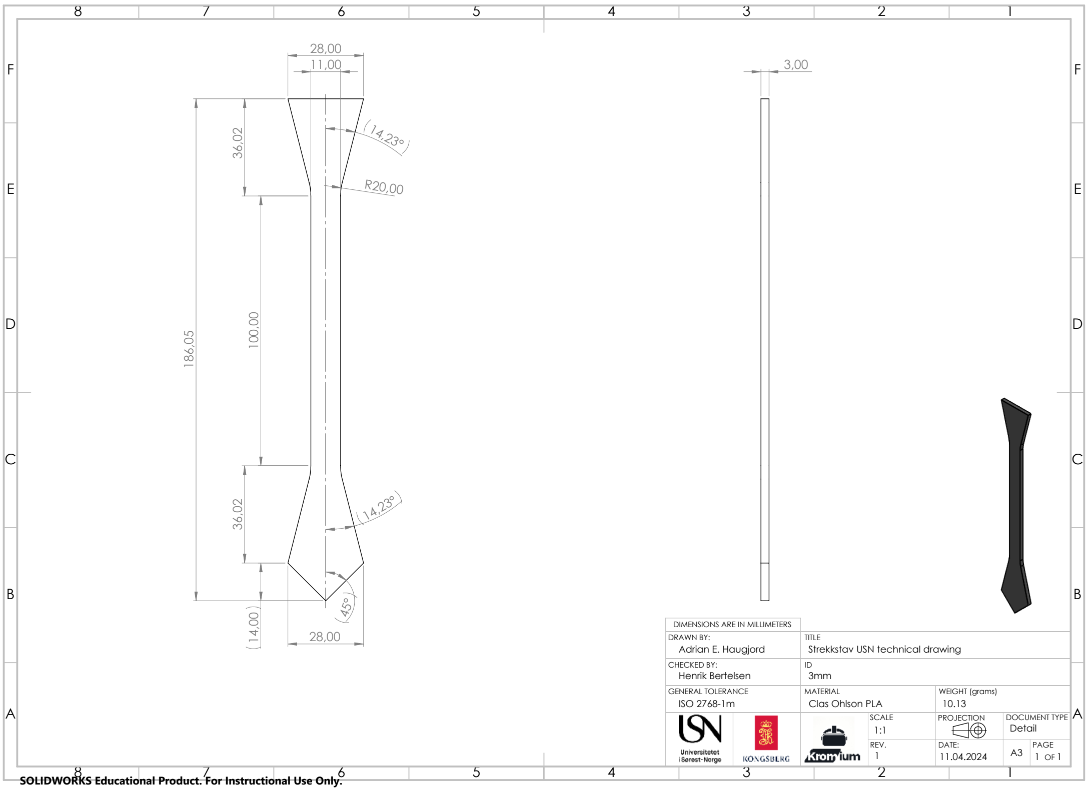


Figure A.2: Tensile test specimen used at USN Kongsberg

B Results test T1

B.1 Results T1-1

MATERIAL TESTING REPORT

Mon Feb 26 18:58:48 2024

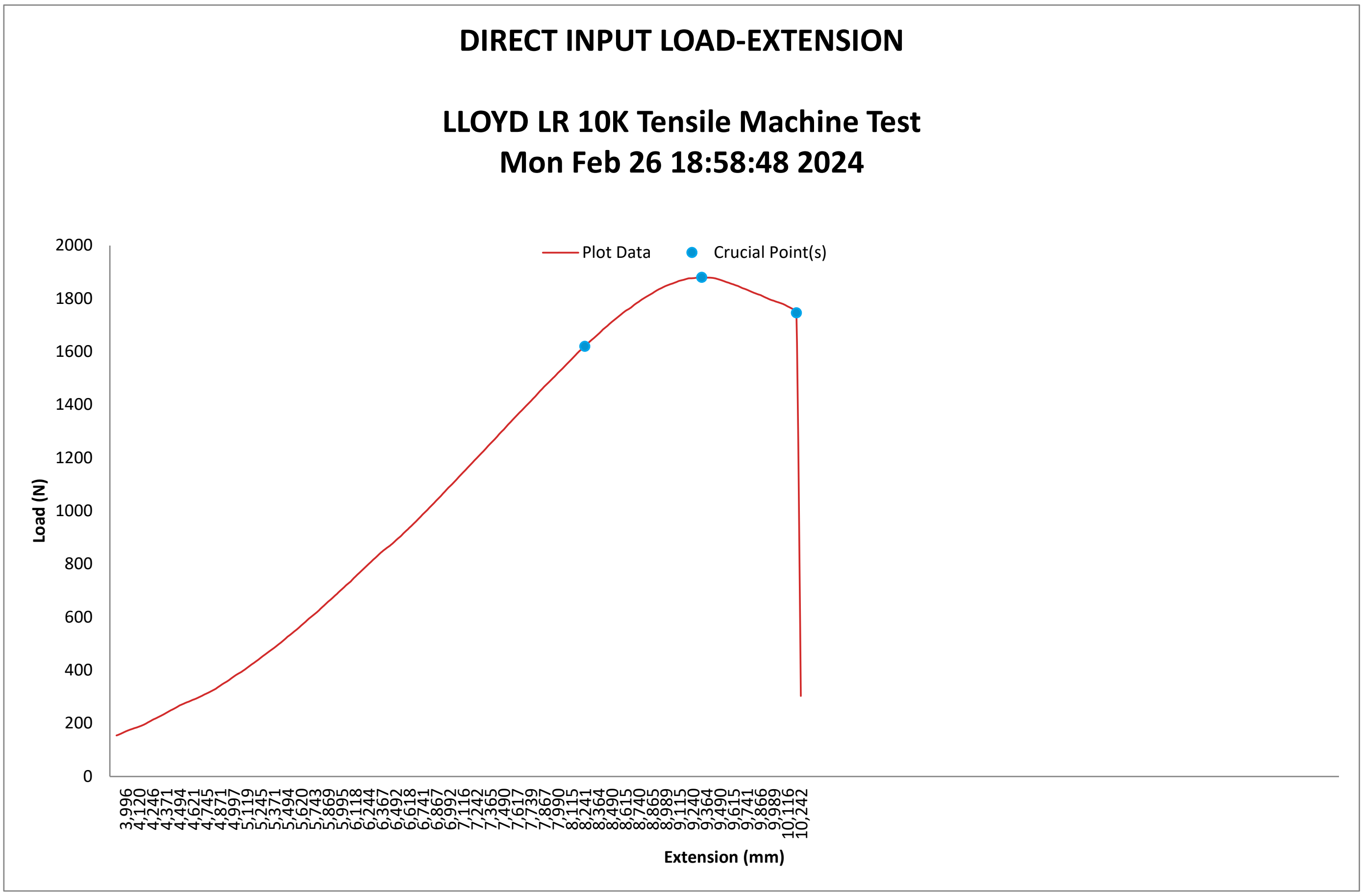
Details:	Test piece T1-1	
Material Properties:		
Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm
Proportional limit:		
Nominal Stress, σ_nom/σ_e (S_y)	**40,498**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,81%**	
Young's modulus, E	**696,489**	MPa [N/mm^2]
True Stress, σ_t	**42,853**	MPa [N/mm^2]
True Strain, ε_t	**5,65%**	
Yielding (lower):		
Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	
Ultimate Tensile Strength:		
Nominal Stress, σ_nom/σ_e (S_ut)	**46,991**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,26%**	
True Stress, σ_t	**50,401**	MPa [N/mm^2]
True Strain, ε_t	**7,00%**	
Fracture:		
Nominal Stress, σ_nom/σ_e (S_y)	**43,659**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,43%**	
True Stress, σ_t	**47,337**	MPa [N/mm^2]
True Strain, ε_t	**8,09%**	

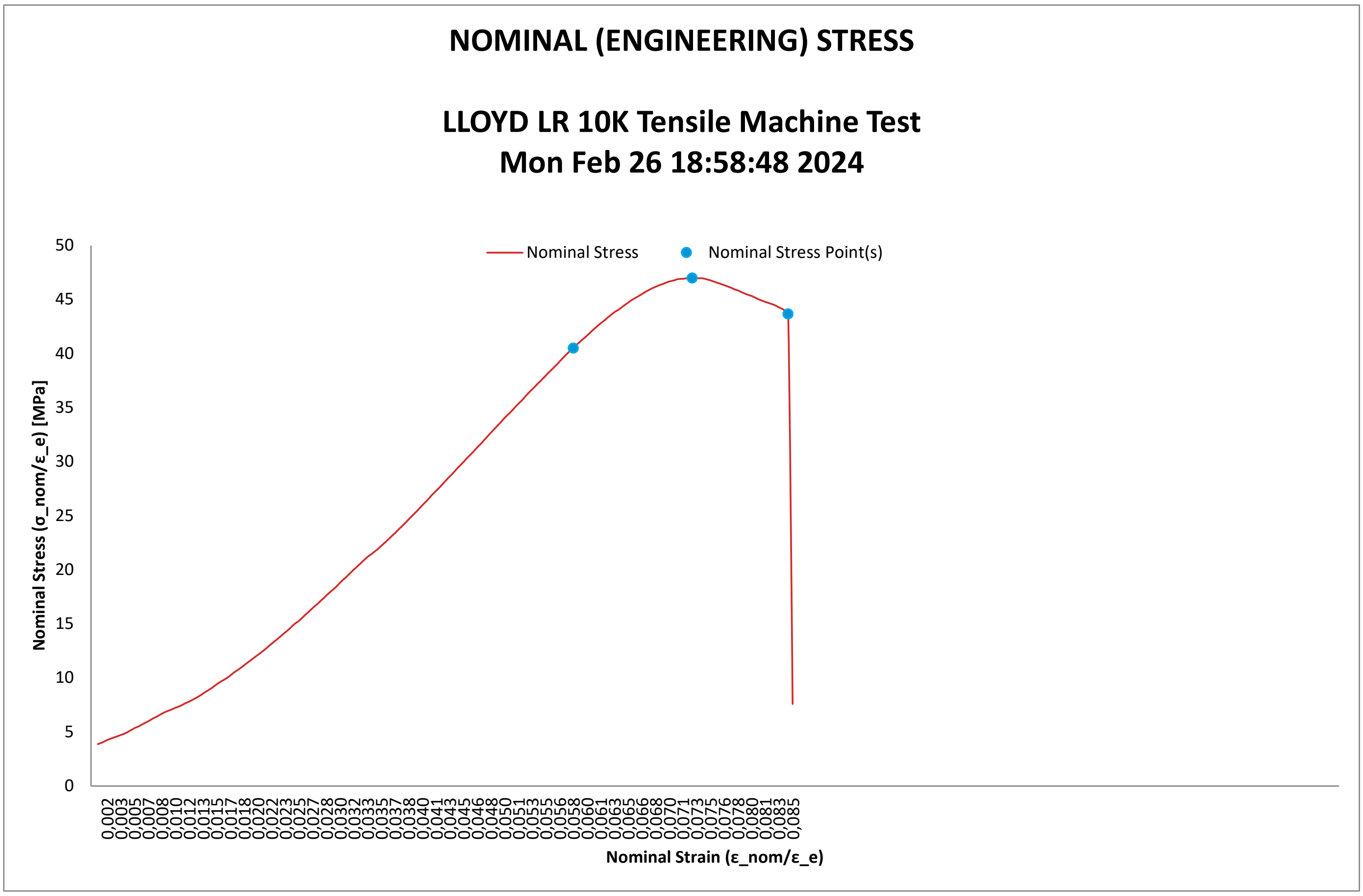
LR 10K Tensile Machine Settings

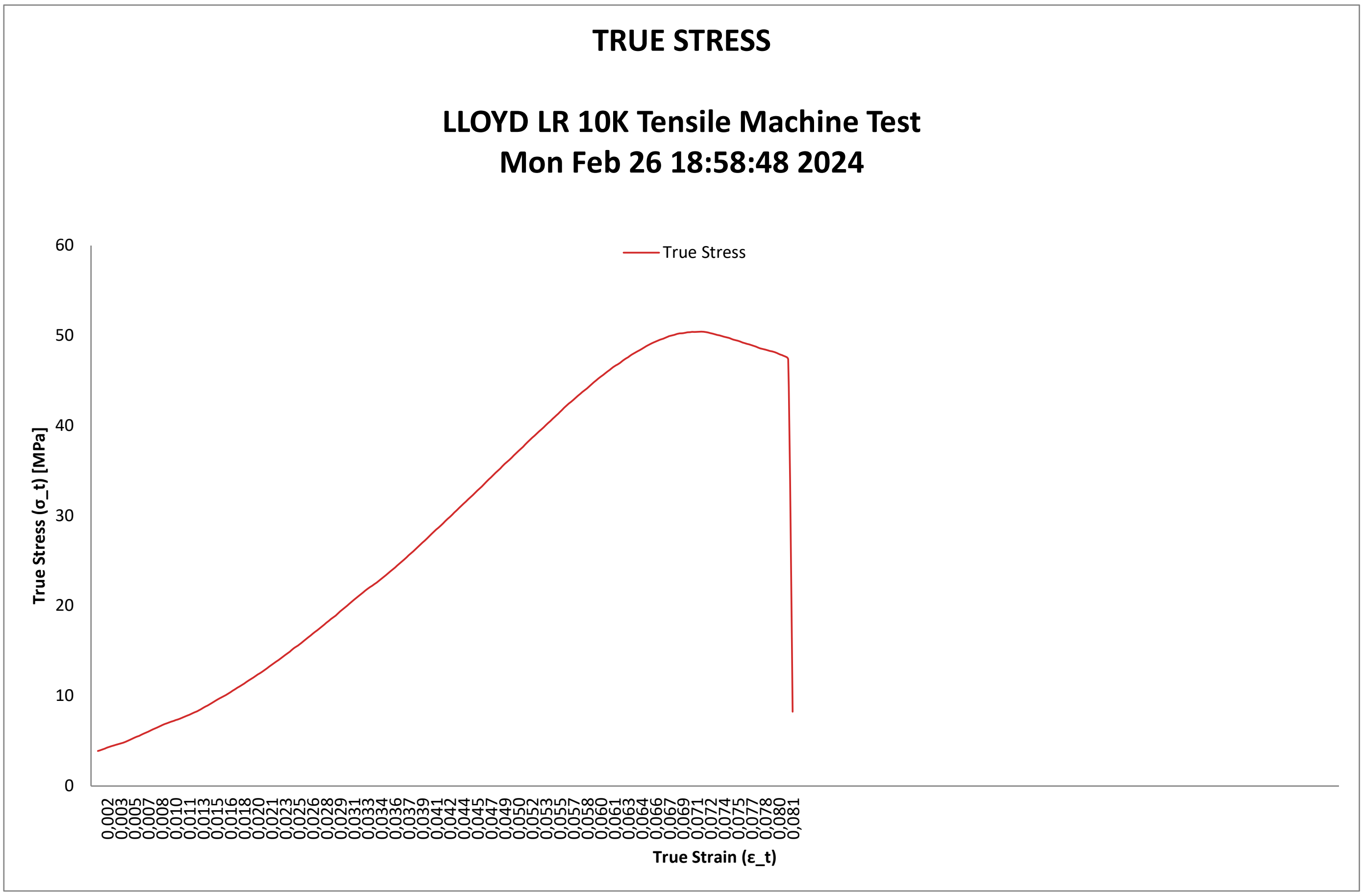
Mon Feb 26 18:58:48 2024

Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 18:58:48 2024
Plot Data
Crucial Point(s)
Load (N)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
3,996 4,120 4,246 4,371 4,494 4,621 4,745 4,871 4,997 5,119 5,245 5,371 5,494 5,620 5,743 5,869 5,995 6,118 6,244 6,367 6,492 6,618 6,741 6,867 6,992 7,116 7,242 7,365 7,490 7,617 7,739 7,867 7,990 8,115 8,241 8,364 8,490 8,615 8,740 8,865 8,989 9,115 9,240 9,364 9,490 9,615 9,741 9,866 9,989 10,116 10,242
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 18:58:48 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 18:58:48 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60

B.2 Results T1-2

MATERIAL TESTING REPORT

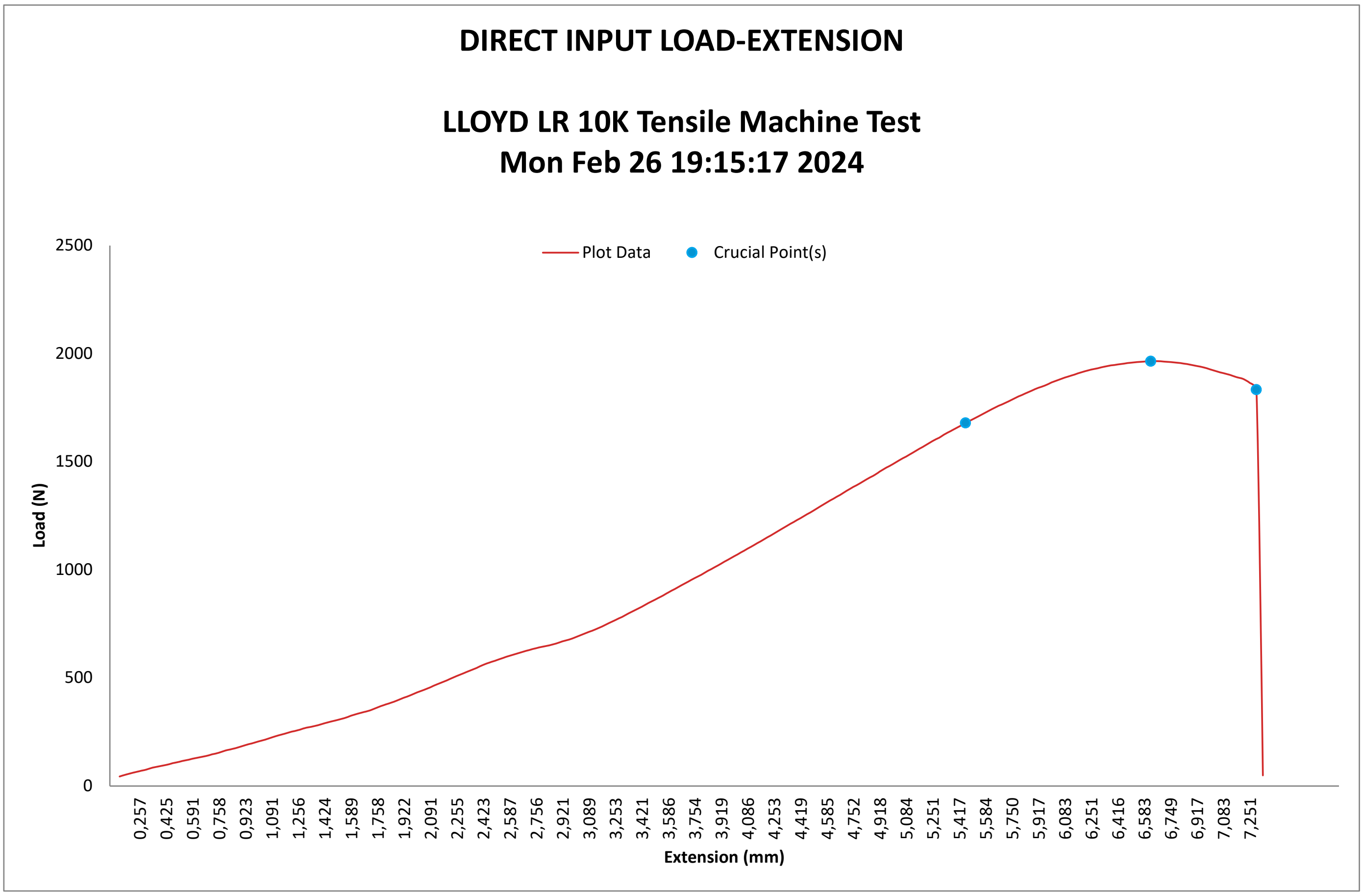
Mon Feb 26 19:15:17 2024		
Details:	Test piece T1-2	
Material Properties:		
Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm
Proportional limit:		
Nominal Stress, σ_nom/σ_e (S_y)	**41,968**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,13%**	
Young's modulus, E	**588,563**	MPa [N/mm^2]
True Stress, σ_t	**44,961**	MPa [N/mm^2]
True Strain, ε_t	**6,89%**	
Yielding (lower):		
Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	
Ultimate Tensile Strength:		
Nominal Stress, σ_nom/σ_e (S_ut)	**49,123**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,69%**	
True Stress, σ_t	**53,390**	MPa [N/mm^2]
True Strain, ε_t	**8,33%**	
Fracture:		
Nominal Stress, σ_nom/σ_e (S_y)	**45,815**	MPa [N/mm^2]
Nominal Strain, ε_n	**9,58%**	
True Stress, σ_t	**50,203**	MPa [N/mm^2]
True Strain, ε_t	**9,15%**	

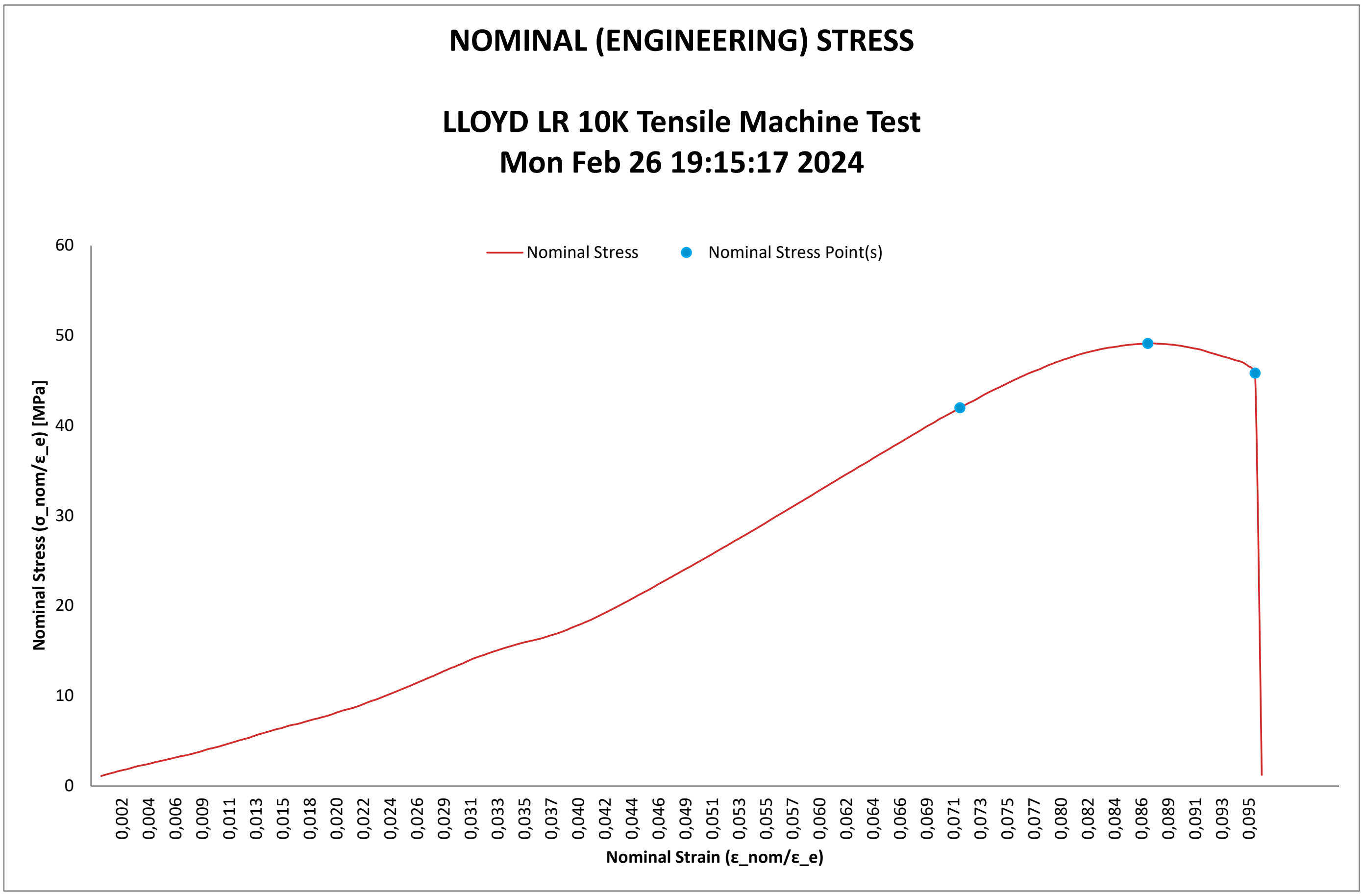
LR 10K Tensile Machine Settings

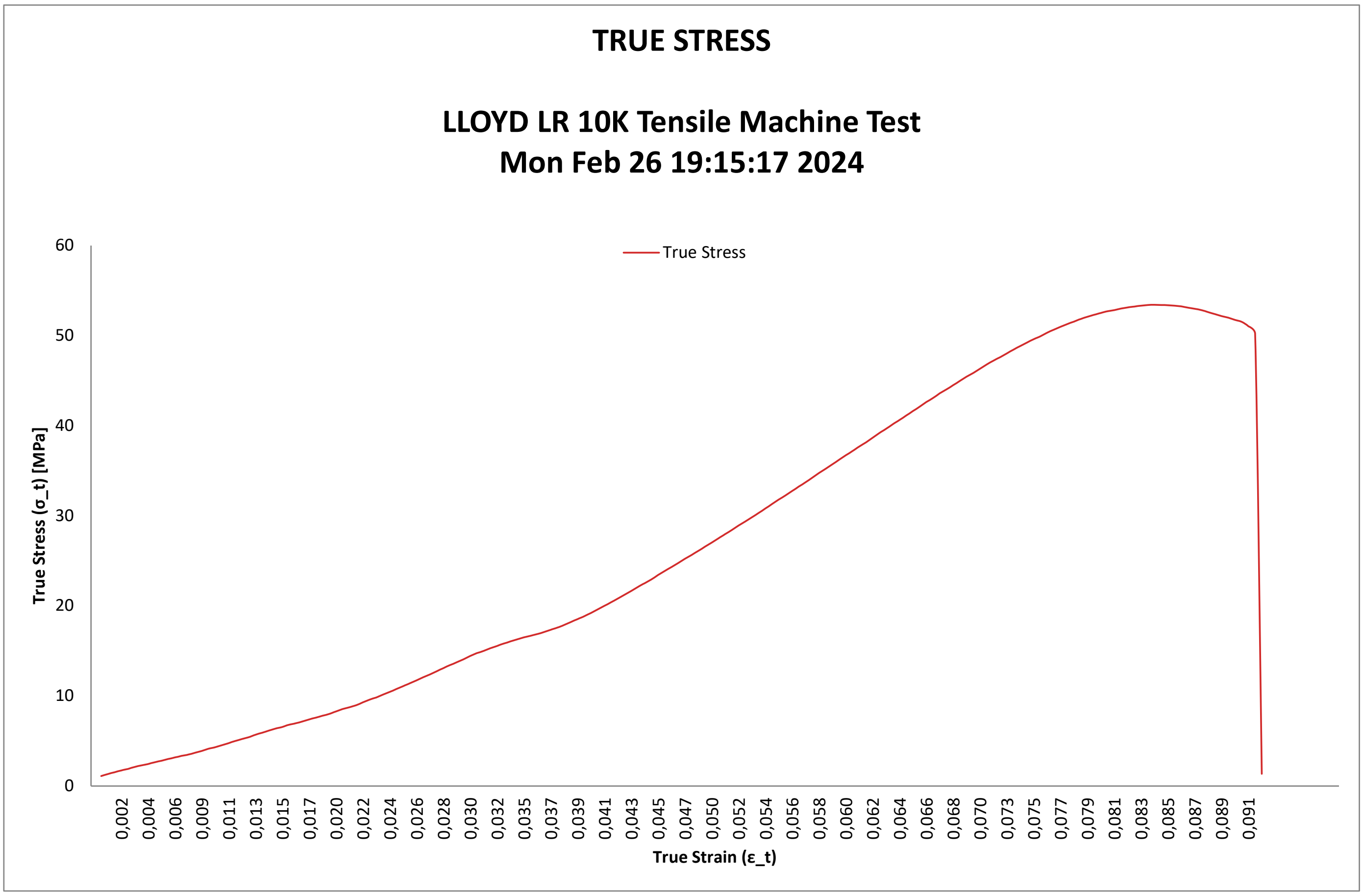
Mon Feb 26 19:15:17 2024

Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:15:17 2024
Plot Data
Crucial Point(s)
Load (N)
2500
2000
1500
1000
500
0
Extension (mm)
0,257
0,425
0,591
0,758
0,923
1,091
1,256
1,424
1,589
1,758
1,922
2,091
2,255
2,423
2,587
2,756
2,921
3,089
3,253
3,421
3,586
3,754
3,919
4,086
4,253
4,419
4,585
4,752
4,918
5,084
5,251
5,417
5,584
5,750
5,917
6,083
6,251
6,416
6,583
6,749
6,917
7,083
7,251


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:15:17 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
0
10
20
30
40
50
60
Nominal Strain (ε_nom/ε_e)
0,002
0,004
0,006
0,009
0,011
0,013
0,015
0,018
0,020
0,022
0,024
0,026
0,029
0,031
0,033
0,035
0,037
0,040
0,042
0,044
0,046
0,049
0,051
0,053
0,055
0,057
0,060
0,062
0,064
0,066
0,069
0,071
0,073
0,075
0,077
0,080
0,082
0,084
0,086
0,089
0,091
0,093
0,095


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:15:17 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60
0,002
0,004
0,006
0,009
0,011
0,013
0,015
0,017
0,020
0,022
0,024
0,026
0,028
0,030
0,032
0,035
0,037
0,039
0,041
0,043
0,045
0,047
0,050
0,052
0,054
0,056
0,058
0,060
0,062
0,064
0,066
0,068
0,070
0,073
0,075
0,077
0,079
0,081
0,083
0,085
0,087
0,089
0,091

B.3 Results T1-3

MATERIAL TESTING REPORT

Mon Feb 26 19:18:47 2024

Details: Tensile test T1-3

Material Properties:

Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**14,651**	MPa [N/mm^2]
Nominal Strain, ε_n	**2,14%**	
Young's modulus, E	**684,626**	MPa [N/mm^2]
True Stress, σ_t	**14,965**	MPa [N/mm^2]
True Strain, ε_t	**2,12%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**46,942**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,97%**	
True Stress, σ_t	**50,214**	MPa [N/mm^2]
True Strain, ε_t	**6,74%**	

Fracture:

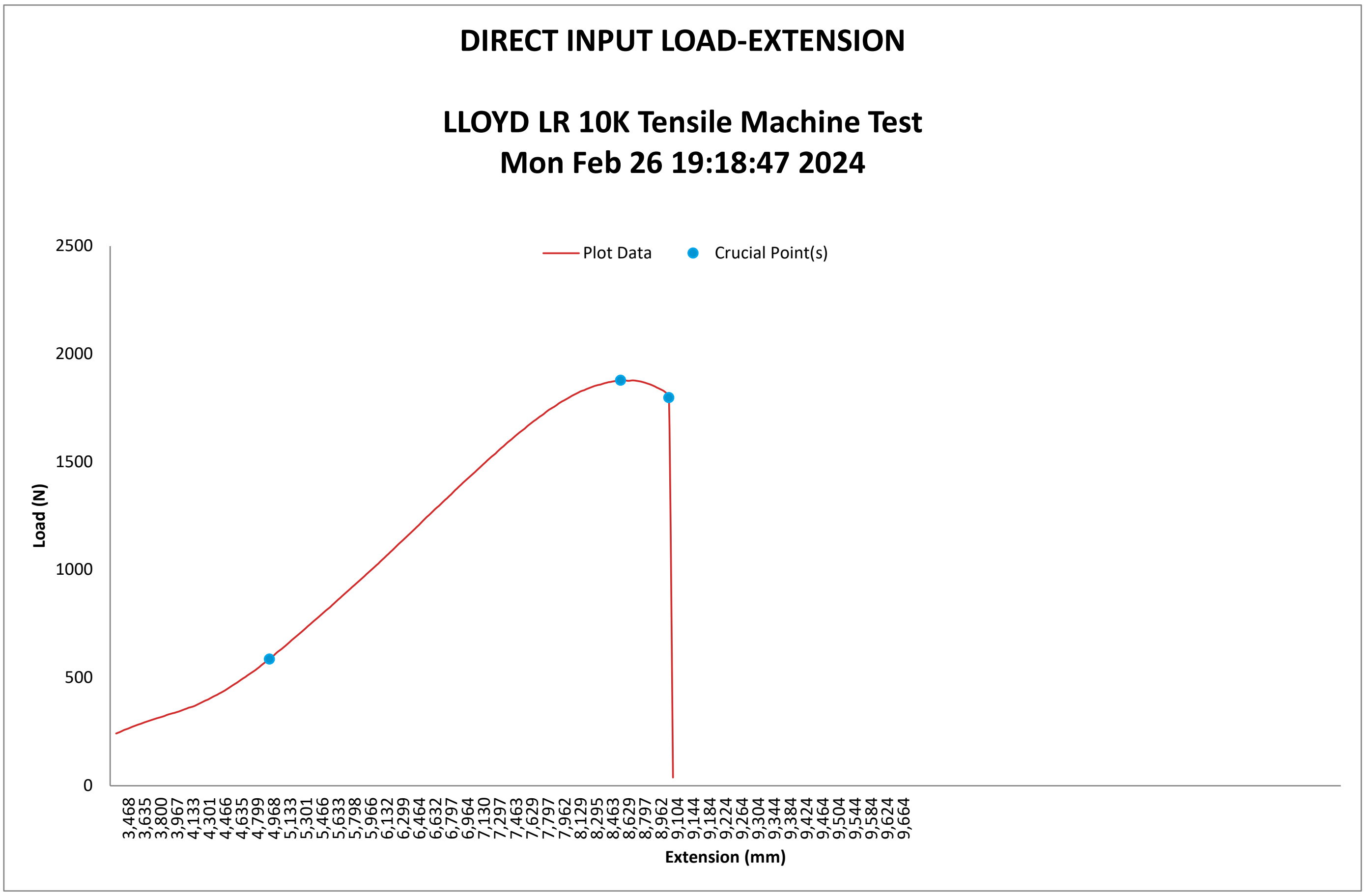
Nominal Stress, σ_nom/σ_e (S_y)	**44,933**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,63%**	
True Stress, σ_t	**48,363**	MPa [N/mm^2]
True Strain, ε_t	**7,36%**	

LR 10K Tensile Machine Settings

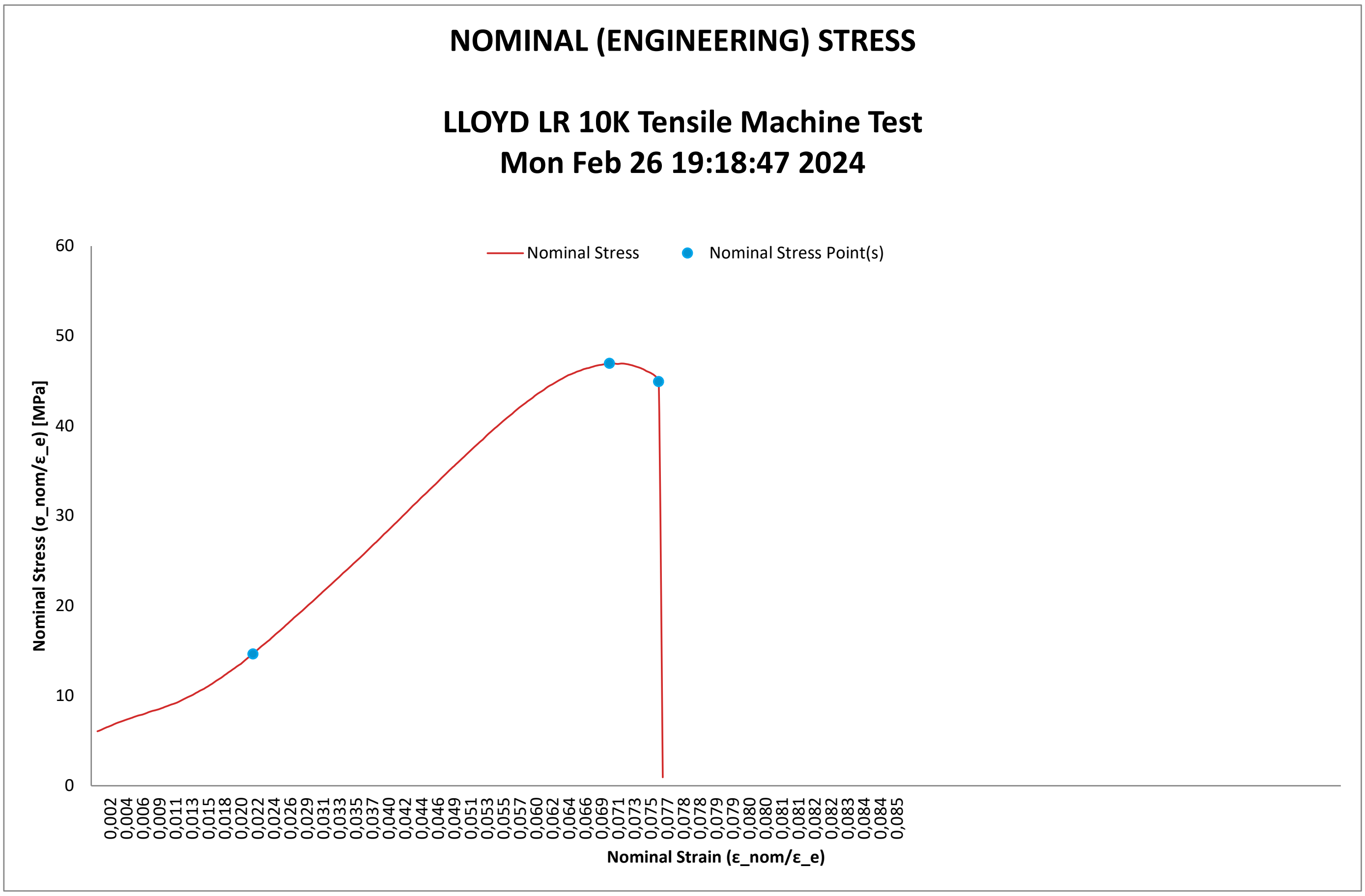
Mon Feb 26 19:18:47 2024

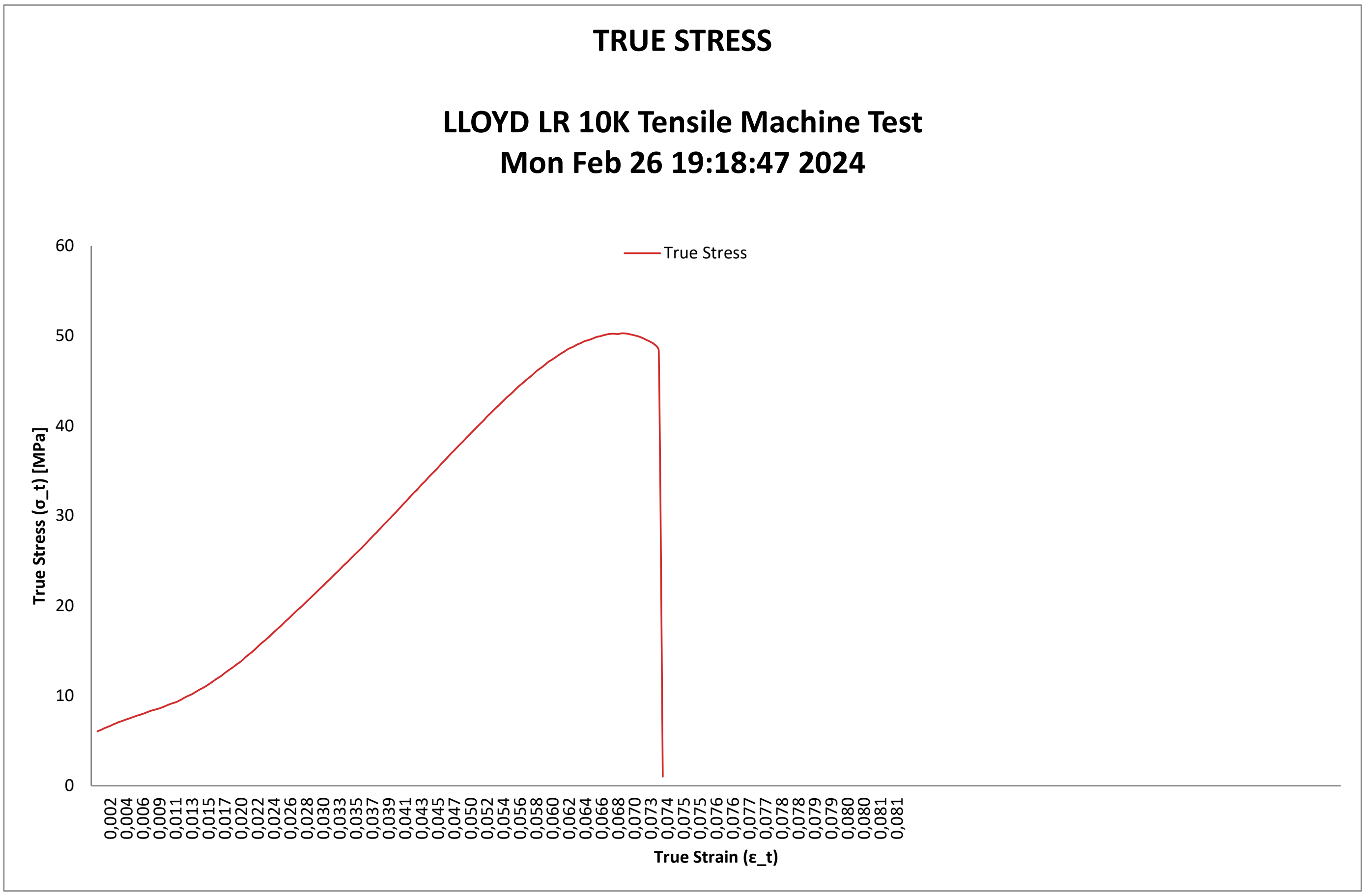
Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%



DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:18:47 2024
Plot Data
Crucial Point(s)
Load (N)
2500
2000
1500
1000
500
0
Extension (mm)
3,468
3,635
3,800
3,967
4,133
4,301
4,466
4,635
4,799
4,968
5,133
5,301
5,466
5,633
5,798
5,966
6,132
6,299
6,464
6,632
6,797
6,964
7,130
7,297
7,463
7,629
7,797
7,962
8,129
8,295
8,463
8,629
8,797
8,962
9,104
9,144
9,184
9,224
9,264
9,304
9,344
9,384
9,424
9,464
9,504
9,544
9,584
9,624
9,664


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:18:47 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)
0
10
20
30
40
50
60


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:18:47 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)

B.4 Results T1-4

MATERIAL TESTING REPORT

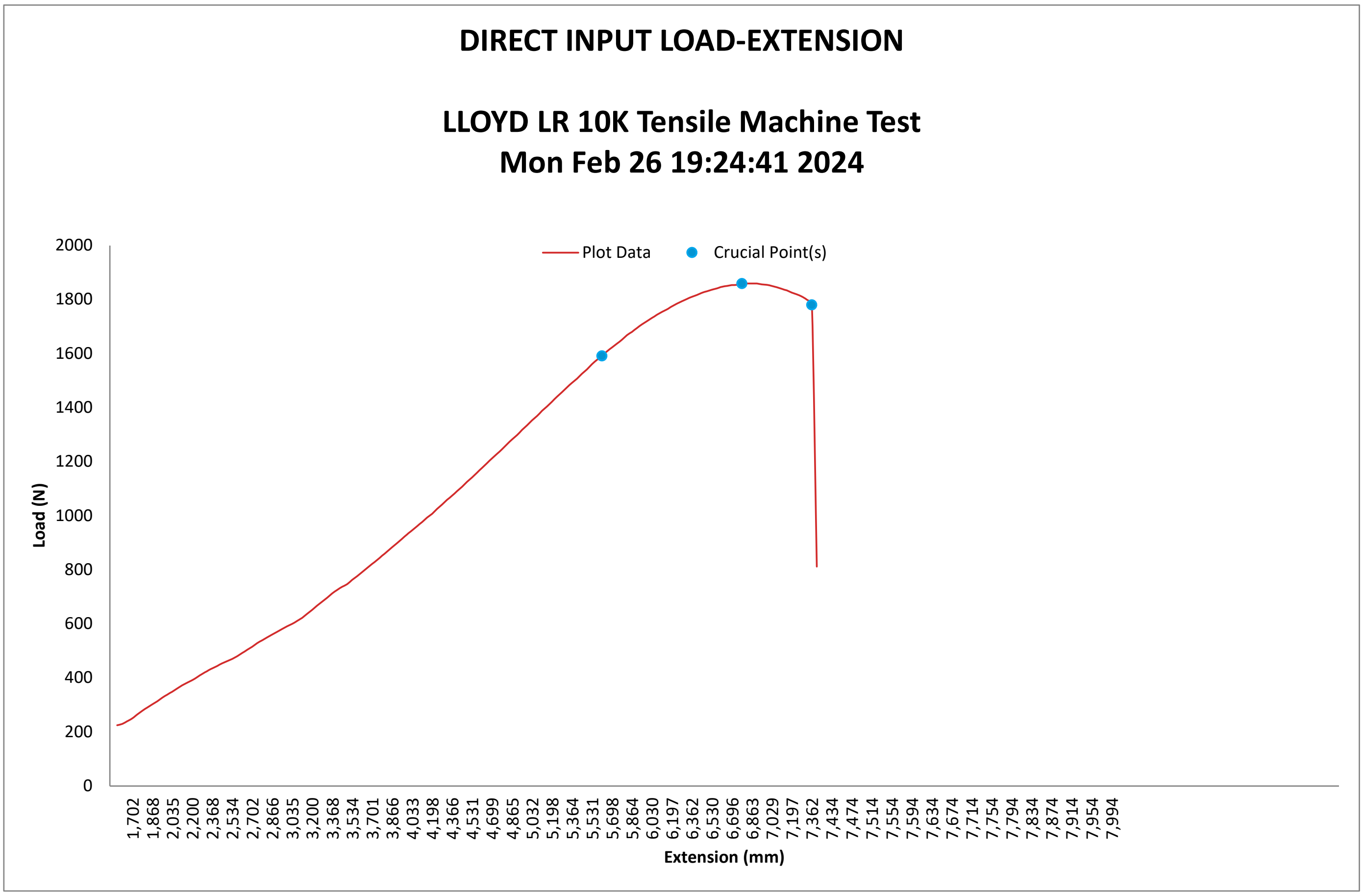
Mon Feb 26 19:24:41 2024

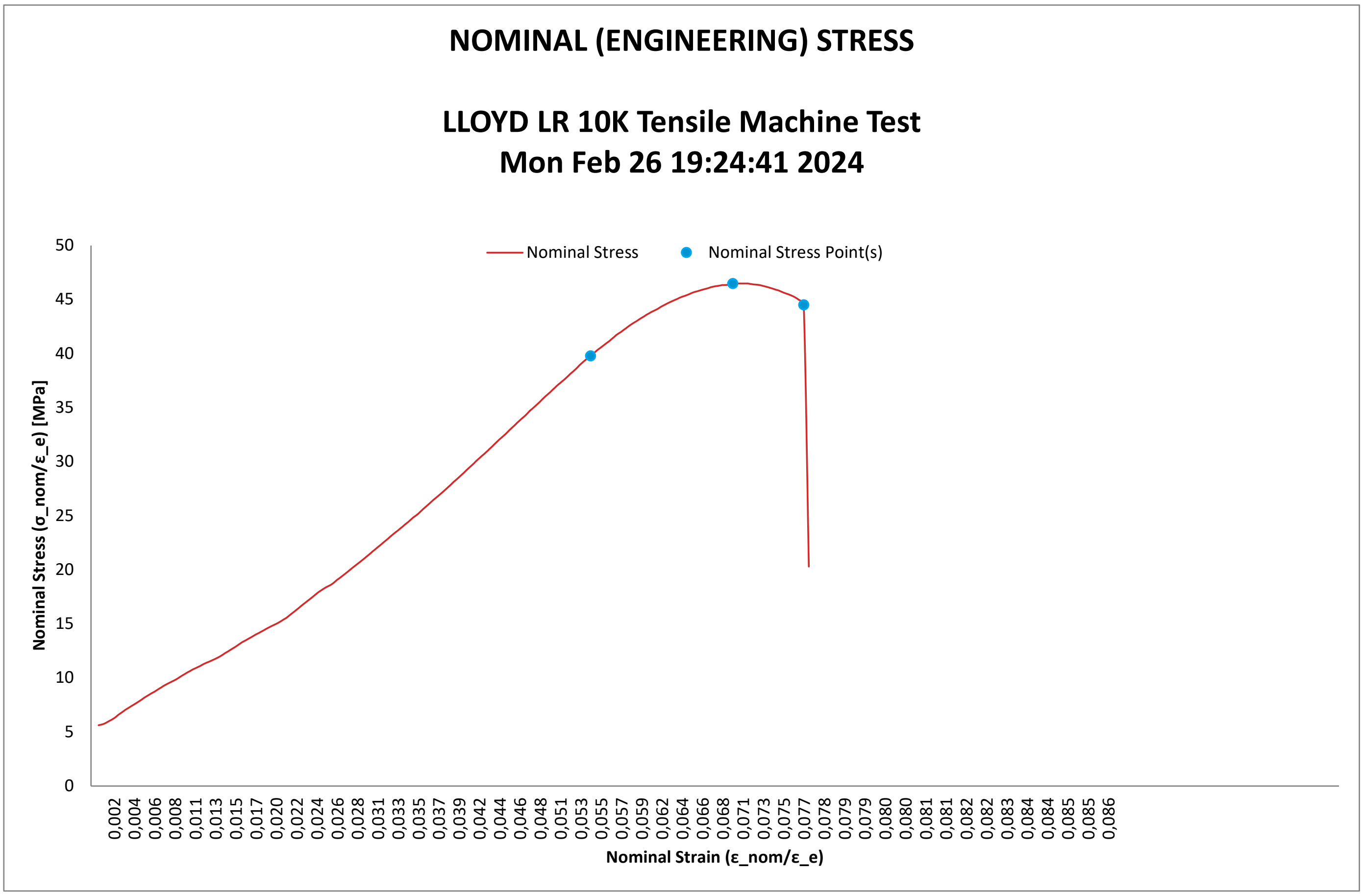
Details:	Test piece T1-4-2	
Material Properties:		
Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm
Proportional limit:		
Nominal Stress, σ_nom/σ_e (S_y)	**39,788**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,39%**	
Young's modulus, E	**737,726**	MPa [N/mm^2]
True Stress, σ_t	**41,934**	MPa [N/mm^2]
True Strain, ε_t	**5,25%**	
Yielding (lower):		
Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	
Ultimate Tensile Strength:		
Nominal Stress, σ_nom/σ_e (S_ut)	**46,477**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,95%**	
True Stress, σ_t	**49,704**	MPa [N/mm^2]
True Strain, ε_t	**6,71%**	
Fracture:		
Nominal Stress, σ_nom/σ_e (S_y)	**44,492**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,72%**	
True Stress, σ_t	**47,928**	MPa [N/mm^2]
True Strain, ε_t	**7,44%**	

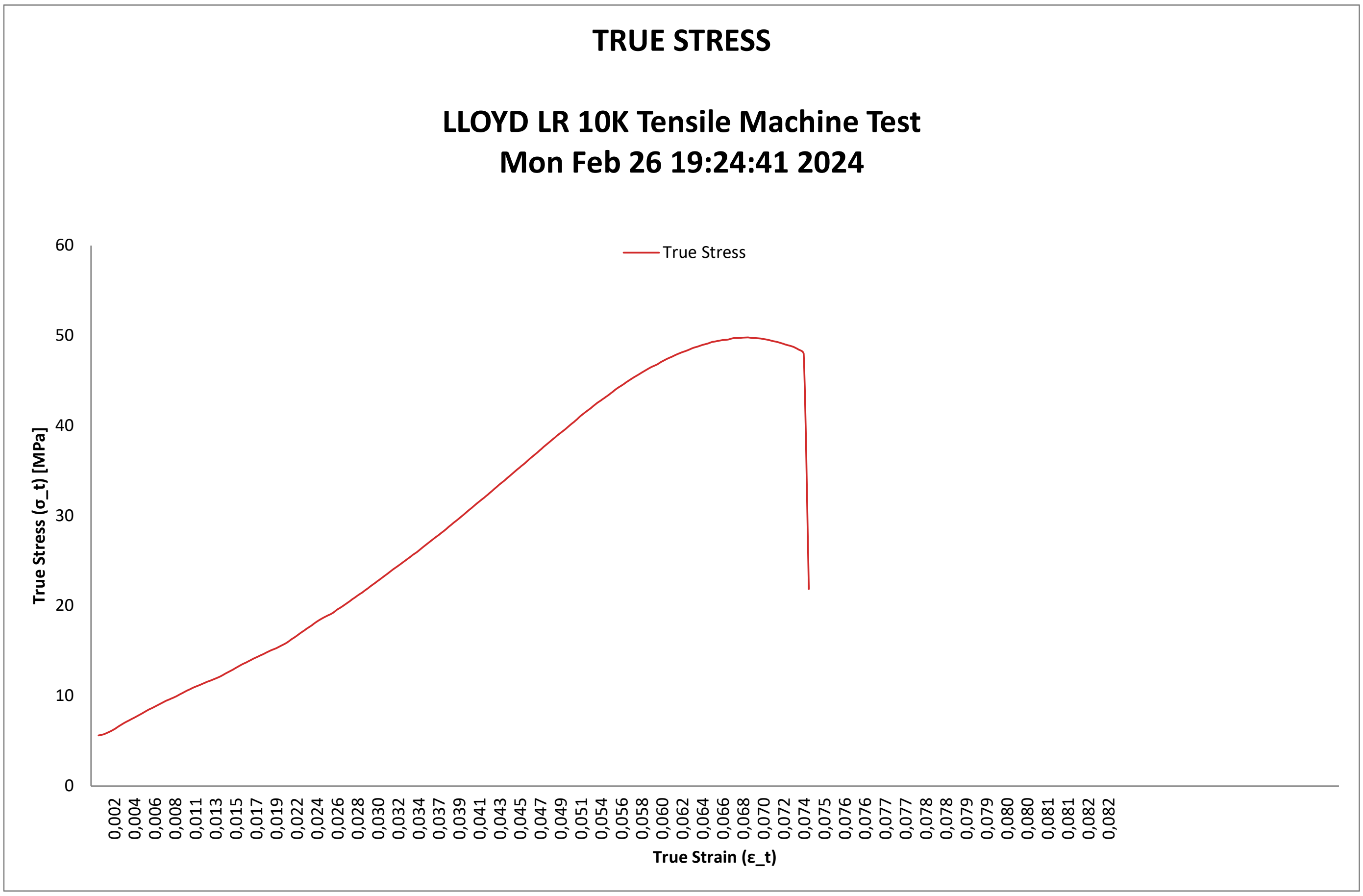
LR 10K Tensile Machine Settings

Mon Feb 26 19:24:41 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:24:41 2024
Plot Data
Crucial Point(s)
Load (N)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Extension (mm)
1,702 1,868 2,035 2,200 2,368 2,534 2,702 2,866 3,035 3,200 3,368 3,534 3,701 3,866 4,033 4,198 4,366 4,531 4,699 4,865 5,032 5,198 5,364 5,531 5,698 5,864 6,030 6,197 6,362 6,530 6,696 6,863 7,029 7,197 7,362 7,434 7,474 7,514 7,554 7,594 7,634 7,674 7,714 7,754 7,794 7,834 7,874 7,914 7,954 7,994


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:24:41 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)
0
5
10
15
20
25
30
35
40
45
50
0,002 0,004 0,006 0,008 0,011 0,013 0,015 0,017 0,020 0,022 0,024 0,026 0,028 0,031 0,033 0,035 0,037 0,039 0,042 0,044 0,046 0,048 0,051 0,053 0,055 0,057 0,059 0,062 0,064 0,066 0,068 0,071 0,073 0,075 0,077 0,078 0,079 0,079 0,080 0,080 0,081 0,081 0,082 0,082 0,083 0,083 0,084 0,084 0,085 0,085 0,086


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:24:41 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60

B.5 Results T1-5

MATERIAL TESTING REPORT

Mon Feb 26 19:27:00 2024

Details: Test piece T1-5

Material Properties:

Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**40,498**	MPa [N/mm^2]
Nominal Strain, ε_n	**4,61%**	
Young's modulus, E	**879,383**	MPa [N/mm^2]
True Stress, σ_t	**42,364**	MPa [N/mm^2]
True Strain, ε_t	**4,50%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**46,967**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,16%**	
True Stress, σ_t	**49,860**	MPa [N/mm^2]
True Strain, ε_t	**5,98%**	

Fracture:

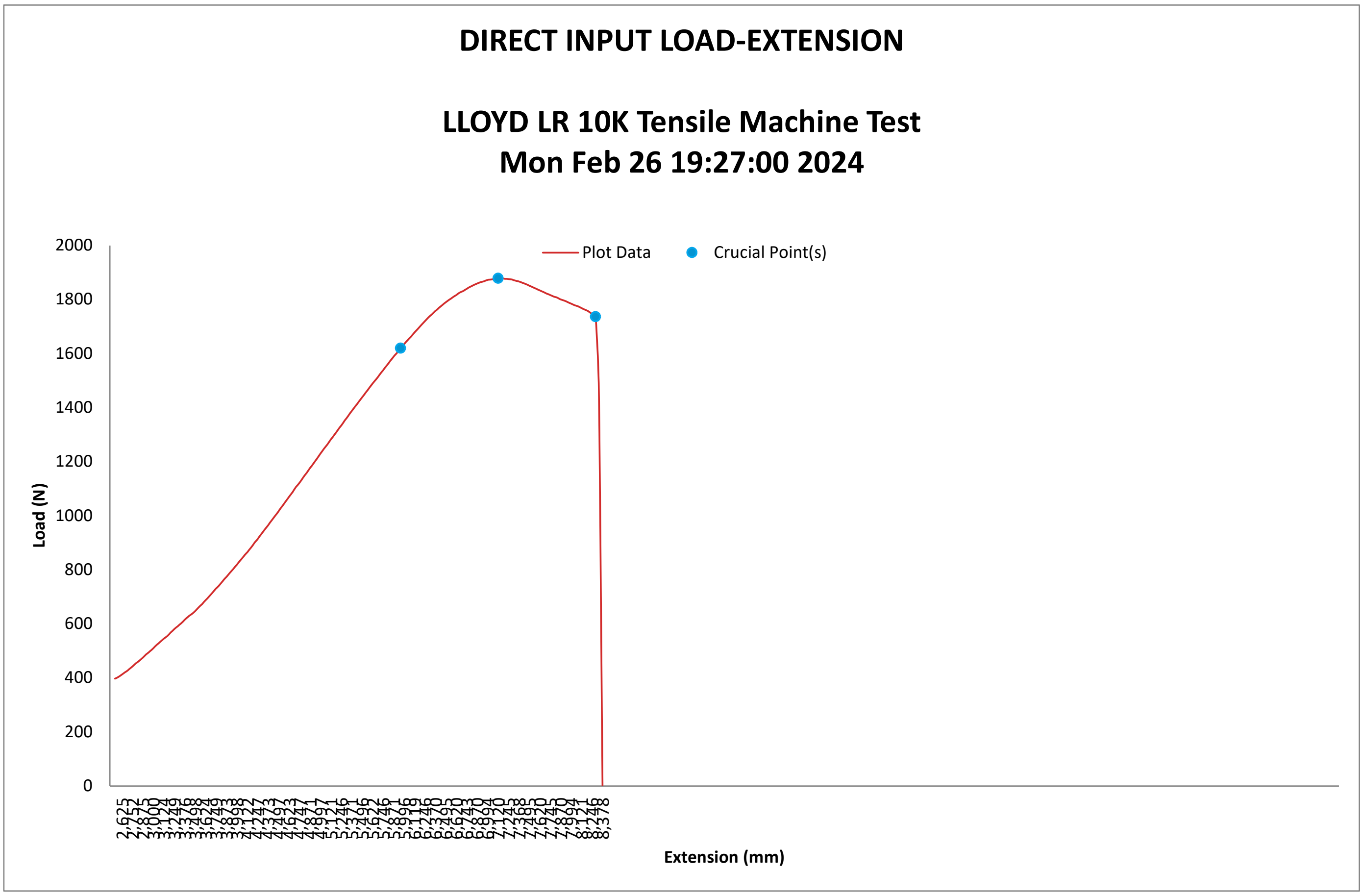
Nominal Stress, σ_nom/σ_e (S_y)	**43,414**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,72%**	
True Stress, σ_t	**46,764**	MPa [N/mm^2]
True Strain, ε_t	**7,43%**	

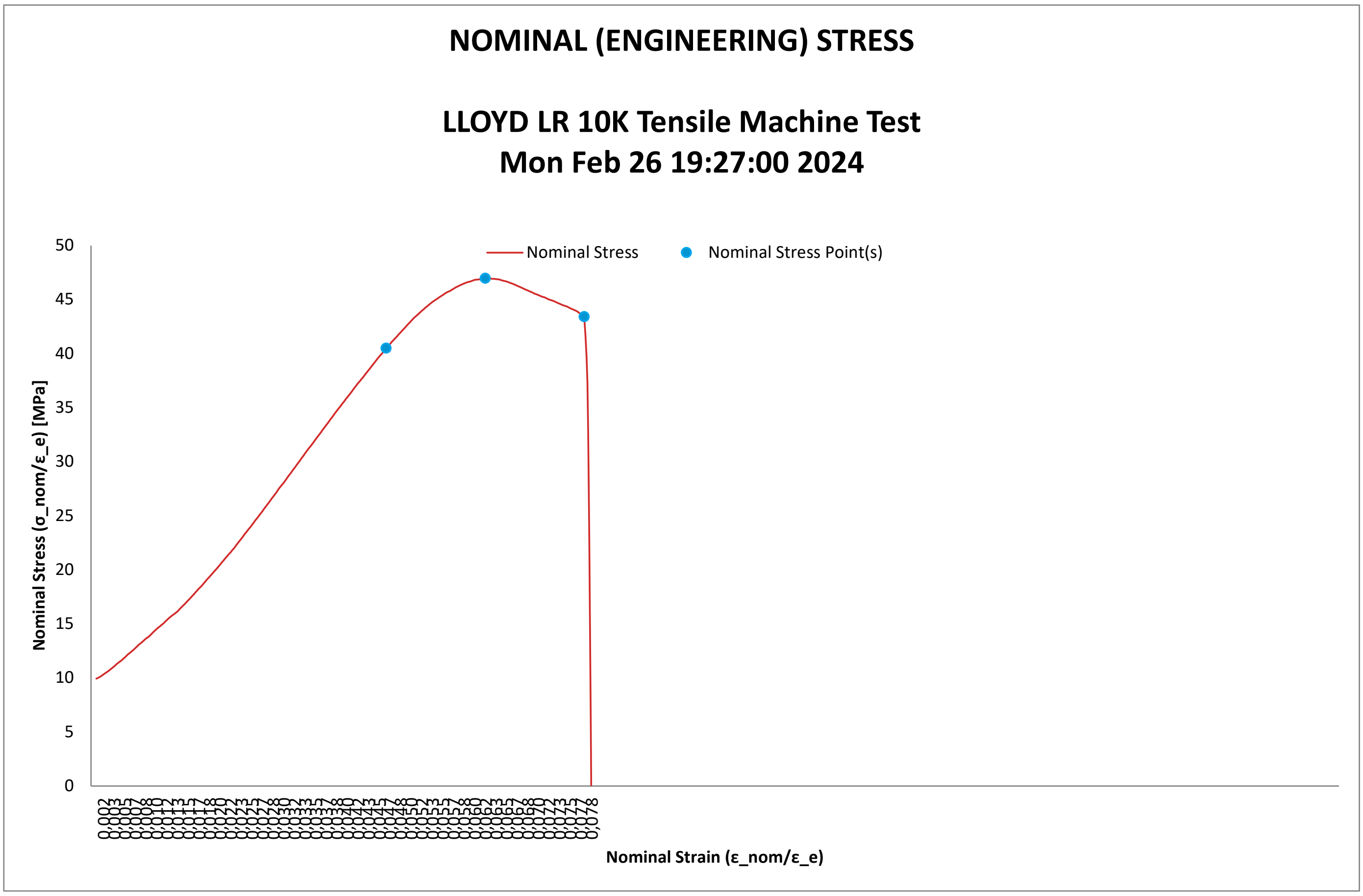
LR 10K Tensile Machine Settings

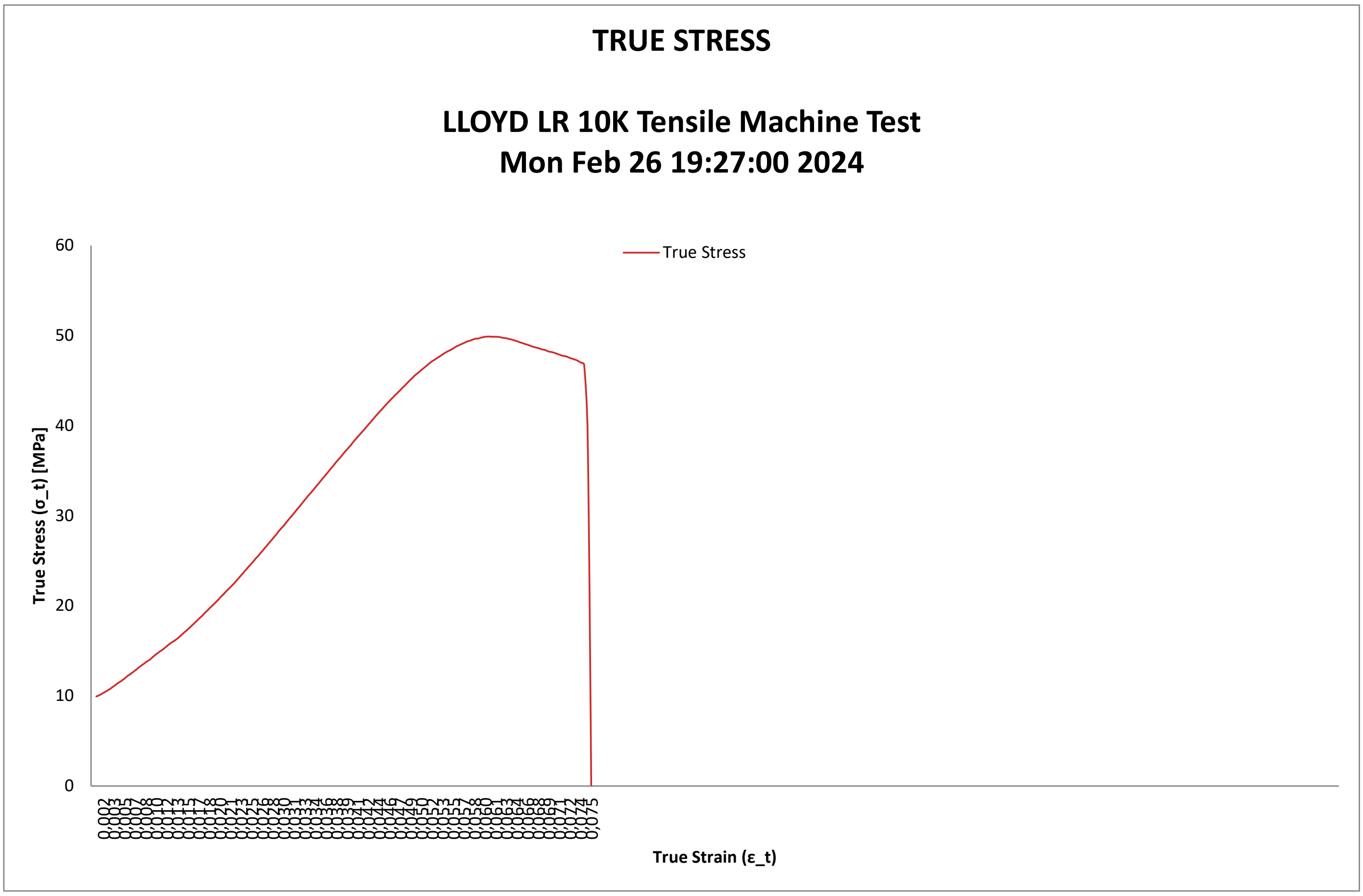
Mon Feb 26 19:27:00 2024

Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:27:00 2024
Plot Data
Crucial Point(s)
Load (N)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2,625
8,378
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:27:00 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
50
45
40
35
30
25
20
15
10
5
0
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:27:00 2024
True Stress
True Stress (σ_t) [MPa]
60
50
40
30
20
10
0
True Strain (ε_t)

B.6 Results T1-6

MATERIAL TESTING REPORT

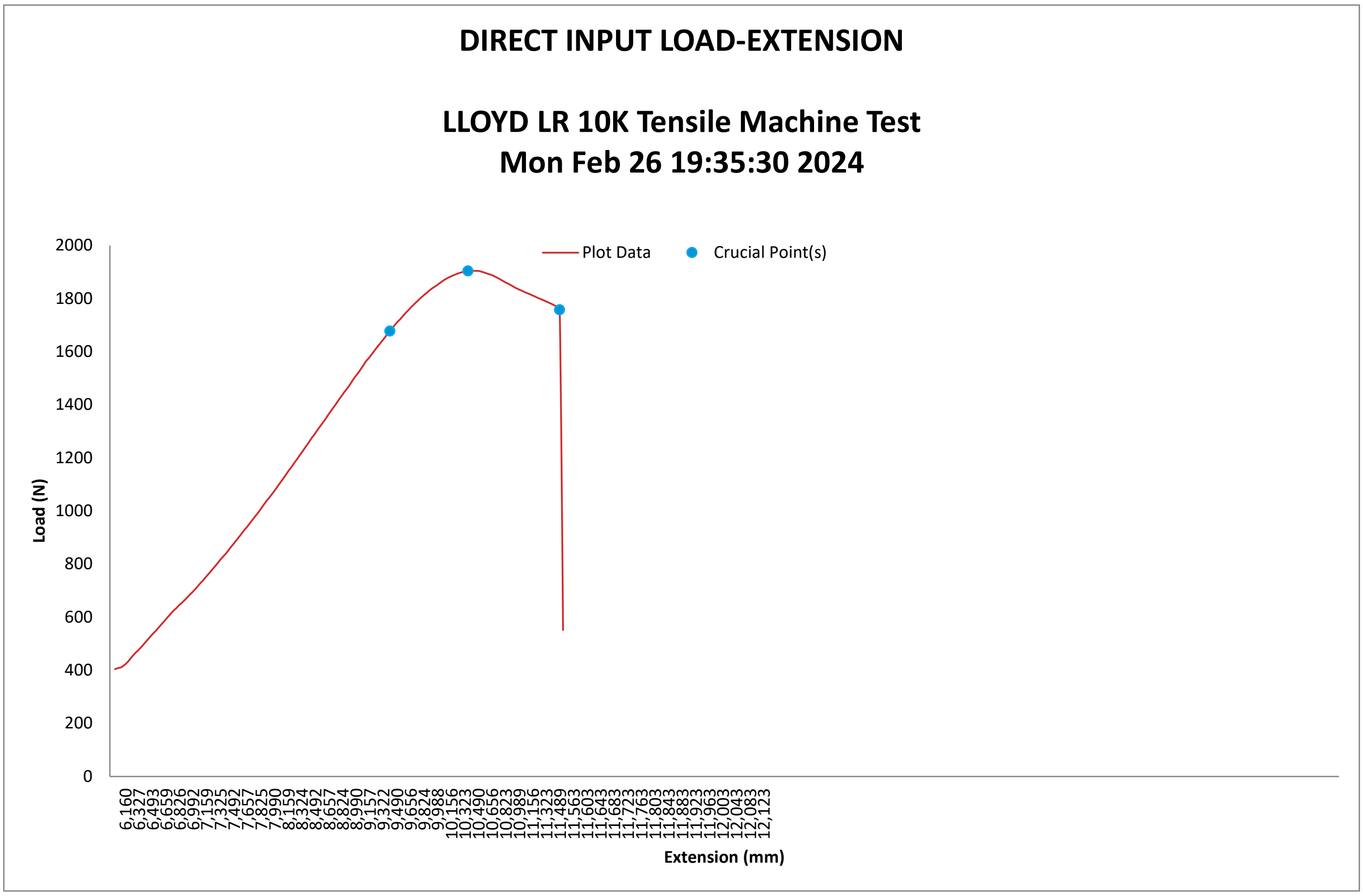
Mon Feb 26 19:35:30 2024

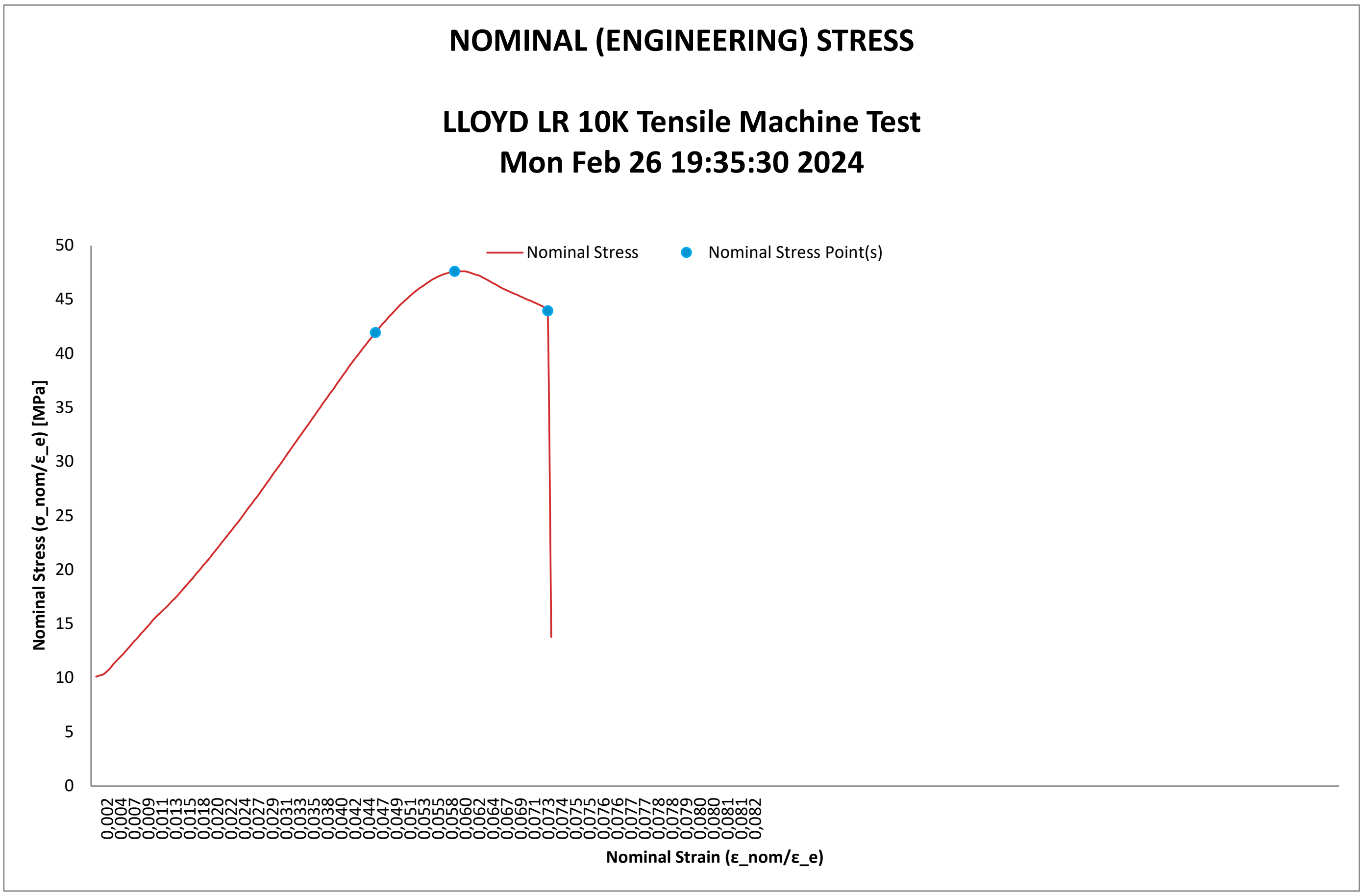
Details:	Test piece T1-6	
Material Properties:		
Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm
Proportional limit:		
Nominal Stress, σ_nom/σ_e (S_y)	**41,944**	MPa [N/mm^2]
Nominal Strain, ε_n	**4,54%**	
Young's modulus, E	**923,334**	MPa [N/mm^2]
True Stress, σ_t	**43,849**	MPa [N/mm^2]
True Strain, ε_t	**4,44%**	
Yielding (lower):		
Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	
Ultimate Tensile Strength:		
Nominal Stress, σ_nom/σ_e (S_ut)	**47,604**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,82%**	
True Stress, σ_t	**50,373**	MPa [N/mm^2]
True Strain, ε_t	**5,66%**	
Fracture:		
Nominal Stress, σ_nom/σ_e (S_y)	**43,953**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,32%**	
True Stress, σ_t	**47,170**	MPa [N/mm^2]
True Strain, ε_t	**7,06%**	

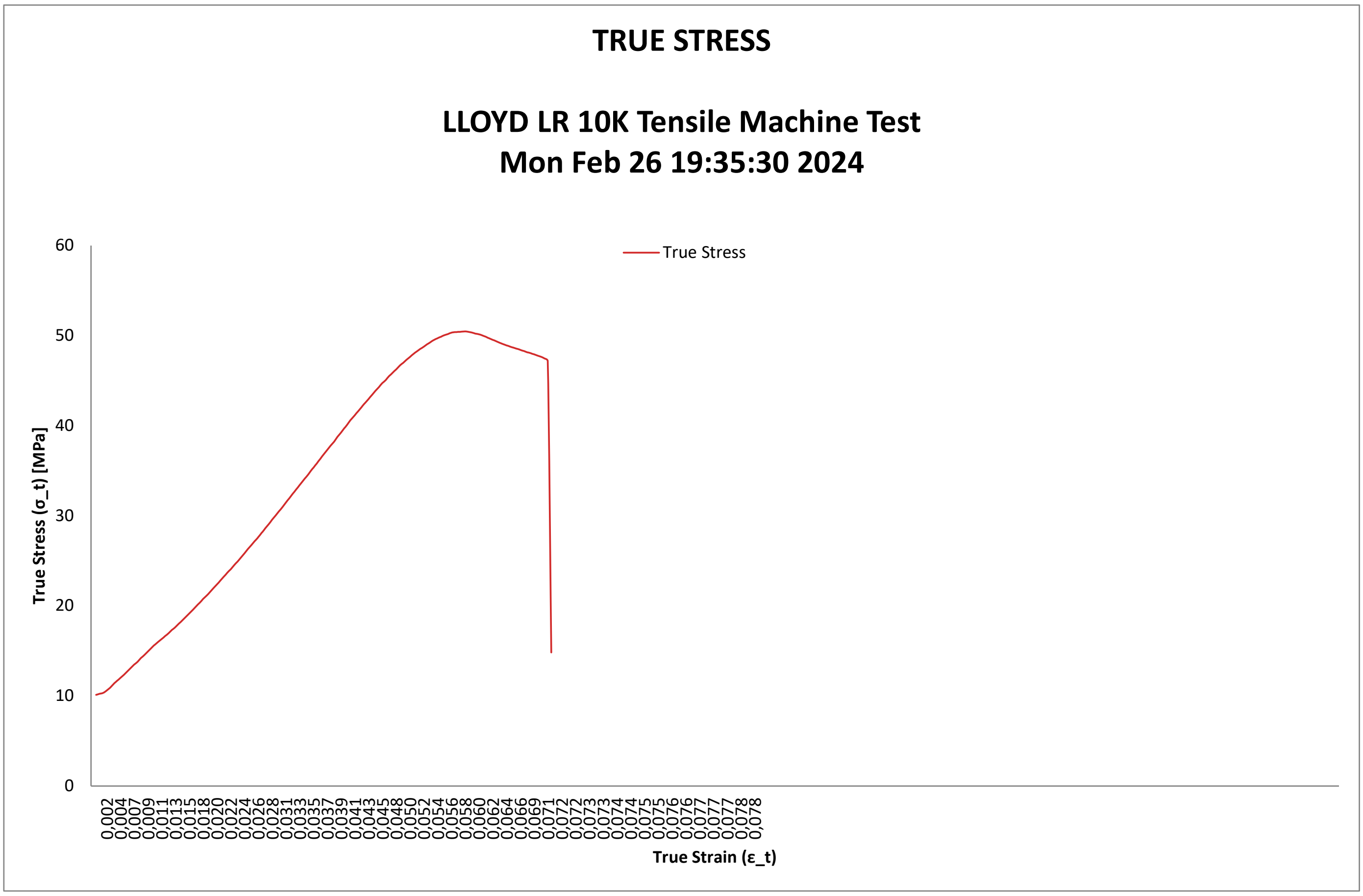
LR 10K Tensile Machine Settings

Mon Feb 26 19:35:30 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:35:30 2024
Plot Data
Crucial Point(s)
Load (N)
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:35:30 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)
0
5
10
15
20
25
30
35
40
45
50


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:35:30 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60

B.7 Results T1-7

MATERIAL TESTING REPORT

Mon Feb 26 19:37:47 2024

Details: Test piece T1-7

Material Properties:

Start Thickness	**4,000**	mm
Start Width	**10,000**	mm
Start Length	**75,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**40,205**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,02%**	
Young's modulus, E	**572,496**	MPa [N/mm^2]
True Stress, σ_t	**43,028**	MPa [N/mm^2]
True Strain, ε_t	**6,79%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**0,000**	MPa [N/mm^2]
Nominal Strain, ε_n	**0,00%**	
True Stress, σ_t	**0,000**	MPa [N/mm^2]
True Strain, ε_t	**0,00%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**46,060**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,47%**	
True Stress, σ_t	**49,960**	MPa [N/mm^2]
True Strain, ε_t	**8,13%**	

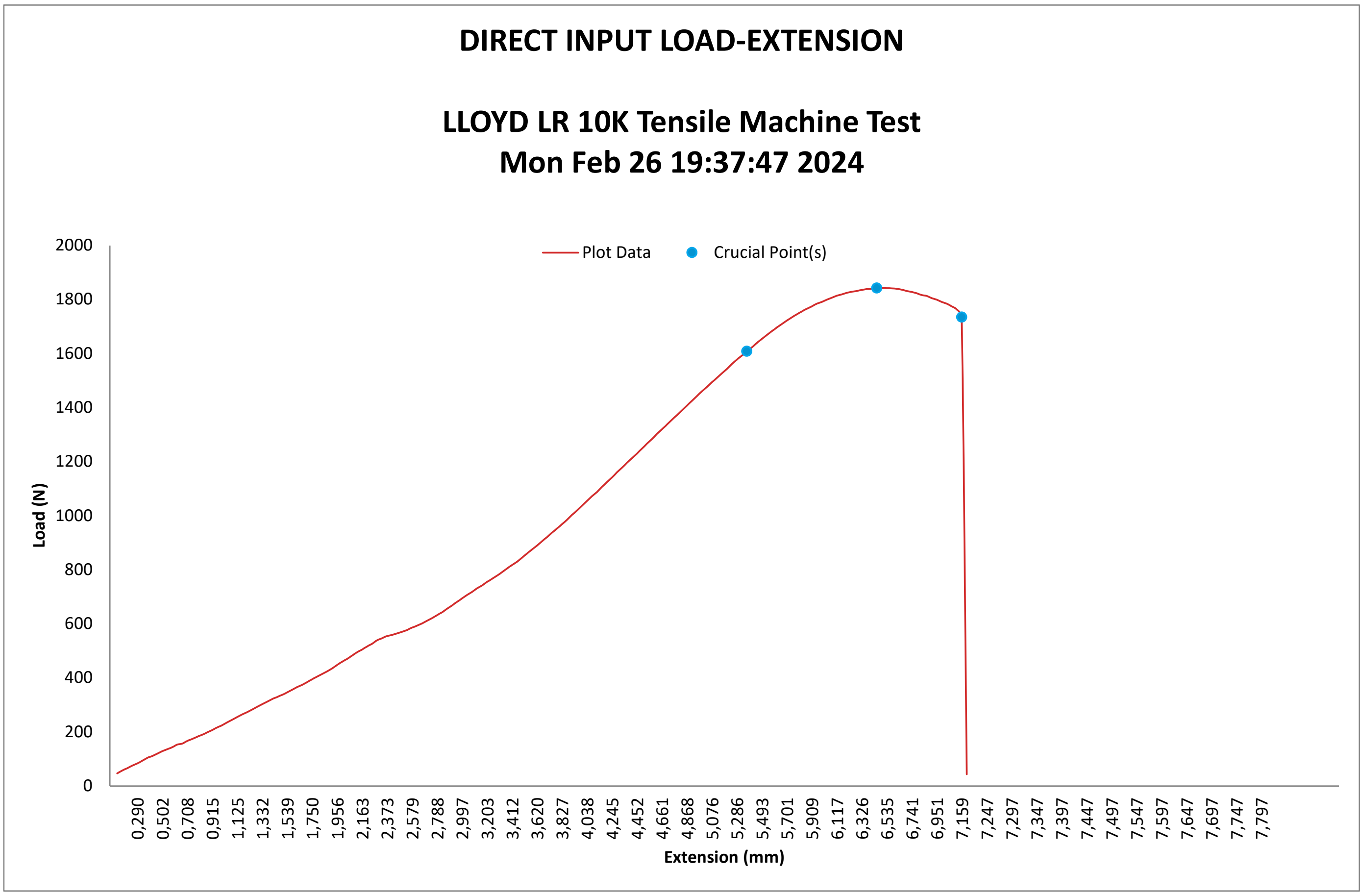
Fracture:

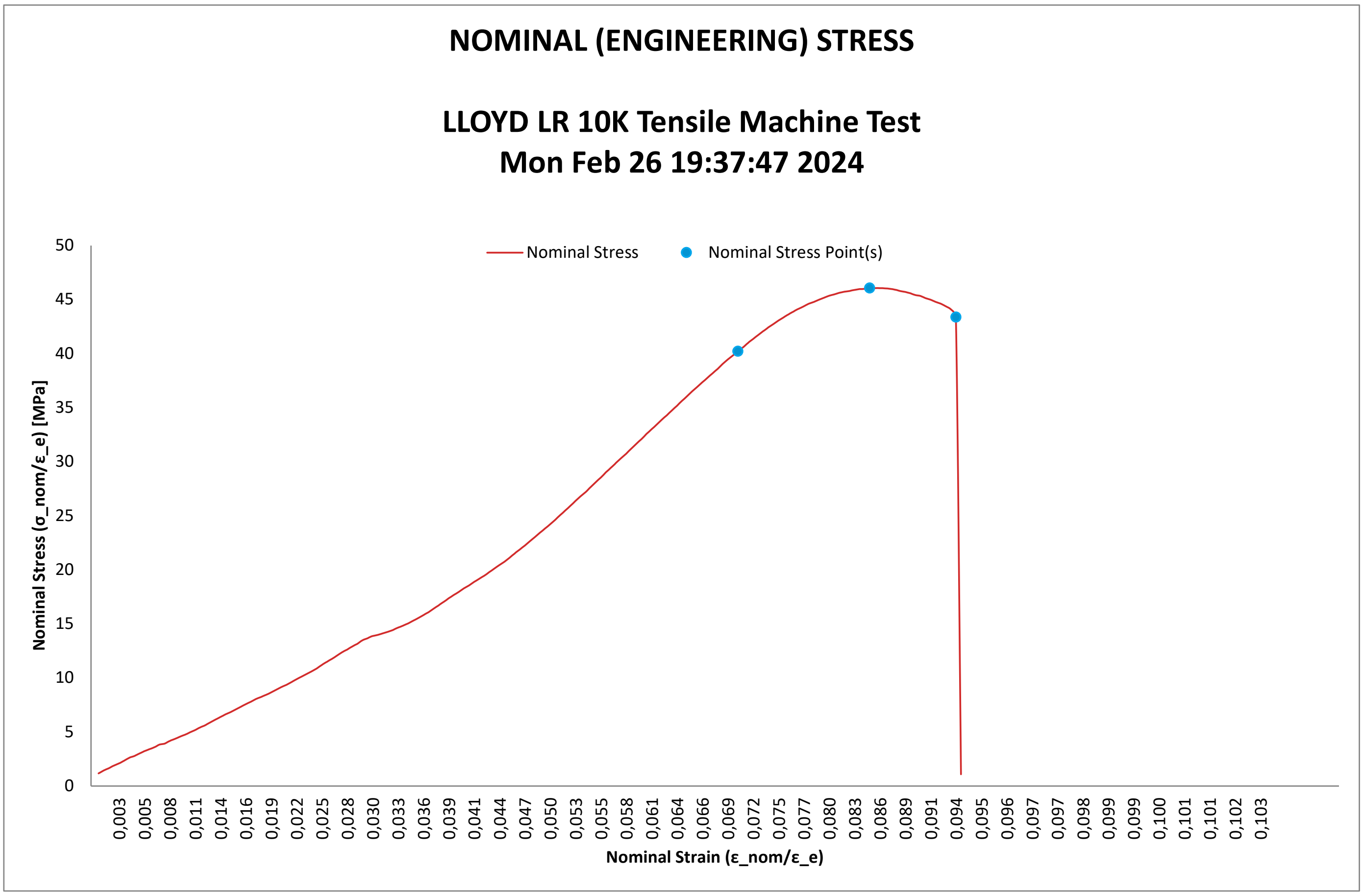
Nominal Stress, σ_nom/σ_e (S_y)	**43,365**	MPa [N/mm^2]
Nominal Strain, ε_n	**9,41%**	
True Stress, σ_t	**47,447**	MPa [N/mm^2]
True Strain, ε_t	**9,00%**	

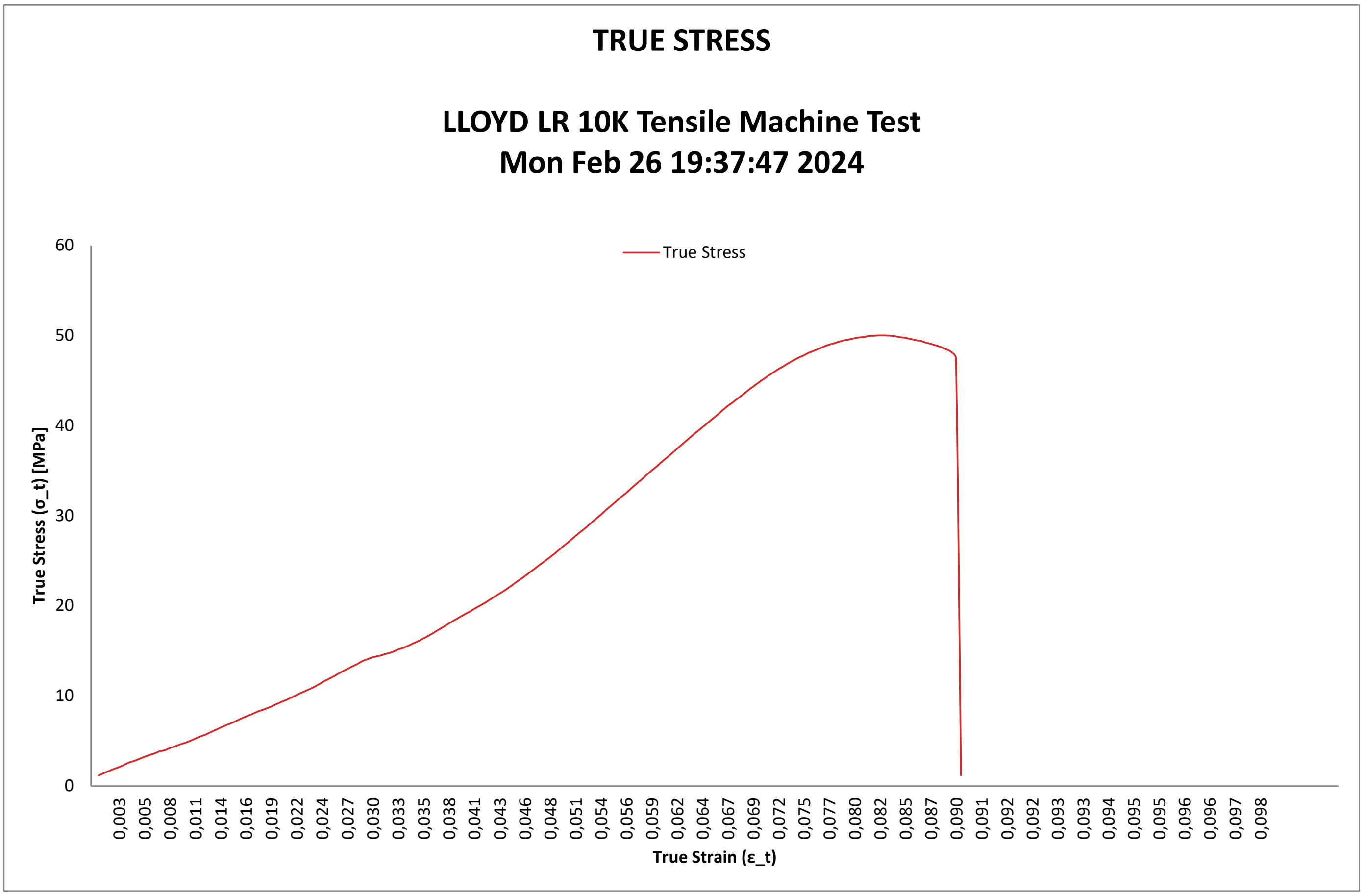
LR 10K Tensile Machine Settings

Mon Feb 26 19:37:47 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:37:47 2024
Plot Data
Crucial Point(s)
Load (N)
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:37:47 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Feb 26 19:37:47 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60
0,003
0,005
0,008
0,011
0,014
0,016
0,019
0,022
0,024
0,027
0,030
0,033
0,035
0,038
0,041
0,043
0,046
0,048
0,051
0,054
0,056
0,059
0,062
0,064
0,067
0,069
0,072
0,075
0,077
0,080
0,082
0,085
0,087
0,090
0,091
0,092
0,092
0,093
0,093
0,094
0,095
0,095
0,096
0,096
0,097
0,098

C Results test T2

C.1 Results T2-1

MATERIAL TESTING REPORT

Mon Mar 25 21:25:27 2024

Details: Test T2-1

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**33,290**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,15%**	
Young's modulus, E	**646,790**	MPa [N/mm^2]
True Stress, σ_t	**35,004**	MPa [N/mm^2]
True Strain, ε_t	**5,02%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**33,290**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,15%**	
True Stress, σ_t	**35,004**	MPa [N/mm^2]
True Strain, ε_t	**5,02%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**46,832**	MPa [N/mm^2]
Nominal Strain, ε_n	**9,06%**	
True Stress, σ_t	**51,077**	MPa [N/mm^2]
True Strain, ε_t	**8,68%**	

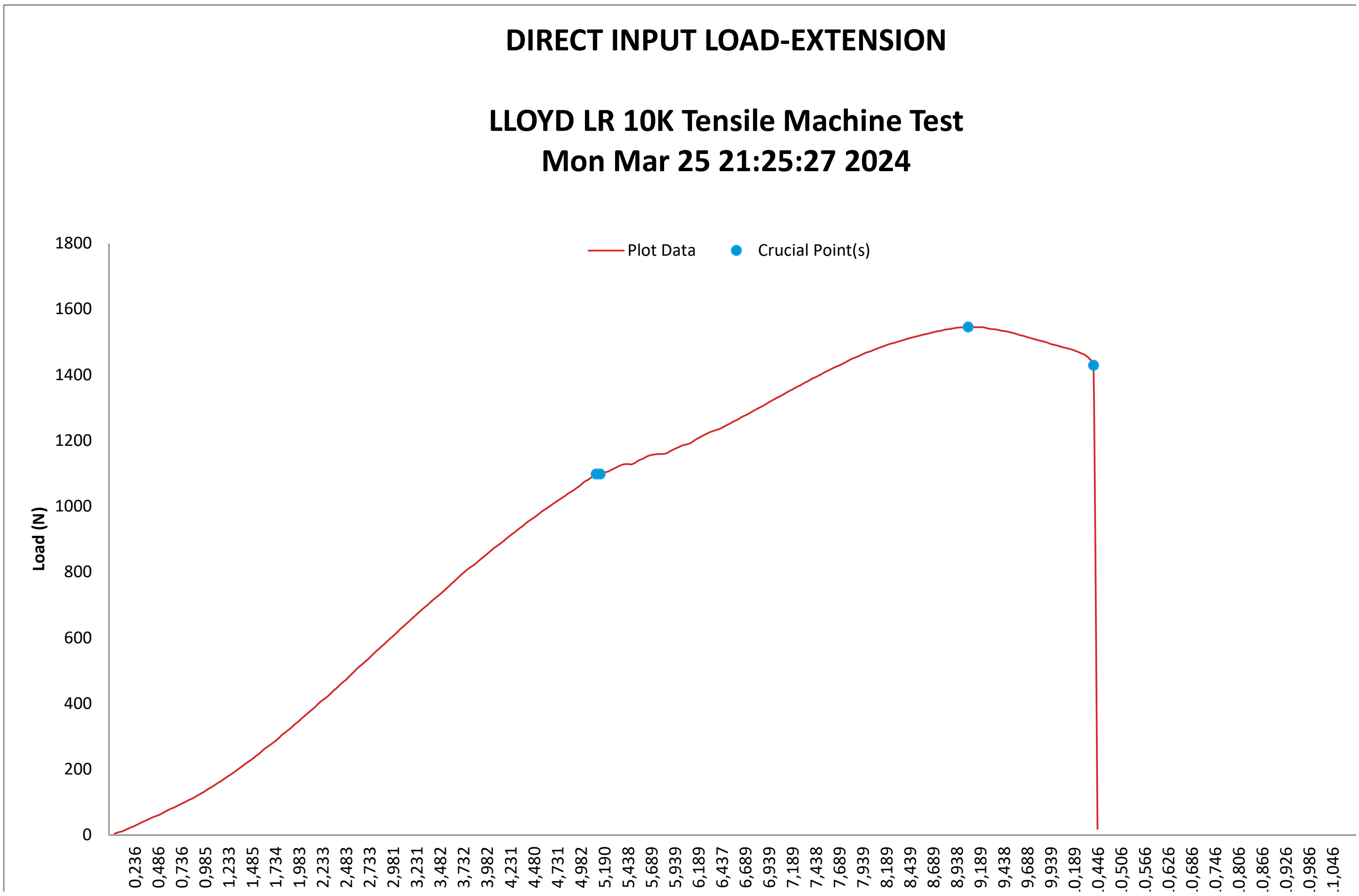
Fracture:

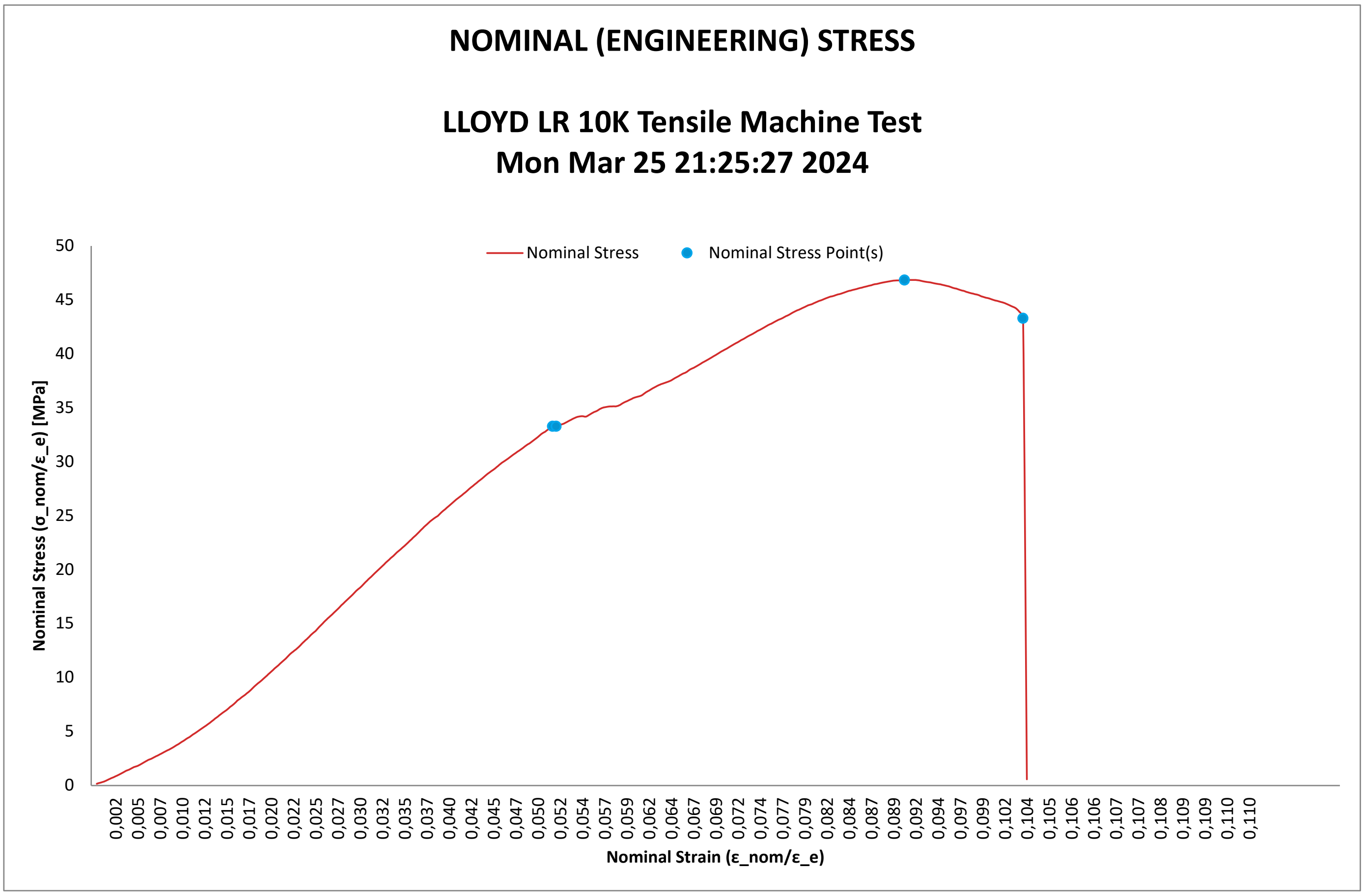
Nominal Stress, σ_nom/σ_e (S_y)	**43,298**	MPa [N/mm^2]
Nominal Strain, ε_n	**10,40%**	
True Stress, σ_t	**47,800**	MPa [N/mm^2]
True Strain, ε_t	**9,89%**	

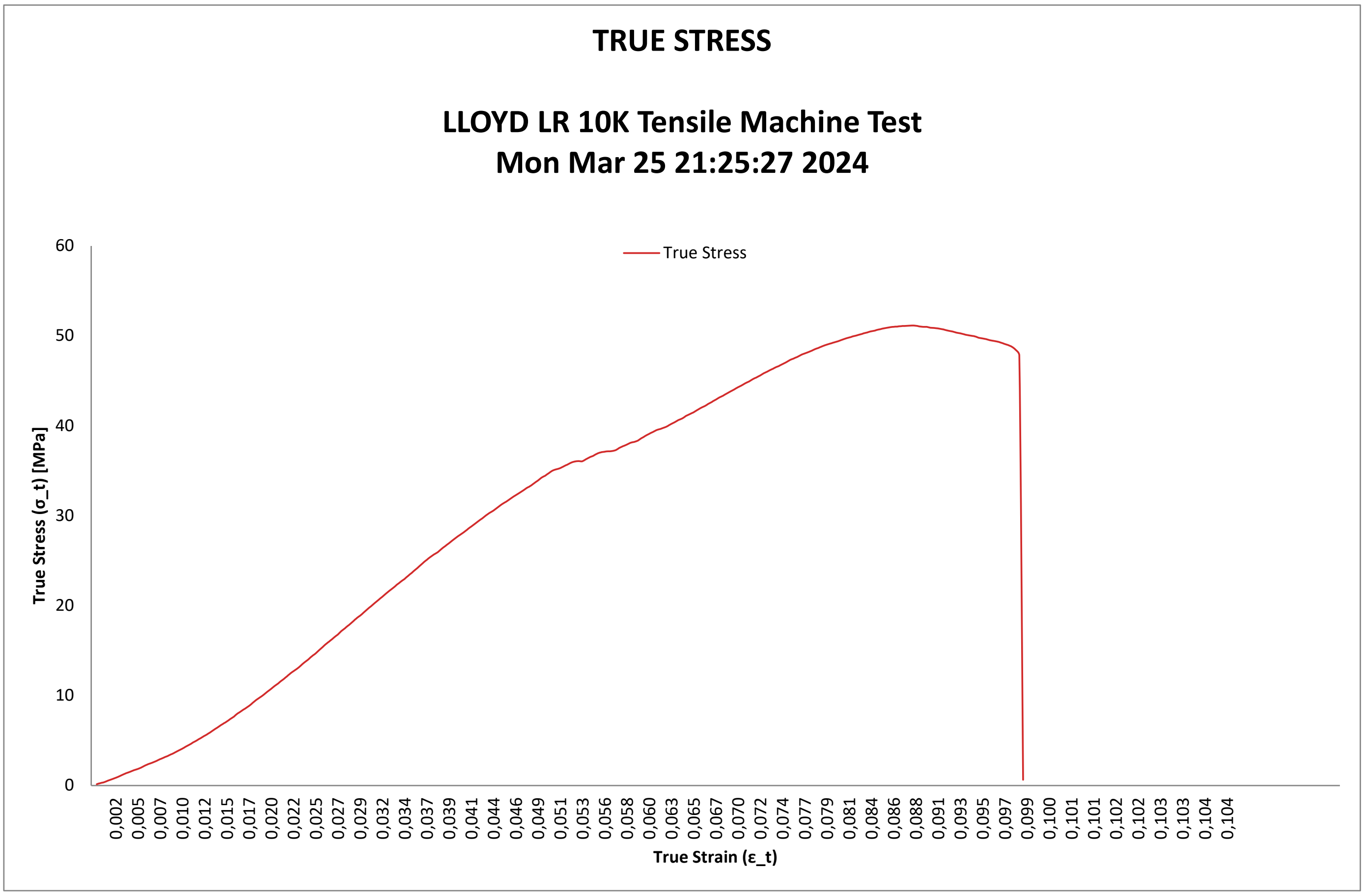
LR 10K Tensile Machine Settings

Mon Mar 25 21:25:27 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Mon Mar 25 21:25:27 2024
Plot Data
Crucial Point(s)
Load (N)
1800
1600
1400
1200
1000
800
600
400
200
0


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Mon Mar 25 21:25:27 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Mon Mar 25 21:25:27 2024
True Stress
True Stress (σ_t) [MPa]
60
50
40
30
20
10
0
0,002
0,005
0,007
0,010
0,012
0,015
0,017
0,020
0,022
0,025
0,027
0,029
0,032
0,034
0,037
0,039
0,041
0,044
0,046
0,049
0,051
0,053
0,056
0,058
0,060
0,063
0,065
0,067
0,070
0,072
0,074
0,077
0,079
0,081
0,084
0,086
0,088
0,091
0,093
0,095
0,097
0,099
0,100
0,101
0,101
0,102
0,102
0,103
0,103
0,104
0,104
True Strain (ε_t)

C.2 Results T2-2

MATERIAL TESTING REPORT

Tue Mar 26 13:47:28 2024

Details: Test T2-2

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**31,241**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,26%**	
Young's modulus, E	**594,052**	MPa [N/mm^2]
True Stress, σ_t	**32,884**	MPa [N/mm^2]
True Strain, ε_t	**5,13%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**31,241**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,26%**	
True Stress, σ_t	**32,884**	MPa [N/mm^2]
True Strain, ε_t	**5,13%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**44,872**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,88%**	
True Stress, σ_t	**48,858**	MPa [N/mm^2]
True Strain, ε_t	**8,51%**	

Fracture:

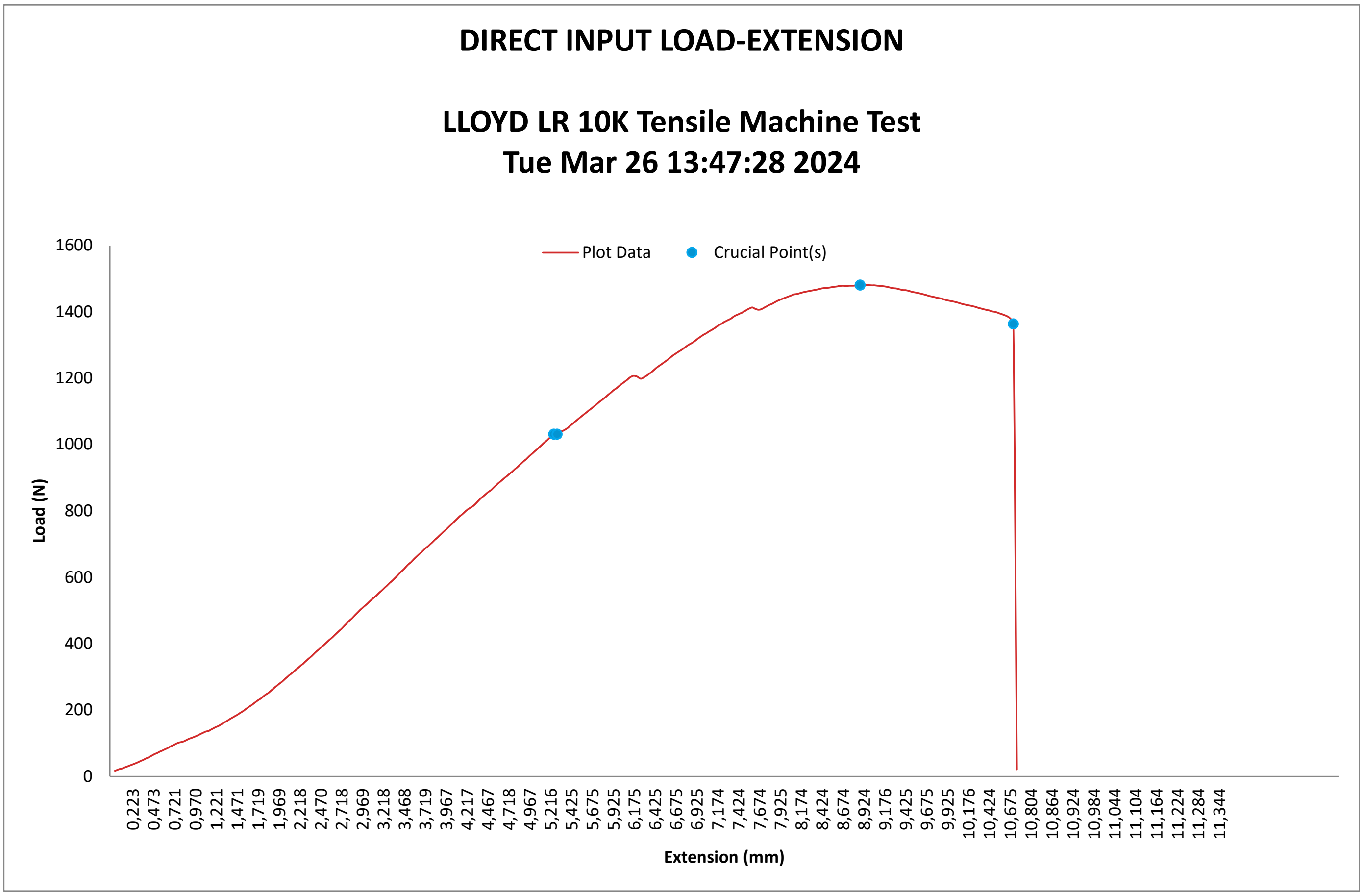
Nominal Stress, σ_nom/σ_e (S_y)	**41,308**	MPa [N/mm^2]
Nominal Strain, ε_n	**10,72%**	
True Stress, σ_t	**45,736**	MPa [N/mm^2]
True Strain, ε_t	**10,18%**	

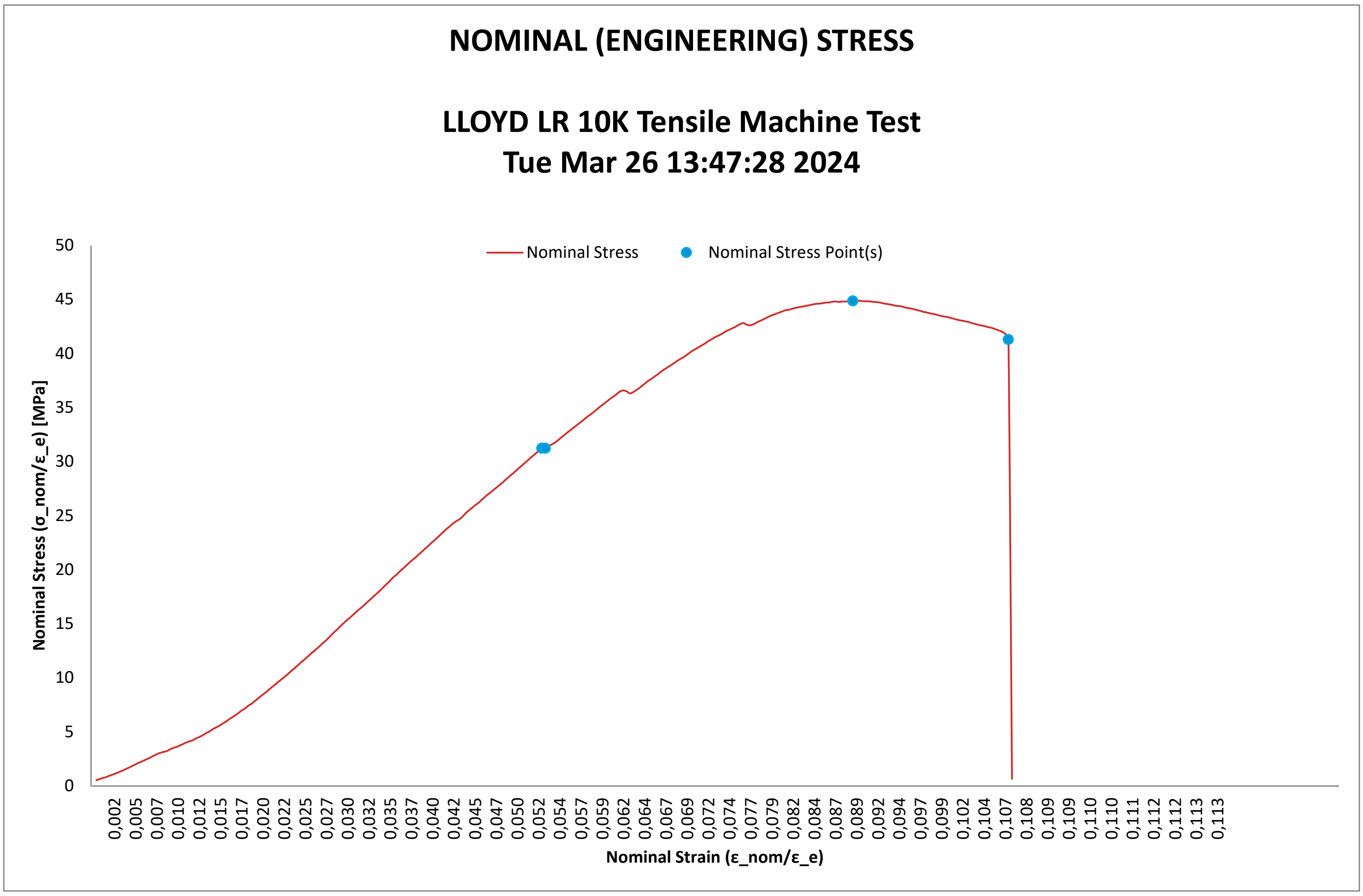
LR 10K Tensile Machine Settings

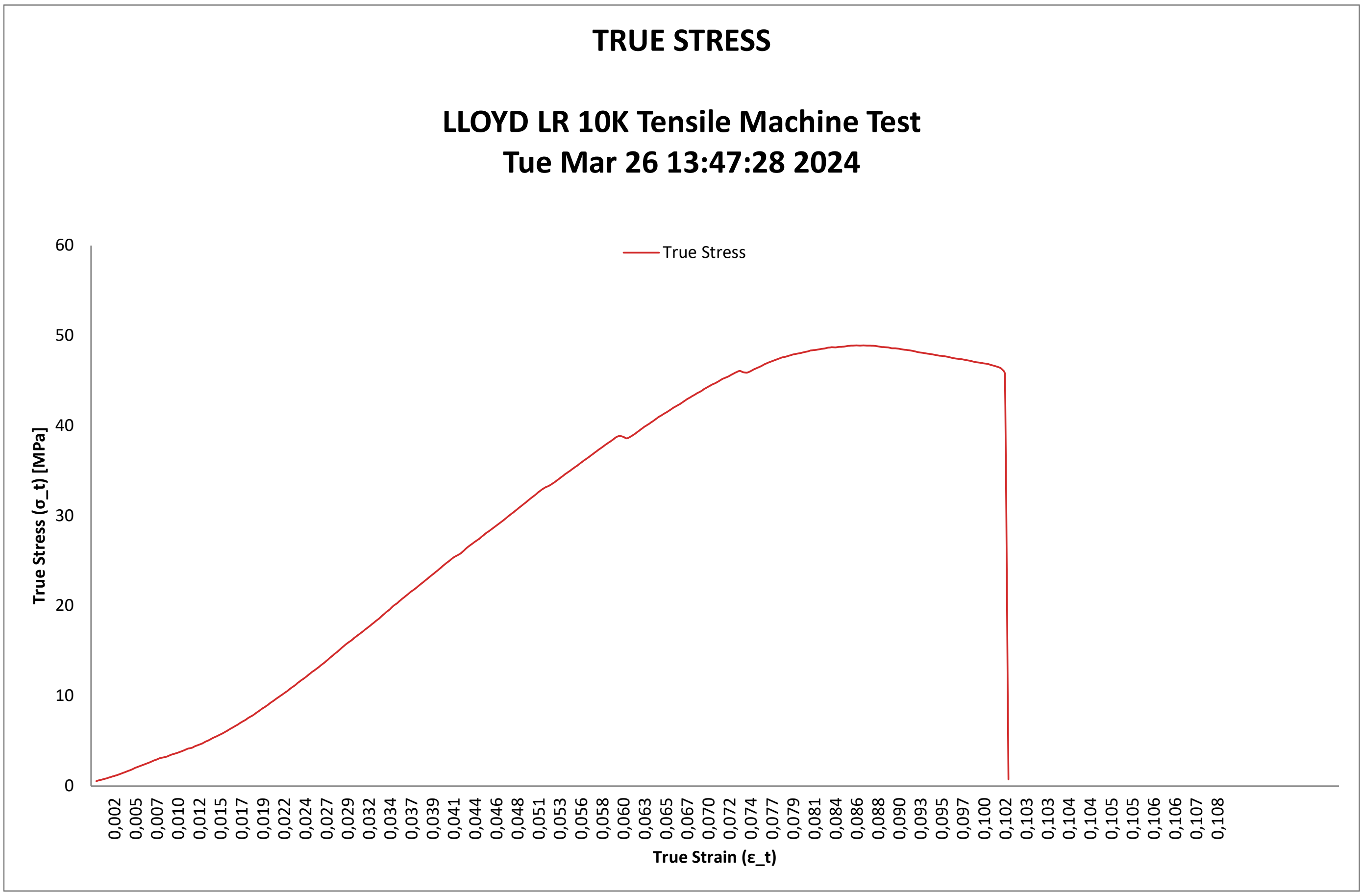
Tue Mar 26 13:47:28 2024

Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 13:47:28 2024
Plot Data
Crucial Point(s)
Load (N)
Extension (mm)
1600
1400
1200
1000
800
600
400
200
0
0,223
0,473
0,721
0,970
1,221
1,471
1,719
1,969
2,218
2,470
2,718
2,969
3,218
3,468
3,719
3,967
4,217
4,467
4,718
4,967
5,216
5,425
5,675
5,925
6,175
6,425
6,675
6,925
7,174
7,424
7,674
7,925
8,174
8,424
8,674
8,924
9,176
9,425
9,675
9,925
10,176
10,424
10,675
10,804
10,864
10,924
10,984
11,044
11,104
11,164
11,224
11,284
11,344


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 13:47:28 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 13:47:28 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60
0,002
0,005
0,007
0,010
0,012
0,015
0,017
0,019
0,022
0,024
0,027
0,029
0,032
0,034
0,037
0,039
0,041
0,044
0,046
0,048
0,051
0,053
0,056
0,058
0,060
0,063
0,065
0,067
0,070
0,072
0,074
0,077
0,079
0,081
0,084
0,086
0,088
0,090
0,093
0,095
0,097
0,100
0,102
0,103
0,103
0,104
0,104
0,105
0,105
0,106
0,106
0,107
0,108

C.3 Results T2-3

MATERIAL TESTING REPORT

Tue Mar 26 14:03:13 2024

Details: Test T2-3

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**38,665**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,86%**	
Young's modulus, E	**660,158**	MPa [N/mm^2]
True Stress, σ_t	**40,930**	MPa [N/mm^2]
True Strain, ε_t	**5,69%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**38,665**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,86%**	
True Stress, σ_t	**40,930**	MPa [N/mm^2]
True Strain, ε_t	**5,69%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**47,010**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,65%**	
True Stress, σ_t	**50,606**	MPa [N/mm^2]
True Strain, ε_t	**7,37%**	

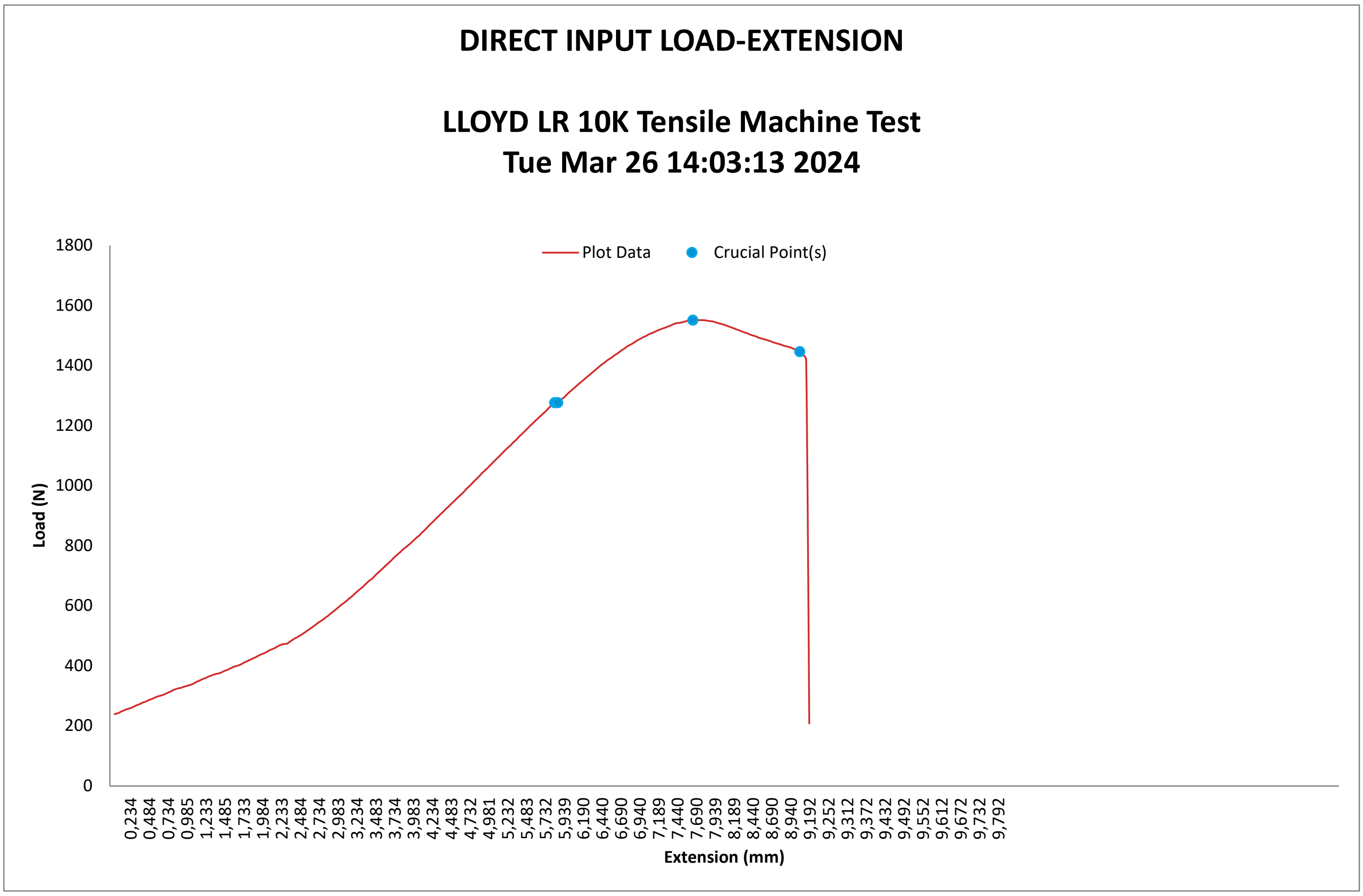
Fracture:

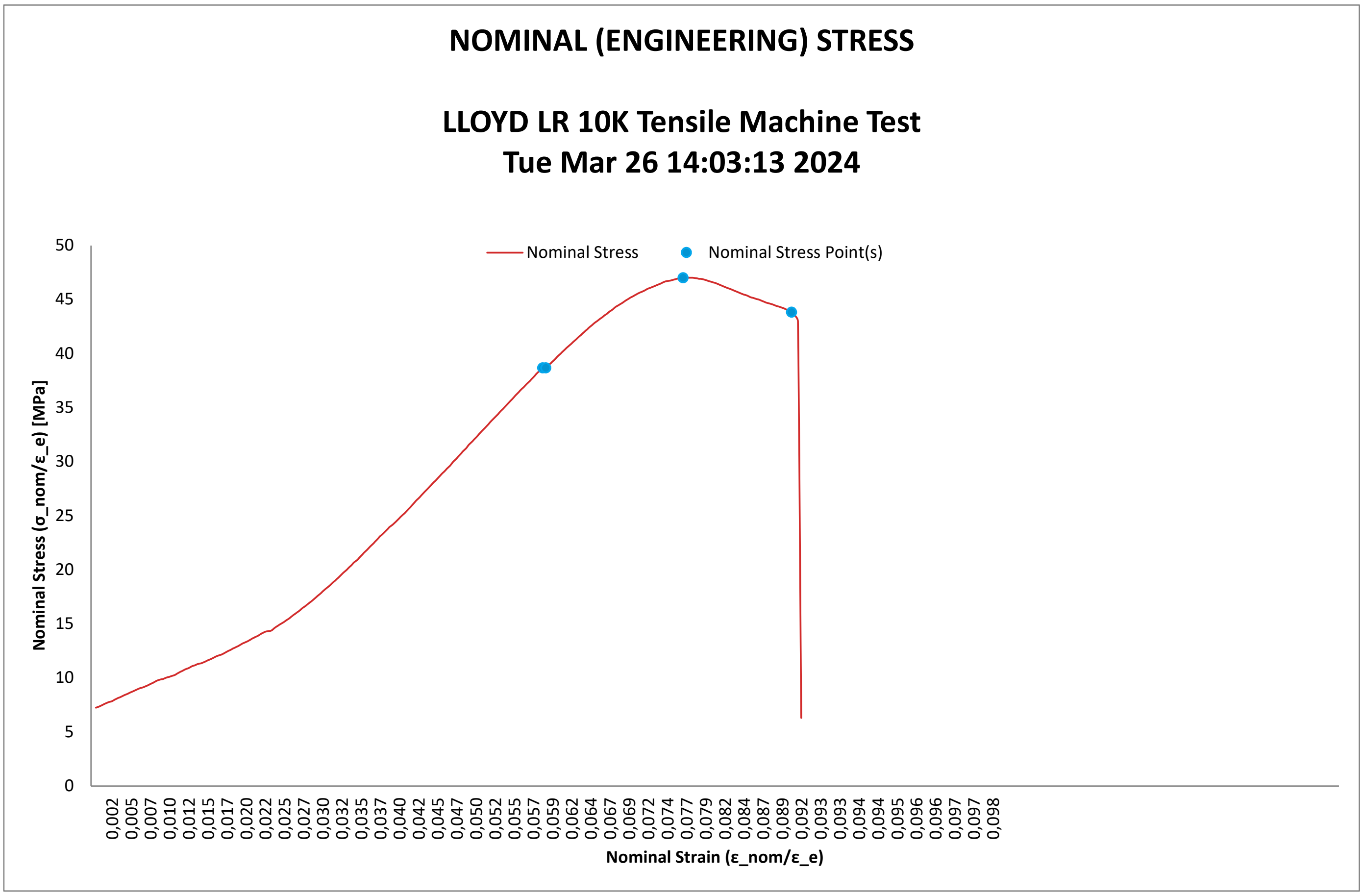
Nominal Stress, σ_nom/σ_e (S_y)	**43,833**	MPa [N/mm^2]
Nominal Strain, ε_n	**9,06%**	
True Stress, σ_t	**47,806**	MPa [N/mm^2]
True Strain, ε_t	**8,68%**	

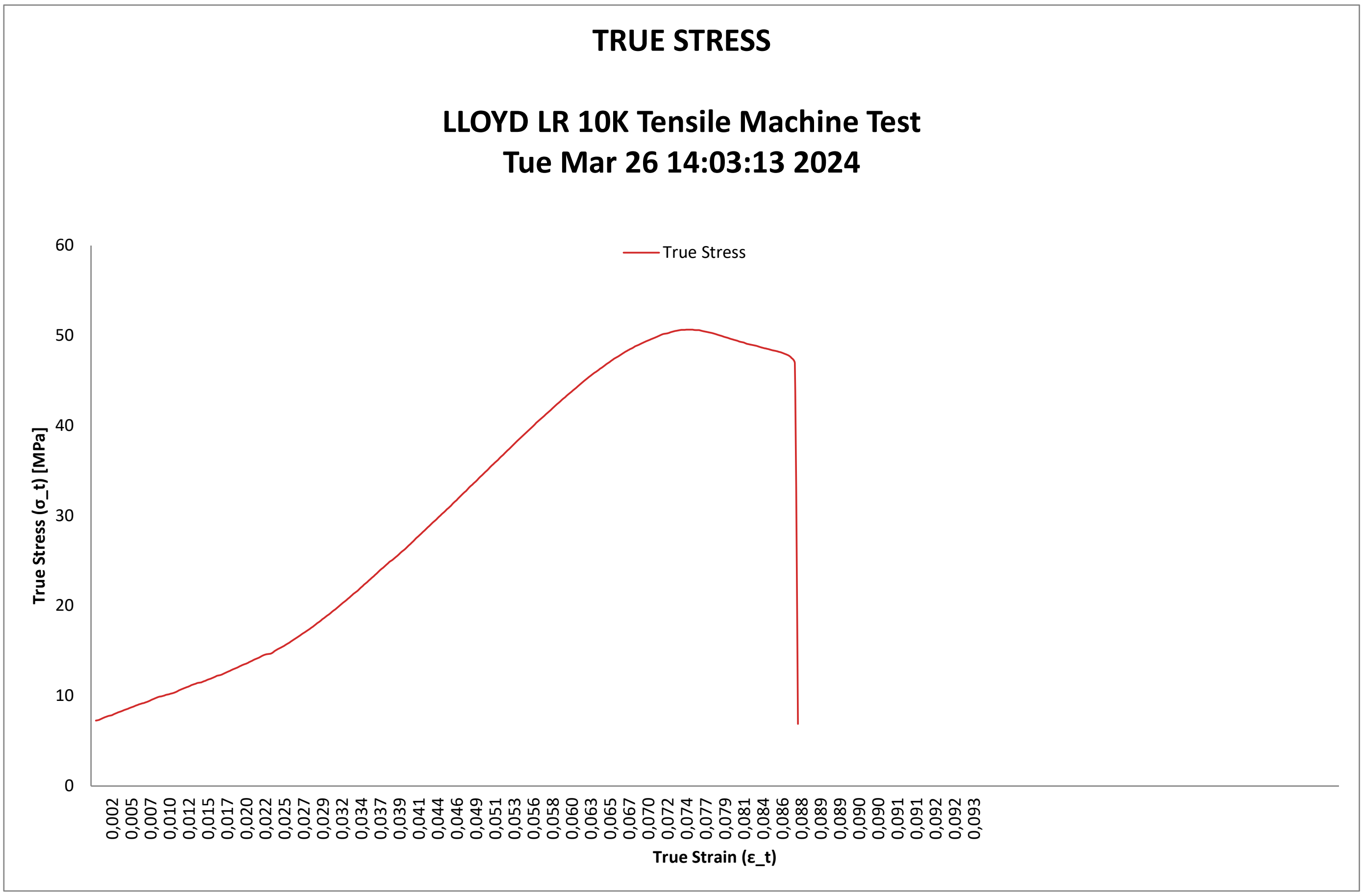
LR 10K Tensile Machine Settings

Tue Mar 26 14:03:13 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:03:13 2024
Plot Data
Crucial Point(s)
Load (N)
1800
1600
1400
1200
1000
800
600
400
200
0
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:03:13 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:03:13 2024
True Stress
True Stress (σ_t) [MPa]
0
10
20
30
40
50
60
0,002
0,005
0,007
0,010
0,012
0,015
0,017
0,020
0,022
0,025
0,027
0,029
0,032
0,034
0,037
0,039
0,041
0,044
0,046
0,049
0,051
0,053
0,056
0,058
0,060
0,063
0,065
0,067
0,070
0,072
0,074
0,077
0,079
0,081
0,084
0,086
0,088
0,089
0,089
0,090
0,090
0,091
0,091
0,092
0,092
0,093
True Strain (ε_t)

C.4 Results T2-4

MATERIAL TESTING REPORT

Tue Mar 26 14:17:10 2024

Details: Test T2-4

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**34,300**	MPa [N/mm^2]
Nominal Strain, ε_n	**3,96%**	
Young's modulus, E	**866,162**	MPa [N/mm^2]
True Stress, σ_t	**35,658**	MPa [N/mm^2]
True Strain, ε_t	**3,88%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**34,300**	MPa [N/mm^2]
Nominal Strain, ε_n	**3,96%**	
True Stress, σ_t	**35,658**	MPa [N/mm^2]
True Strain, ε_t	**3,88%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**43,179**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,42%**	
True Stress, σ_t	**45,951**	MPa [N/mm^2]
True Strain, ε_t	**6,22%**	

Fracture:

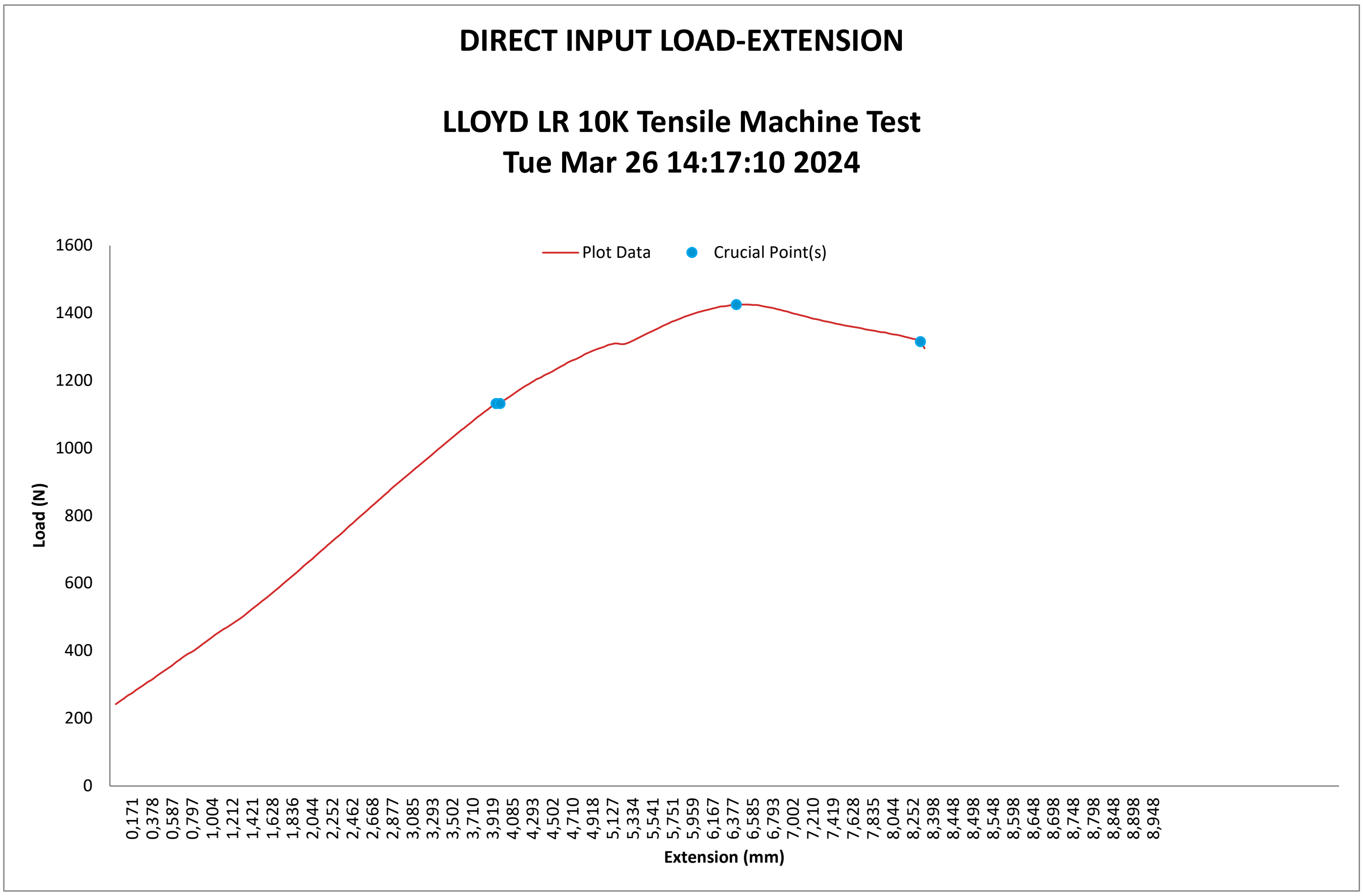
Nominal Stress, σ_nom/σ_e (S_y)	**39,853**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,34%**	
True Stress, σ_t	**43,176**	MPa [N/mm^2]
True Strain, ε_t	**8,01%**	

LR 10K Tensile Machine Settings

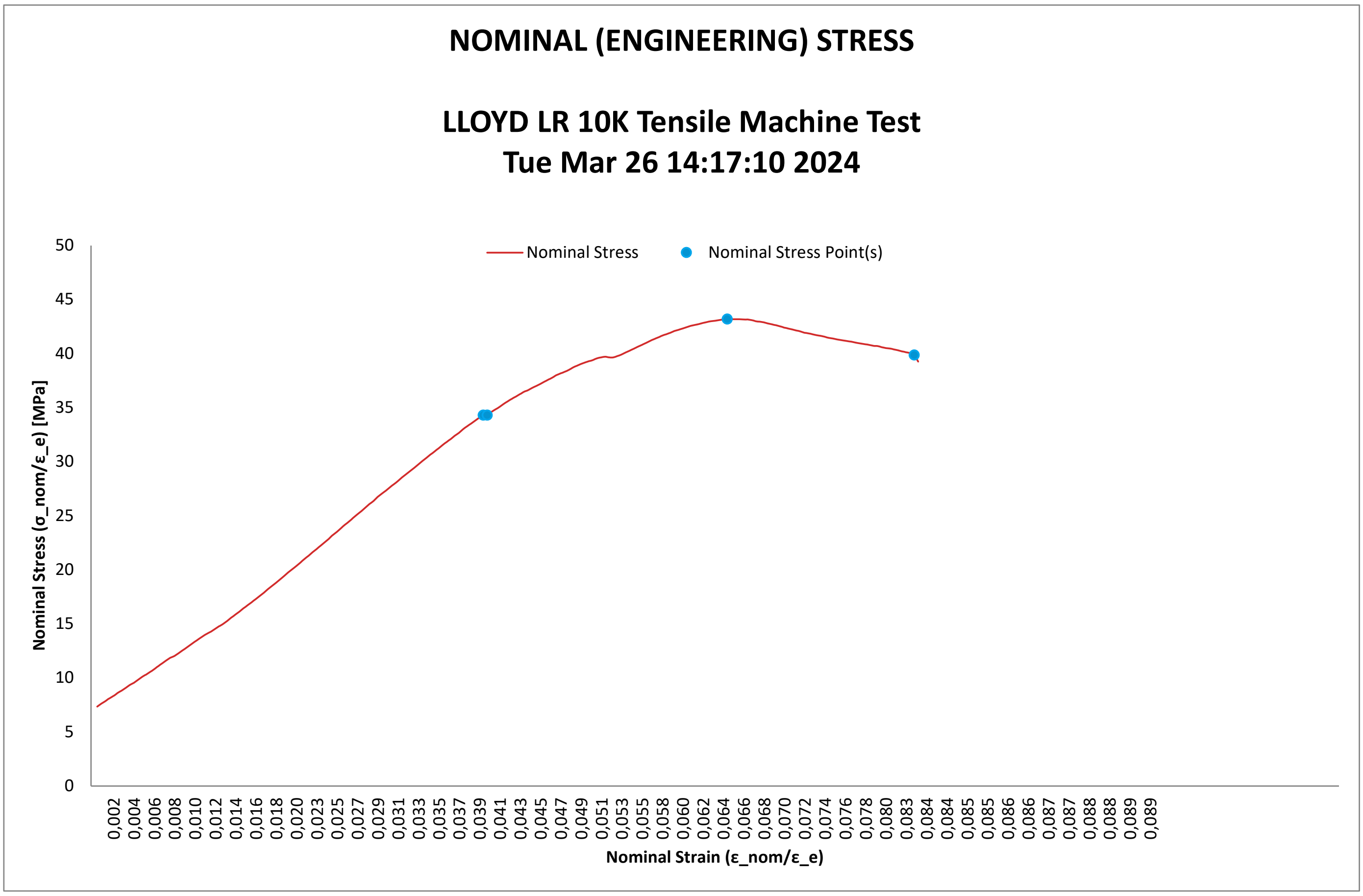
Tue Mar 26 14:17:10 2024

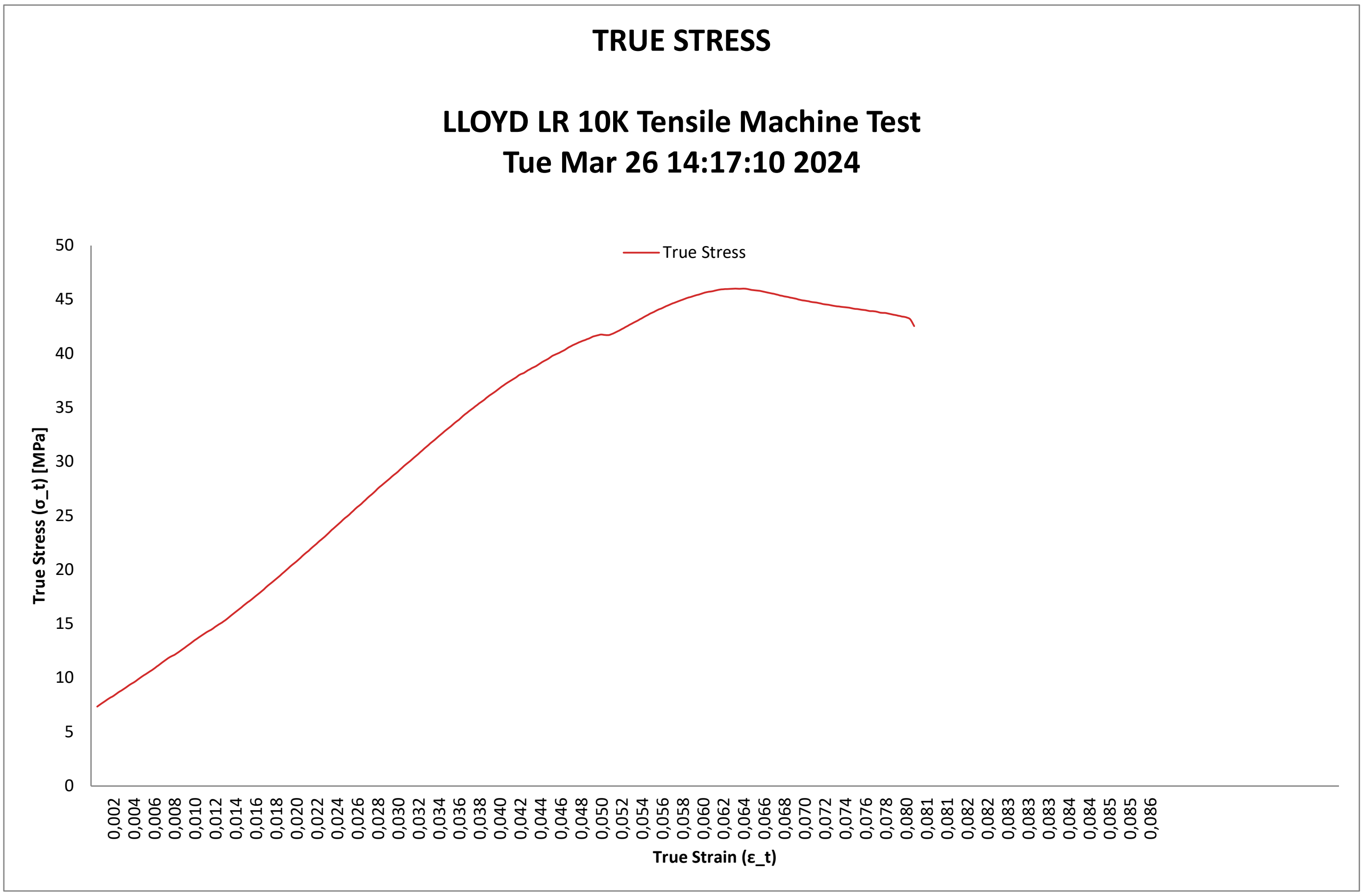
Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%



DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:17:10 2024
Plot Data
Crucial Point(s)
Load (N)
Extension (mm)
0
200
400
600
800
1000
1200
1400
1600
0,171
0,378
0,587
0,797
1,004
1,212
1,421
1,628
1,836
2,044
2,252
2,462
2,668
2,877
3,085
3,293
3,502
3,710
3,919
4,085
4,293
4,502
4,710
4,918
5,127
5,334
5,541
5,751
5,959
6,167
6,377
6,585
6,793
7,002
7,210
7,419
7,628
7,835
8,044
8,252
8,398
8,448
8,498
8,548
8,598
8,648
8,698
8,748
8,798
8,848
8,898
8,948


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:17:10 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
50
45
40
35
30
25
20
15
10
5
0
0,002
0,004
0,006
0,008
0,010
0,012
0,014
0,016
0,018
0,020
0,023
0,025
0,027
0,029
0,031
0,033
0,035
0,037
0,039
0,041
0,043
0,045
0,047
0,049
0,051
0,053
0,055
0,058
0,060
0,062
0,064
0,066
0,068
0,070
0,072
0,074
0,076
0,078
0,080
0,083
0,084
0,084
0,085
0,085
0,086
0,086
0,087
0,087
0,088
0,088
0,089
0,089
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:17:10 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)

C.5 Results T2-5

MATERIAL TESTING REPORT

Tue Mar 26 14:32:53 2024

Details: T2-5

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**29,667**	MPa [N/mm^2]
Nominal Strain, ε_n	**4,43%**	
Young's modulus, E	**668,935**	MPa [N/mm^2]
True Stress, σ_t	**30,983**	MPa [N/mm^2]
True Strain, ε_t	**4,34%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**29,667**	MPa [N/mm^2]
Nominal Strain, ε_n	**4,43%**	
True Stress, σ_t	**30,983**	MPa [N/mm^2]
True Strain, ε_t	**4,34%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**43,655**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,35%**	
True Stress, σ_t	**46,864**	MPa [N/mm^2]
True Strain, ε_t	**7,09%**	

Fracture:

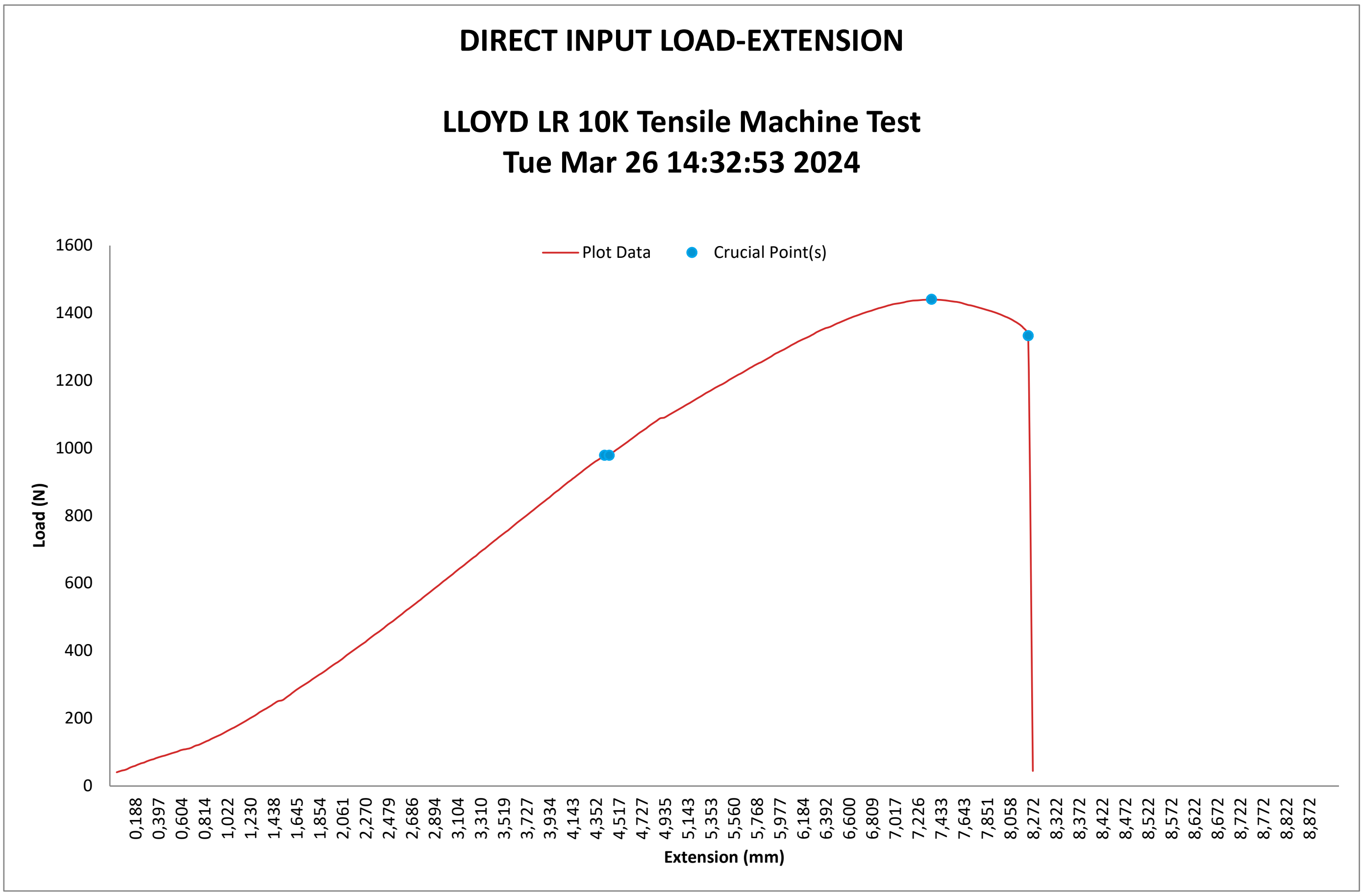
Nominal Stress, σ_nom/σ_e (S_y)	**40,388**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,23%**	
True Stress, σ_t	**43,711**	MPa [N/mm^2]
True Strain, ε_t	**7,91%**	

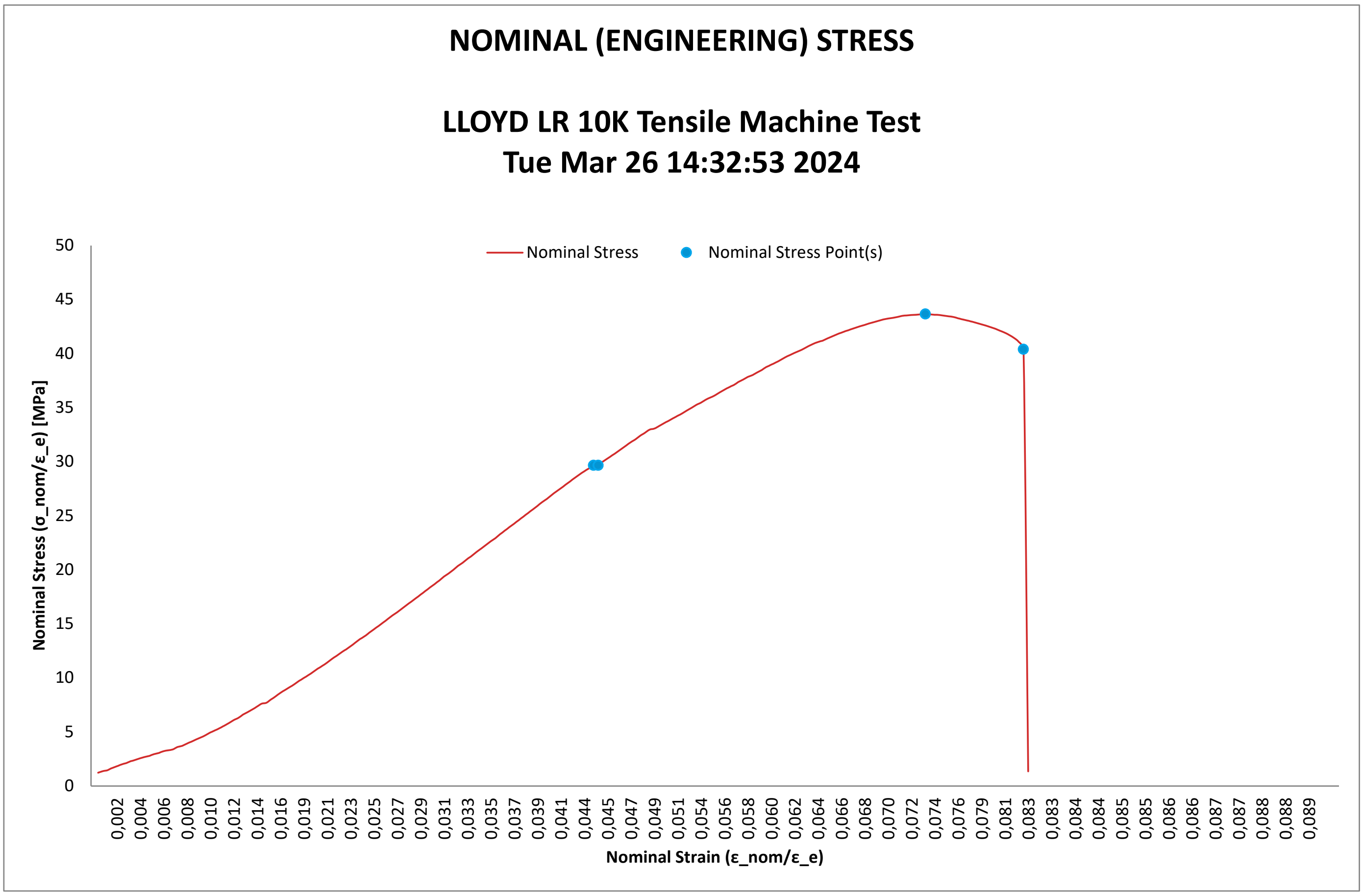
LR 10K Tensile Machine Settings

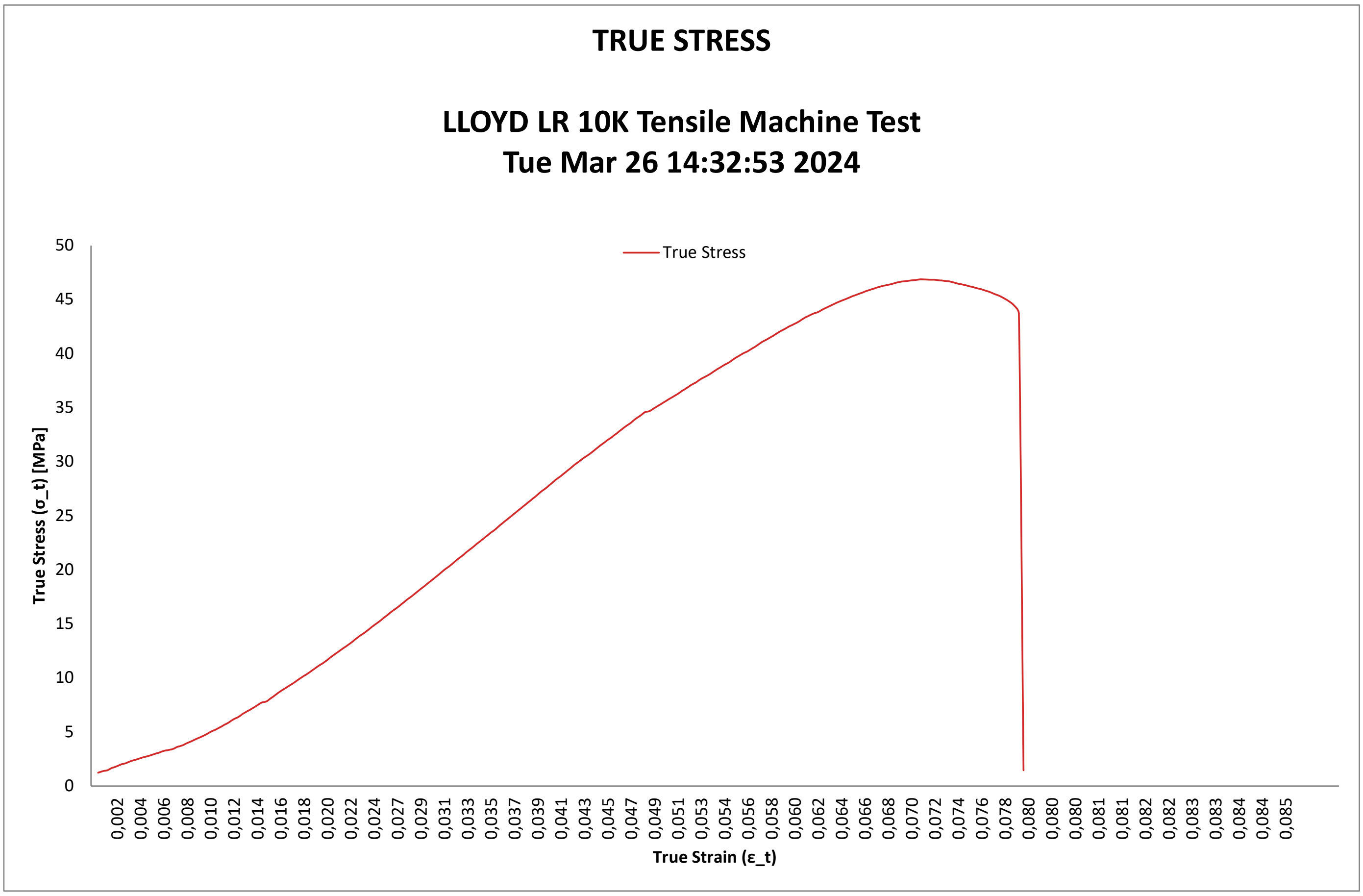
Tue Mar 26 14:32:53 2024

Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:32:53 2024
Plot Data
Crucial Point(s)
Load (N)
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:32:53 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:32:53 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
5
10
15
20
25
30
35
40
45
50
0,002
0,004
0,006
0,008
0,010
0,012
0,014
0,016
0,018
0,020
0,022
0,024
0,027
0,029
0,031
0,033
0,035
0,037
0,039
0,041
0,043
0,045
0,047
0,049
0,051
0,053
0,054
0,056
0,058
0,060
0,062
0,064
0,066
0,068
0,070
0,072
0,074
0,076
0,078
0,080
0,080
0,080
0,081
0,081
0,082
0,082
0,083
0,083
0,084
0,084
0,085

C.6 Results T2-6

MATERIAL TESTING REPORT

Tue Mar 26 14:44:46 2024

Details: Test T2-6

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**30,024**	MPa [N/mm^2]
Nominal Strain, ε_n	**3,94%**	
Young's modulus, E	**762,796**	MPa [N/mm^2]
True Stress, σ_t	**31,205**	MPa [N/mm^2]
True Strain, ε_t	**3,86%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**30,024**	MPa [N/mm^2]
Nominal Strain, ε_n	**3,94%**	
True Stress, σ_t	**31,205**	MPa [N/mm^2]
True Strain, ε_t	**3,86%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**44,159**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,31%**	
True Stress, σ_t	**47,387**	MPa [N/mm^2]
True Strain, ε_t	**7,06%**	

Fracture:

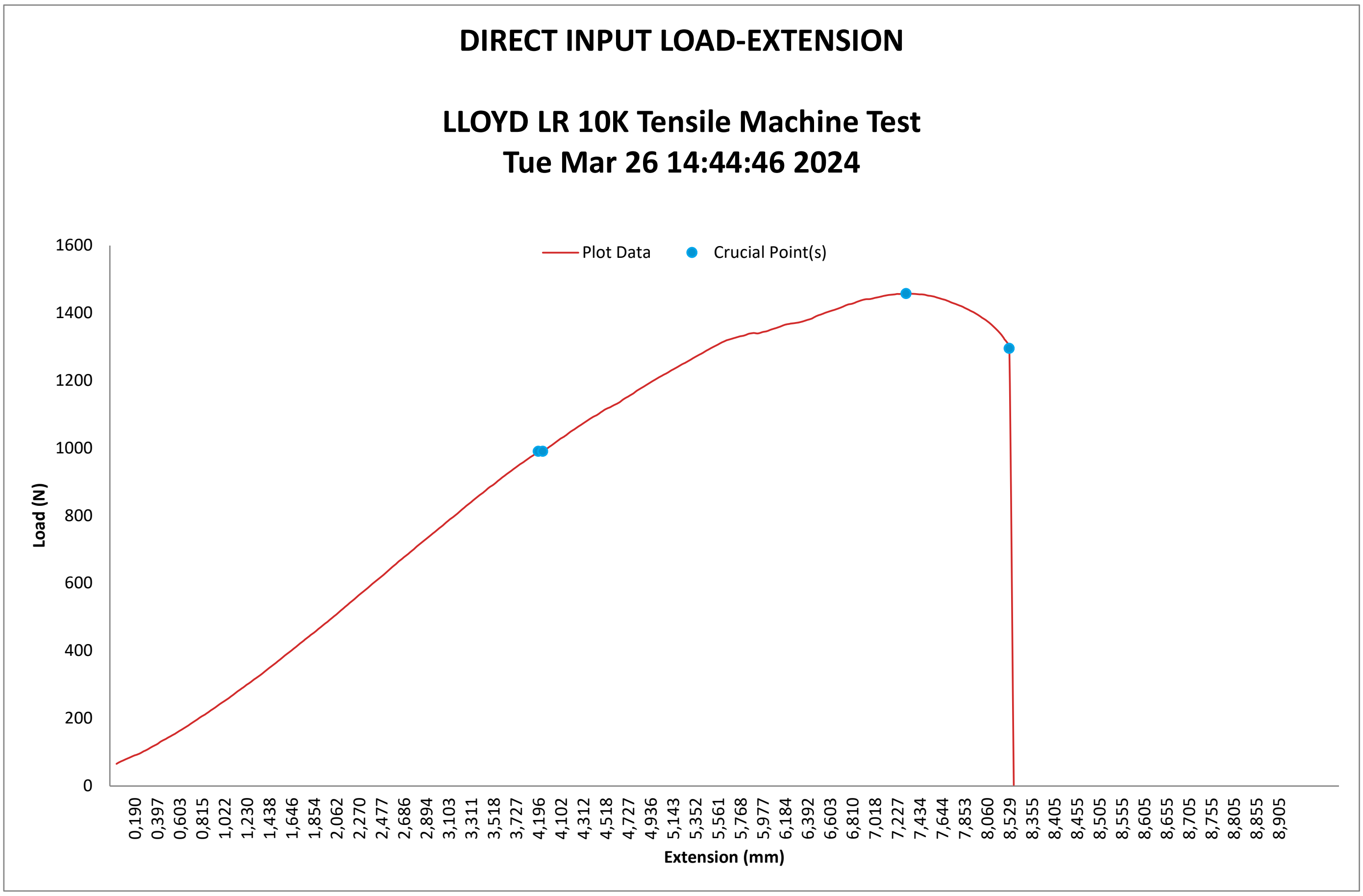
Nominal Stress, σ_nom/σ_e (S_y)	**39,259**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,27%**	
True Stress, σ_t	**42,506**	MPa [N/mm^2]
True Strain, ε_t	**7,94%**	

LR 10K Tensile Machine Settings

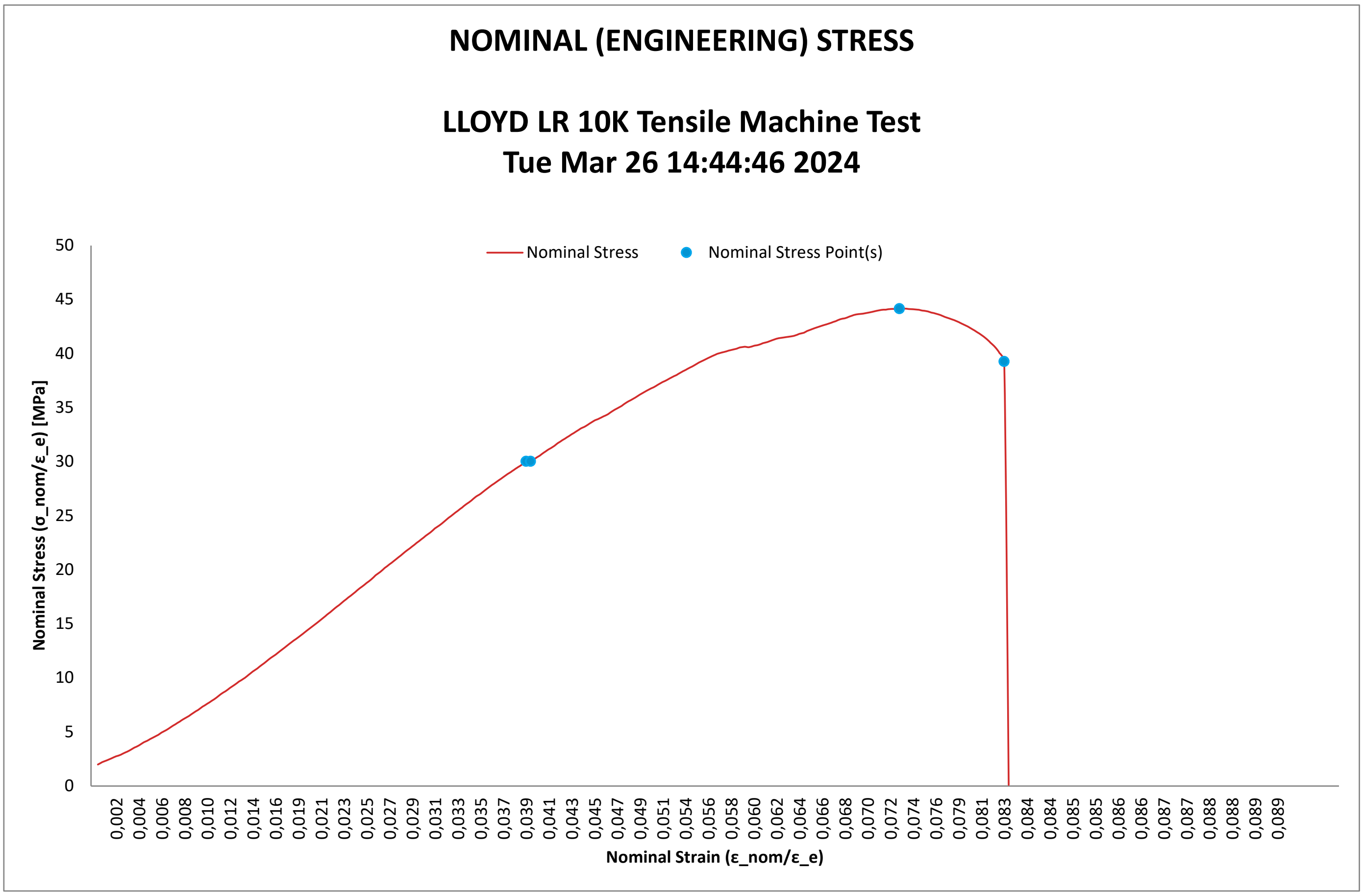
Tue Mar 26 14:44:46 2024

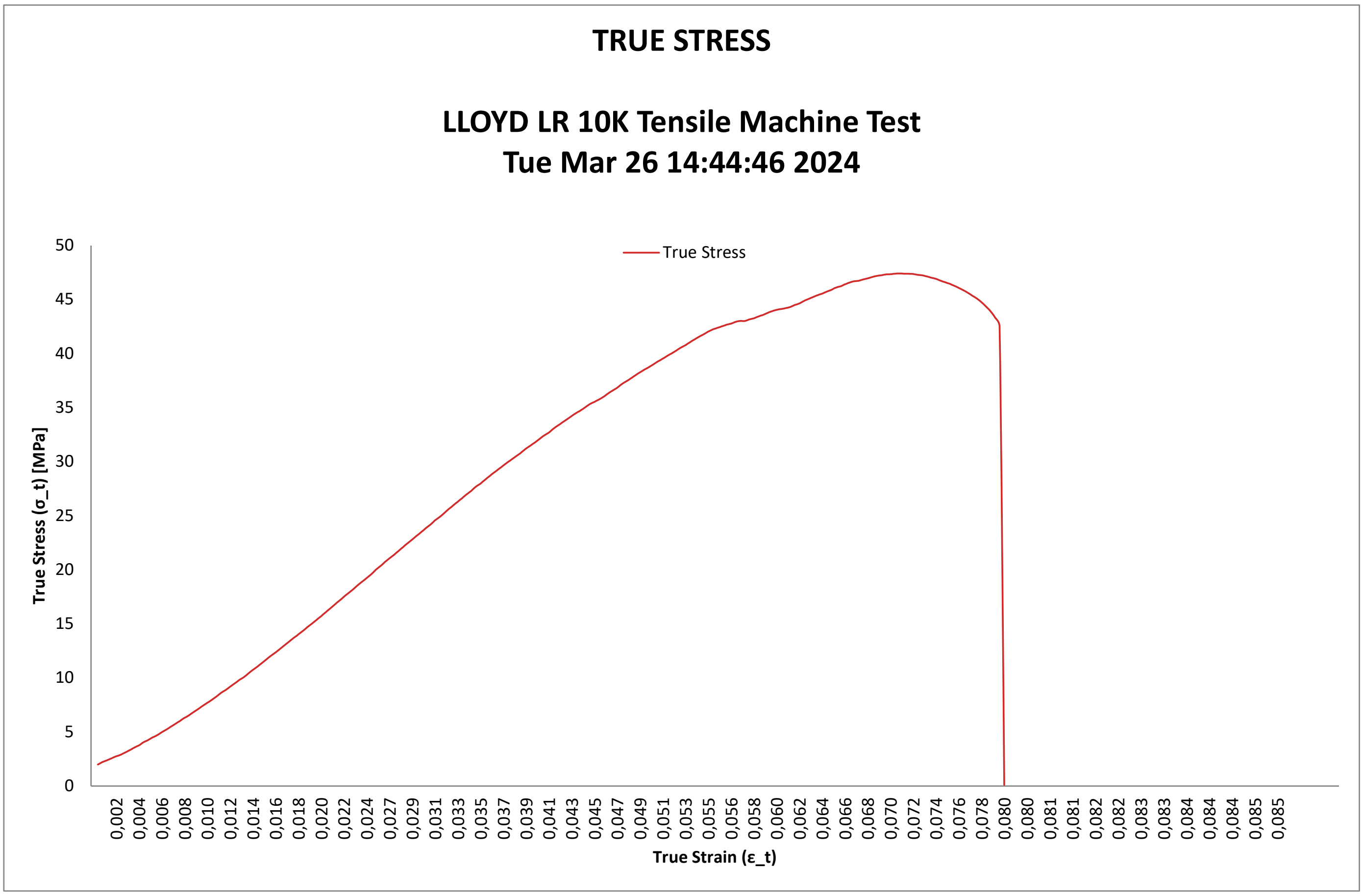
Details: **...**

Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%



DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:44:46 2024
Plot Data
Crucial Point(s)
Load (N)
1600
1400
1200
1000
800
600
400
200
0
0,190
0,397
0,603
0,815
1,022
1,230
1,438
1,646
1,854
2,062
2,270
2,477
2,686
2,894
3,103
3,311
3,518
3,727
4,196
4,102
4,312
4,518
4,727
4,936
5,143
5,352
5,561
5,768
5,977
6,184
6,392
6,603
6,810
7,018
7,227
7,434
7,644
7,853
8,060
8,529
8,355
8,405
8,455
8,505
8,555
8,605
8,655
8,705
8,755
8,805
8,855
8,905
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:44:46 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 14:44:46 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
5
10
15
20
25
30
35
40
45
50

C.7 Results T2-7

MATERIAL TESTING REPORT

Tue Mar 26 15:06:15 2024

Details: T2-7

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**33,676**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,64%**	
Young's modulus, E	**597,099**	MPa [N/mm^2]
True Stress, σ_t	**35,576**	MPa [N/mm^2]
True Strain, ε_t	**5,49%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**33,676**	MPa [N/mm^2]
Nominal Strain, ε_n	**5,64%**	
True Stress, σ_t	**35,576**	MPa [N/mm^2]
True Strain, ε_t	**5,49%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**43,565**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,68%**	
True Stress, σ_t	**46,912**	MPa [N/mm^2]
True Strain, ε_t	**7,40%**	

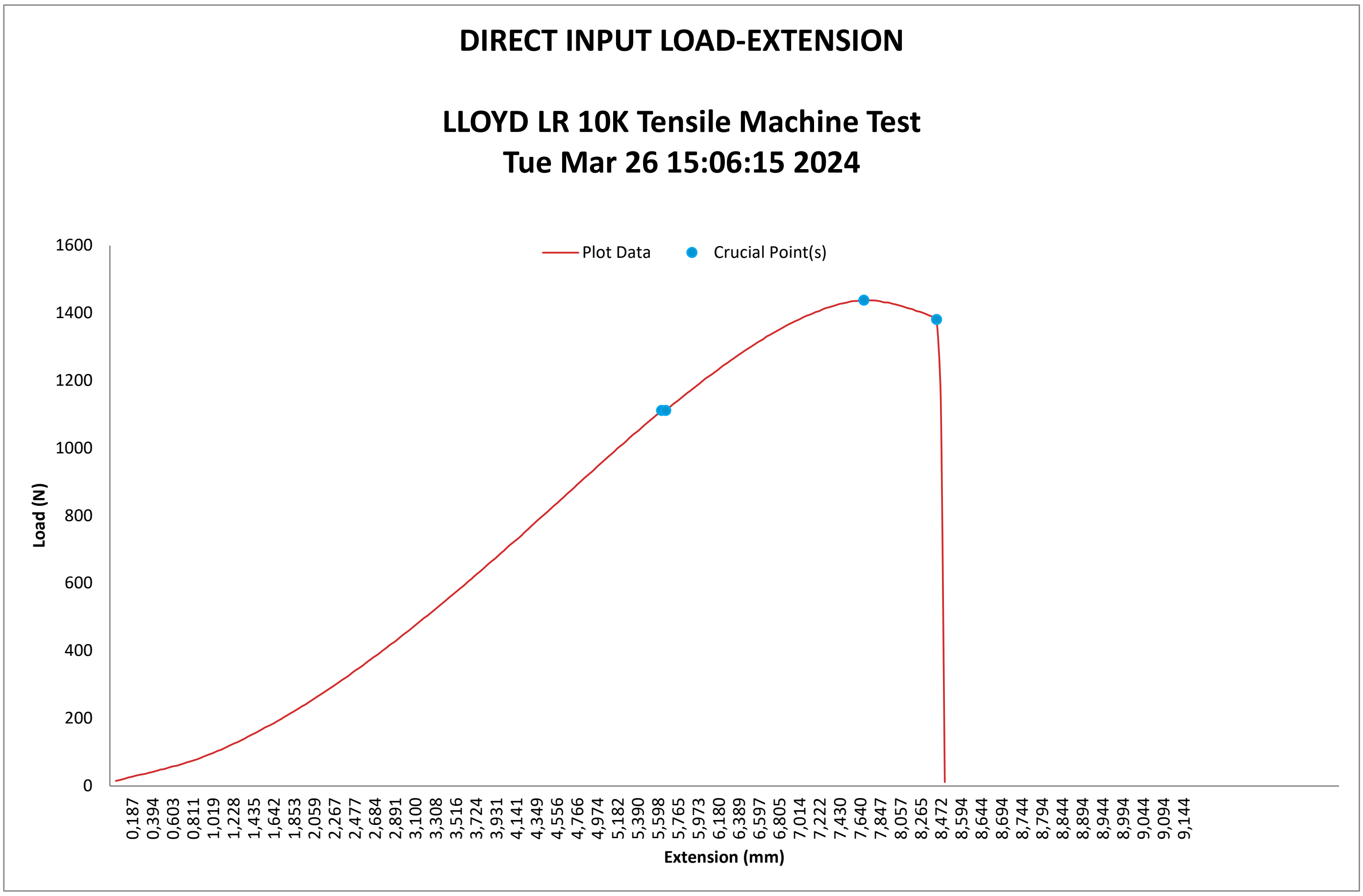
Fracture:

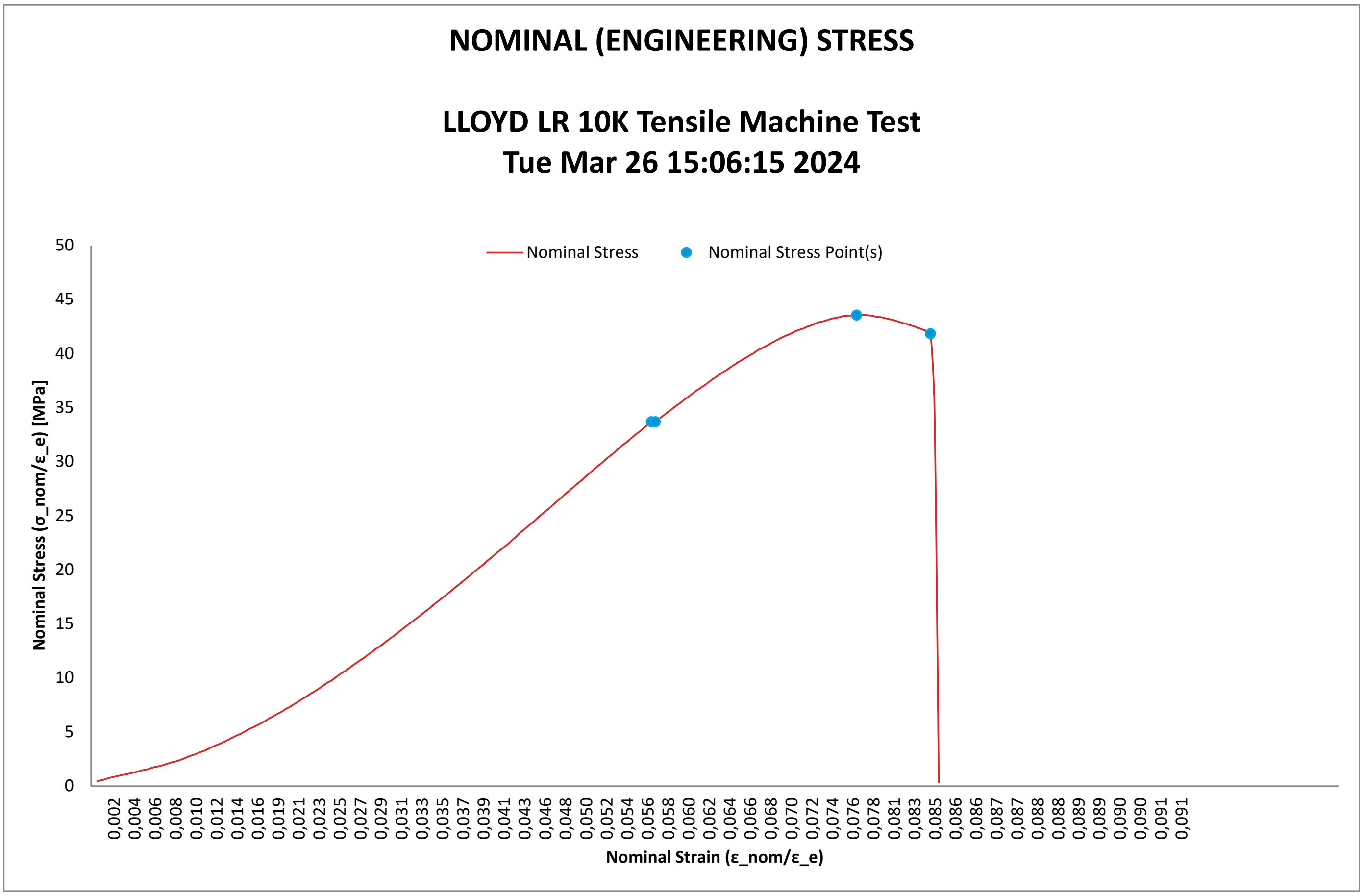
Nominal Stress, σ_nom/σ_e (S_y)	**41,843**	MPa [N/mm^2]
Nominal Strain, ε_n	**8,43%**	
True Stress, σ_t	**45,370**	MPa [N/mm^2]
True Strain, ε_t	**8,09%**	

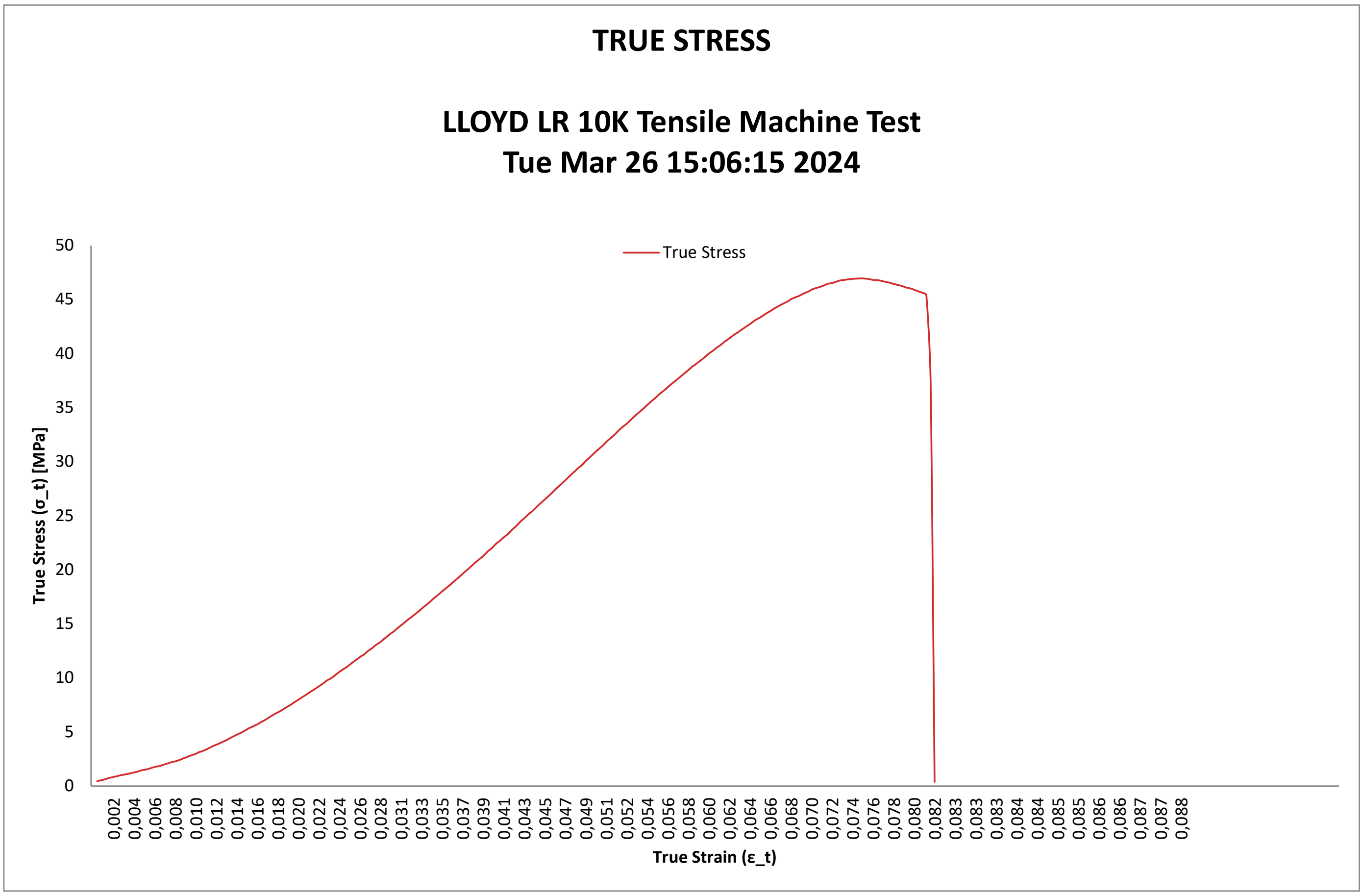
LR 10K Tensile Machine Settings

Tue Mar 26 15:06:15 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:06:15 2024
Plot Data
Crucial Point(s)
Load (N)
1600
1400
1200
1000
800
600
400
200
0
Extension (mm)
0,187
0,394
0,603
0,811
1,019
1,228
1,435
1,642
1,853
2,059
2,267
2,477
2,684
2,891
3,100
3,308
3,516
3,724
3,931
4,141
4,349
4,556
4,766
4,974
5,182
5,390
5,598
5,765
5,973
6,180
6,389
6,597
6,805
7,014
7,222
7,430
7,640
7,847
8,057
8,265
8,472
8,594
8,644
8,694
8,744
8,794
8,844
8,894
8,944
8,994
9,044
9,094
9,144


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:06:15 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:06:15 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
50
45
40
35
30
25
20
15
10
5
0
0,002
0,004
0,006
0,008
0,010
0,012
0,014
0,016
0,018
0,020
0,022
0,024
0,026
0,028
0,031
0,033
0,035
0,037
0,039
0,041
0,043
0,045
0,047
0,049
0,051
0,052
0,054
0,056
0,058
0,060
0,062
0,064
0,066
0,068
0,070
0,072
0,074
0,076
0,078
0,080
0,082
0,083
0,083
0,084
0,084
0,085
0,085
0,086
0,086
0,087
0,087
0,088

C.8 Results T2-8

MATERIAL TESTING REPORT

Tue Mar 26 15:21:13 2024

Details: Test T2-8

Material Properties:

Start Thickness	**3,000**	mm
Start Width	**11,000**	mm
Start Length	**100,000**	mm

Proportional limit:

Nominal Stress, σ_nom/σ_e (S_y)	**40,121**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,34%**	
Young's modulus, E	**632,418**	MPa [N/mm^2]
True Stress, σ_t	**42,666**	MPa [N/mm^2]
True Strain, ε_t	**6,15%**	

Yielding (lower):

Nominal Stress, σ_nom/σ_e (S_y)	**40,121**	MPa [N/mm^2]
Nominal Strain, ε_n	**6,34%**	
True Stress, σ_t	**42,666**	MPa [N/mm^2]
True Strain, ε_t	**6,15%**	

Ultimate Tensile Strength:

Nominal Stress, σ_nom/σ_e (S_ut)	**46,595**	MPa [N/mm^2]
Nominal Strain, ε_n	**7,97%**	
True Stress, σ_t	**50,307**	MPa [N/mm^2]
True Strain, ε_t	**7,67%**	

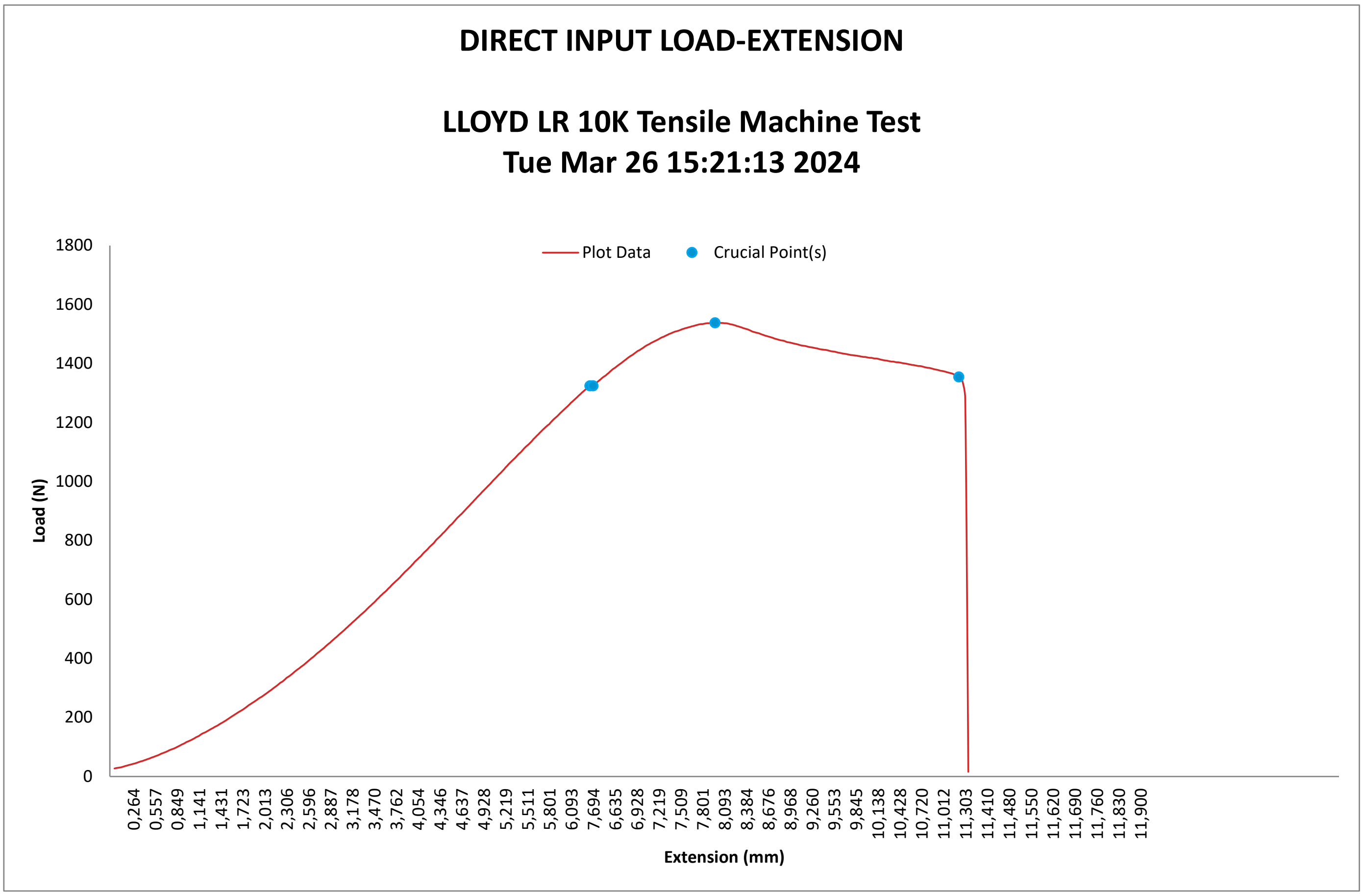
Fracture:

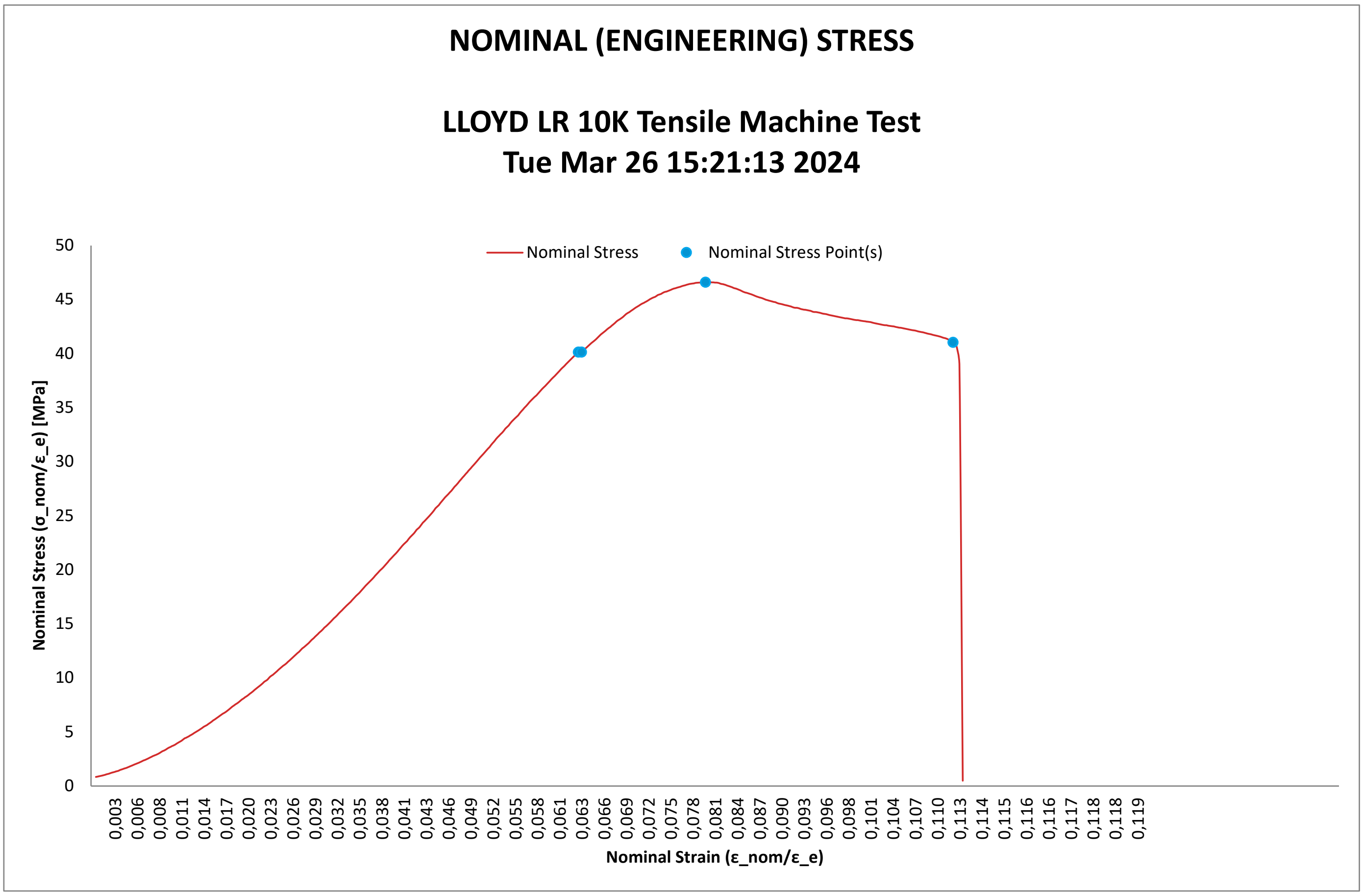
Nominal Stress, σ_nom/σ_e (S_y)	**41,041**	MPa [N/mm^2]
Nominal Strain, ε_n	**11,22%**	
True Stress, σ_t	**45,646**	MPa [N/mm^2]
True Strain, ε_t	**10,63%**	

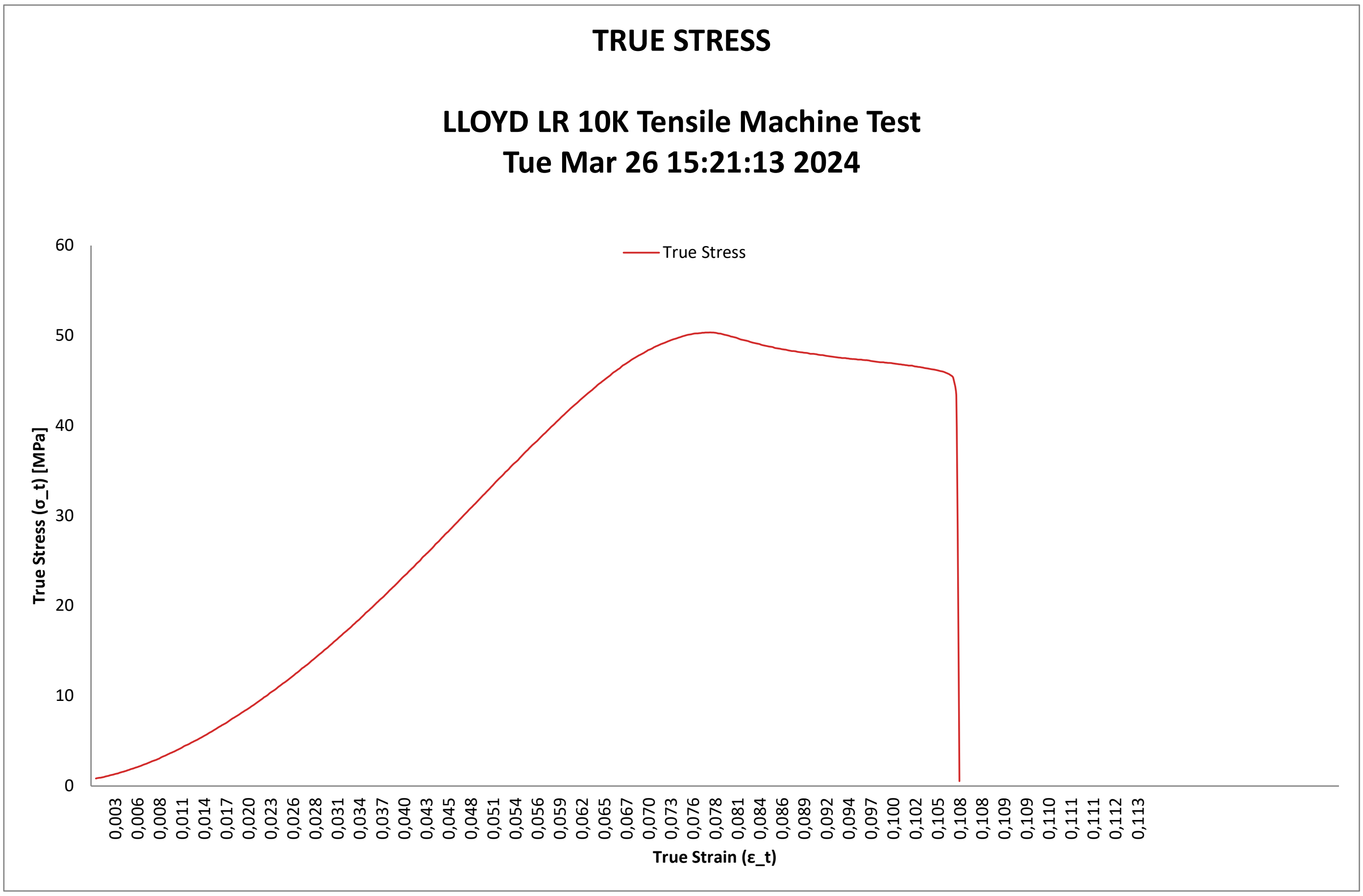
LR 10K Tensile Machine Settings

Tue Mar 26 15:21:13 2024

Details:	**...**	
Crosshead Speed	**50,000**	mm/min
(Jog speed)	**100,000**	mm/min
Load error (graph)	**-2,000**	%


DIRECT INPUT LOAD-EXTENSION
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:21:13 2024
Plot Data
Crucial Point(s)
Load (N)
1800
1600
1400
1200
1000
800
600
400
200
0
0,264
0,557
0,849
1,141
1,431
1,723
2,013
2,306
2,596
2,887
3,178
3,470
3,762
4,054
4,346
4,637
4,928
5,219
5,511
5,801
6,093
7,694
6,635
6,928
7,219
7,509
7,801
8,093
8,384
8,676
8,968
9,260
9,553
9,845
10,138
10,428
10,720
11,012
11,303
11,410
11,480
11,550
11,620
11,690
11,760
11,830
11,900
Extension (mm)


NOMINAL (ENGINEERING) STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:21:13 2024
Nominal Stress
Nominal Stress Point(s)
Nominal Stress (σ_nom/ε_e) [MPa]
Nominal Strain (ε_nom/ε_e)


TRUE STRESS
LLOYD LR 10K Tensile Machine Test
Tue Mar 26 15:21:13 2024
True Stress
True Stress (σ_t) [MPa]
True Strain (ε_t)
0
10
20
30
40
50
60
0,003
0,006
0,008
0,011
0,014
0,017
0,020
0,023
0,026
0,028
0,031
0,034
0,037
0,040
0,043
0,045
0,048
0,051
0,054
0,056
0,059
0,062
0,065
0,067
0,070
0,073
0,076
0,078
0,081
0,084
0,086
0,089
0,092
0,094
0,097
0,100
0,102
0,105
0,108
0,108
0,109
0,109
0,110
0,111
0,111
0,112
0,113

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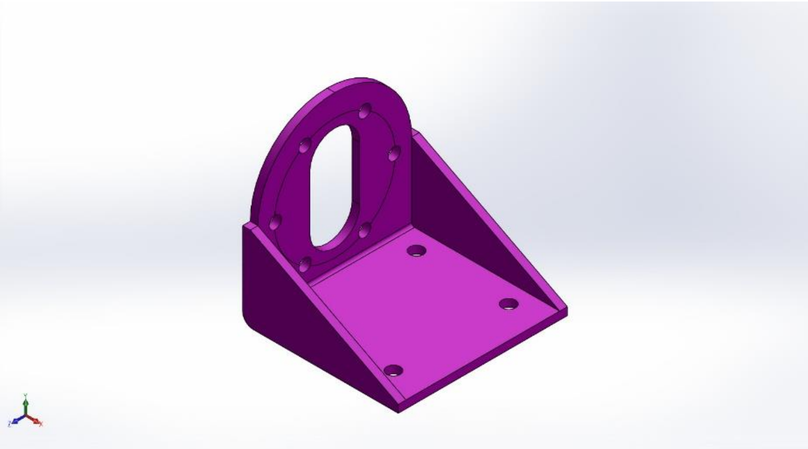


Simulation of 520 DC motor fastener

Date: fredag 17. mai 2024
Designer: Adrian Elias Haugjord
Study name: Weight
Analysis type: Static

Table of Contents

Description

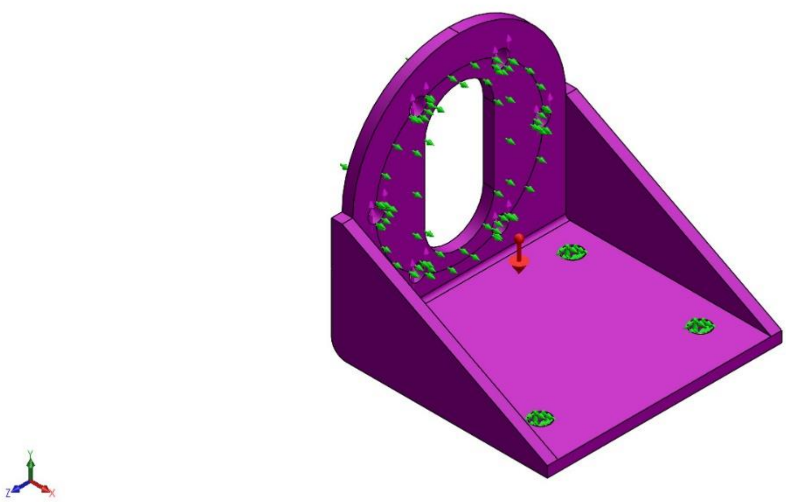
No Data

Assumptions

When mounted on the car, the force from the weight of the car will work parallel to the ZY-plane in the positive Y direction.

The weight of the car is 5,4 kilograms distributed over the four brackets. 1,35 kilograms of load will be applied on the bracket, for the simulation we rounded this up to 15 Newtons.

Model Information



Model name: 520 DC motor fastener
Current Configuration: 3d printable

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Split Line1 	Solid Body	**Mass:0,00920958 kg** **Volume:7,25164e-06 m^3** **Density:1 270 kg/m^3** **Weight:0,0902539 N**	**C:\Users\haugj\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Final model\Robot car iteration 3-2024_04_29_1428\Brackets & fasteners\520 DC motor fastener.SLDPRT** May 17 13:26:00 2024

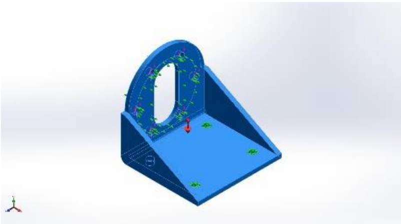
Study Properties

Study name	Weight
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\haugj\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Final model\Robot car iteration 3-2024_04_29_1428\Brackets & fasteners)

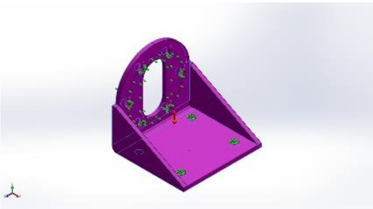
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Material Properties

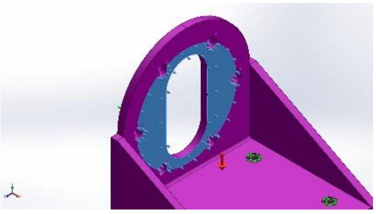
Model Reference	Properties	Components
	**Name:** Clas Ohlson PLA **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 35,607 N/mm^2 **Tensile strength:** 48,859 N/mm^2 **Elastic modulus:** 651,75 N/mm^2 **Poisson's ratio:** 0,36 **Mass density:** 1,27 g/cm^3	SolidBody 1(Split Line1)(520 DC motor fastener)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Roller/Slider-1		**Entities:** 2 face(s) **Type:** Roller/Slider

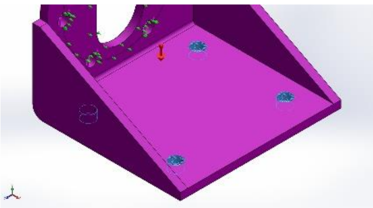
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-27,4228	-15,2269	0,00790618	31,3667
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Roller/Slider-2		**Entities:** 1 face(s) **Type:** Roller/Slider

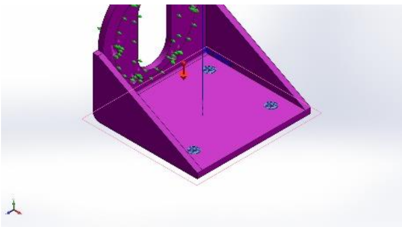
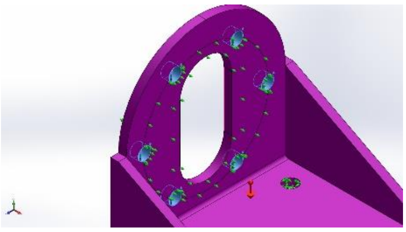
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	23,1315	8,02534e-14	-4,01267e-15	23,1315
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 4 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	4,69682	0,246572	6,11799e-08	4,70329
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Gravity-1		**Reference:** Top Plane **Values:** 0 0 -9,81 **Units:** m/s^2
Force-1		**Entities:** 6 face(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---; ---; 15 N

Connector Definitions

No Data

Interaction Information

No Data

Mesh information

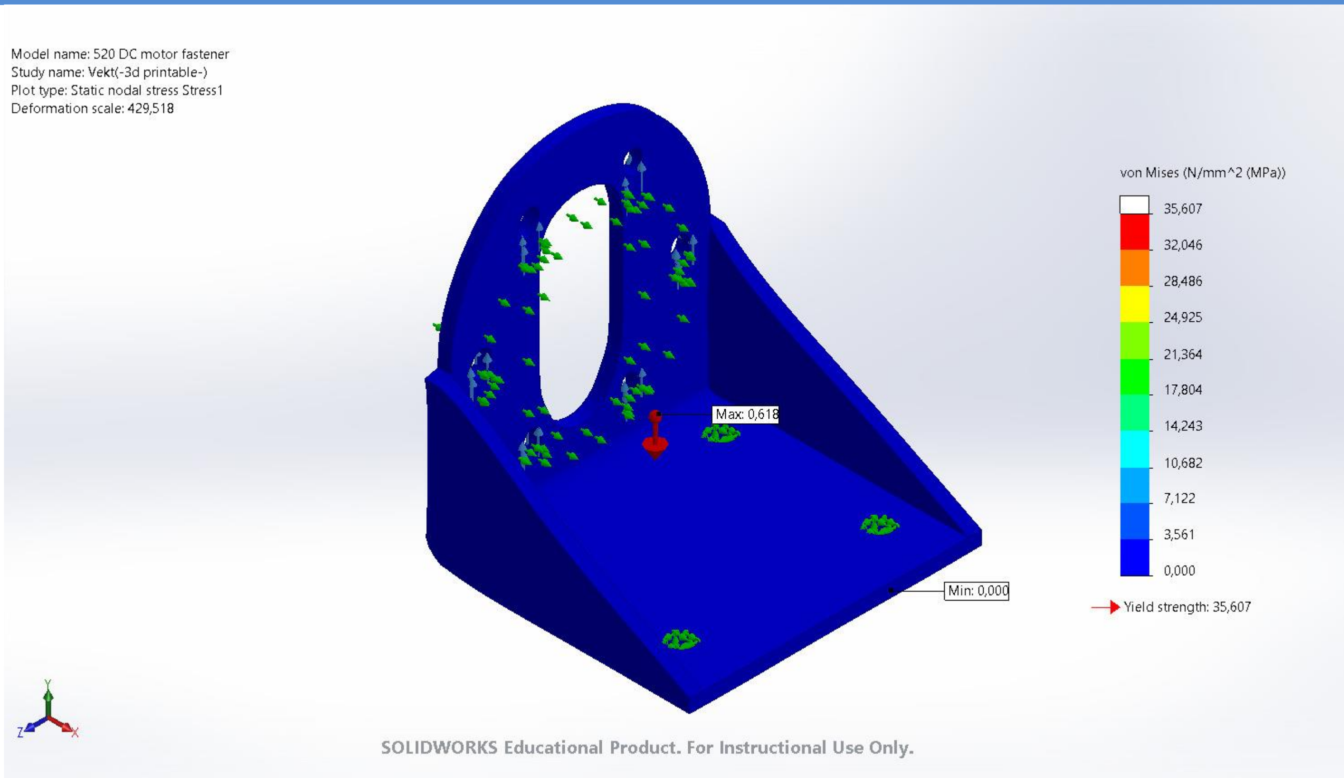
Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	2,52973 mm
Minimum element size	0,563769 mm
Mesh Quality	High

Mesh information - Details

Total Nodes	17449
Total Elements	9128
Maximum Aspect Ratio	5,871
% of elements with Aspect Ratio < 3	96,6
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:07
Computer name:	

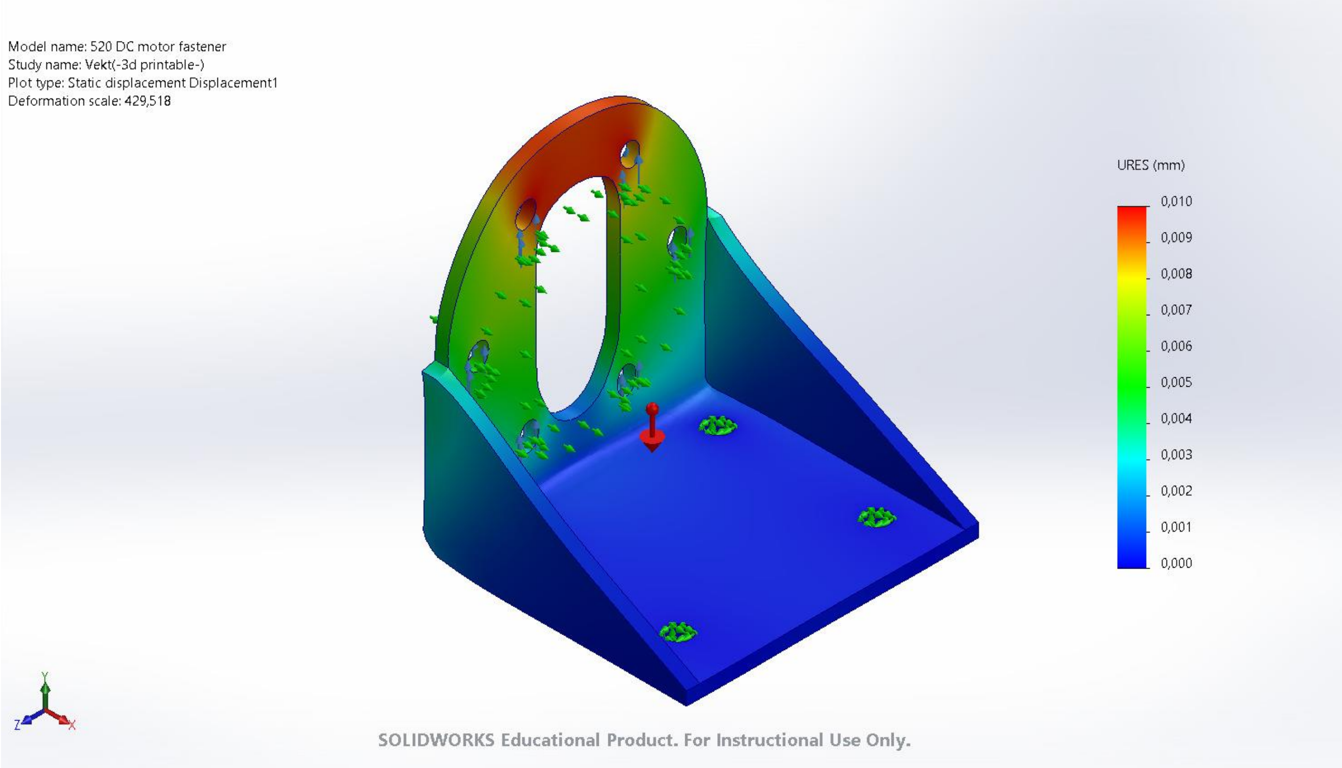
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0,000N/mm^2 (MPa) Node: 16838	0,618N/mm^2 (MPa) Node: 14905



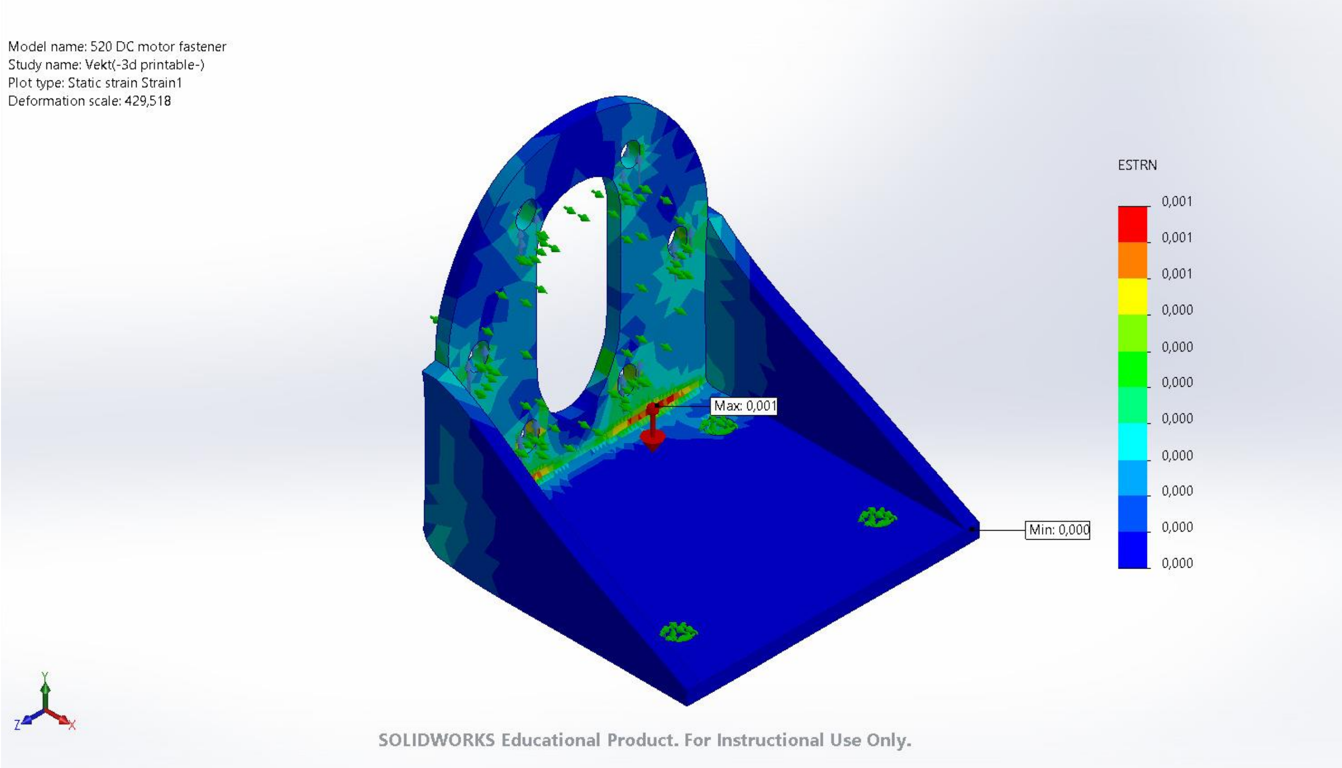
520 DC motor fastener-Vekt-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000mm Node: 18	0,010mm Node: 13826



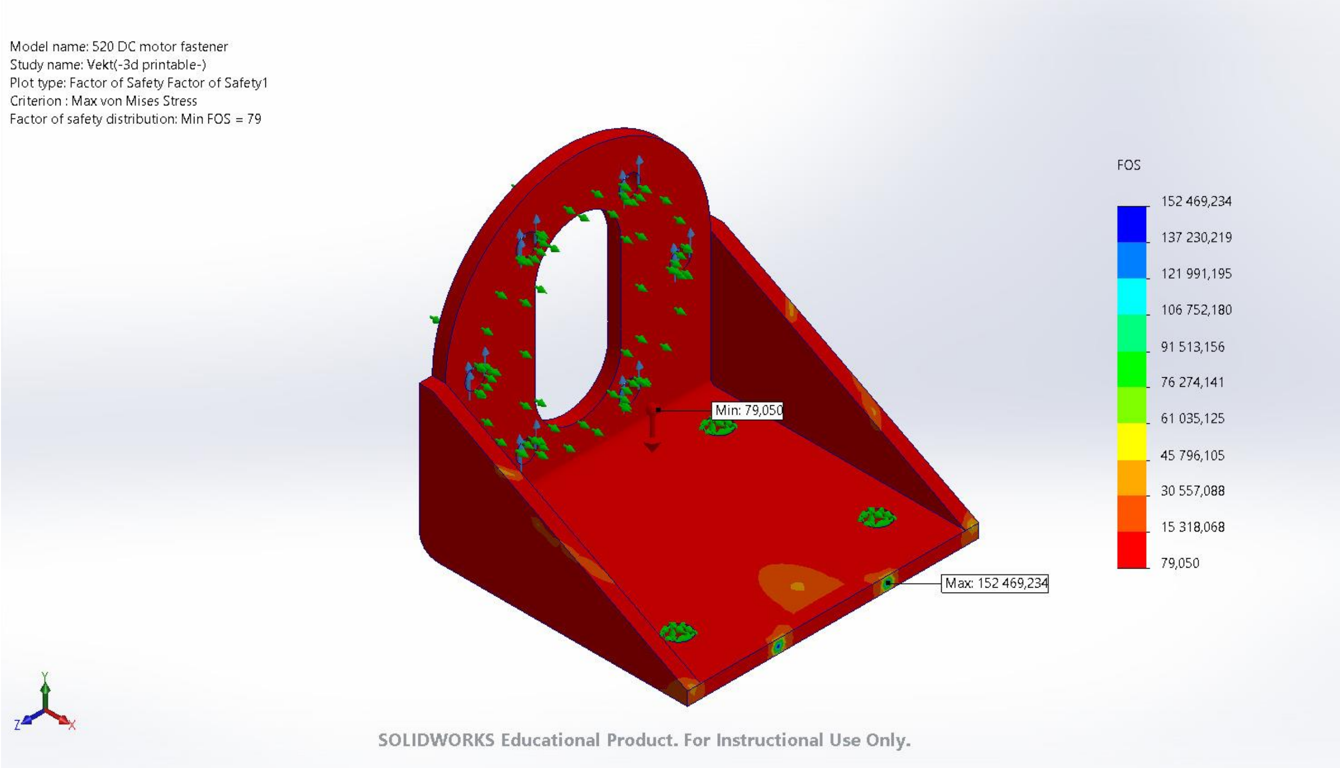
520 DC motor fastener-Vekt-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0,000 Element: 8118	0,001 Element: 7524



520 DC motor fastener-Vekt-Strain-Strain1

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	79,050 Node: 14905	152 469,234 Node: 16838

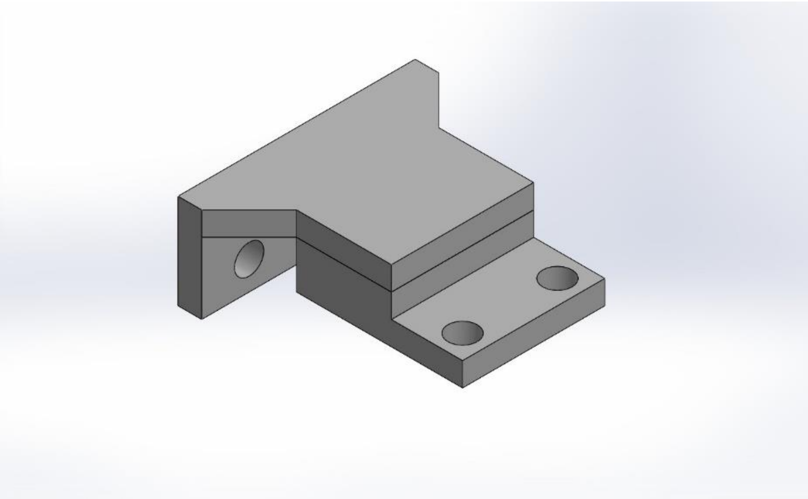


520 DC motor fastener-Vekt-Factor of Safety-Factor of Safety1

Conclusion

When only taking the weight of the car into consideration the brackets will work without a problem.

KROMIUM
https://itfag.usn.no/grupper/D03-24/



Simulation of Wall attachment bracket assy

Date: fredag 17. mai 2024
Designer: Henrik Bertelsen
Study name: Static 1
Analysis type: Static

Table of Contents

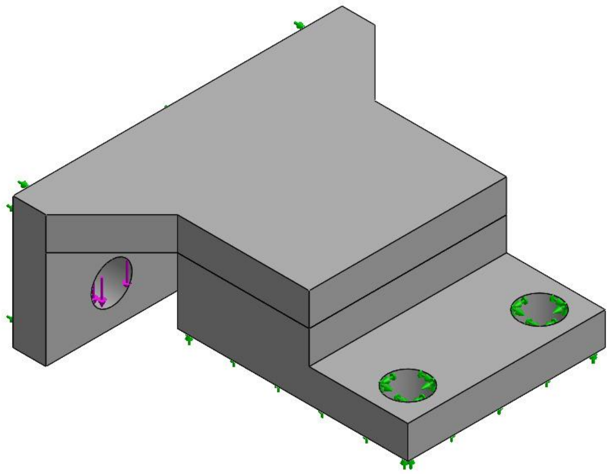
Description

Simulation of wall bracket assembly

Assumptions

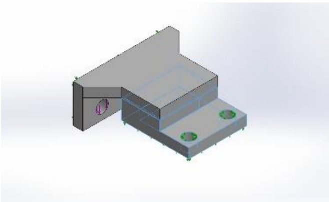
Comments:
Assuming the lower part are attached to the robot car and the upper part are attached to the wall. The forces represent the wall being put in to its attachment (lower bracket), the force is sat to 2.5 Newtons.

Model Information



Model name: Wall attachment bracket assy
Current Configuration: Default

Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Female bracket hole camfer 	Solid Body	Mass:0,000810232 kg Volume:6,37978e-07 m^3 Density:1 270 kg/m^3 Weight:0,00794028 N	C:\Users\Henrik\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Individuelle deler\Walls\Wall attachment bracket female.SLDPRT May 10 17:11:56 2024
Support camfer 	Solid Body	Mass:0,00196926 kg Volume:1,55059e-06 m^3 Density:1 270 kg/m^3 Weight:0,0192987 N	C:\Users\Henrik\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Individuelle deler\Walls\Wall attachment bracket male.SLDPRT May 10 17:11:21 2024

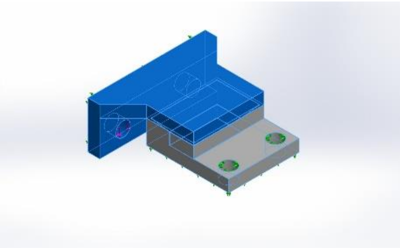
Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	On
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Henrik\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Individuelle deler\Walls)

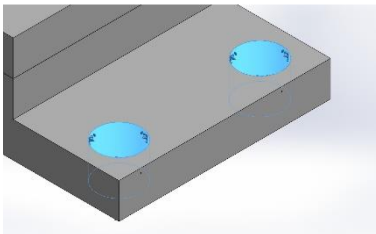
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

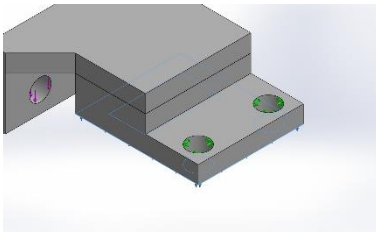
Model Reference	Properties	Components
	**Name:** Clas Ohlson PLA **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 3,5607e+07 N/m^2 **Tensile strength:** 4,8859e+07 N/m^2 **Elastic modulus:** 6,5175e+08 N/m^2 **Poisson's ratio:** 0,331 **Mass density:** 1 270 kg/m^3	SolidBody 1(Female bracket hole camfer)(Wall attachment bracket female-1), SolidBody 1(Support camfer)(Wall attachment bracket male-1)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 2 face(s) **Type:** Fixed Geometry

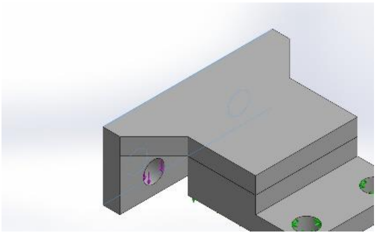
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0,219818	0,0310233	-3,31784e-08	0,221996
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Roller/Slider-1		**Entities:** 1 face(s) **Type:** Roller/Slider

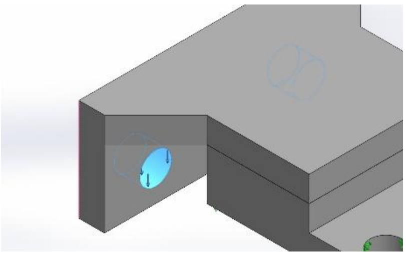
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0,0115366	9,96546	0,000215633	9,96547
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Roller/Slider-2		**Entities:** 1 face(s) **Type:** Roller/Slider

Resultant Forces

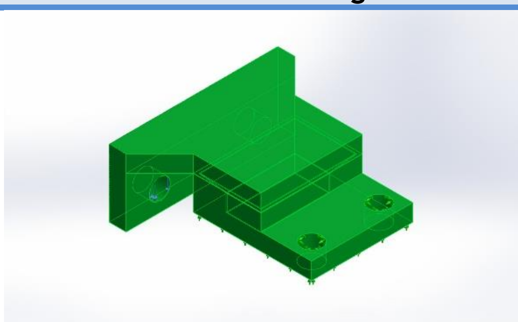
Components	X	Y	Z	Resultant
Reaction force(N)	-0,219787	0	0	0,219787
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---; ---; -5 N

Connector Definitions

No Data

Interaction Information

Interaction	Interaction Image	Interaction Properties
Component Interaction-1		**Type:** Contact (Surface to surface) **Components:** 2 Solid Body (s)

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	0,90923 mm
Minimum element size	0,303074 mm
Mesh Quality	High
Remesh failed parts independently	Off

Mesh information - Details

Total Nodes	38081
Total Elements	23822
Maximum Aspect Ratio	3,8851
% of elements with Aspect Ratio < 3	99,9
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:10
Computer name:	

Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	3,02866e-05	10,0001	-3,31784e-08	10,0001

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	0	0	0

Free body moments

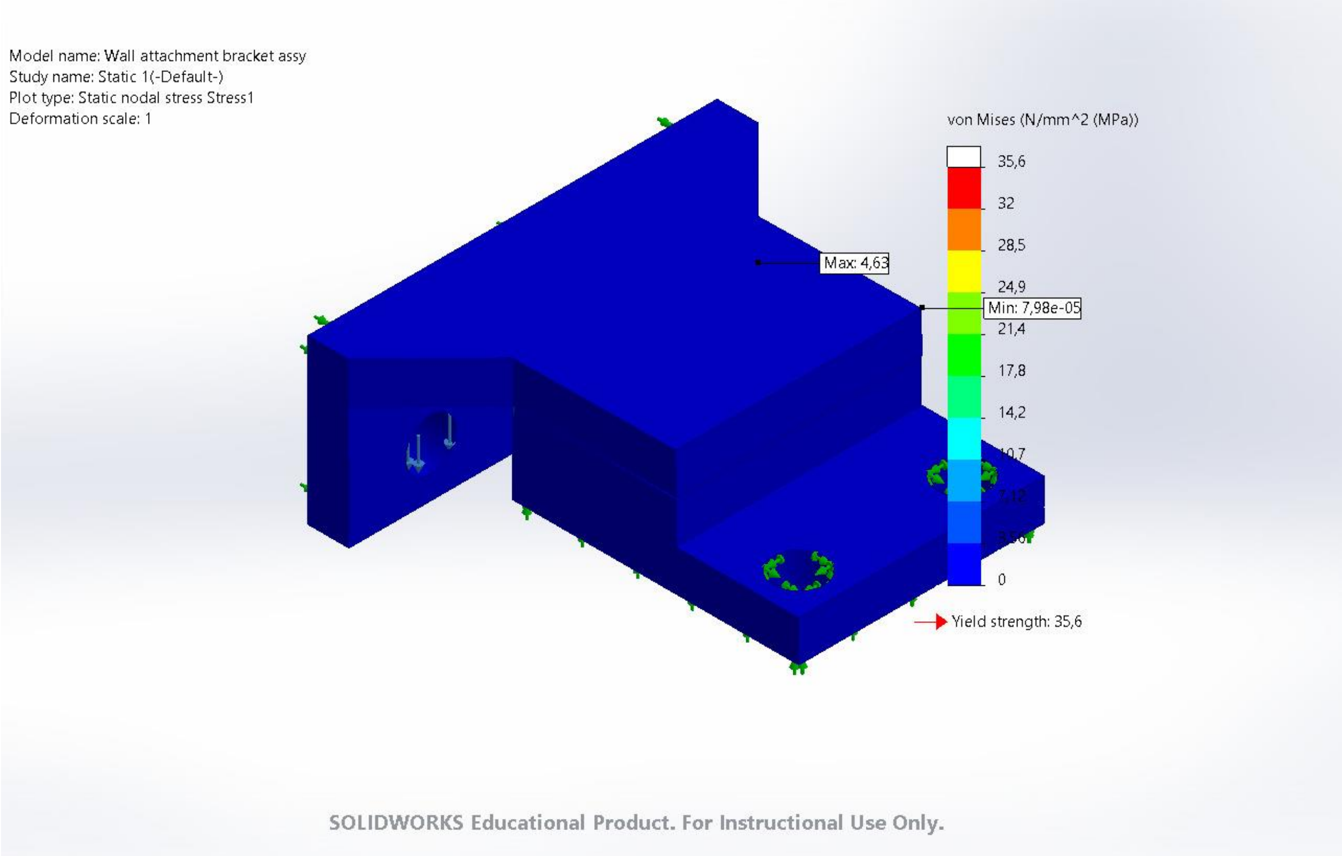
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

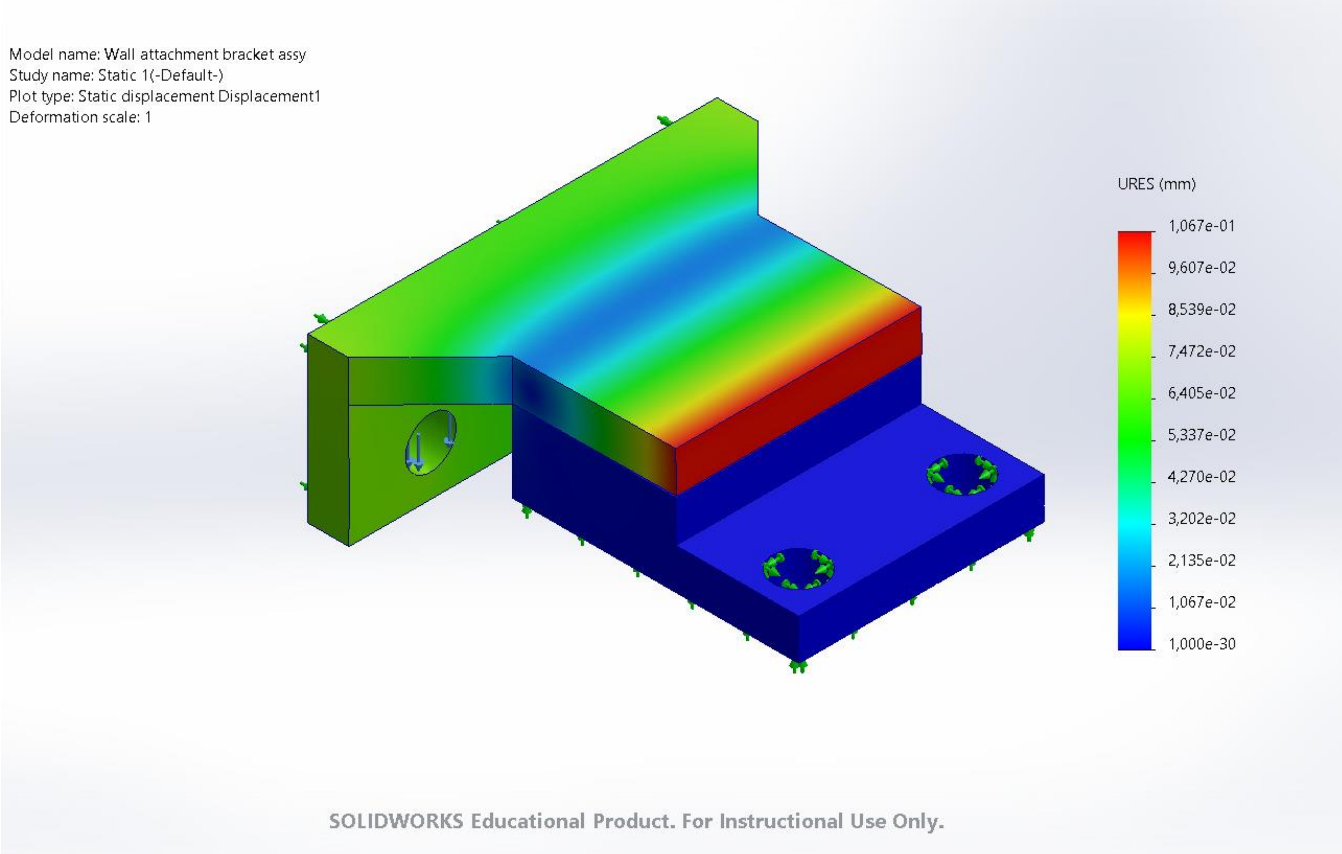
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	7,98e-05N/mm^2 (MPa) Node: 11894	4,63N/mm^2 (MPa) Node: 1



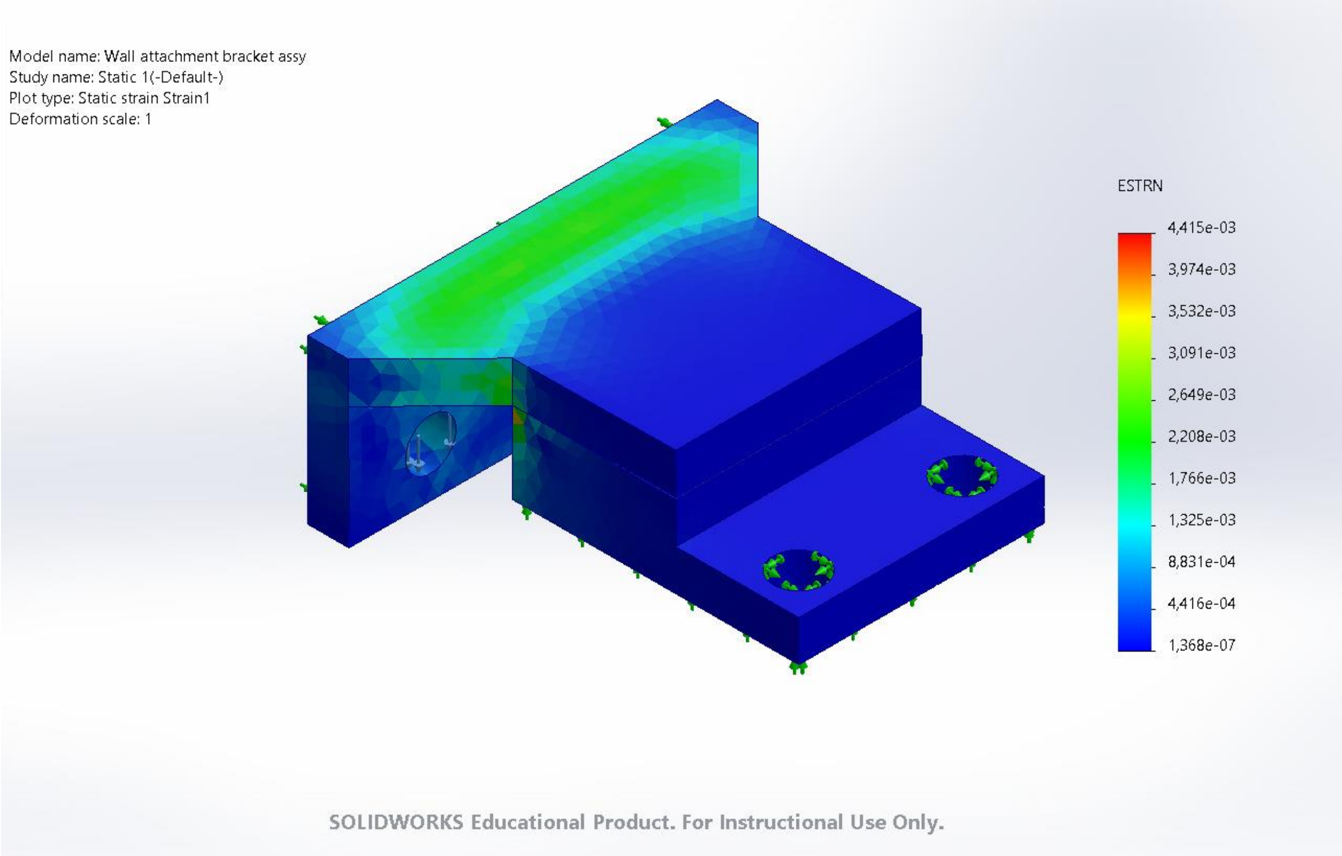
Wall attachment bracket assy-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000e+00mm Node: 5	1,067e-01mm Node: 12166



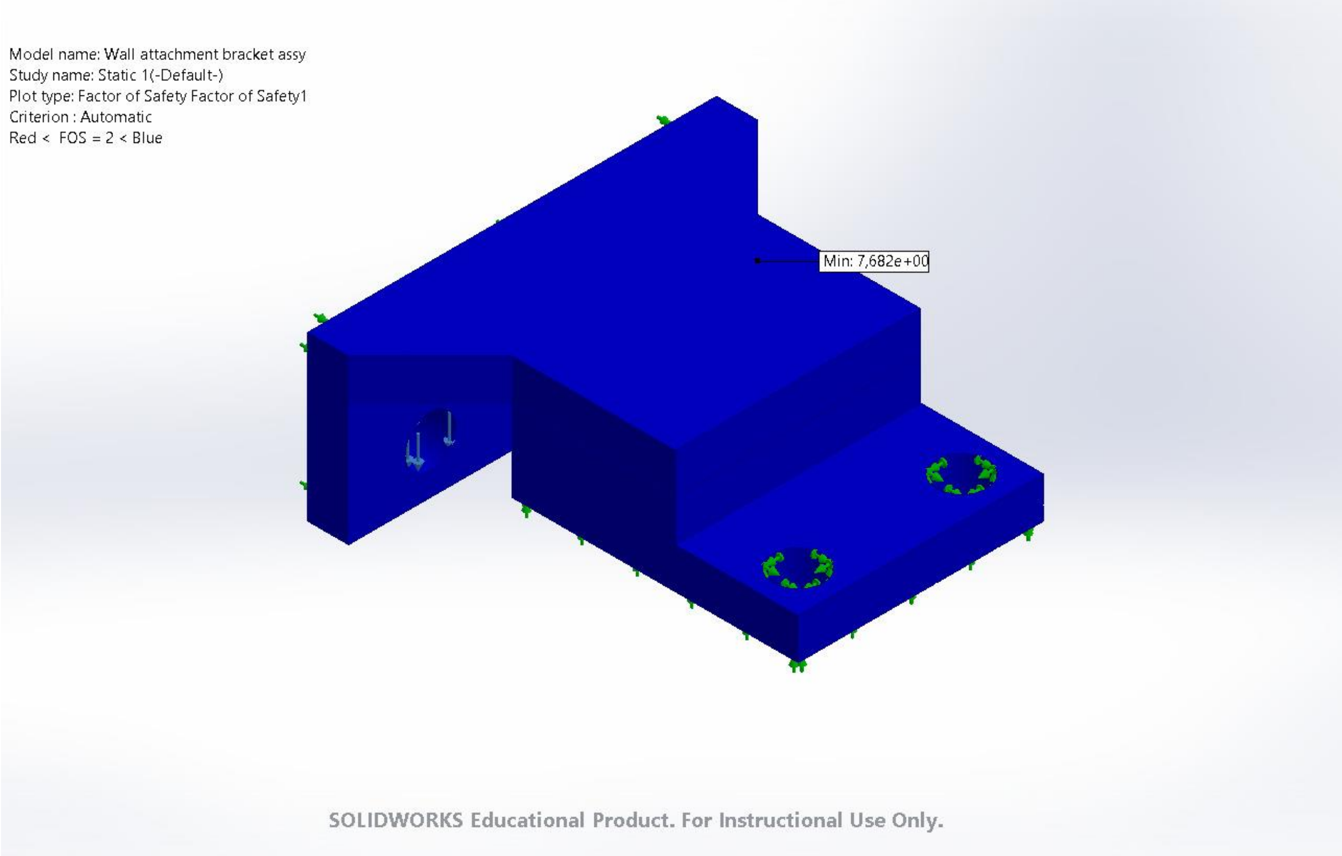
Wall attachment bracket assy-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1,368e-07 Element: 23035	4,415e-03 Element: 1807



Wall attachment bracket assy-Static 1-Strain-Strain1

Name	Type	Min	Max
Factor of Safety1	Automatic	7,682e+00 Node: 1	4,464e+05 Node: 11894

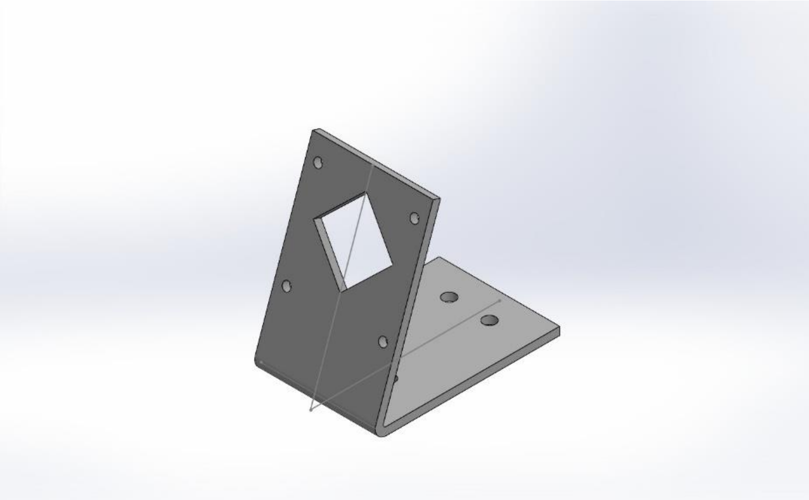


Wall attachment bracket assy-Static 1-Factor of Safety-Factor of Safety1

Conclusion

Comments:
The brackets will hold the weight of the walls and the clips attaching and detaching.

KROMIUM
https://itfag.usn.no/grupper/D03-24/



Simulation of Arm cam holder fixed angle

Date: fredag 17. mai 2024
Designer: Henrik Bertelsen
Study name: Static 1
Analysis type: Static

Table of Contents

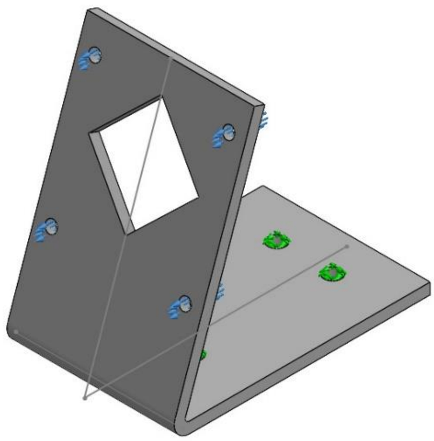
Description

Simulation of a part

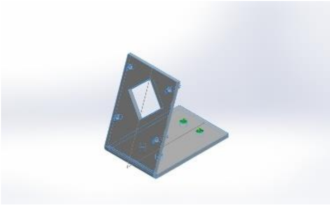
Assumptions

Comments:
If the arm camera cable is too loos it can attach itself to the car. The forces added to the simulation is ment to represent the forces of the cable draging in the arm camera bracket.

Model Information



Model name: Arm cam holder fixed angle
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Arm screw holes diam.3.1mm 	Solid Body	**Mass:0,00626532 kg Volume:4,93332e-06 m^3 Density:1 270 kg/m^3 Weight:0,0614001 N**	**C:\Users\Henrik\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Individuelle deler\Arm camera\Arm cam holder fixed angle.SLDPRT** May 17 19:53:44 2024

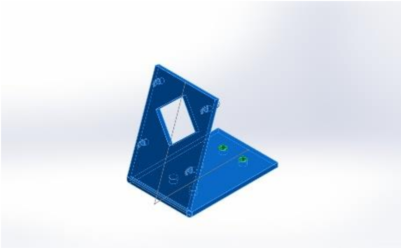
Study Properties

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	On
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Henrik\OneDrive - USN\Dokumenter - Bachelor gruppe\04 Mekanikk\Deler\3D-models\Individuelle deler\Arm camera)

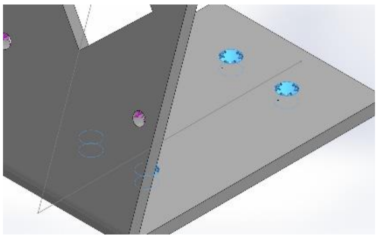
Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material Properties

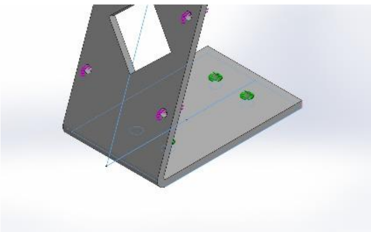
Model Reference	Properties	Components
	**Name:** Clas Ohlson PLA **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Yield strength:** 3,5607e+07 N/m^2 **Tensile strength:** 4,8859e+07 N/m^2 **Elastic modulus:** 6,5175e+08 N/m^2 **Poisson's ratio:** 0,331 **Mass density:** 1 270 kg/m^3	SolidBody 1(Arm screw holes diam.3.1mm)(Arm cam holder fixed angle)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 4 face(s) **Type:** Fixed Geometry

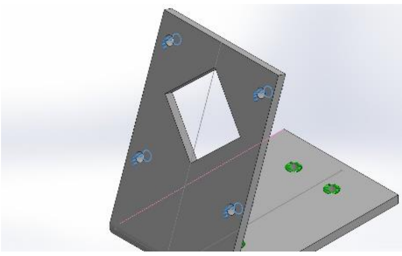
Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-4,18797e-05	0,662924	-10	10,022
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Reference Geometry-1		**Entities:** 1 face(s) **Reference:** Edge< 1 > **Type:** Use reference geometry **Translation:** ---; ---; 0 **Units:** mm

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	0	-0,81006	0	0,81006
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** 4 edge(s) **Reference:** Edge< 1 > **Type:** Apply force **Values:** ---; ---; -2,5 N

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	1,43595 mm
Minimum element size	0,380544 mm
Mesh Quality	High

Mesh information - Details

Total Nodes	34131
Total Elements	19869
Maximum Aspect Ratio	4,6722
% of elements with Aspect Ratio < 3	99,5
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:06
Computer name:	

Sensor Details

No Data

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-4,18797e-05	-0,000537096	-10	10

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	0	0	0

Free body moments

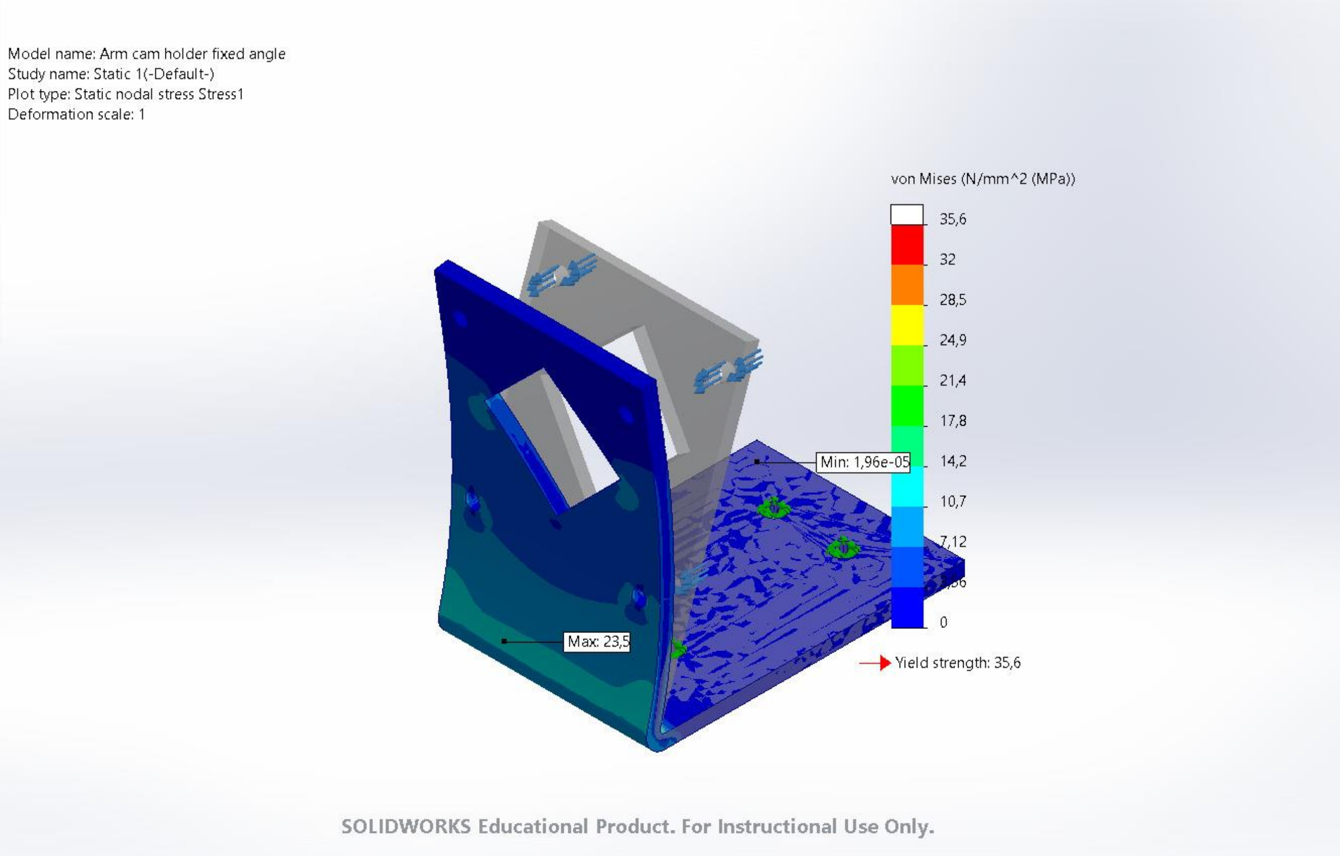
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

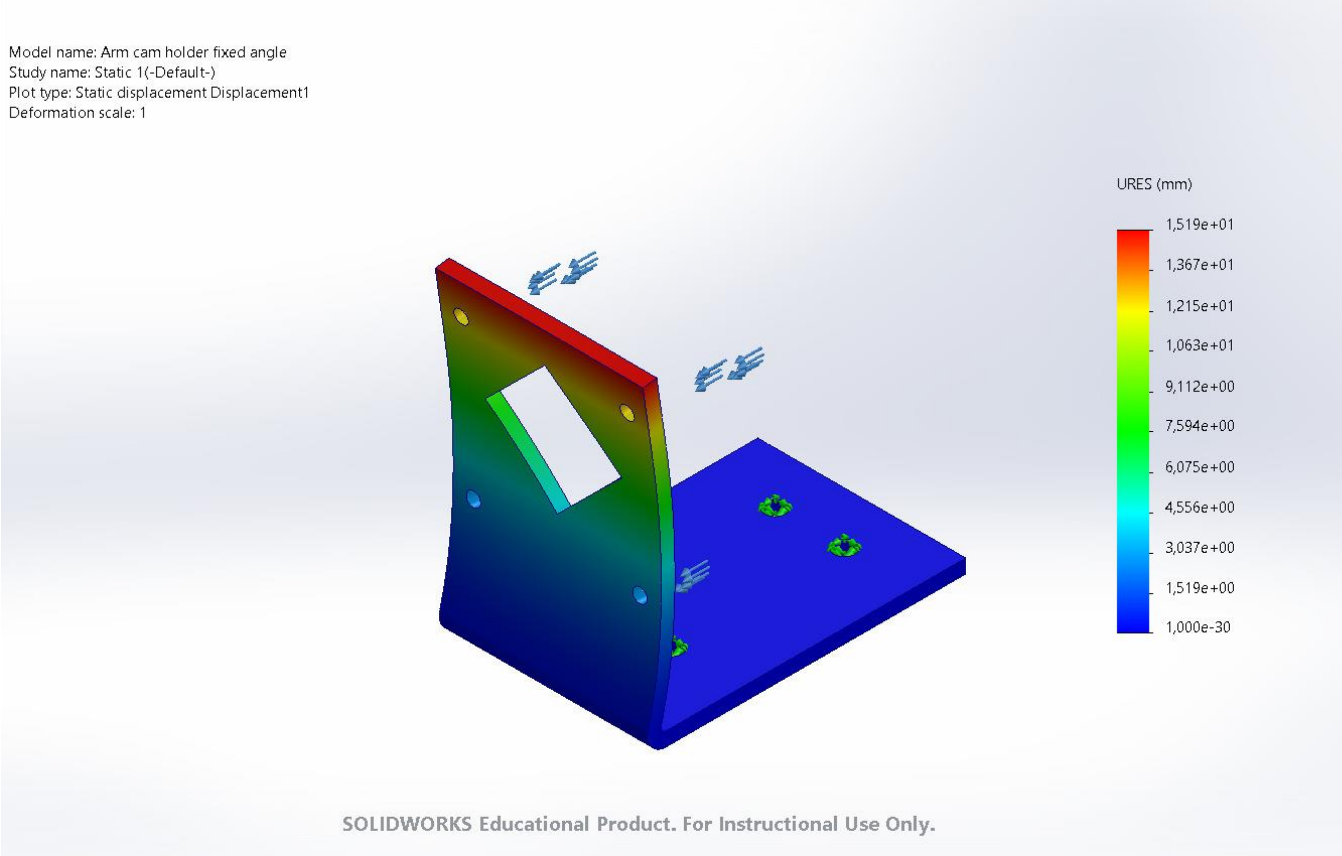
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1,96e-05N/mm^2 (MPa) Node: 20109	23,5N/mm^2 (MPa) Node: 1991



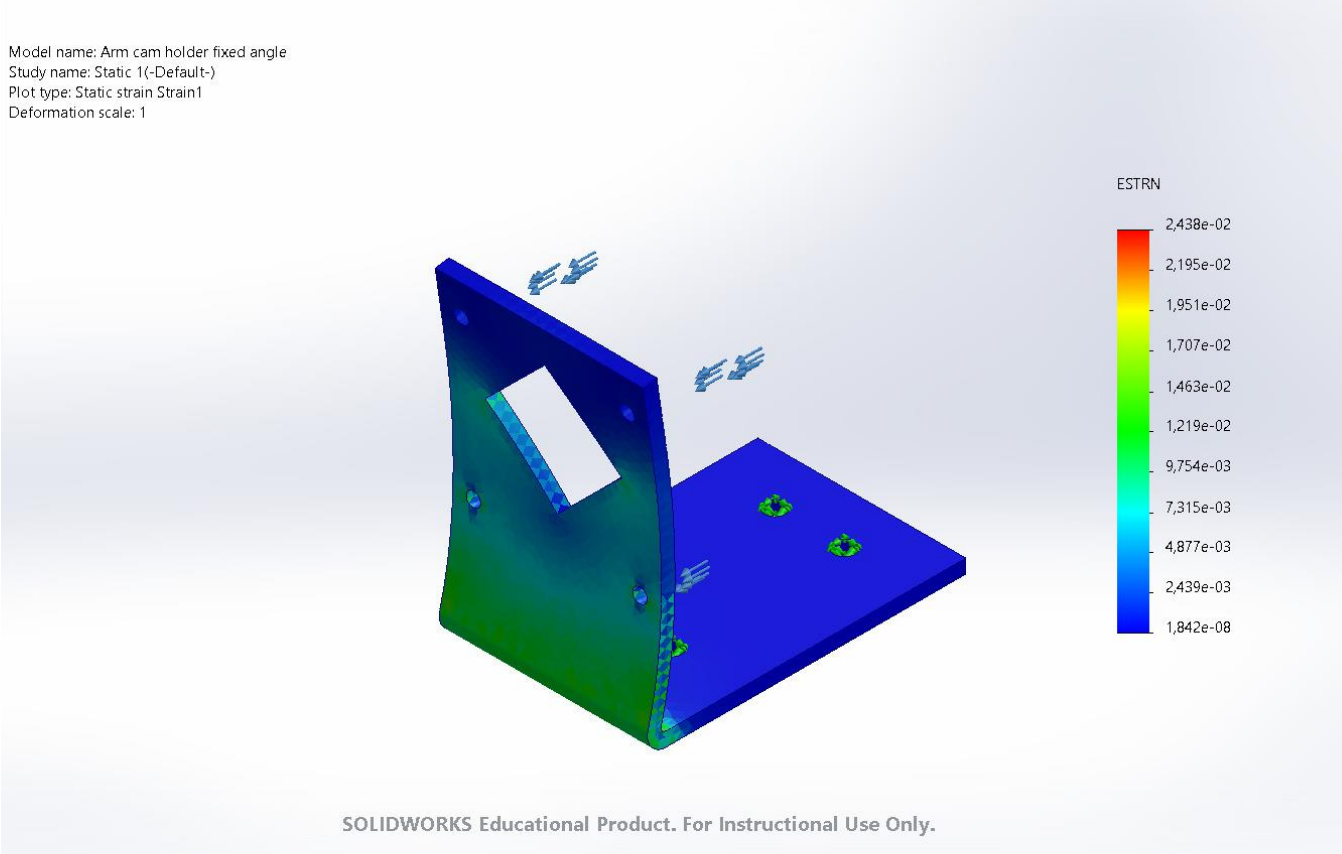
Arm cam holder fixed angle-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0,000e+00mm Node: 13	1,519e+01mm Node: 6



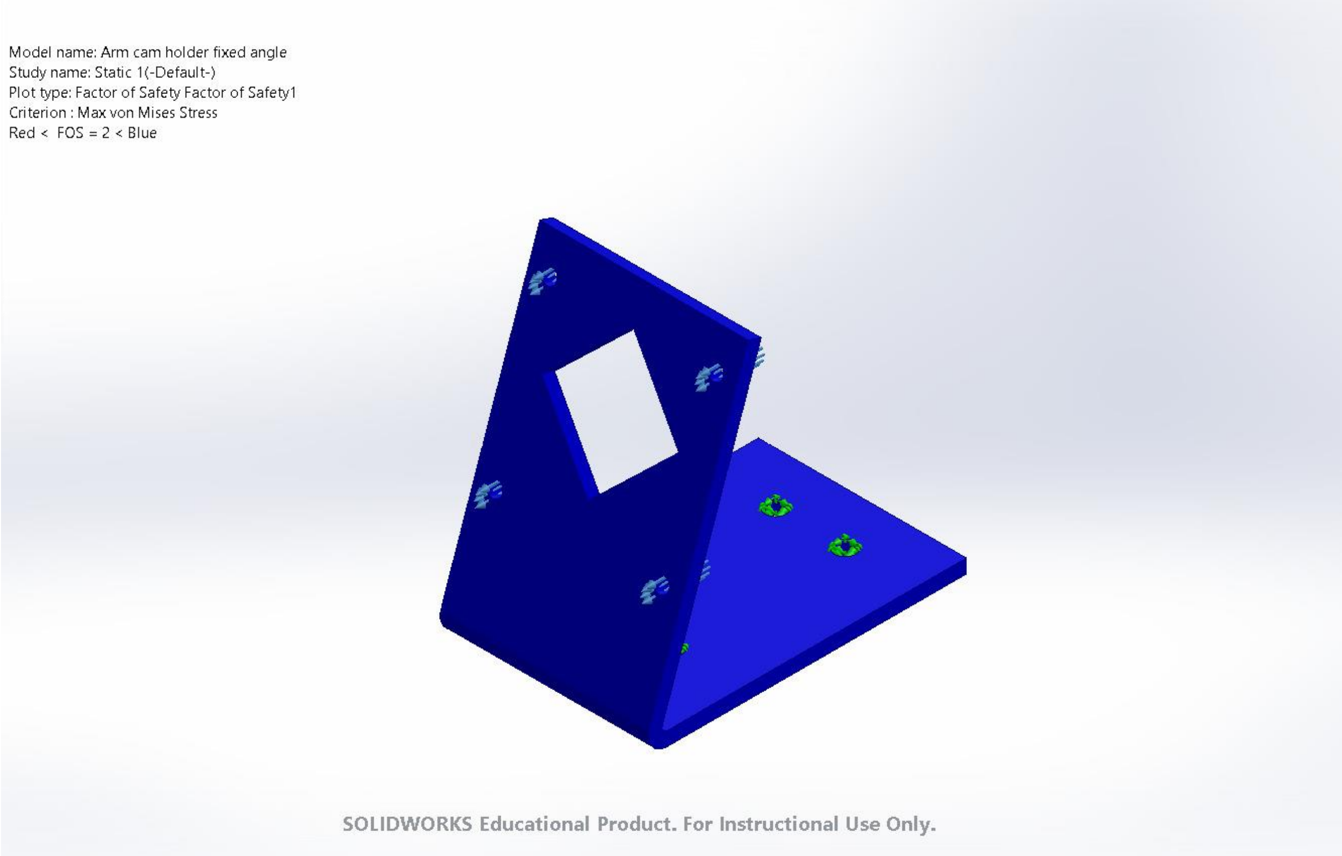
Arm cam holder fixed angle-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1,842e-08 Element: 12522	2,438e-02 Element: 7657



Arm cam holder fixed angle-Static 1-Strain-Strain1

Name	Type	Min	Max
Factor of Safety1	Max von Mises Stress	1,513e+00 Node: 1991	1,818e+06 Node: 20109



Arm cam holder fixed angle-Static 1-Factor of Safety-Factor of Safety1

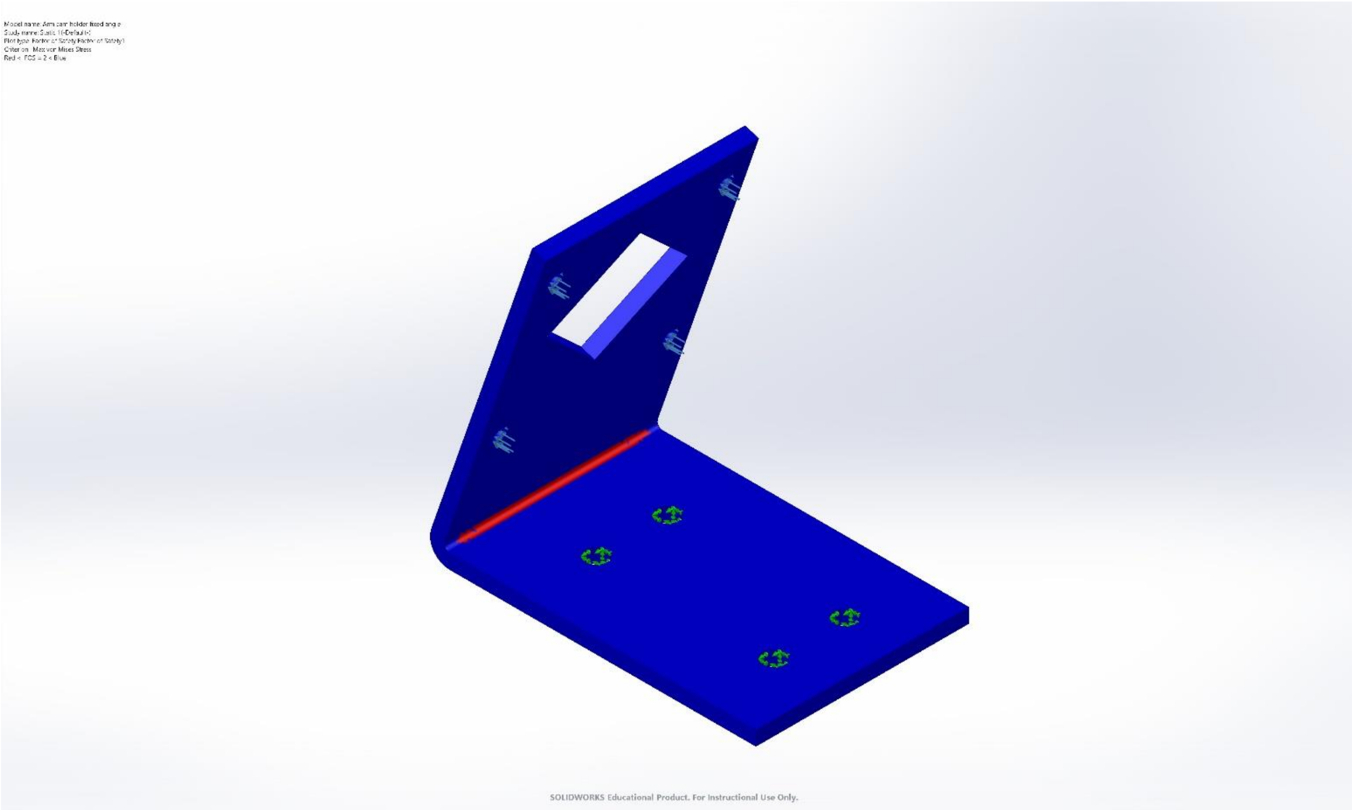


Image-1

Conclusion

Comments:
The bracket will most likely bend and take some of the load off the cable. If the load is greater than asumed, the bracket will most likely break.