BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING
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ilac-MRA

Z 7008

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Steel testing
ZO 2021/1

Brno University of Technology
Proficiency testing provider at the SZK FAST
Veveří 95, Brno 602 00
Czech Republic

www.szk.fce.vutbr.cz
www.ptprovider.cz

Date: November 24, 2021

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Ing. Petr Misák, Ph.D.
Coordinator of PTP results assessment

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1 Introduction and Important Contacts

In the year 2021, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZO 2021/1 whose aim was to verify and assess the conformity of test results across laboratories when testing steel.

The assessment of the results of the Proficiency Testing Program was carried out by a committee consisting of the following PT Provider employees:

Head of the PT Provider, PTP coordinator

Assoc. Prof. Ing. Tomáš Vymazal, Ph.D.
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Coordinator of PTP result assessment PrZZ

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The subjects of proficiency testing were the following testing procedures:

1. **EN ISO 6892-1** – Tensile strength [1],
2. **EN ISO 6892-1** – Yield strength [1],
3. **EN ISO 6892-1** – Percentage elongation after fracture [1],
4. **EN ISO 6892-1** – Percentage reducation of area [1].

Test procedures number 2 and 4 were not open due to the low number of participants.

The preparation of test samples and their homogeneity and stability was ensured by PoZZ. The test samples were distributed among the individual participants of the PrZZ so that their properties could not be affected.

The test results from individual PTP participants were compared via a method involving the statistical analysis of all their results in a manner complying with ISO 5725-2 [2] and with EN ISO/IEC 17043 [3]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

5 laboratories took part in the program. In order to maintain the anonymity of the PTP, each laboratory was given an identification number that will be used henceforth in this document. An integral part of the present final report is a Certificate of Participation in the Proficiency Testing Program. It is unique for each participant and includes the participant's ID used in this report. The following chart shows the participation of laboratories in individual parts of the PTP.

Table 1: Participation of individual laboratories in the PTP

ID/Method	1	2	3	4
ad508e	X	-	X	-
9fe85e	X	-	X	-
8fda41	X	-	-	-
52a4bf	X	-	X	-
317a71	X	-	X	-

Table 2: List of participants (laboratories) – the order in the table does not correspond to the identification number in previous table

Laboratory	Address	Accreditation number
Bautechnische Versuchs- und Forschungsanstalt Salzburg	Alpenstraße 157, Salzburg, 5020, Austria	0003
Bechtel ENKA UK Limited Ogranak Beograd	Jasicki put 52 đ, Kruševac, 37000, Serbia	-
ENVIFORM, a.s.	Průmyslová 1045, Třinec - Staré Město, 739 61, Česká republika	L1609
Skanska a.s.	Křižíkova 682/34a, Praha 8 -Karlín, 186 00, Česká republika	178
Výzkumný a zkušební letecký ústav, a.s.	Beranových 130, Praha - Letňany, 199 05, Česká republika	L1756

2 Procedures used in the Statistical Analysis of Laboratory Results

The statistical analysis is based on the following steps:

1. Evaluation of intralaboratory variabilities by Cochran's C test: If 5% or 1% critical value is exceeded, the effect of the individual observations is first considered. If the results indicate that high participant variability is caused by a single observation, this value is excluded from the experiment, but the participant is not excluded as outlying. By overcoming 1% of the critical value, the participant's results can be marked as outlying and excluded from the experiment (symbol **X**).
2. The numerical critical evaluation of the test results using Grubbs' test: By overcoming 1% critical value, the participant's results can be marked as outlying and excluded from the experiment (symbol **X**).
3. Graphical determination of the consistency of laboratories (Mandel's statistics): The exceedance of the critical values of Mandel's statistics does not indicate that the results of the laboratories concerned are wrong; it only suggests minor inconsistencies.
4. Evaluation of descriptive statistics and, if possible, taking into account the number of observations, the repeatability and reproducibility.
5. Evaluation of the assigned value.
6. The performance evaluation: The most significant outcome of the PT Program is the so-called z-score and ζ-score (zeta-score). These characteristics assess the performance of individual participants by comparing it with the assigned value and measurement uncertainties. z-score and ζ-score are compared with limit values. The resulting ζ-score values are not taken into account during the final evaluation of the performance of participants as they are to a considerable degree dependent on the values of the measurement uncertainties of the assessed institutions. The following scales are applied for the z-score values:
   - $|z\text{-score}| < 2 \Rightarrow$ shows that the laboratory performance is **satisfactory** and generates no signal – ✓.
   - $2 \leq |z\text{-score}| < 3 \Rightarrow$ shows that the laboratory performance is **questionable** and generates an action signal – **?**.
   - $|z\text{-score}| \geq 3 \Rightarrow$ shows that the laboratory performance is **unsatisfactory** and generates an action signal – **!**.

Procedures used in the statistical analysis of proficiency testing programs can be found here: http://ptprovider.cz/?lang=en.

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program ZO 2021/1 (PT Program) organized by the PT Provider at the SZK FAST. 5 participants (laboratories) took part in the PT Program. The program focused on ordinary standardized testing of steel. The test results are evaluated separately for each testing procedure examined. An evaluation of statistical characteristics is included in the Appendix, as well as test results and graphic presentations. Testing methods can be found in part 1 of this report.

Table 3: Evaluation of overall performance and outliers.
✓ – satisfactory performance; ? – questionable performance; ! – unsatisfactory performance; X – outlier;

ID / Method	1	2	3	4
ad508e	✓	-	✓	-
9fe85e	✓	-	✓	-
8fda41	✓	-	-	-
52a4bf	✓	-	✓	-
317a71	✓	-	✓	-

References

[1] EN ISO 6892-1. *Metallic materials - Tensile testing - Part 1: Method of test at room temperature*. 2021.

[2] ISO 5725-2. *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*. 1997.

[3] EN ISO/IEC 17043. *Conformity assessment - General requirements for proficiency testing*. 2010.

1 Appendix – EN ISO 6892-1 – Tensile strength

1.1 Test results

Table 4: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]						u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
ad508e	609	591	604	598	595	599	-	599	6.4	1.07
52a4bf	607	602	600	607	610	606	3	605	3.5	0.58
9fe85e	616	618	618	600	615	599	10	611	9.0	1.47
317a71	613	608	608	671	619	624	-	624	23.9	3.84
8fda41	637	636	628	638	634	636	-	635	3.6	0.57

1.2 The Numerical Procedure for Determining Outliers

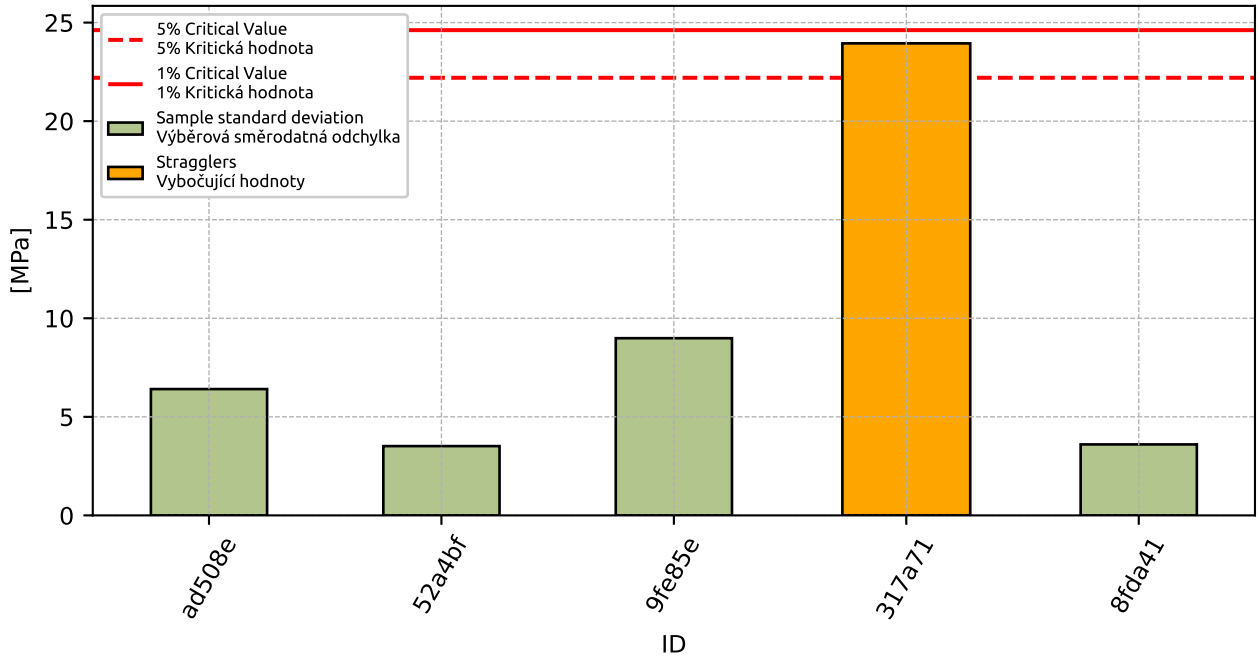

Figure 1: **Cochran's test** - sample standard deviations

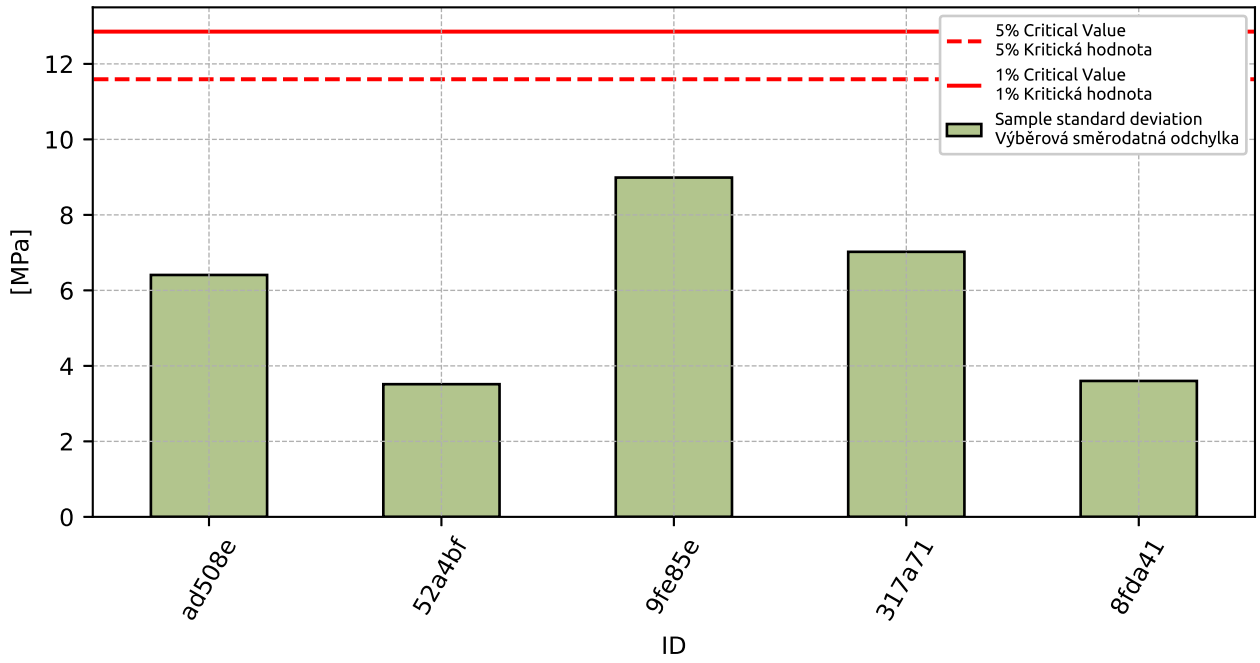

Figure 2: **Cochran's test** - sample standard deviations without outliers

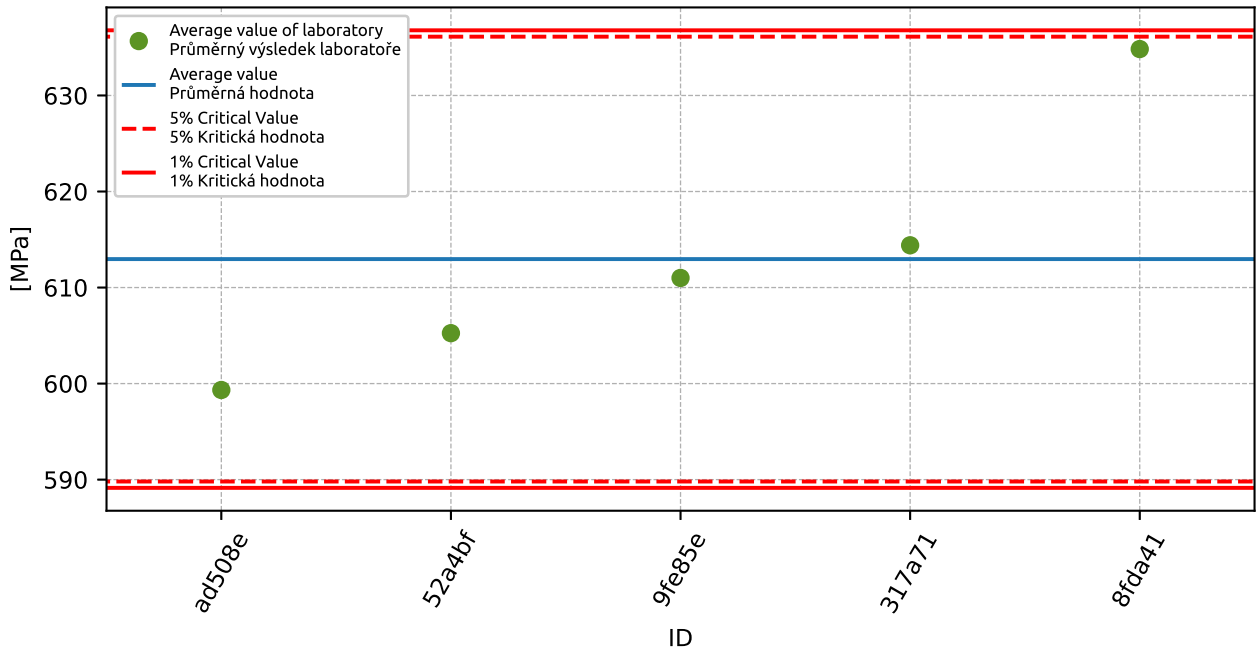

Figure 3: **Grubbs' test** - average values

1.3 Mandel's Statistics

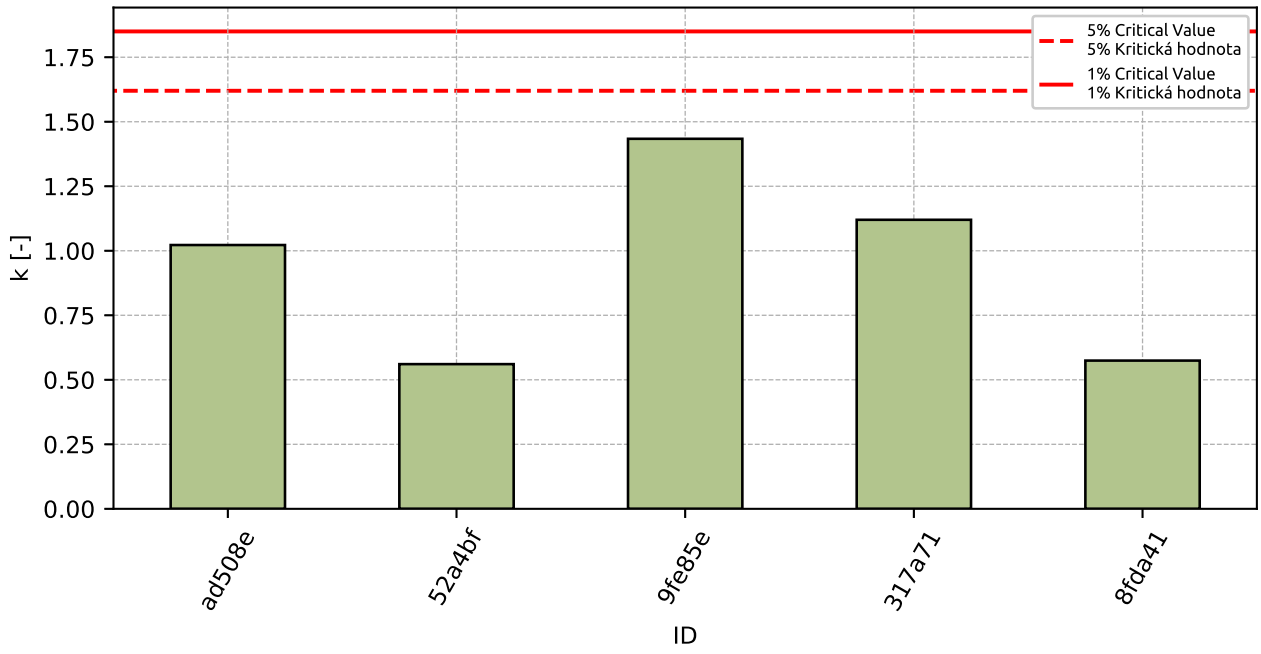

Figure 4: Intralaboratory Consistency Statistic

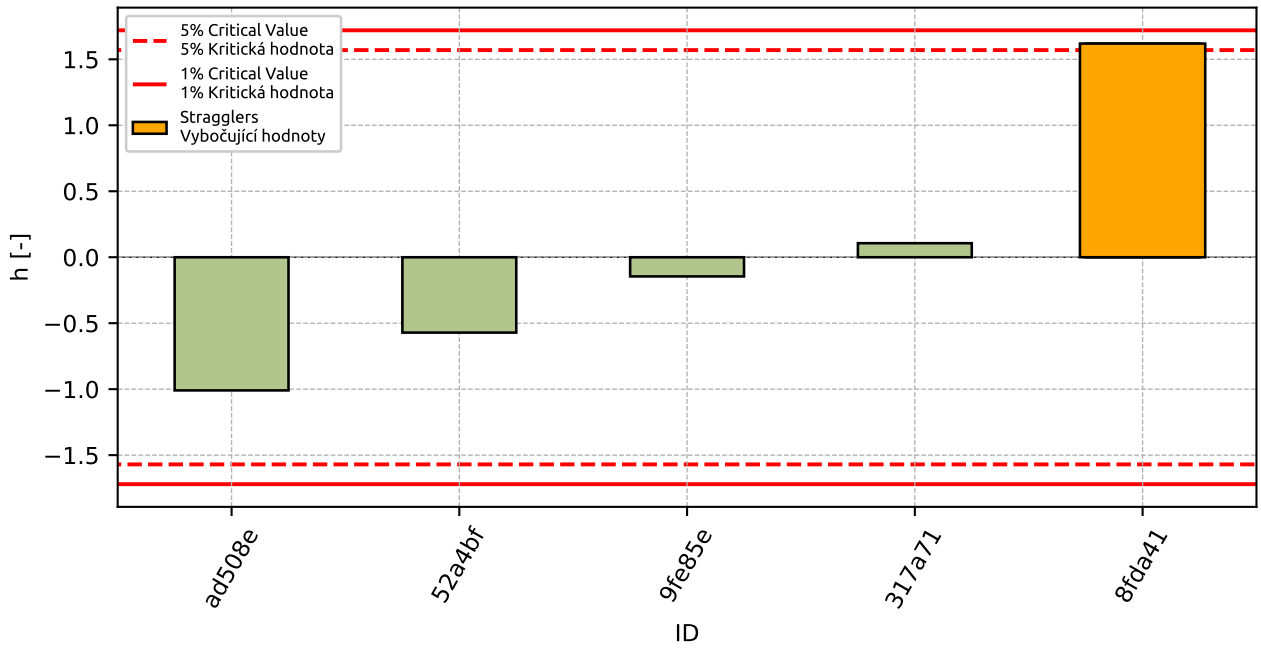

Figure 5: Interlaboratory Consistency Statistic

1.4 Descriptive statistics

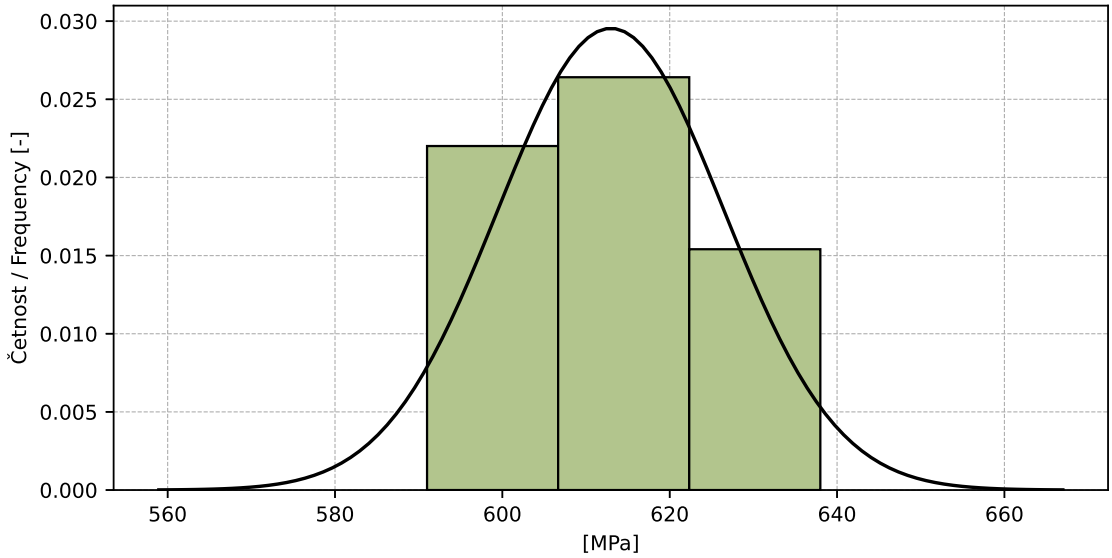

Figure 6: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	**[MPa]**
Average value – $\bar{x}$	613.0
Sample standard deviation – s	13.5
Asigned value – x^*	613.0
Robust standard deviation – s^*	13.7
Measurement uncertainty of asigned value – u_X	7.7
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	13.3
Repeatability standard deviation – s_r	6.3
Reproducibility standard deviation – s_R	14.7
Repeatability – r	18.0
Reproducibility – R	41.0

1.5 Evaluation of Performance Statistics

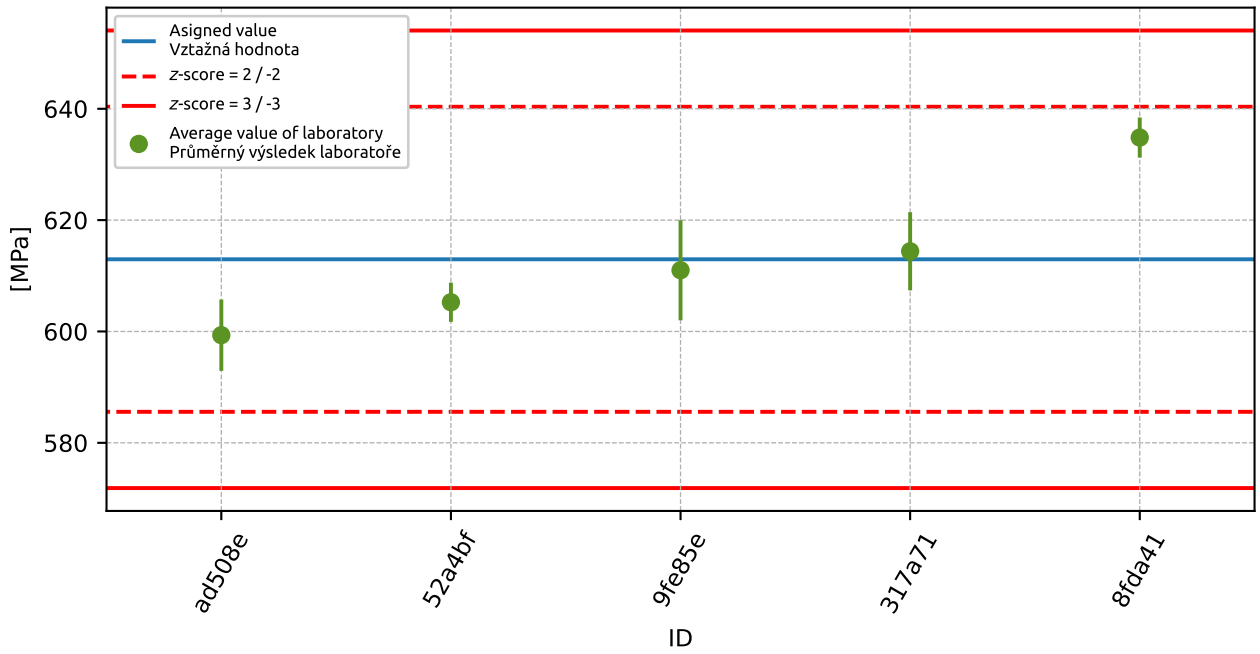

Figure 7: Average values and sample standard deviations

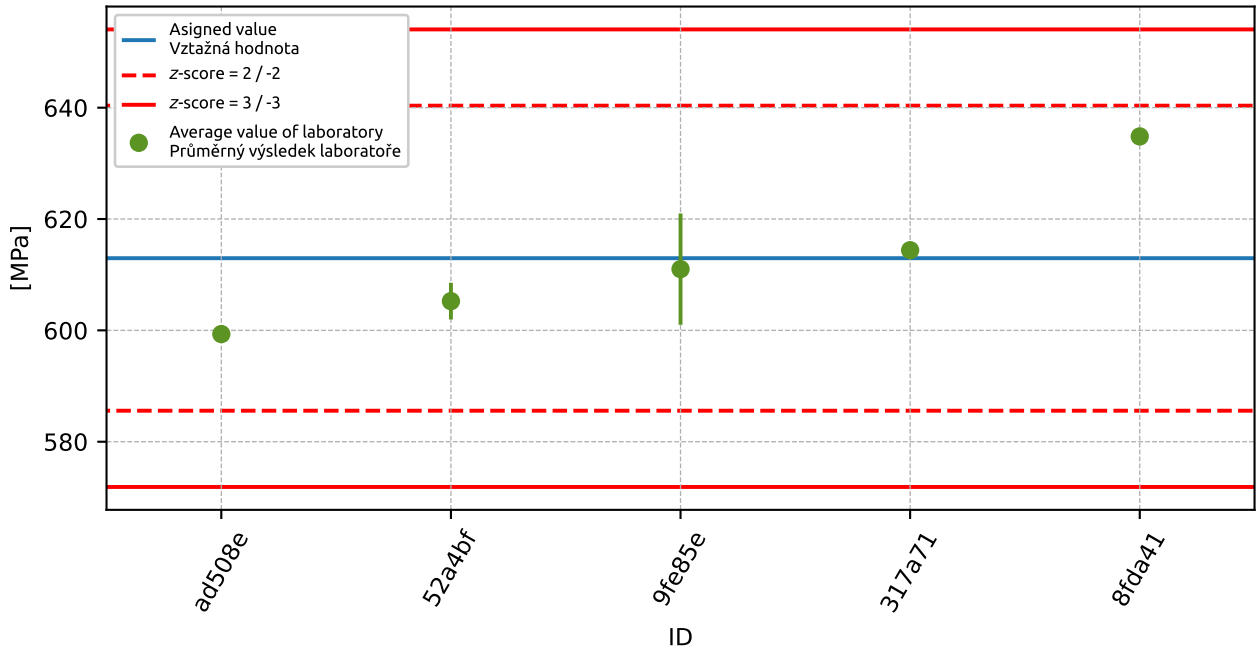

Figure 8: Average values and extended uncertainties of measurement

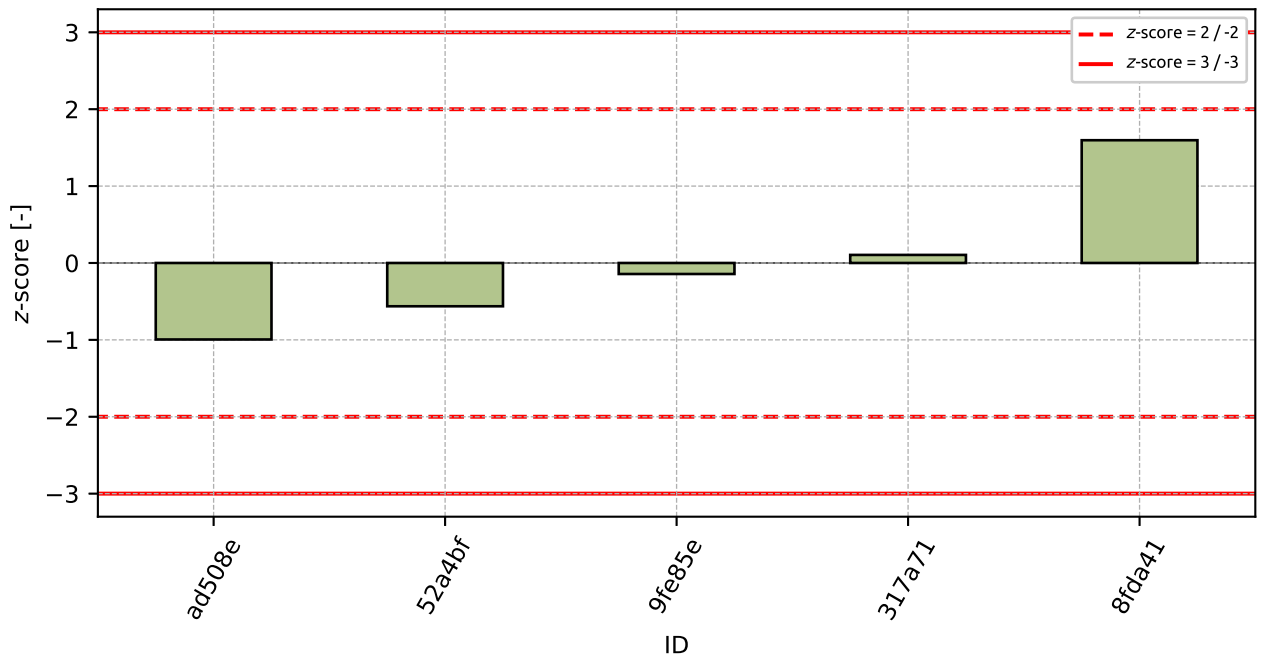

Figure 9: z-score

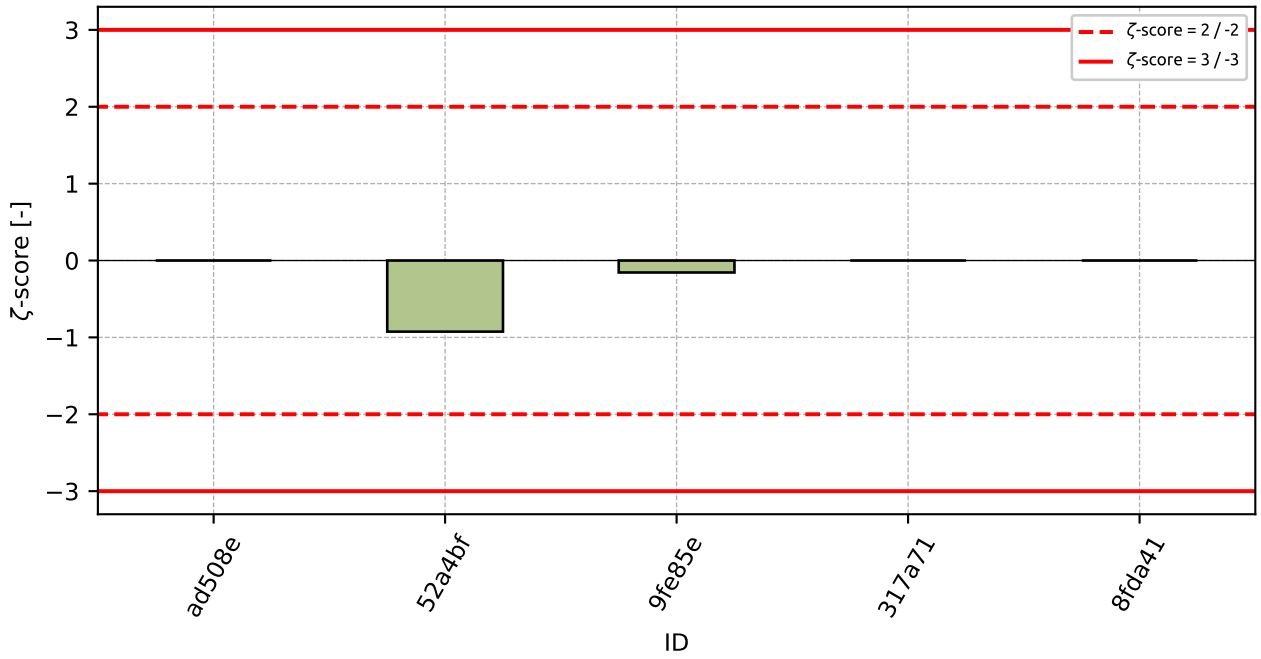

Figure 10: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
ad508e	-1.0	-
52a4bf	-0.56	-0.93
9fe85e	-0.14	-0.16
317a71	0.1	-
8fda41	1.6	-

2 Appendix – EN ISO 6892-1 – Yield strength

This part of PT program was not opened due to the low number of participants.

3 Appendix – EN ISO 6892-1 – Percentage elongation after fracture

3.1 Test results

Table 7: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [%]						u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
ad508e	14.5	16.0	15.0	18.0	17.5	15.0	-	16.0	1.45	9.06
317a71	23.7	22.4	20.0	23.3	23.4	22.4	-	22.5	1.35	6.0
52a4bf	22.4	23.9	24.5	24.7	26.1	26.5	1.6	24.7	1.49	6.05
9fe85e	25.5	24.5	24.0	24.5	28.0	26.0	9.0	25.4	1.46	5.76

3.2 The Numerical Procedure for Determining Outliers

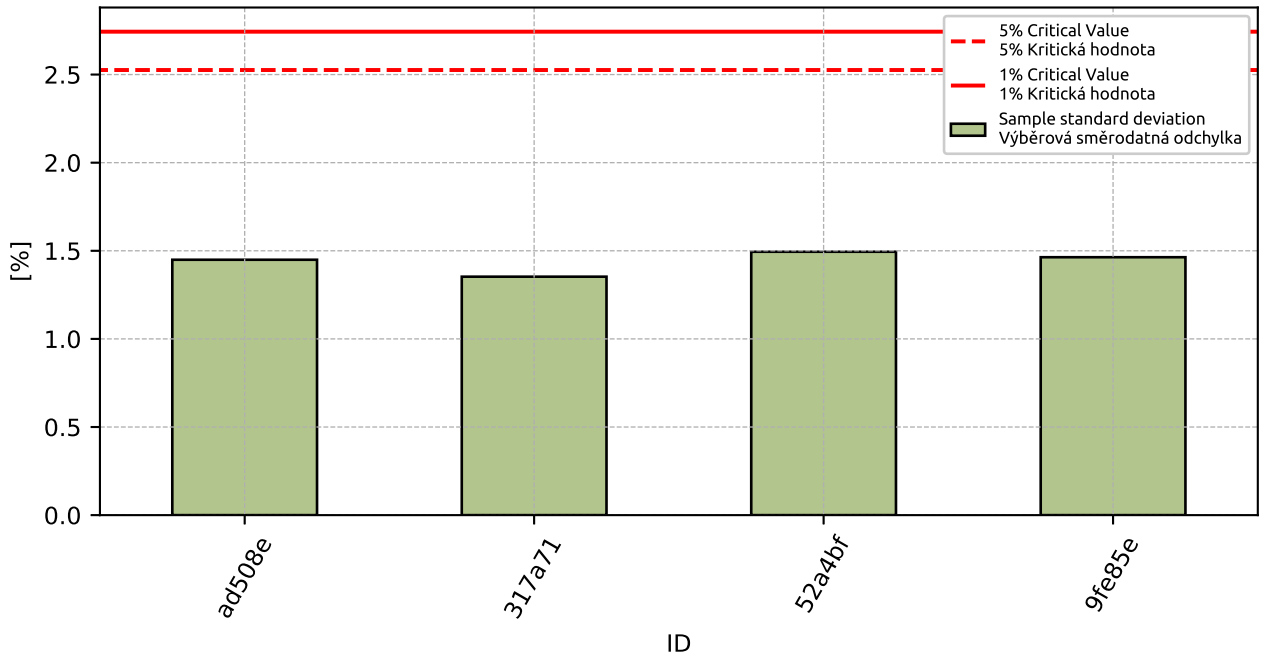

Figure 11: **Cochran's test** - sample standard deviations

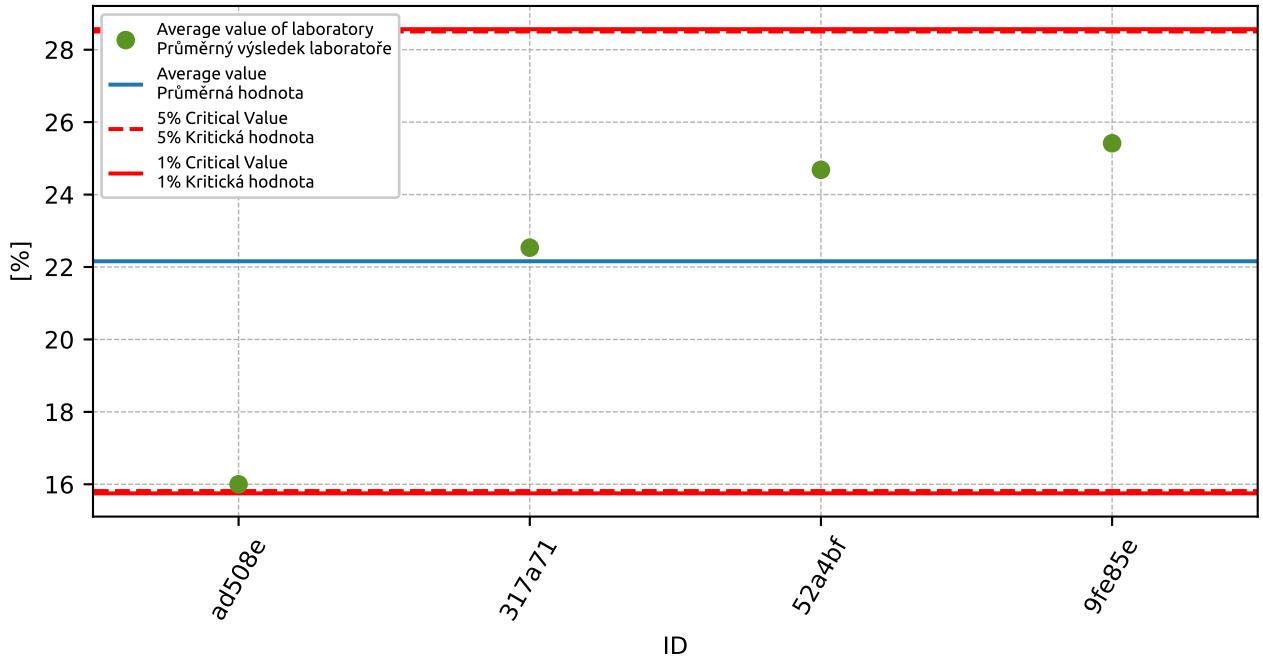

Figure 12: **Grubbs' test** - average values

3.3 Mandel's Statistics

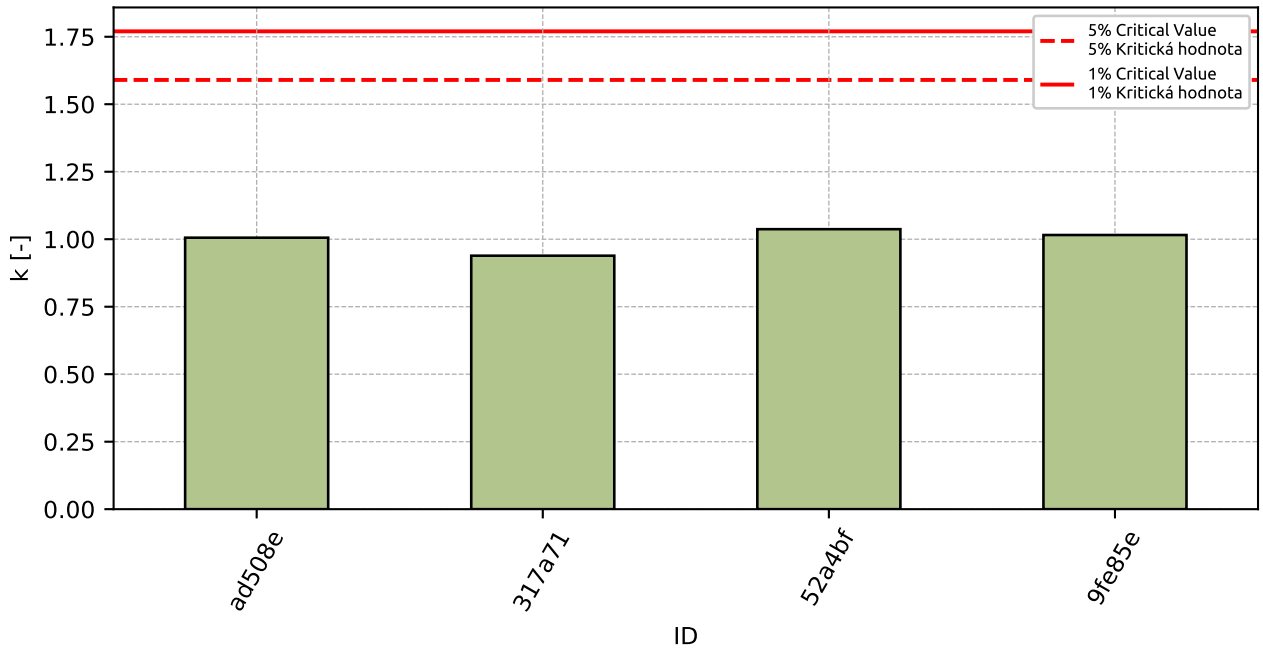

Figure 13: Intralaboratory Consistency Statistic

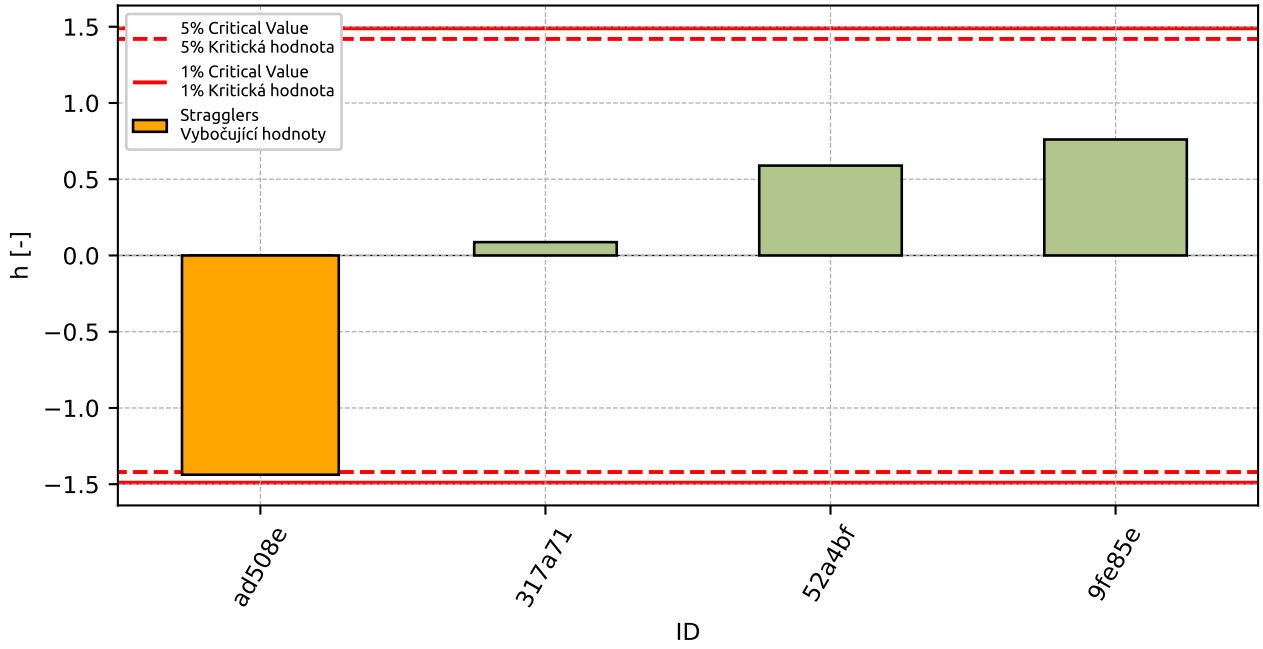

Figure 14: Interlaboratory Consistency Statistic

3.4 Descriptive statistics

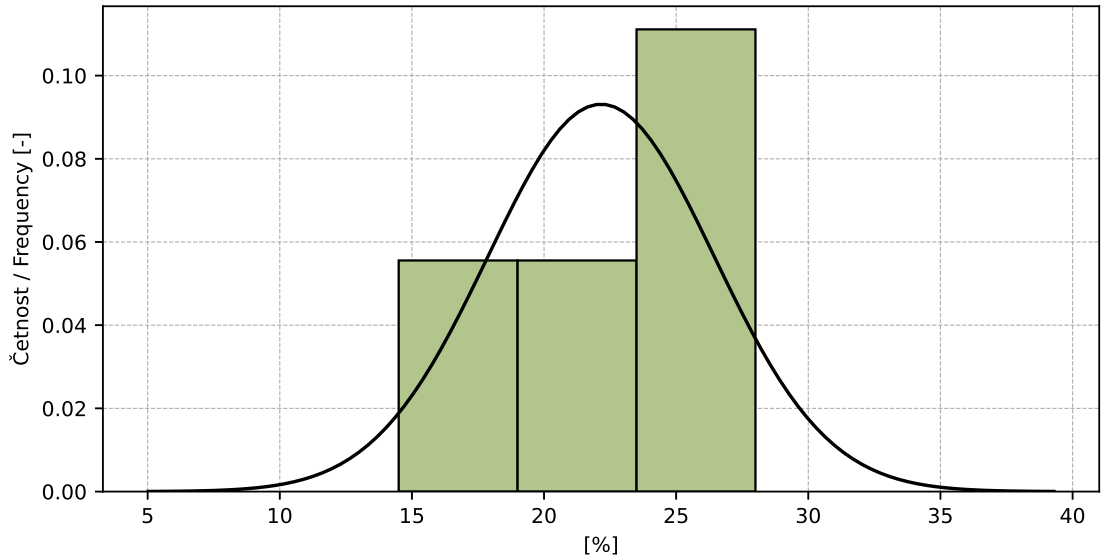

Figure 15: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	22.2
Sample standard deviation – s	4.28
Asigned value – x^*	22.2
Robust standard deviation – s^*	4.28
Measurement uncertainty of asigned value – u_X	2.07
p-value of normality test	0.009 [-]
Interlaboratory standard deviation – s_L	4.24
Repeatability standard deviation – s_r	1.44
Reproducibility standard deviation – s_R	4.48
Repeatability – r	4.0
Reproducibility – R	12.5

3.5 Evaluation of Performance Statistics

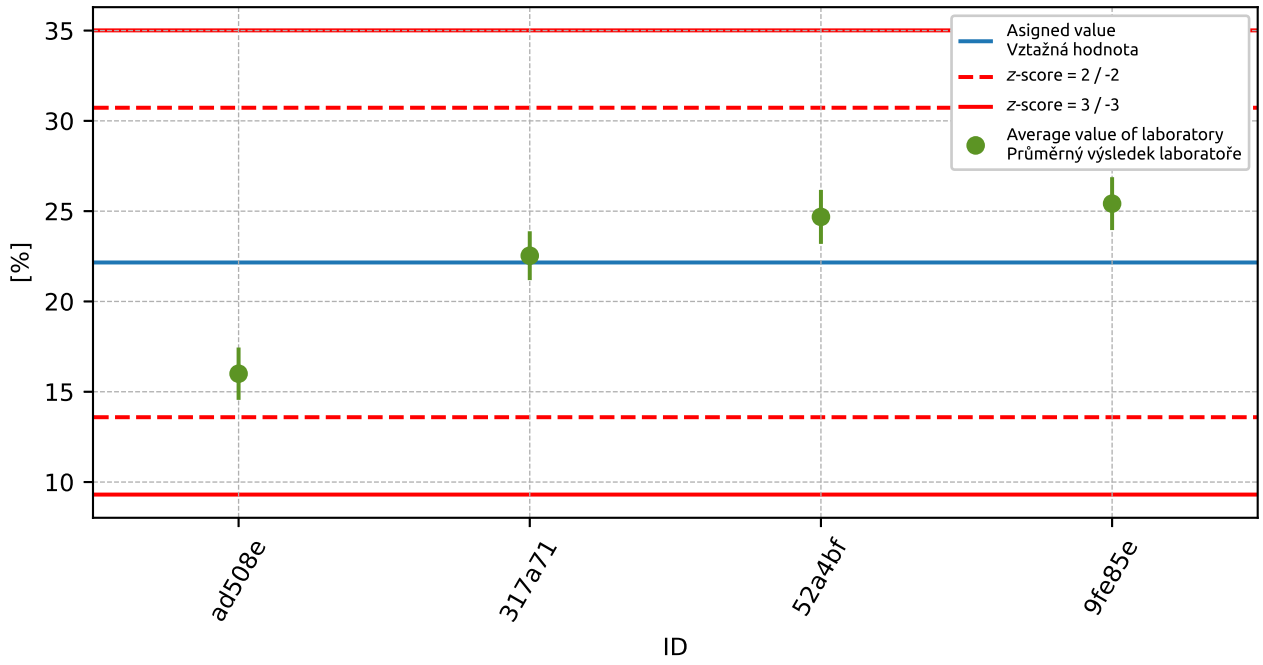

Figure 16: Average values and sample standard deviations

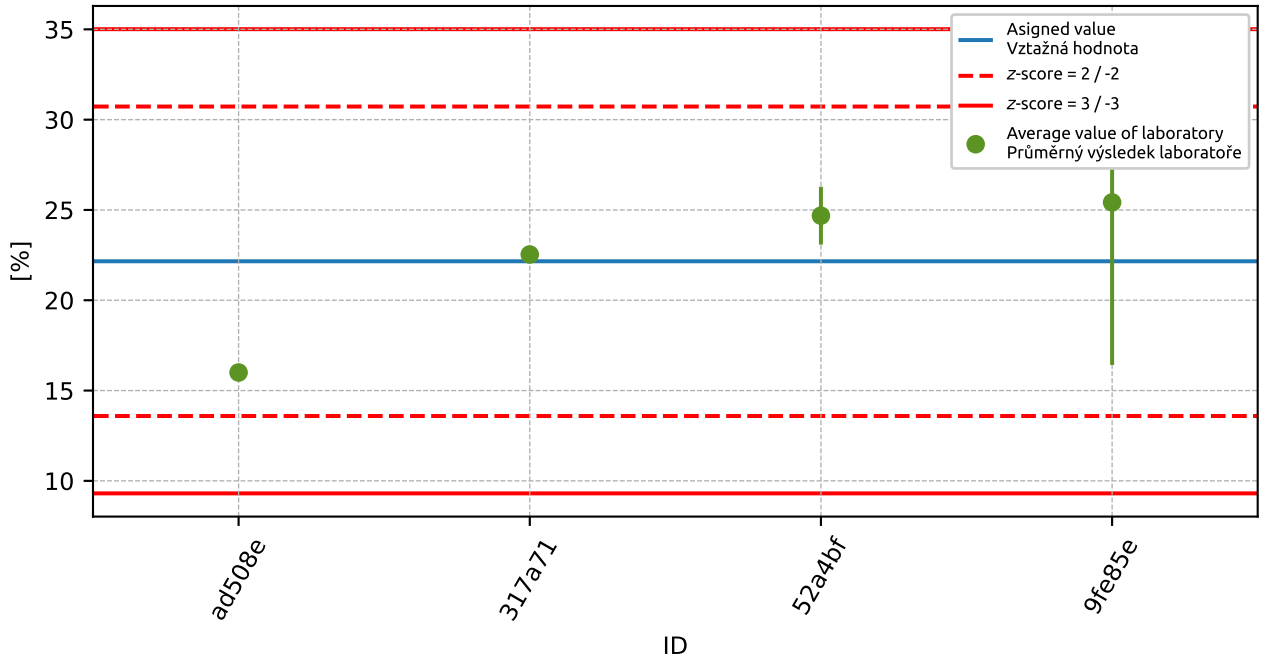

Figure 17: Average values and extended uncertainties of measurement

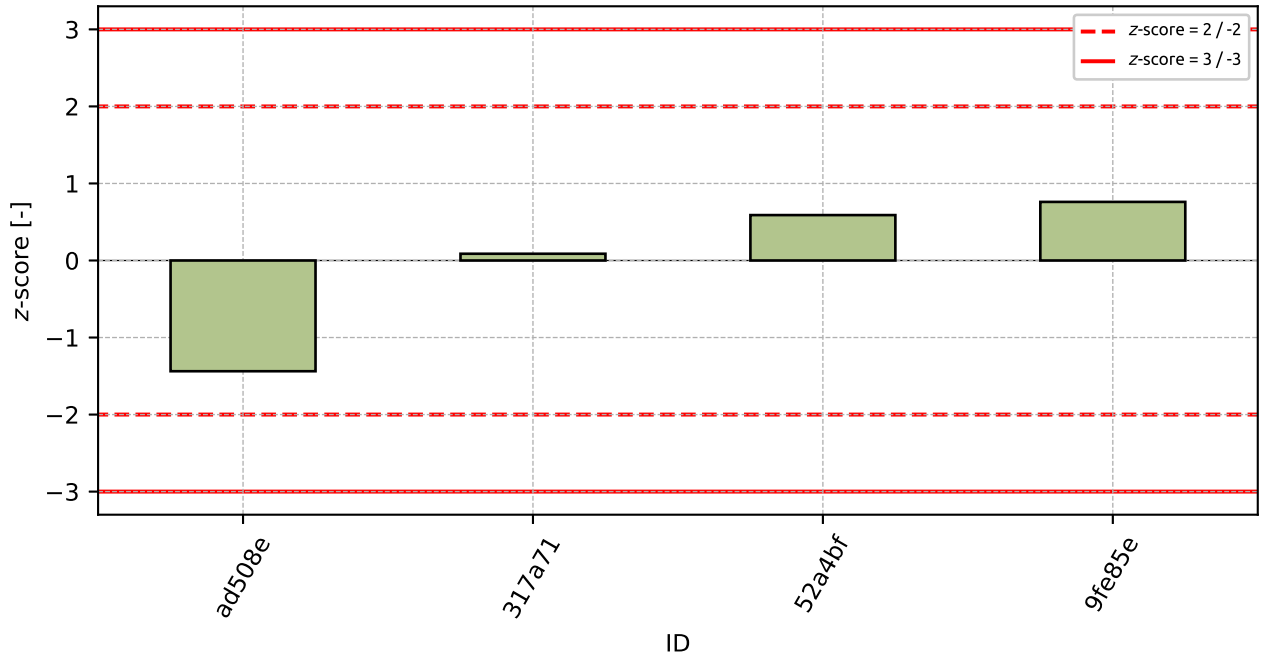

Figure 18: z-score

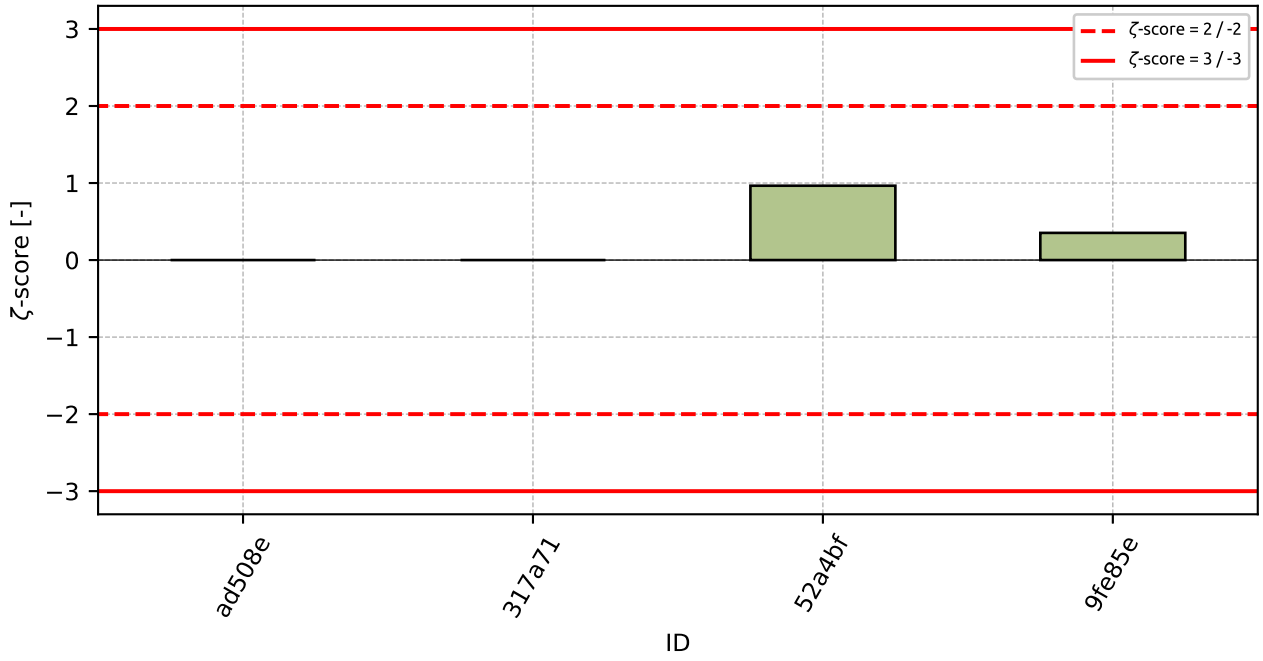

Figure 19: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
ad508e	-1.44	-
317a71	0.09	-
52a4bf	0.59	0.97
9fe85e	0.76	0.35

4 Appendix – EN ISO 6892-1 – Percentage reducation of area

This part of PT program was not opened due to the low number of participants.