Diagnosis of Pneumatic Cylinders Using Acoustic Emission Methods

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ÚSTAV
KONSTRUOVÁNÍ

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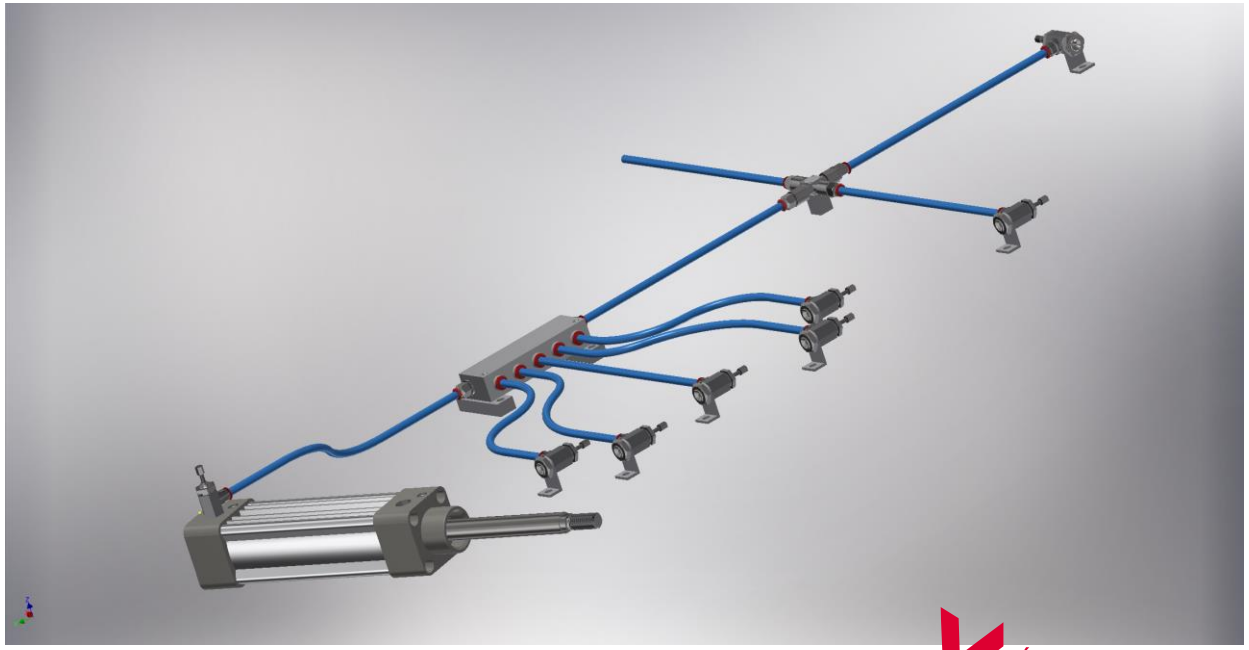


Introduction

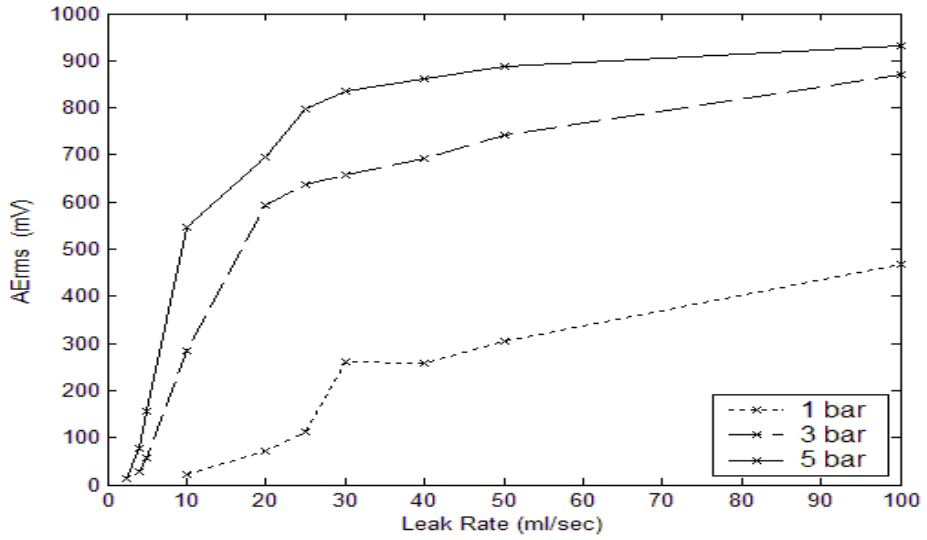
- This study tried effectively to apply real-time diagnostics to detect any malfunctions in automatic production lines and in the transport field, and looking for new ways to inspect and predict any defects.
- Non-destructive testing (NDT)
- Acoustic emission
- Pneumatic cylinders
- The reason of testing the pneumatic cylinder by AE condition monitoring

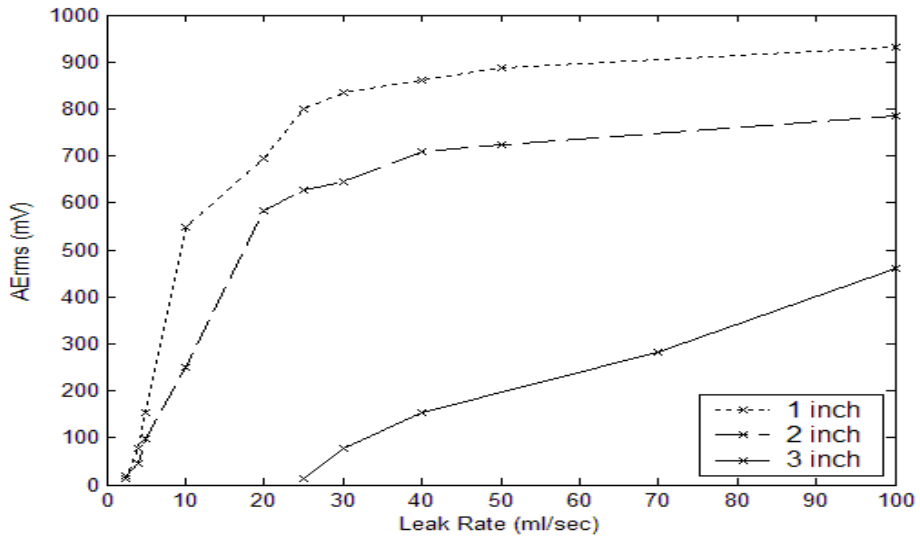
State of the art

Relationship between AE and leakage

- Parameters of acoustic emission
- Apparatus of acoustic emission
- Leakage and RMS of acoustic emission :

many researcher studied the relation between RMS and leak as :
Bezn and Joon-Hyun Lee et al W. (2005)
Kaewwaewnoi, A. Prateepasen and A. Kaewtrakulpong (2007)

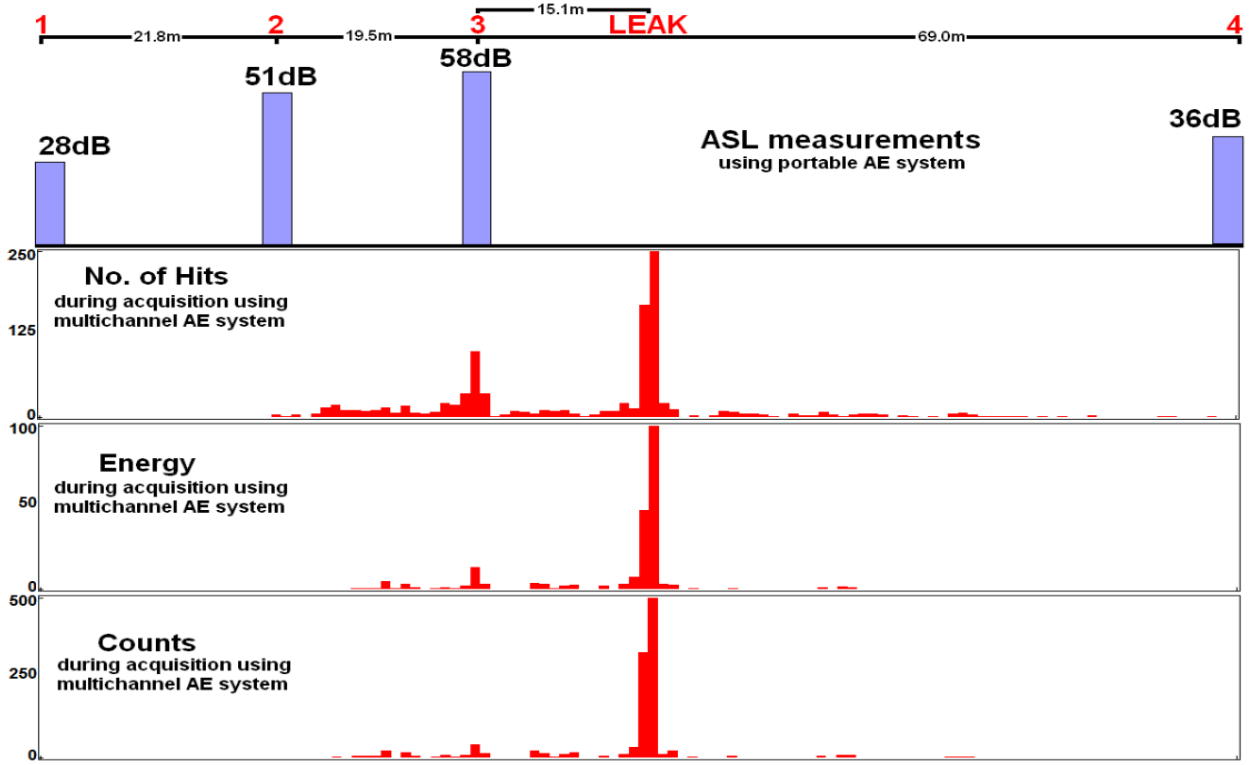




Relationship between AErms and leakage rates of 1inch ball valve at different pressures and leakage rates of different valve sizes at P = 5 bar W.

State of the art

- Identification and location of leakage

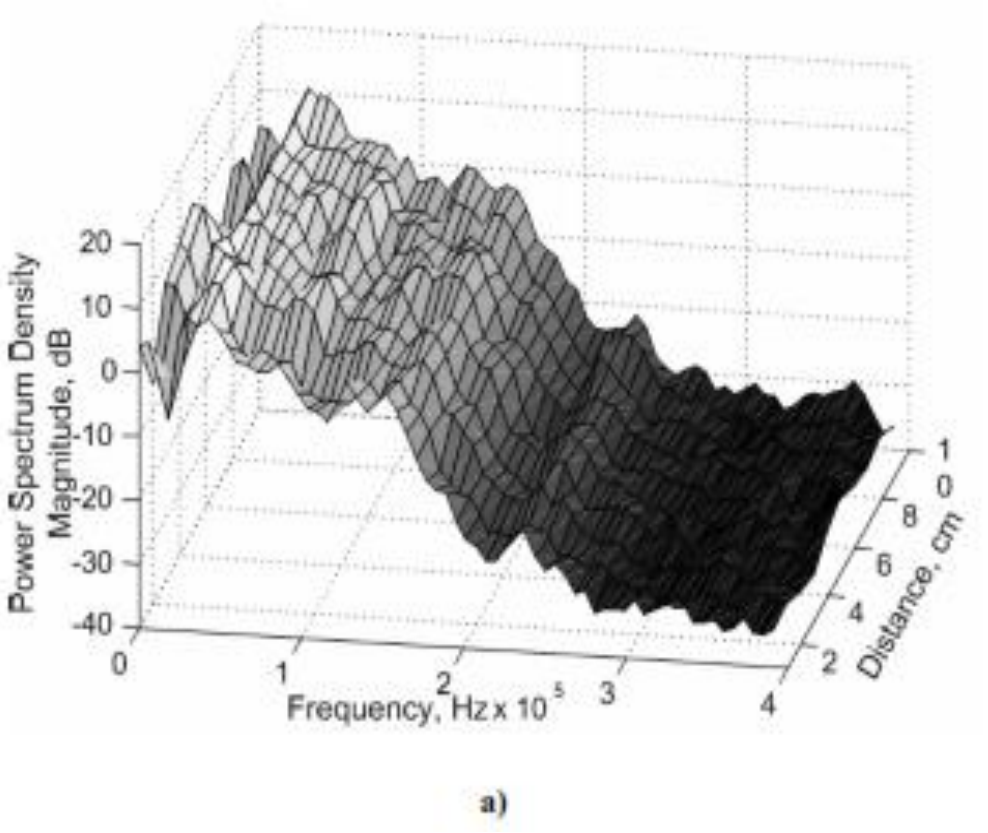


ASL vs. channel (top) and linear location indicating the leak point based on number of hits, energy and counts (bottom) of the acquired signals 2009.

- Several researchers has studied the AE since 1980s as:
- Kupperman et al (1985).
- Anastasopoulos, D. Kourousis and K. Bollas (2009)
- Z. Farova, Z. Prevorovsky , V. Kus, Serge Dos Santos (2011)
- Shama,A.; El-Shaib,M.; Sharara,A.; Nasser,D.Y (2017).

State of the art

Augutis and Saunoris 2004 studied pneumatic cylinders.



Power spectrum densities of the HFV high frequency voltage at various measurement points: a) new pneumatic cylinder; b) worn pneumatic cylinder.

Analysis and evaluation of Previous studies

- Testing methods of leaks is rarely used to test the leak in cylinders [10 -12] .
- They tried to apply AE to detect leak and reduce the noises and to find the relation between the AE parameters and leak. All experiments had tried the frequency spectrum in the first [13 - 31].
- All results have shown that the AE technique can work well in the field of valves [32].
- Typical AE is able to determine the location of defect in all last researches [33 - 50].
- When the leak rate increases the amplitude of AE increases [51].
- The change of load does not affect much at the piston velocity [52,53].

Objectives of the research

The aim of this work is to develop a new efficient diagnostic procedure for checking the function of pneumatic cylinders using acoustic emission in cooperation with the producer.

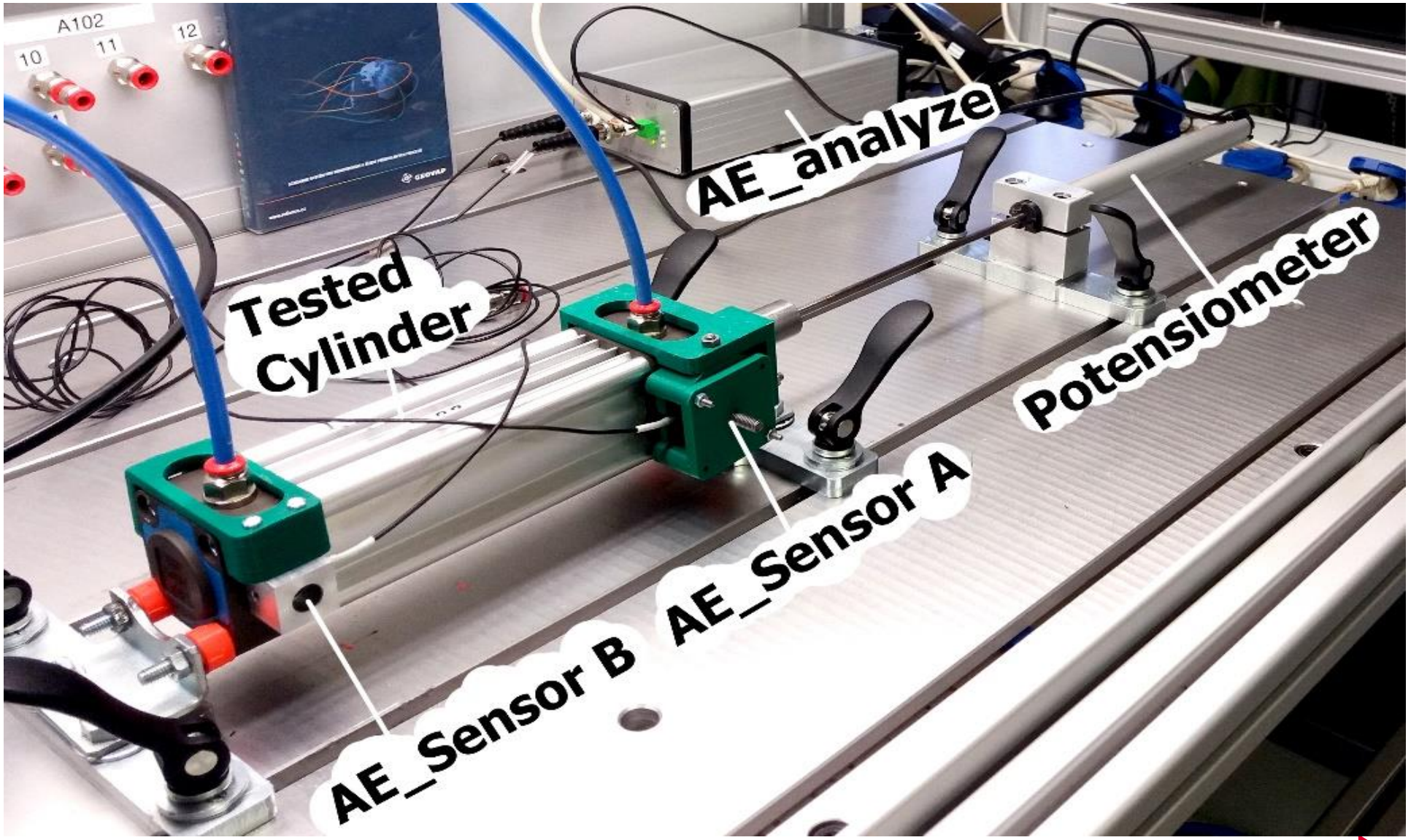
This diagnostic procedure is able to detect distinctive differences that determine whether the cylinder is damaged or undamaged.

Determination of the relationship between parameters of AE and defects in the cylinders.

Determination of the diagnostic criteria that evaluate the pneumatic cylinder and detect the defects.

New software and methodology depends on our results.

Experiment


A102
10
11
12
AE_analyze
Tested Cylinder
Potensiometer
AE_Sensor B
AE_Sensor A

Result and Discussion

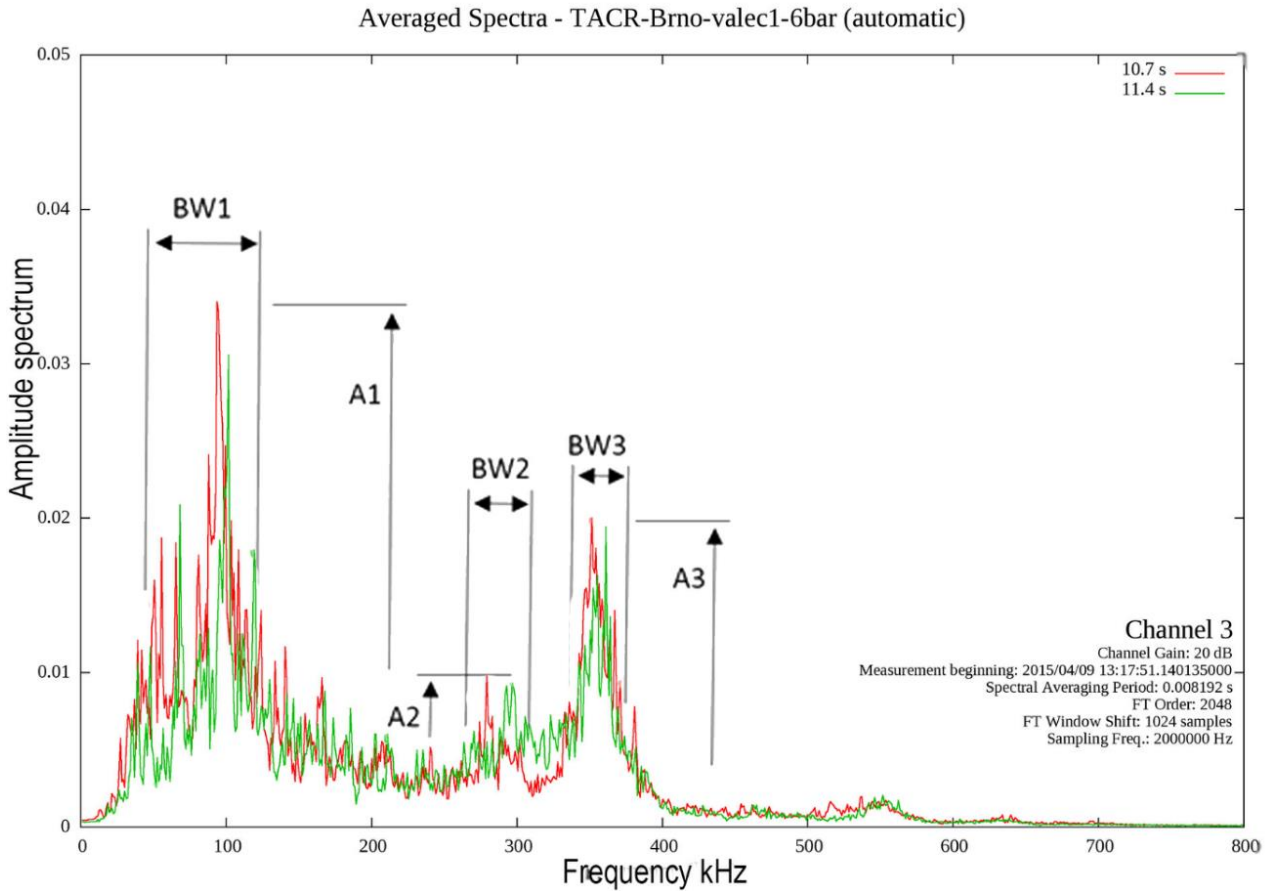
The results were divided to four main stages

- **Frequency spectrum**
- **The behavior of cylinder movement and RMS**
- **The basic criteria**
- **The load on the cylinders**

Result and Discussion

Frequency spectrum

Unit of amplitude of spectrum V^2/Hz



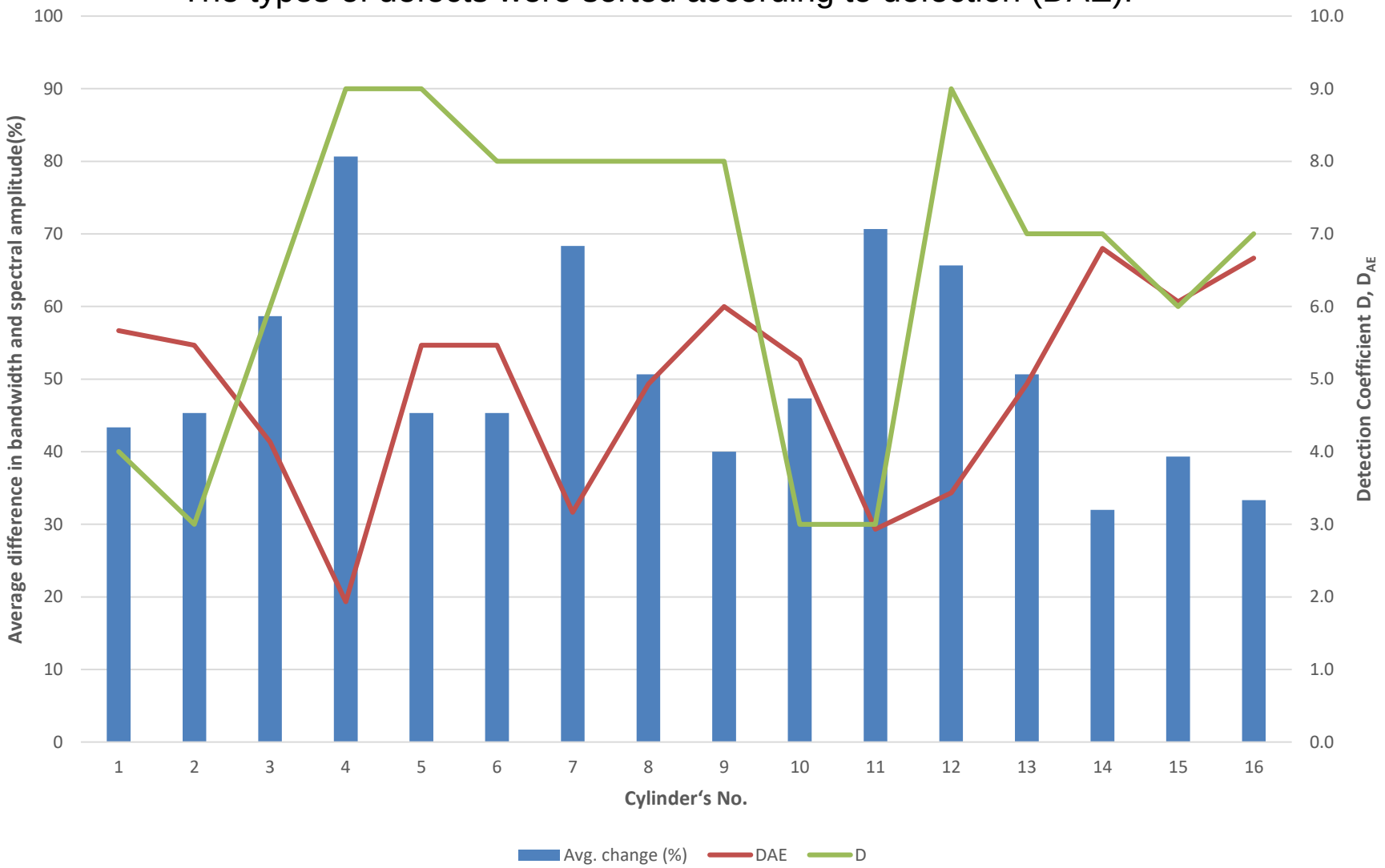
Sample determination bandwidth max. Amplitude at cylinders undamaged PS

the frequency depends on the sensor characteristic

Result and Discussion

Frequency spectrum

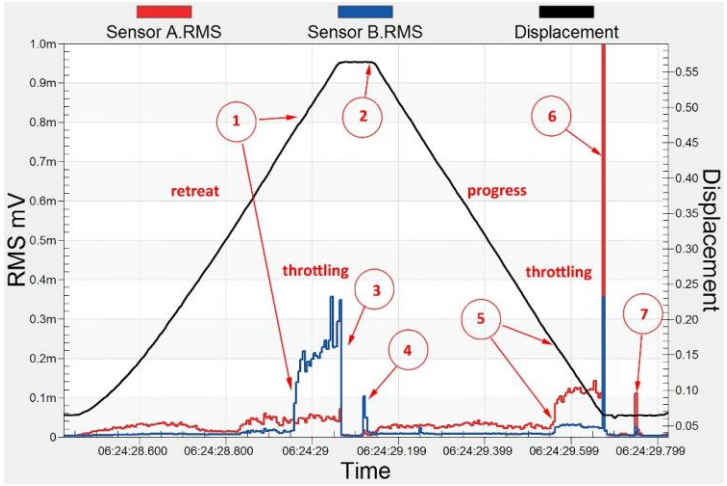
The types of defects were sorted according to defection (DAE).



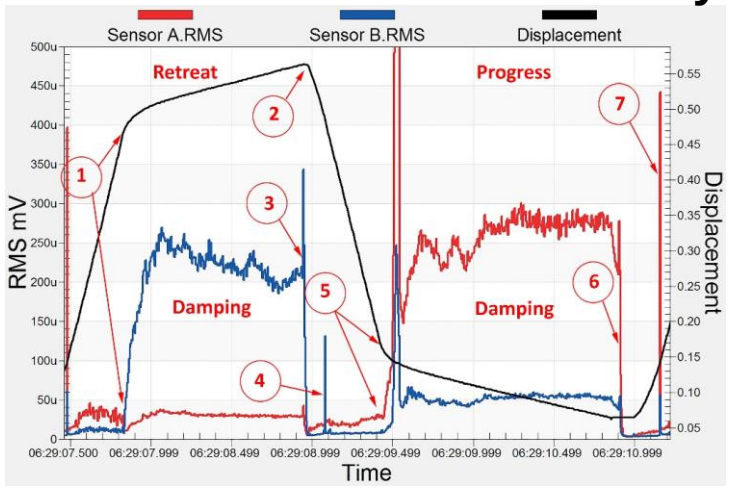
Rate changes caused by that damage coefficient and defection (DAE).

Result and Discussion

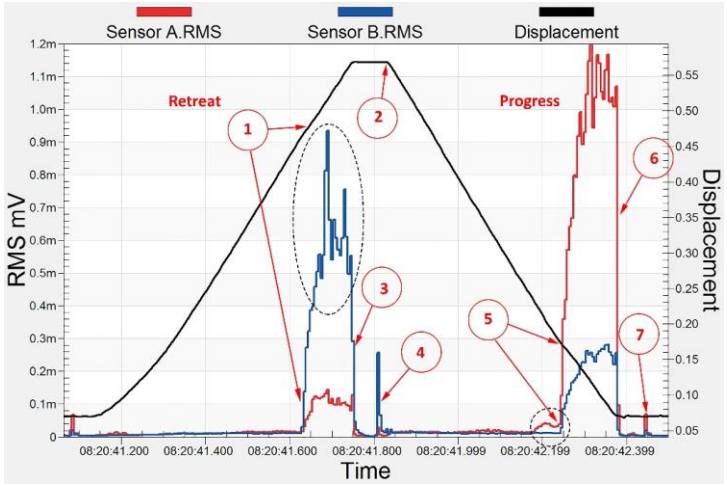
The behavior of cylinder movement and RMS



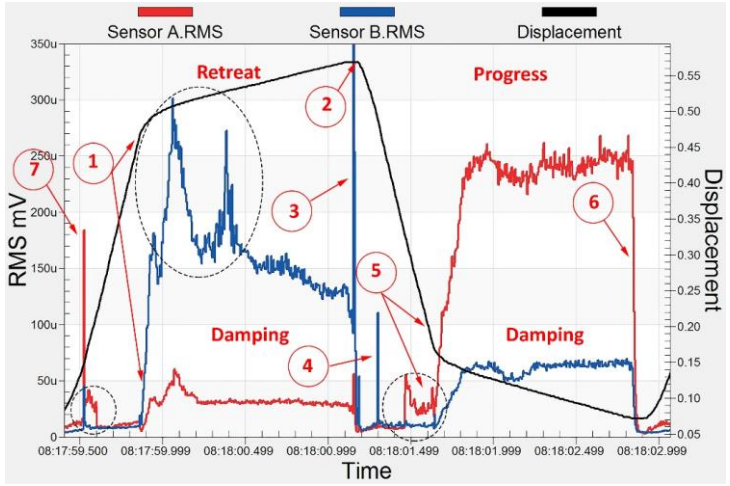
Undamaged cylinder without damping



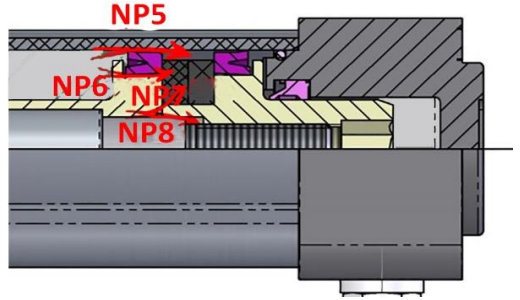
Undamaged cylinder with damping.



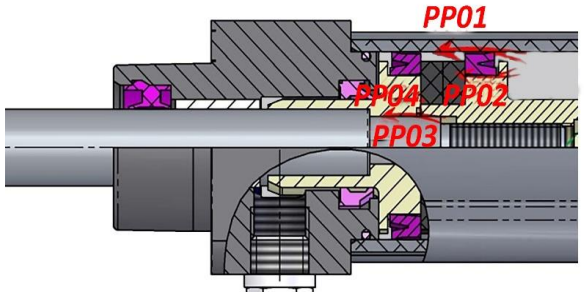
Damaged cylinder without damping.



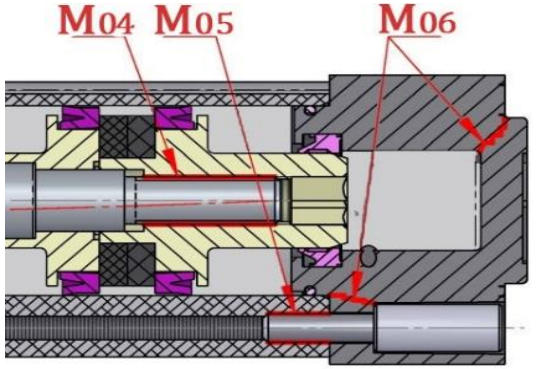
Damaged cylinder with damping



Leaks above the piston in the retreat stroke



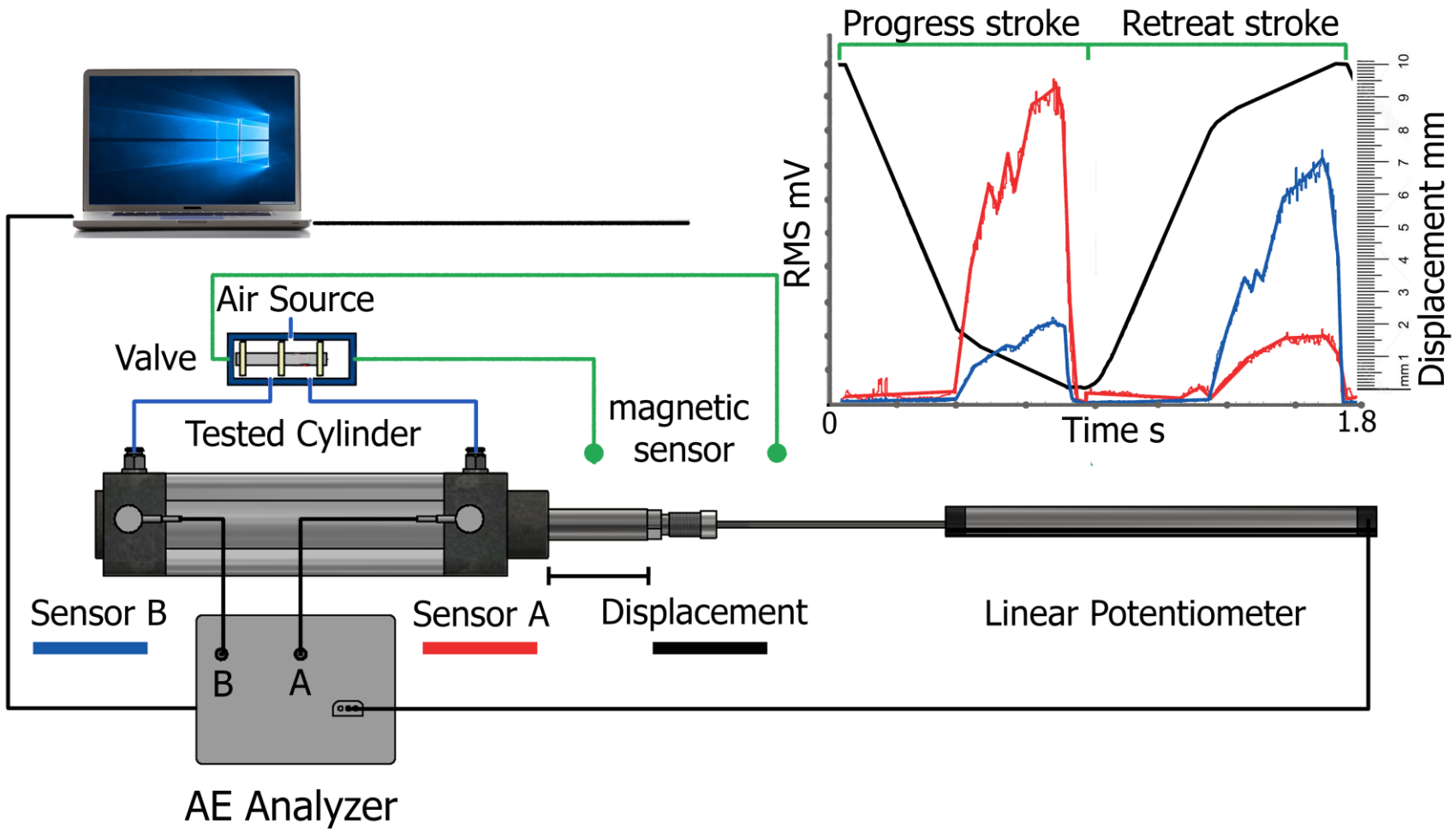
Leaks below the piston in progress stroke



Mechanical defects

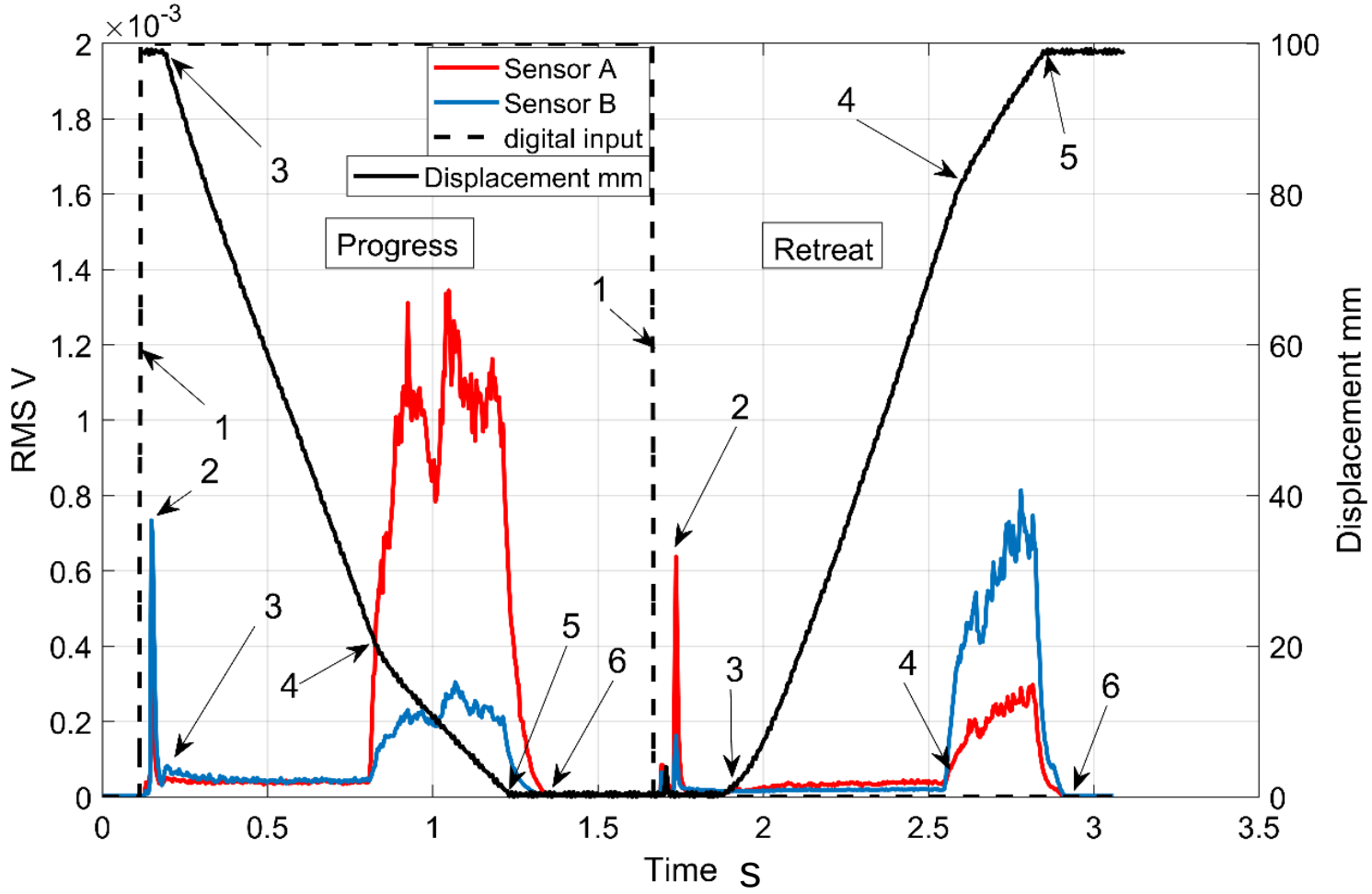
Comparing between damaged and damaged cylinders

Result and Discussion



Assembly of experimental equipment

Result and Discussion



(1) the valve is opened by the digital input to let the air pass through the port, (2) the impact of the air at the cushion piston, (3) the initiation of movement, (4) the initiation of the damping phase 21.7mm before the TDC, (5) when the cushion piston impacts the cushion cap, and stops, (6) the end of venting air and relaxing and the end of the stroke.

Result and Discussion

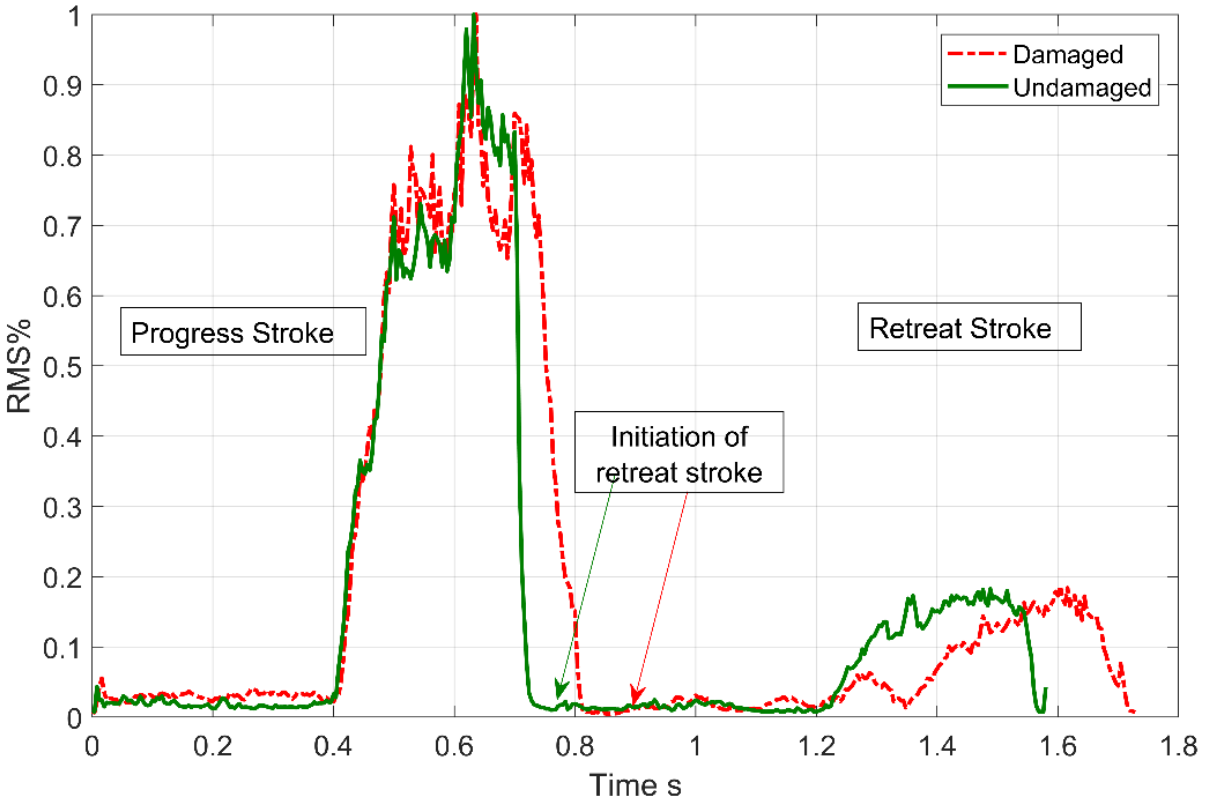
Four types of defects were chosen according to DAE

Result and Discussion

The basic criteria

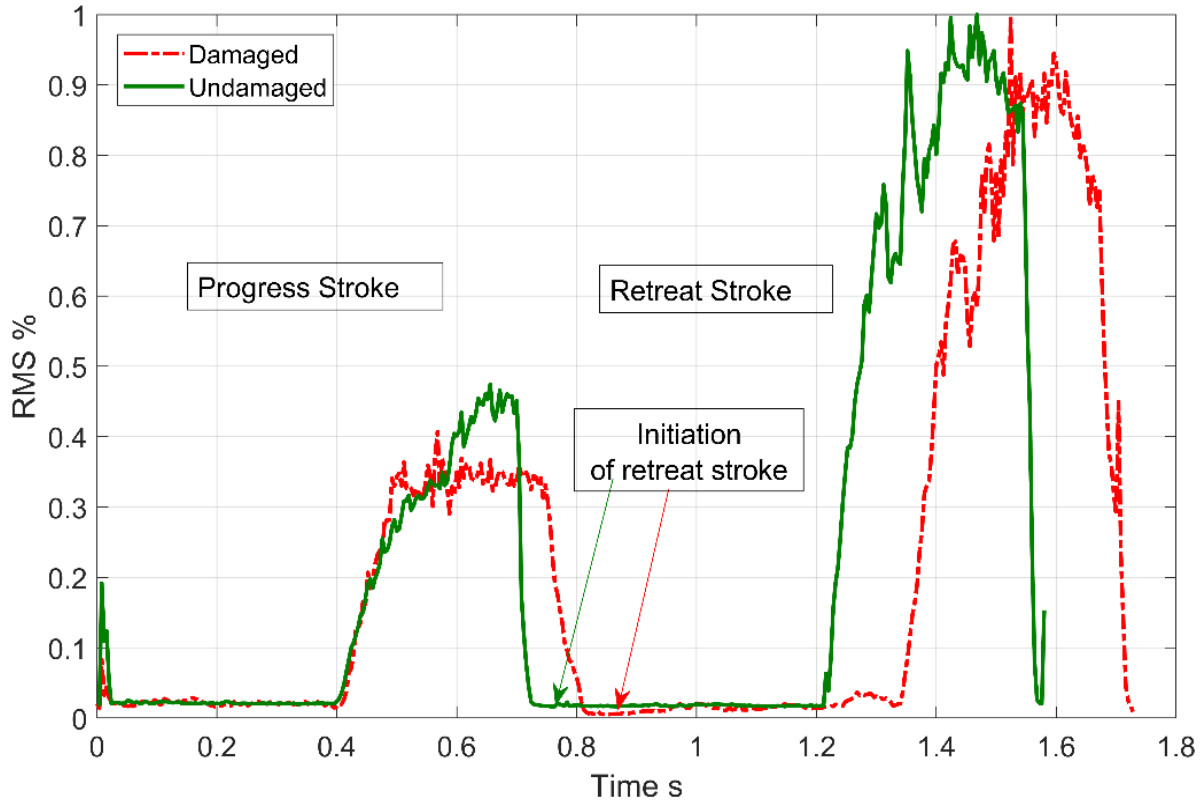
The first criterion is comparing between damaged and undamaged cylinders according to the delay in the signal

sensor A



Comparing between damaged and undamaged cylinders, NP07 according to the RMS values derived from the sensor A

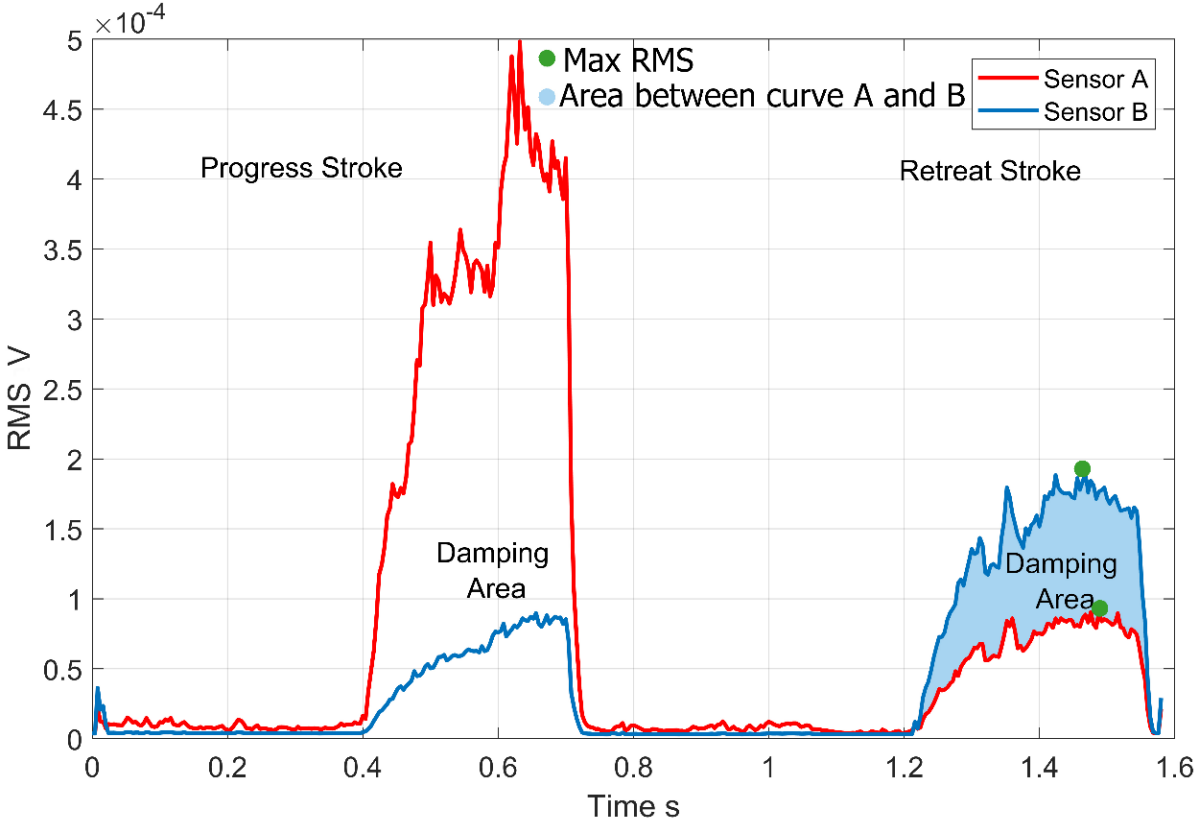
sensor B



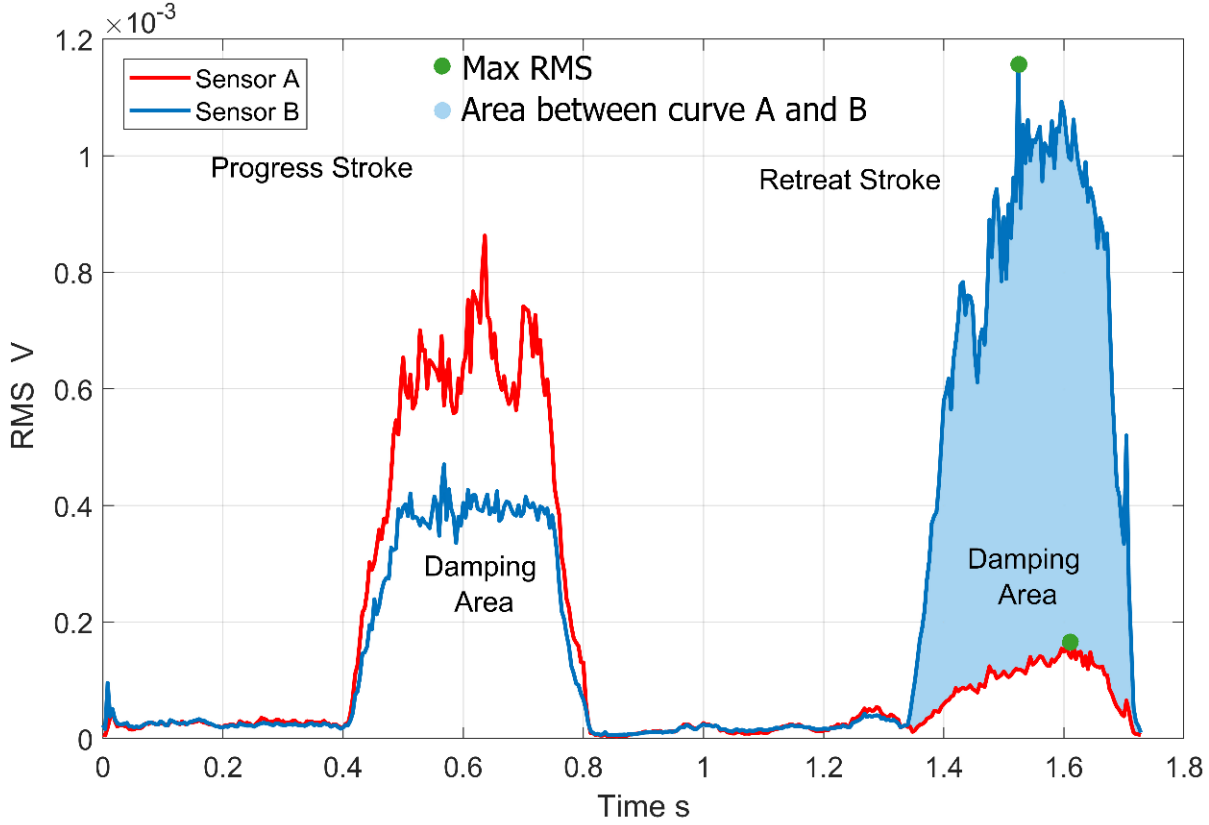
Comparing between damaged and undamaged cylinders, NP07 according to the RMS values derived from the sensor B

Result and Discussion

The second criterion is comparing between damaged and undamaged cylinders according to the ratio of max RMS signal between sensor A and sensor B in the retreat stroke



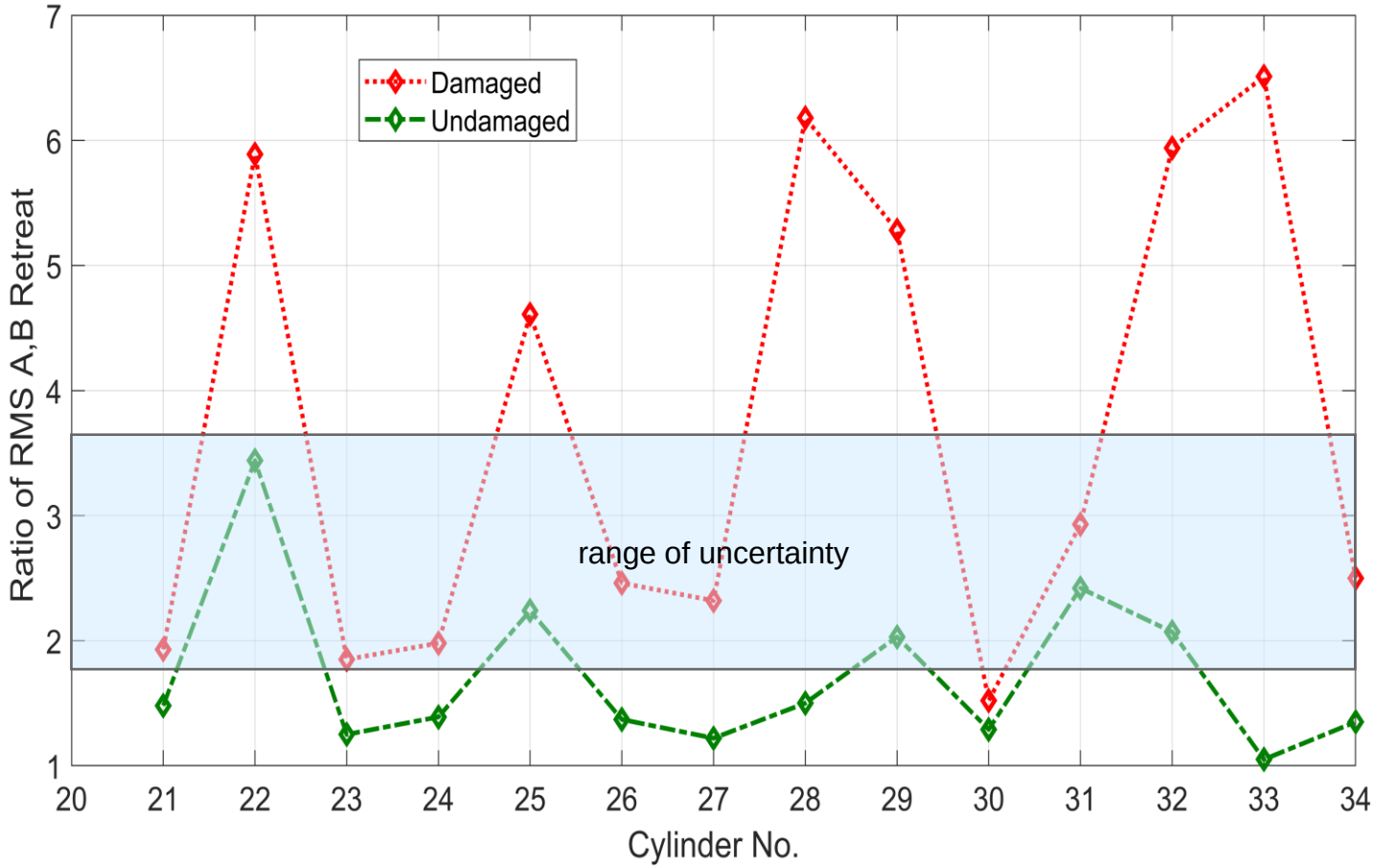
RMS dependency on time for undamaged cylinder with damping



RMS dependency on time for damaged cylinder with damping

Result and Discussion

The basic criteria

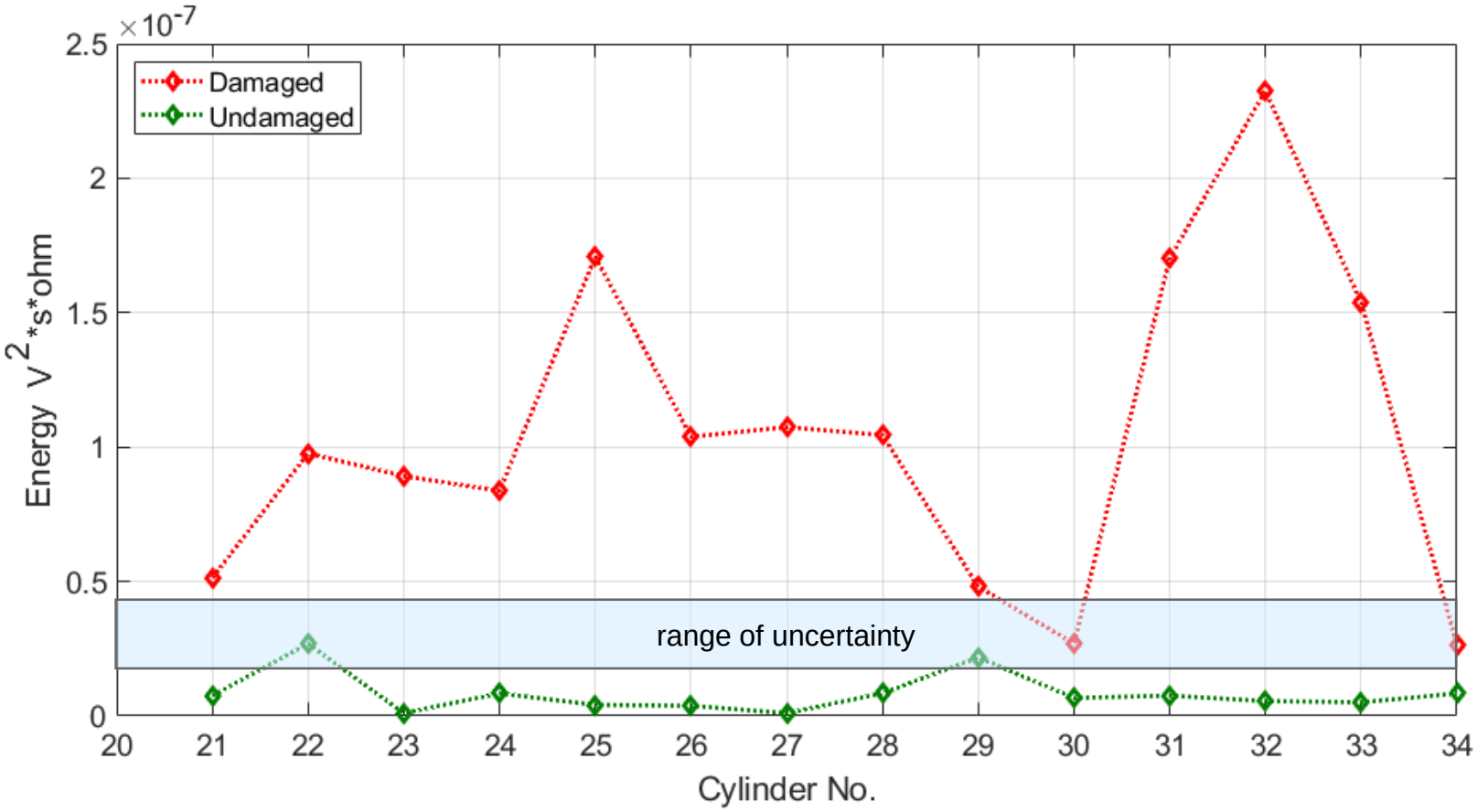


Comparing between damaged and undamaged cylinders according to the ratio of RMS values

Result and Discussion

The basic criteria

$$E = \sum U_{retreat\ B}[i]^2 * \mathrm{dT} - \sum U_{retreat\ A}[i]^2 * \mathrm{dT} \quad [V^2 * s * ohm]$$

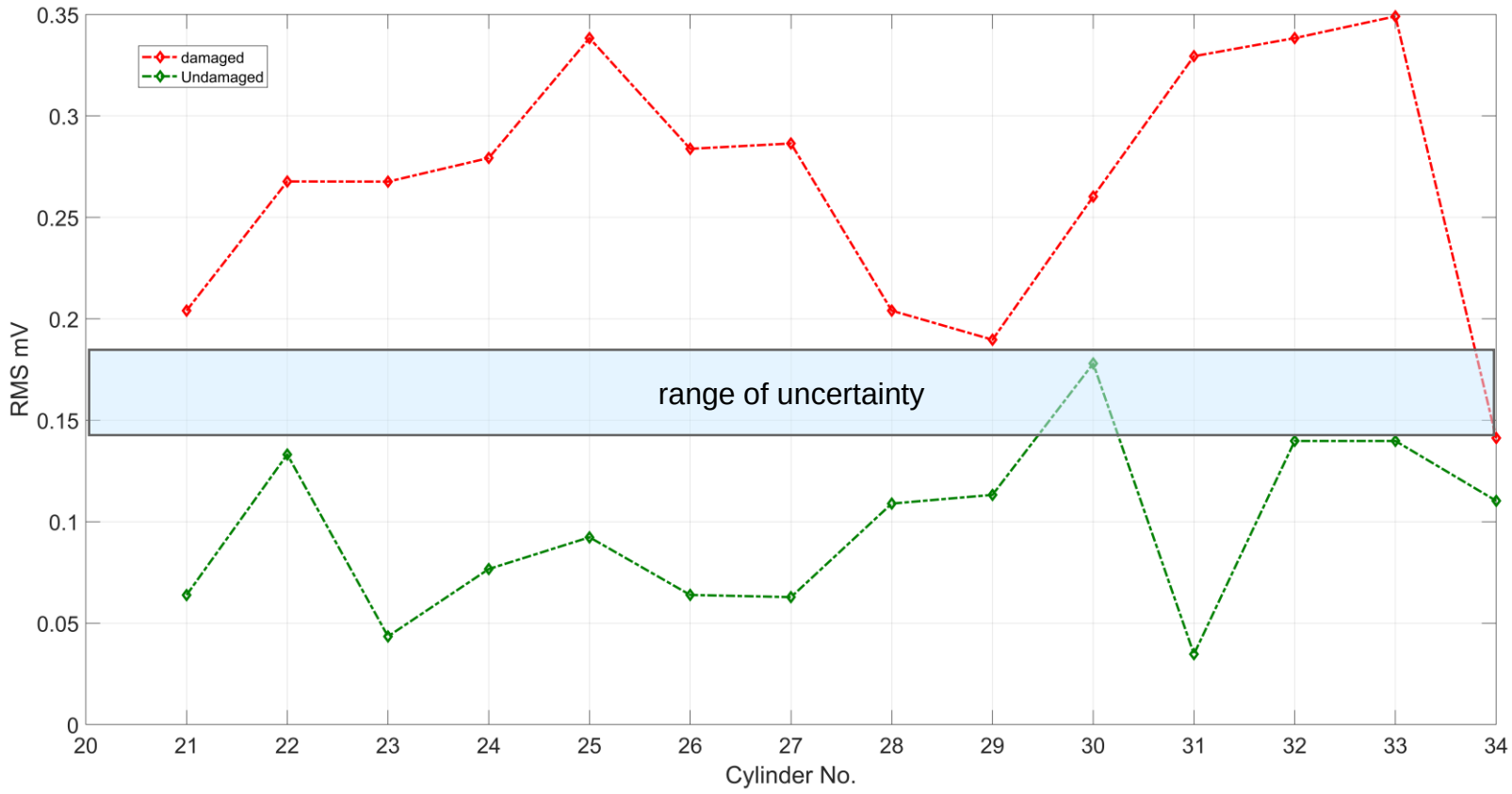


Comparing between damaged and undamaged cylinders according to the energy values

Result and Discussion

The basic criteria

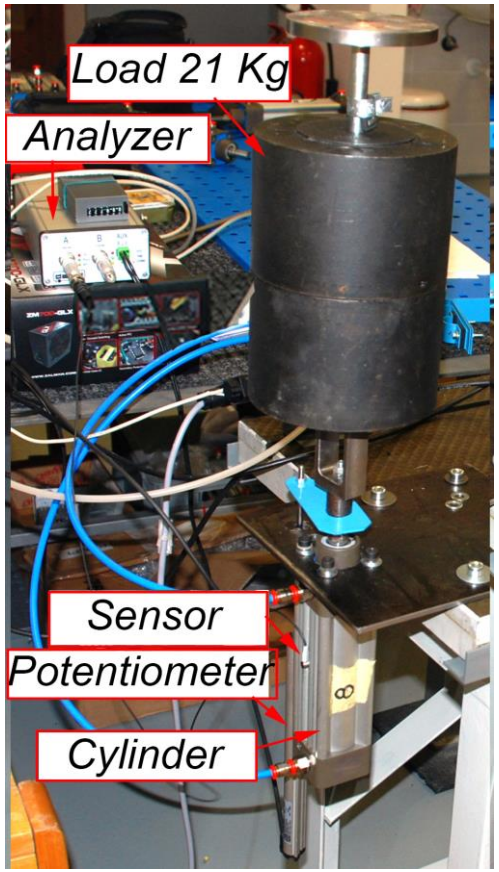
$$\mathrm{RMS} = \sqrt{\sum(U[i]^2)/N}$$



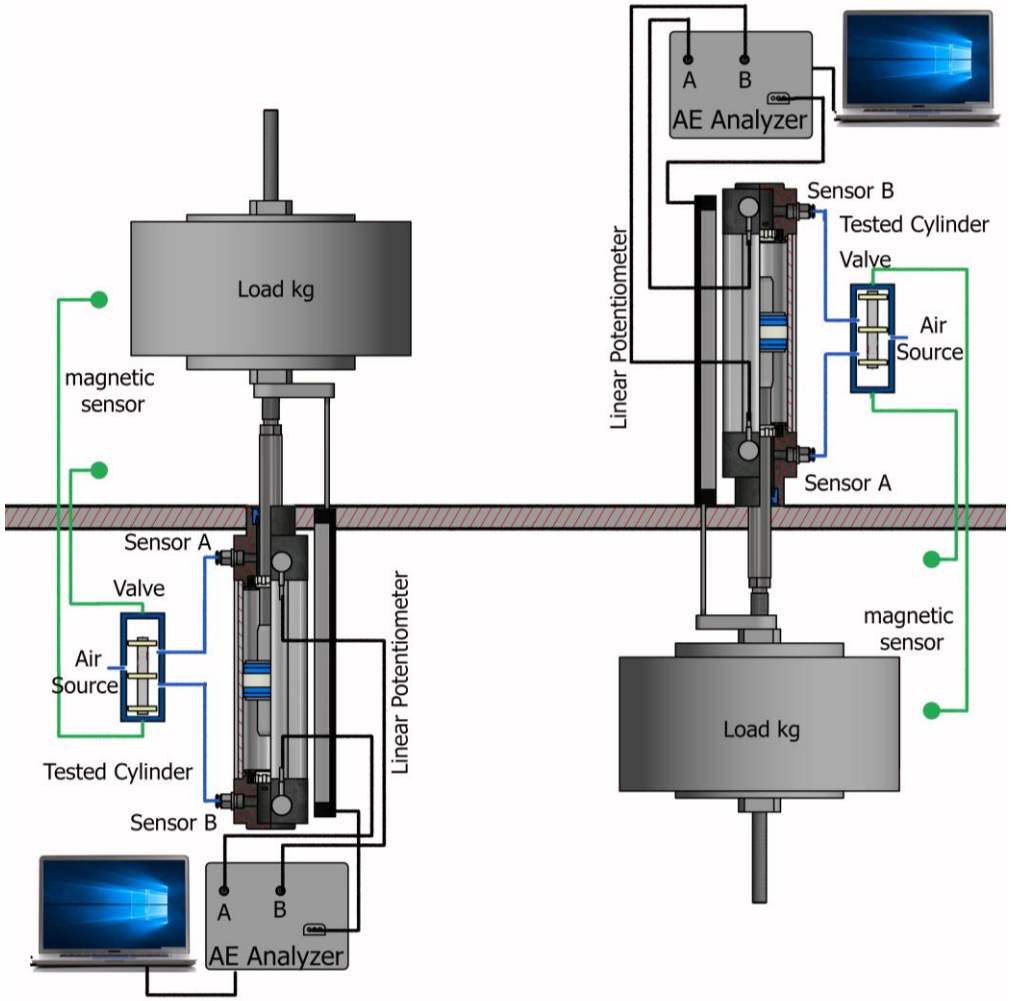
Comparing between damaged and undamaged cylinders NP08, PP03, NP07 according to the RMS values

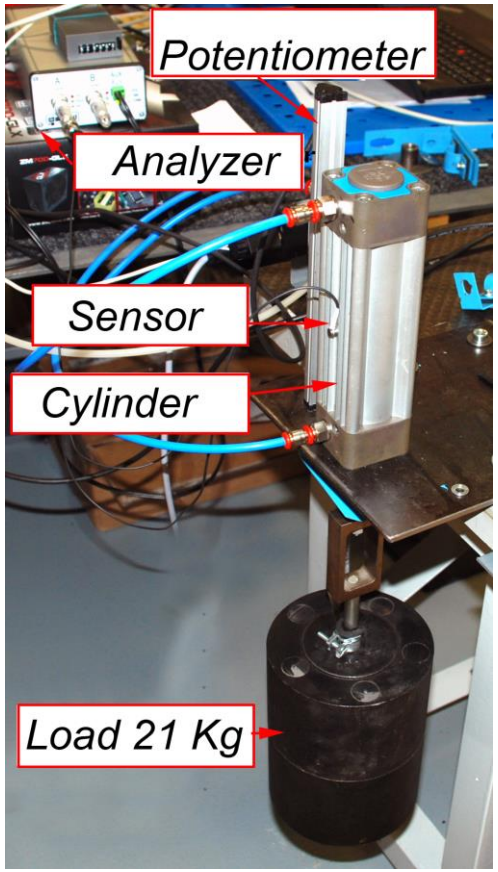
Result and Discussion

The load on the cylinders



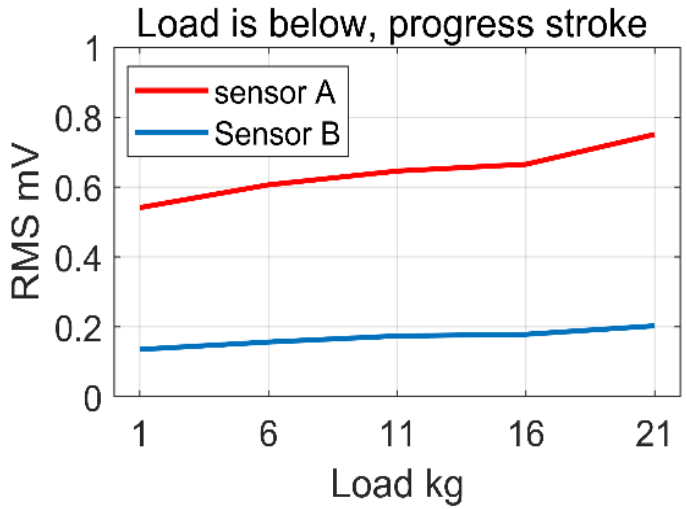
b) Loading above the rod of cylinder

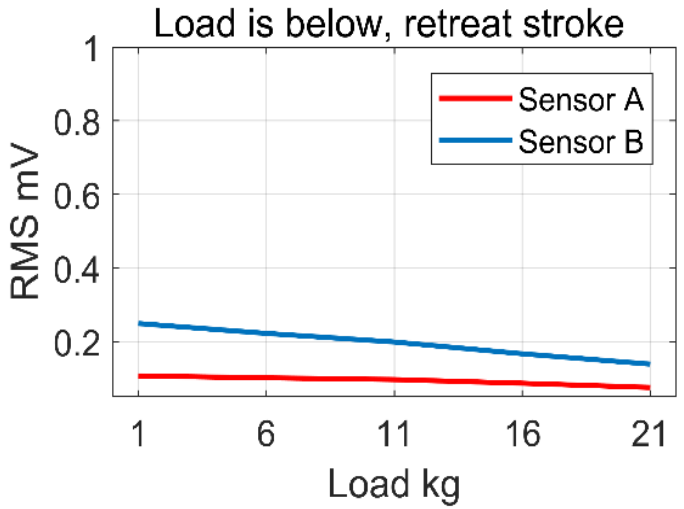


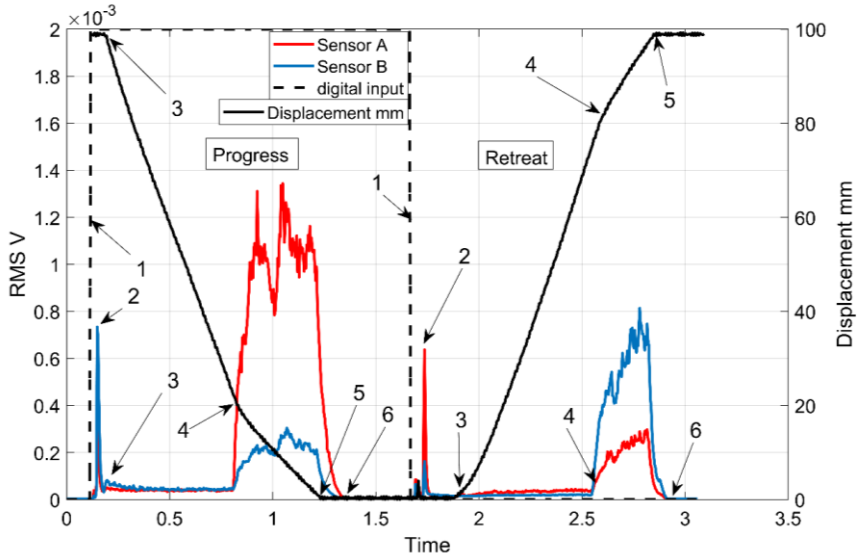


a) Loading below the rod of cylinder

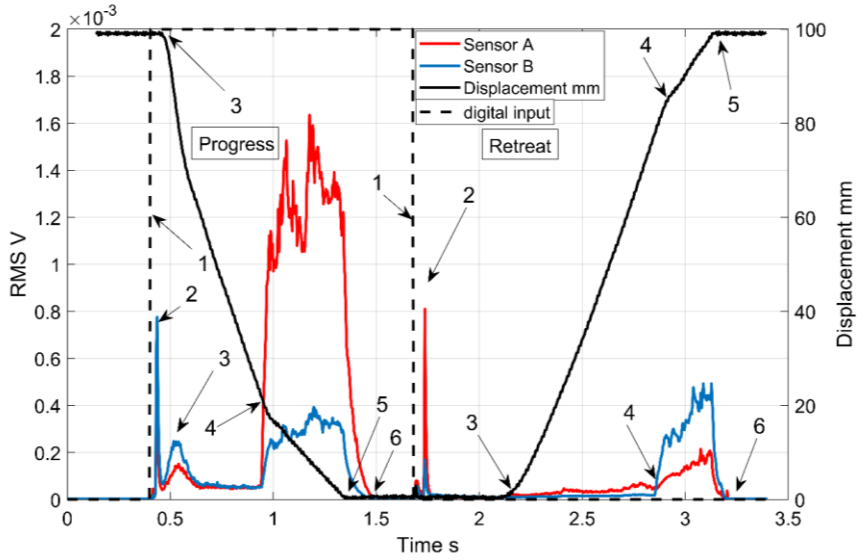
Result and Discussion





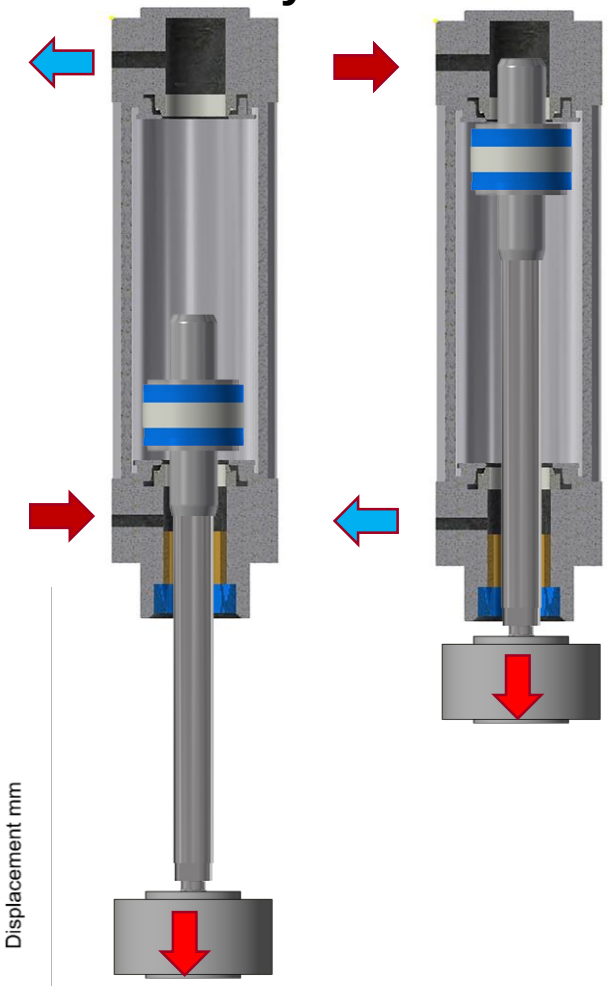


Load of 1 kg was applied



Load 21 kg was applied

The load on the cylinders



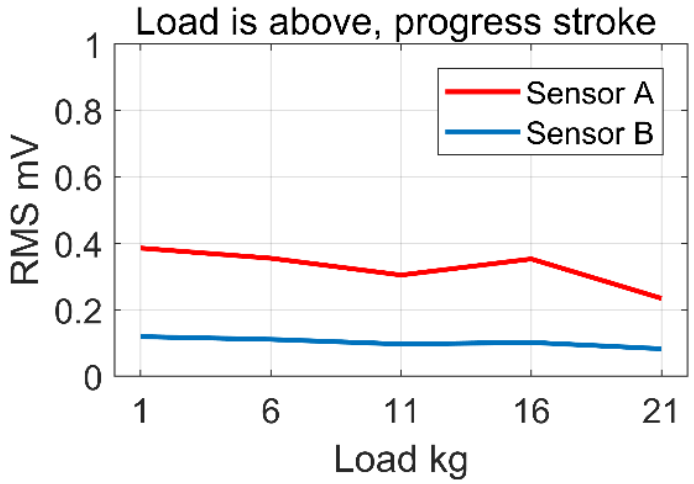
Retreat stroke

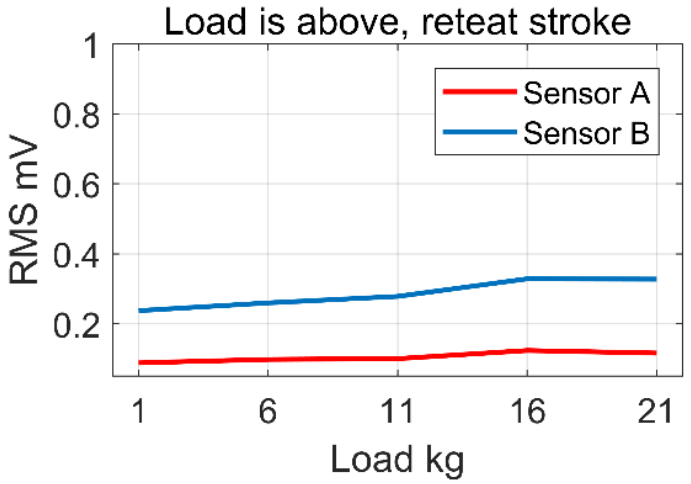
Progress stroke

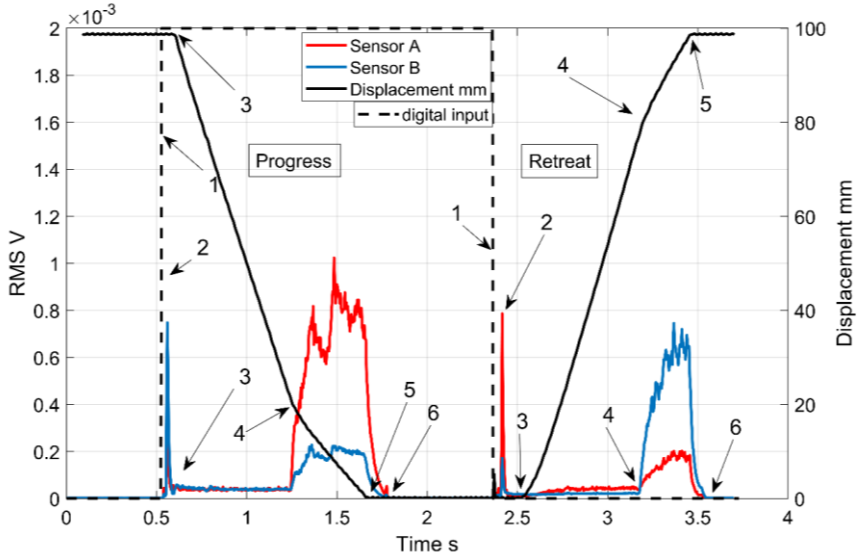
Load is below piston

below the undamaged cylinder

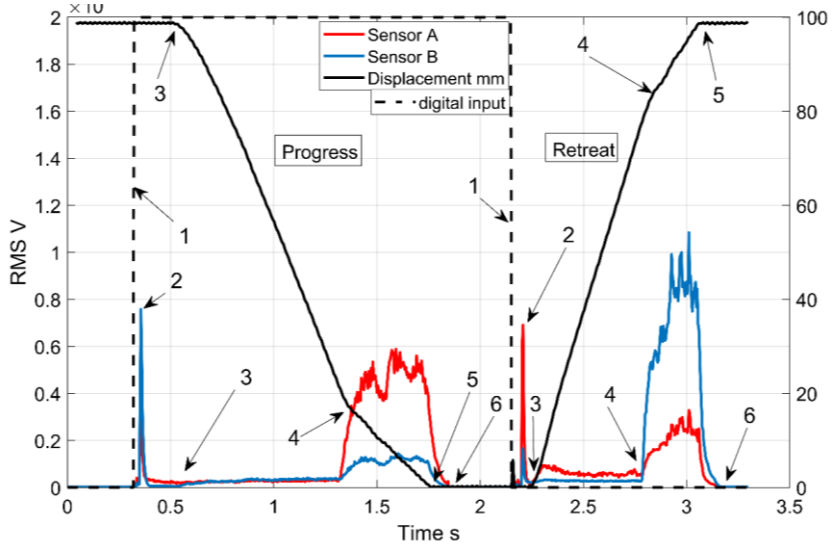
Result and Discussion





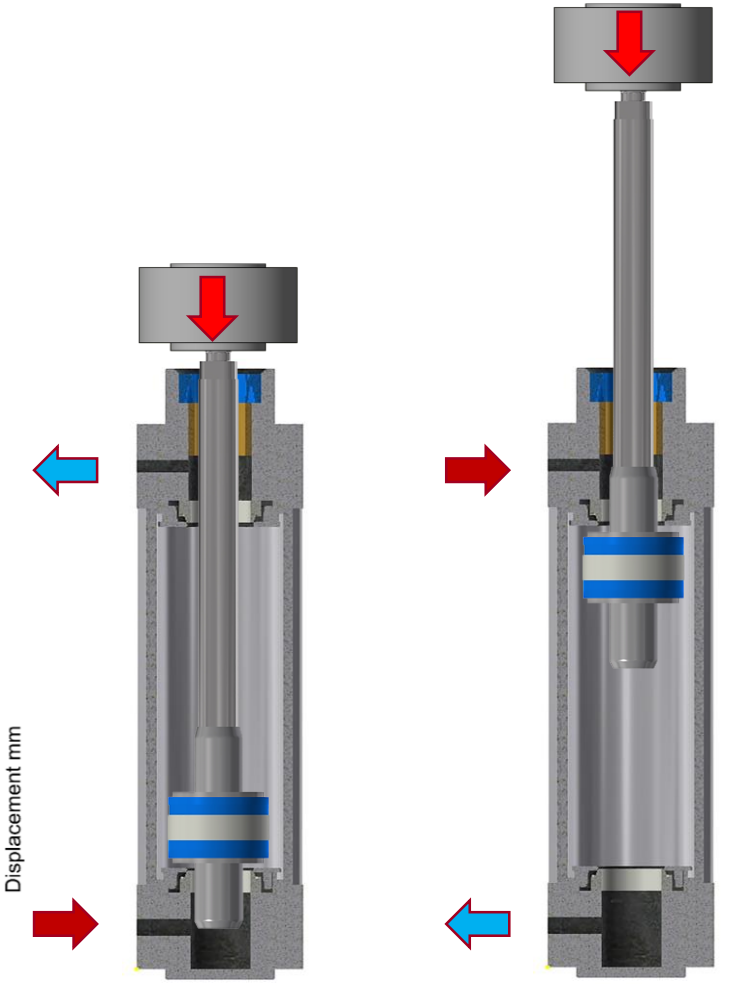


Load 1 kg was applied



Load 21 kg was applied

The load on the cylinders



Progress stroke

Retreat stroke

Load is above piston

Acoustic Emission Testing above the undamaged cylinder

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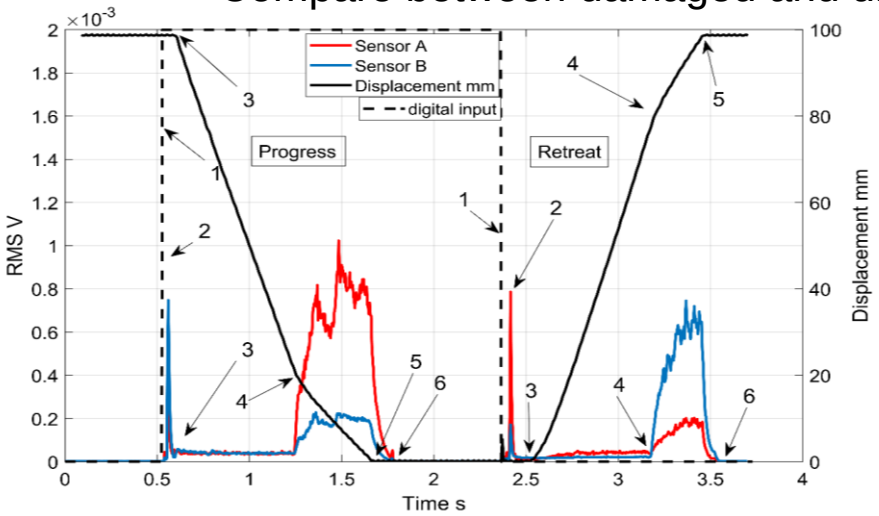
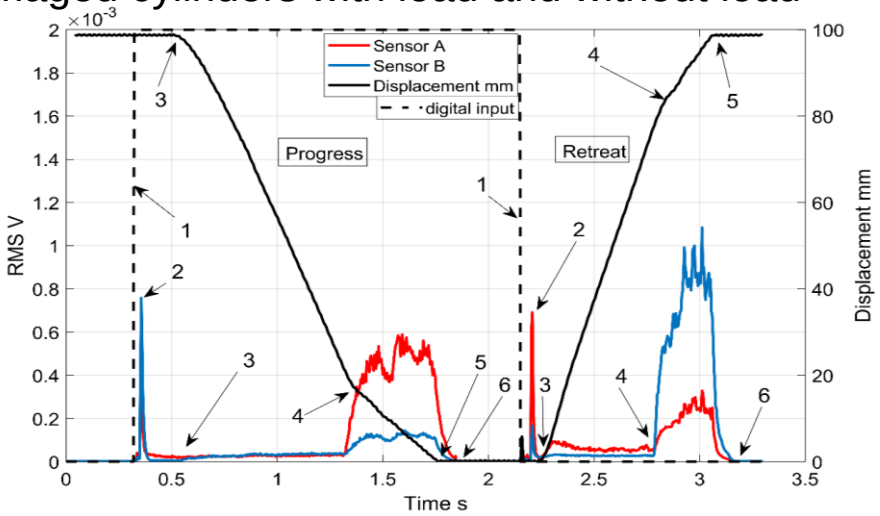
Result and Discussion

The load on the cylinders

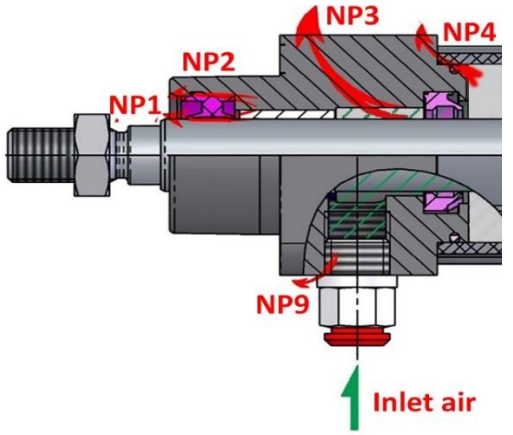
Compare between damaged and undamaged cylinders with load and without load

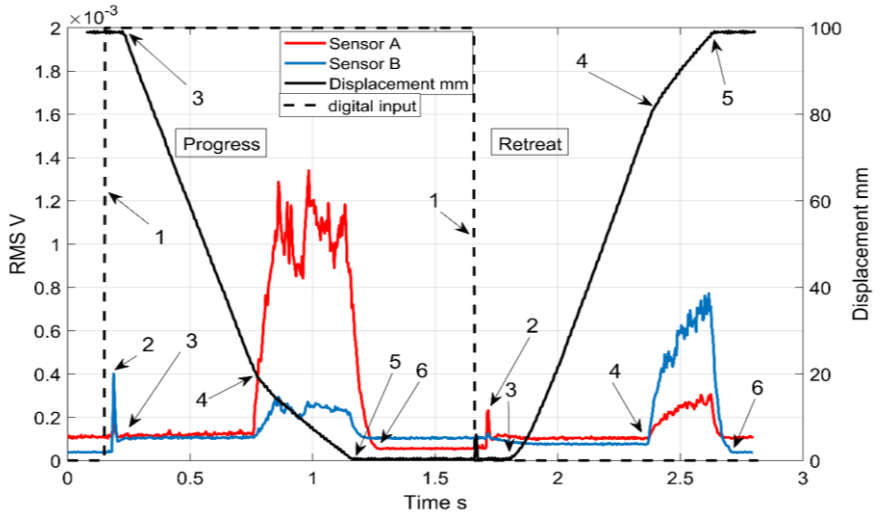


Load 1 kg was applied above the undamaged cylinder

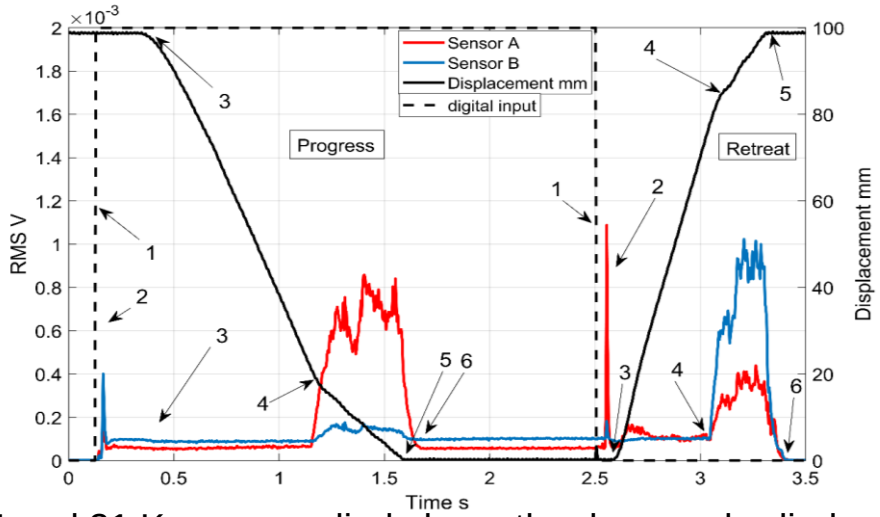


Load 21 Kg was applied above the undamaged cylinde،

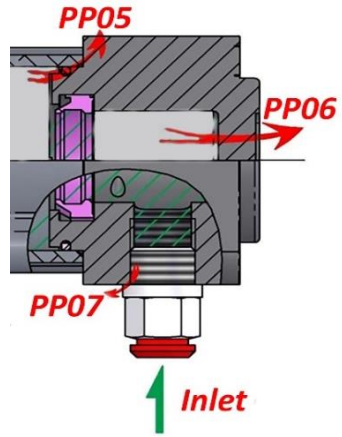




Load 1 kg was applied above the damaged cylinder



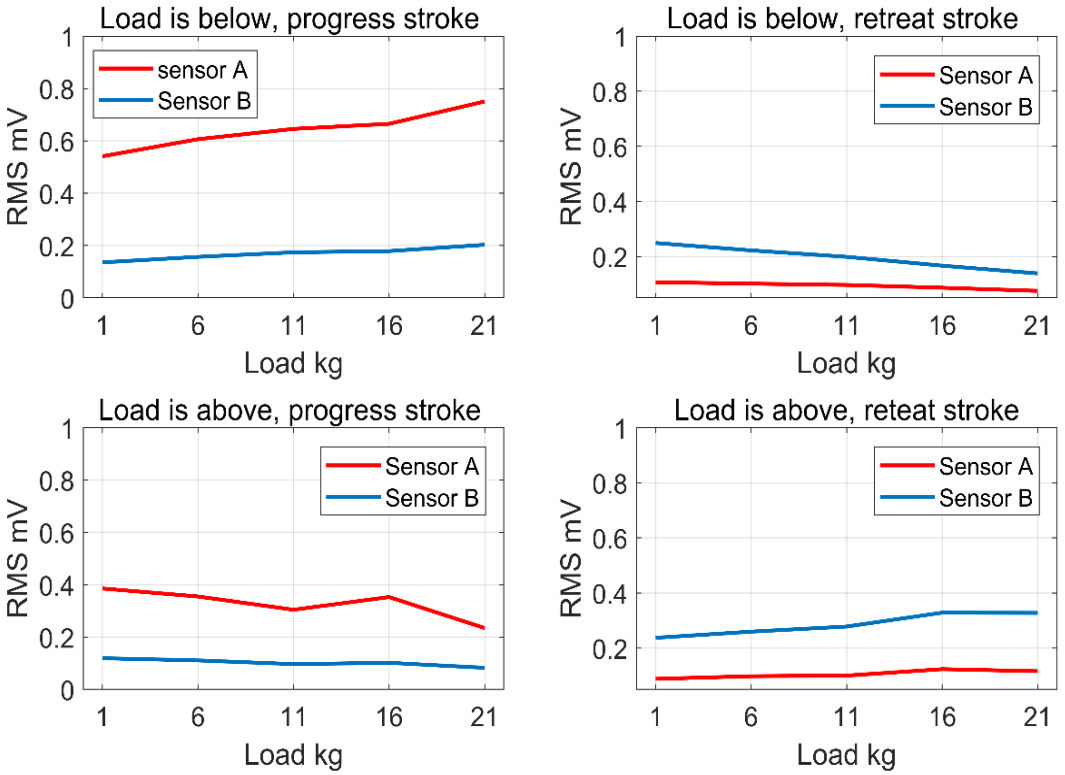
Load 21 Kg was applied above the damaged cylinder



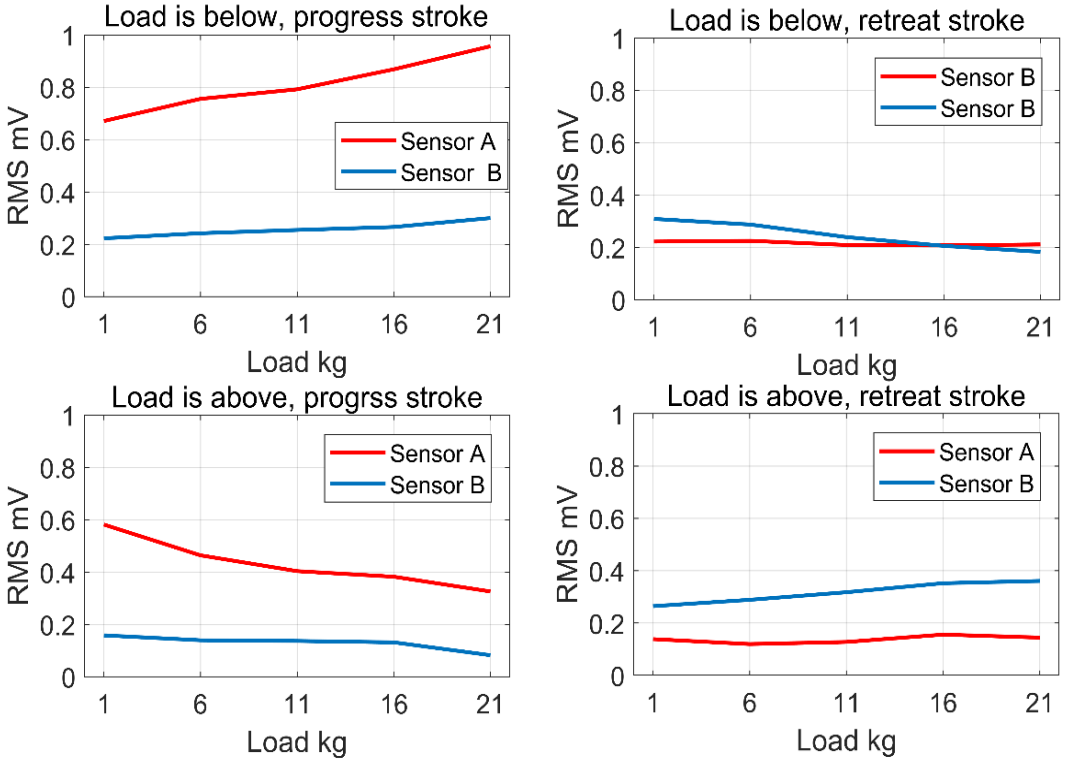
Result and Discussion

The load on the cylinders

Compare between damaged and undamaged cylinders with load and without load



Relationship between RMS and loading on undamaged cylinder during one cycle.



Relationship between RMS and loading during one cycle of the damaged cylinder.

Conclusion

There are four criteria to evaluate the cylinder respectively:

- Delay in the stroke
- When the ratio of RMS is bigger than 3 the cylinder is damaged if the ratio is smaller than 1.7 the cylinder is undamaged.
- At signal energy $E_{B-A} > 0.27\text{x}10^{-7}$ V2 *s*Ohm the cylinder is damaged, and at $E_{B-A} < 0.2\text{x}10^{-7}$ V2 *s*Ohm it is undamaged.
- At $\sum RMS > 0.18$ mV the cylinder is damaged, and at $\sum RMS < 0.14$ mV it is undamaged.
- The relationship between RMS and Loads is approximate linear.
- When there is intersection between RMS vs load curves the cylinder is damaged.

Author or co-author of publications

Impacted Journals

1. MAHMOUD, H., F. VLAŠIC, P. MAZAL and M. JÁNA. Leakage Analysis of Pneumatic Cylinders Using Acoustic Emission. Insight BINDT, 2017 vol. 59,No.9, p. 500-505. ISSN: 1354-2575 impacted journal (0.7).
2. MAHMOUD, H., P. MAZAL and F. VLAŠIC. Relationship Between Acoustic Emission Signal and Loads on Pneumatic Cylinders, Non-destructive Testing and Evaluation, 2019, impacted journal (1.957) in Taylor & Francis under review.
3. MAHMOUD, H., P. MAZAL, F. VLAŠIC. Detecting the Defects of Pneumatic Actuators Using Acoustic Emission Monitoring. Insight BINDT impacted journal (0.7) 2019 will be published .

Reveiwed Journal

1. MAHMOUD, H.; MAZAL, P.; VLAŠIC, F. Метод акустической эмиссии для неразрушающего контроля пневматических цилиндров “Using Acoustic Emission Testing for Pneumatic Actuators Monitoring”. NDT world, 2018, roč. 21, č. 4, s. 64-67. ISSN: 1609-3178.

Conferences

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Participation of projects

- A new system of dismantling diagnostics of pneumatic and hydraulic components 2015 – 2017 Technology Agency of CR
- NETME and NETME+ New Engineering Technologies for Mechanical Engineering 2015 – 2018 Ministry of Education, Youth and Sports
- Research and development of the design and technology of the new generation of spherical roller bearings 2017 – 2020 Technology Agency of CR
- Mobile apparatus for the detection of defects in pneumatic systems 2017 – 2020 Technology Agency of CR
- Continuous acoustic emission analyzer for diagnostics of erosion corrosion and creep damage of piping systems 2016 – 2019 Ministry of Industry and Trade of CR
- New generation of bearings for railway applications with extended service interval 2017 – 2020 Ministry of Industry and Trade of CR

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CERTIFIKÁT

o uznání přezkoušené metodiky
evidenční číslo: 002/17

Zákazník:	**Vysoké učení technické v Brně** **Fakulta strojního inženýrství, Ústav konstruování** **Technická 2896/2, 616 69 Brno** **Česká republika**
IČO:	**00216305**
Metoda:	**Hodnocení provozního stavu přímočarých pneumotorů pomocí metody akustické emise**
Autoři metodiky:	**Ing. František Vlašic, Ph.D.** **doc. Ing. Pavel Mazal, CSc.** **Ing. Houssam Mahmoud** **Ing. Vladimír Bukáček**
Označení:	**TA04011374**
Interní informační označení metodiky:	**Testy pneuválců akustickou emisí**
Místo uložení metodiky:	**Poličské strojírny a.s.,** **Bořiny 1145, Horní Předměstí, 572 01 Polička**

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Certifikační a inspekční společnost TÜV NORD Czech 10 TÜV NORD Czech, s.r.o.

Praha, 07.12.2017
Místo a datum

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Thank you for attention

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