Diagnosis of Pneumatic Cylinders Using Acoustic Emission Methods

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Discourse on Dissertation thesis

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Institute of Machine and Industrial Design

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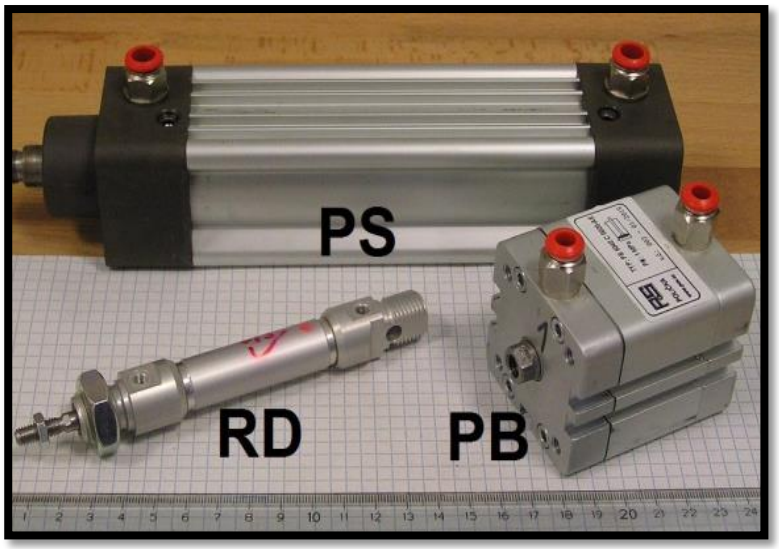
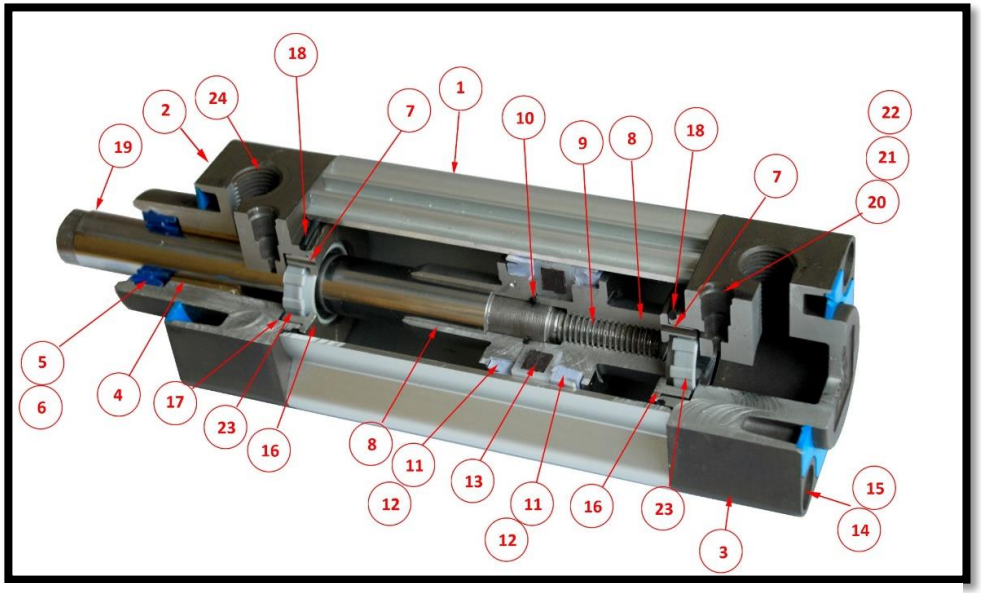
- Introduction
- Leak testing methods (LT)
- Analysis and evaluation of Previous study
- Current state solution of dissertation
- Future work
- Conclusion

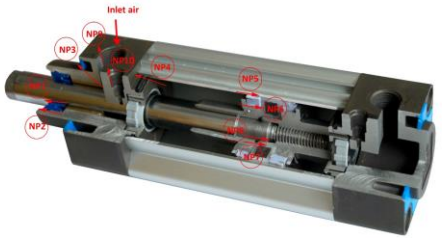
Motivation

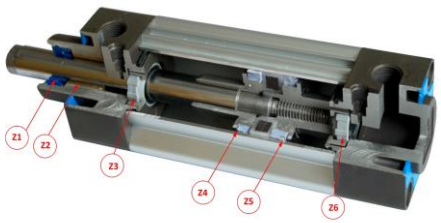
- Improve the quality of pneumatic cylinders.
- Monitoring the function of pneumatic cylinders.
- Finding the relationship between AE signal and defect.
- Determining new appropriated parameters of AE.

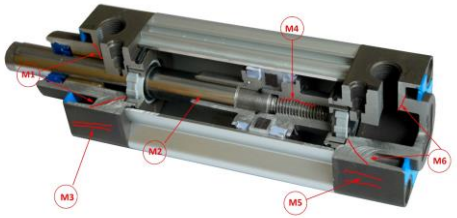


Specification of pneumatic cylinders



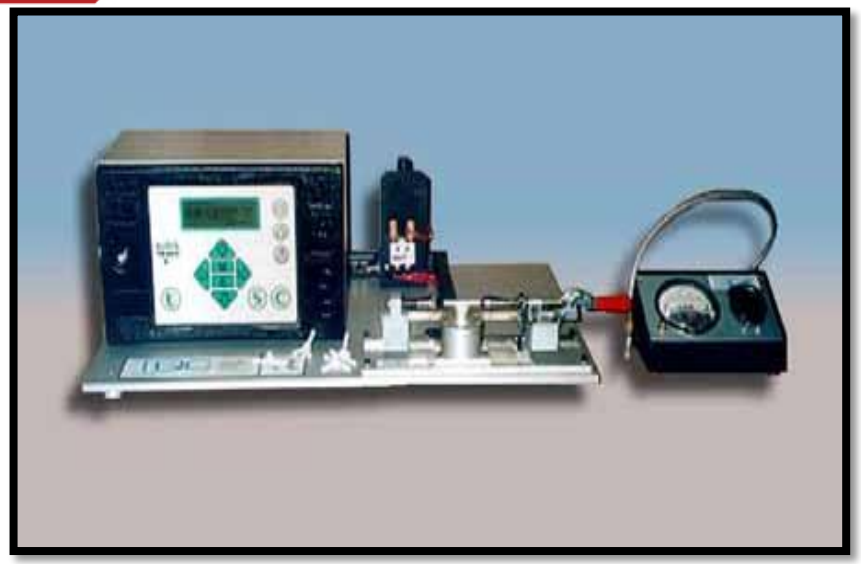




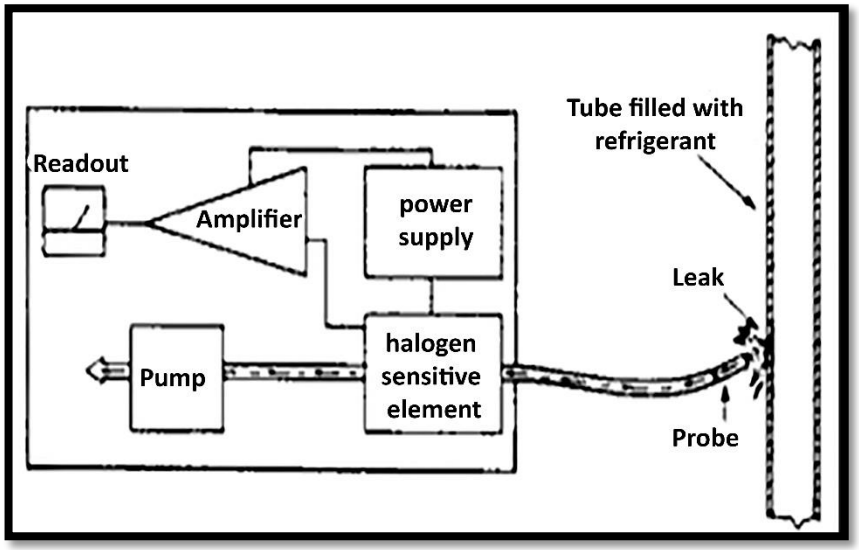


(1) Cylinder body (barrel). (2) Head cap. (3) Rear cap. (4) Rod Bearing. (5) Rod wiper (Wiper Seal). (6) Rod Seal lip-seal. (7) Needle valve. (8) Head and rear Piston. (9) Piston fastener (Tie Rods). (10) O- ring seal piston fastener. (11) Piston seal lip-seal. (12) Piston seal bumper seal. (13)Magnetic ring. (14) Head cap fastener. (15) Rear Cap fastener. (16) Head cap cushion, rear cap cushion. (17) O- Ring seal needle valve. (18) O- Ring seal cap cushion. (19) Piston rod. (20) Throttle needle valve. (21) O- ring seal throttle needle valve. (22) Throttle knop. (23) Cushion check seal. (24) Porting.

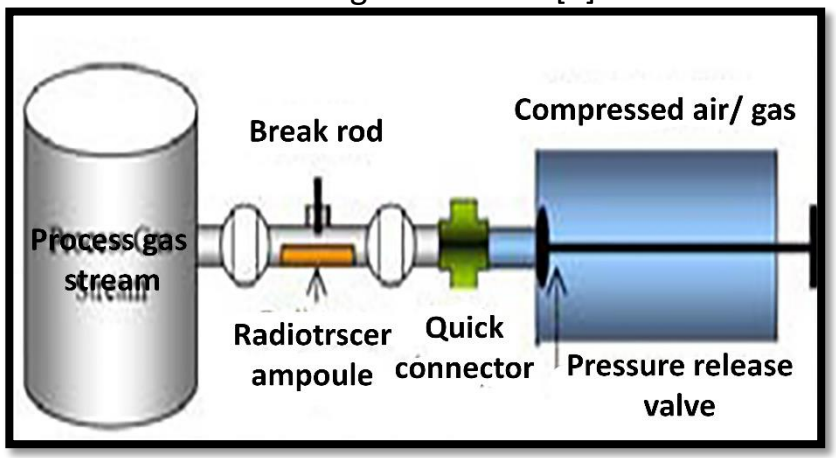
Overview of Leak testing methods (LT)



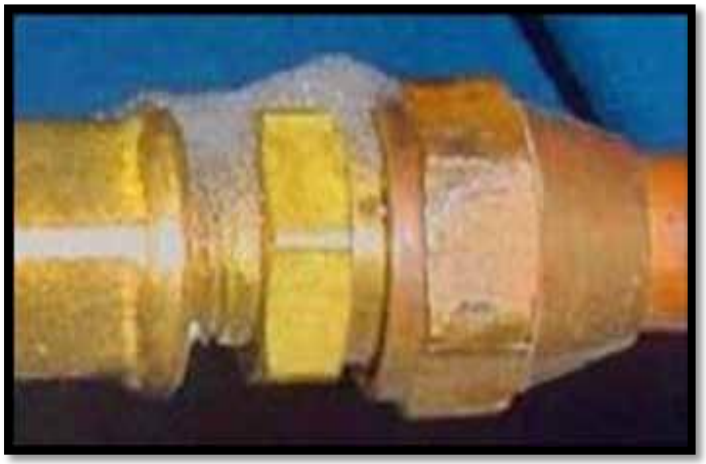
Testing by means of pressure Leak testing small medical tubing connection [1]



Test by detection of halogens [1]



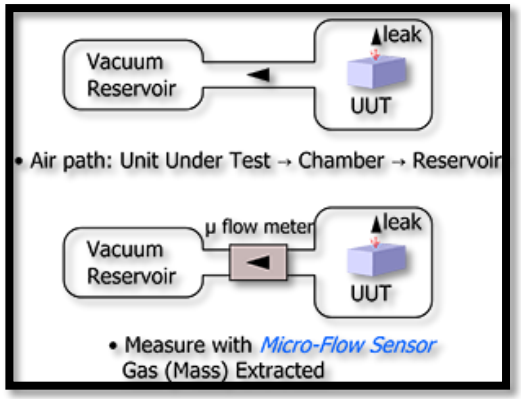
Radioactive tracers Gaseous radiotracer injector [1]



Foam film and bubbles to detect gas [1]

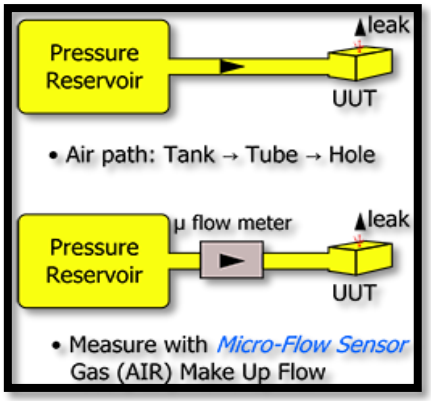
Overview of Leak testing methods (LT)

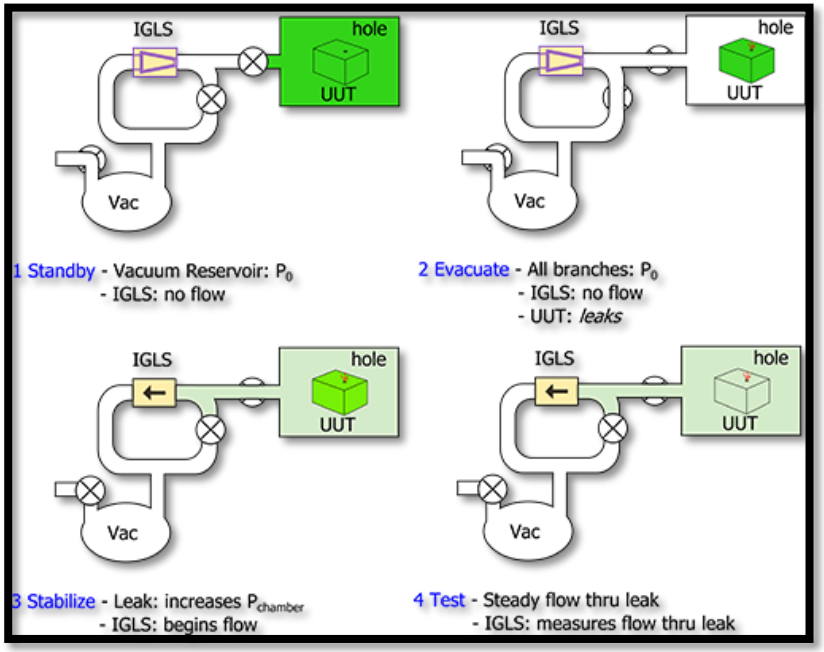
ATC micro-flow sensor to measure the leak, pressure test



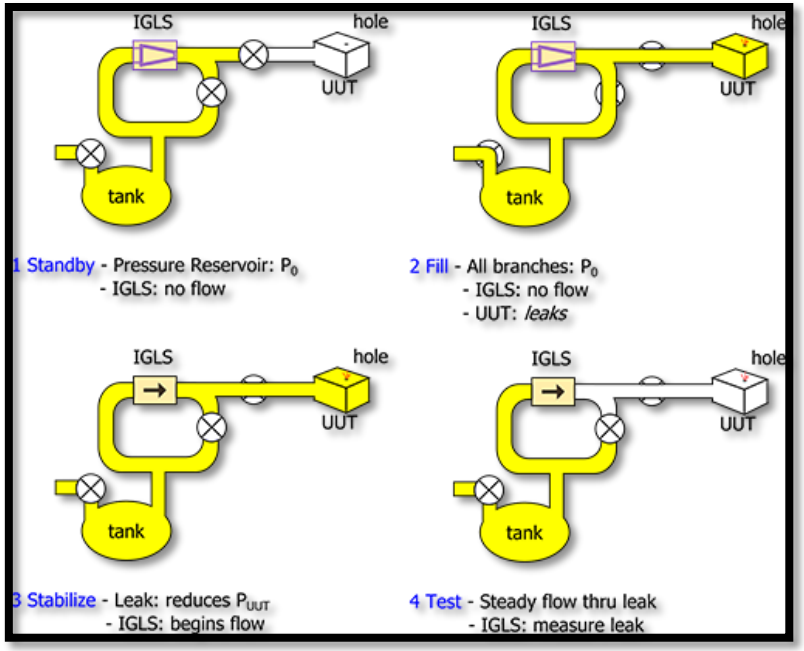
(IGLS), Intelligent Gas Flow Sensor

(ATC), Advanced Test Concepts





Method of operation– vacuum test [2]

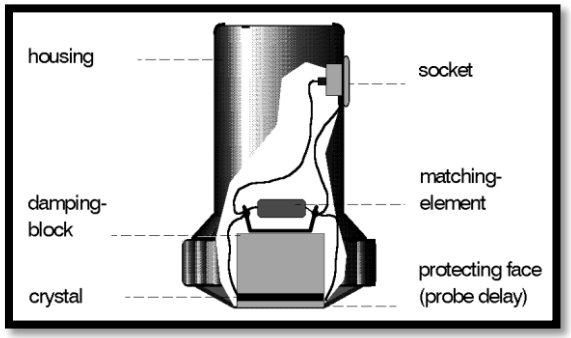


Method of operation– pressure test [2]

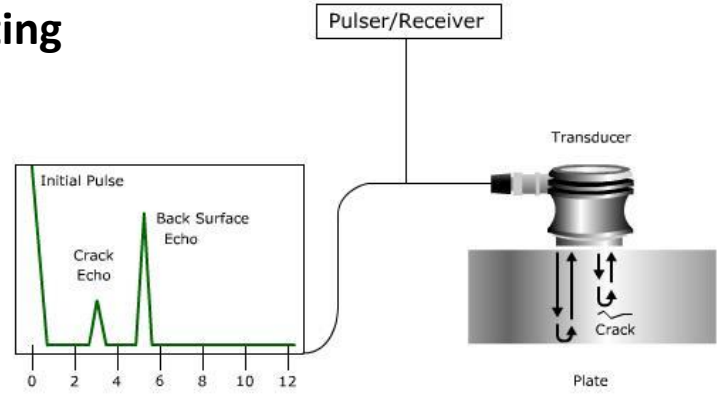
http://atcinc.net/how-it-works/

Overview of Leak testing methods (LT)

Ultrasonic testing



Sensor UT[3]



Ultrasonic Testing (UT) uses high frequency sound energy

http://ultrasonicinfo.blogspot.cz/

Acoustic emission (AE)

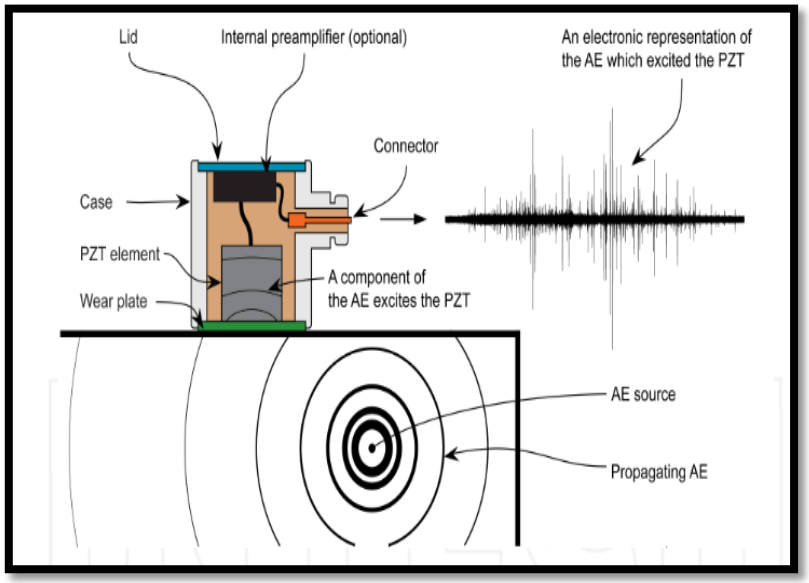
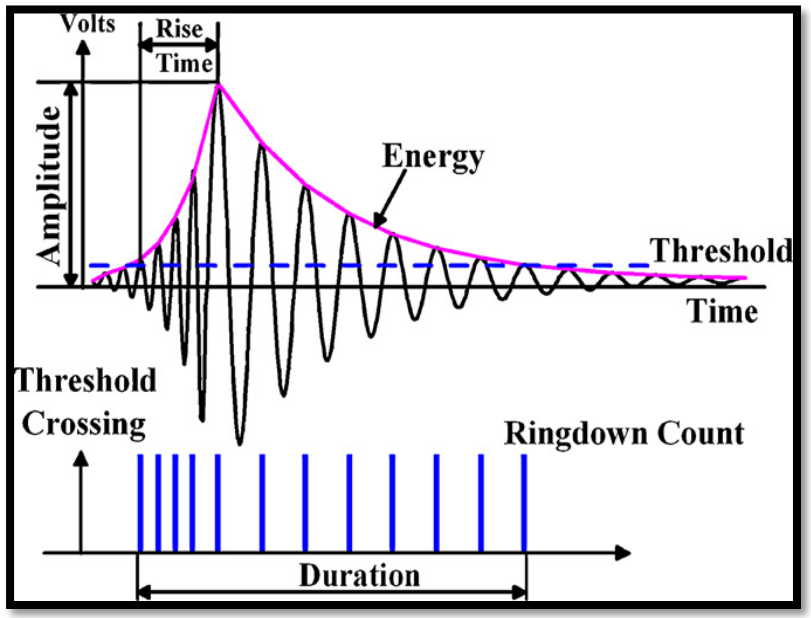


Illustration of a typical resonant piezoelectric AE transducer and how an AE is converted into an electric representation[4]



Method of extracting AE parameters [5]

Previous studies

A study on correlation of AE signals from different AE sensors in valve leakage rate [6]

Watit Kaewwaewnoi, Asa Prateepasen, akorn Kaewtrakulpong 2007

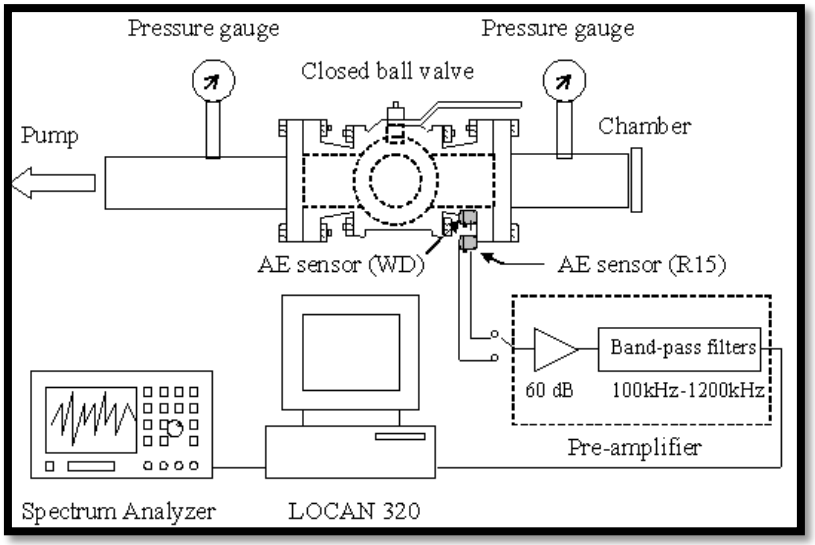
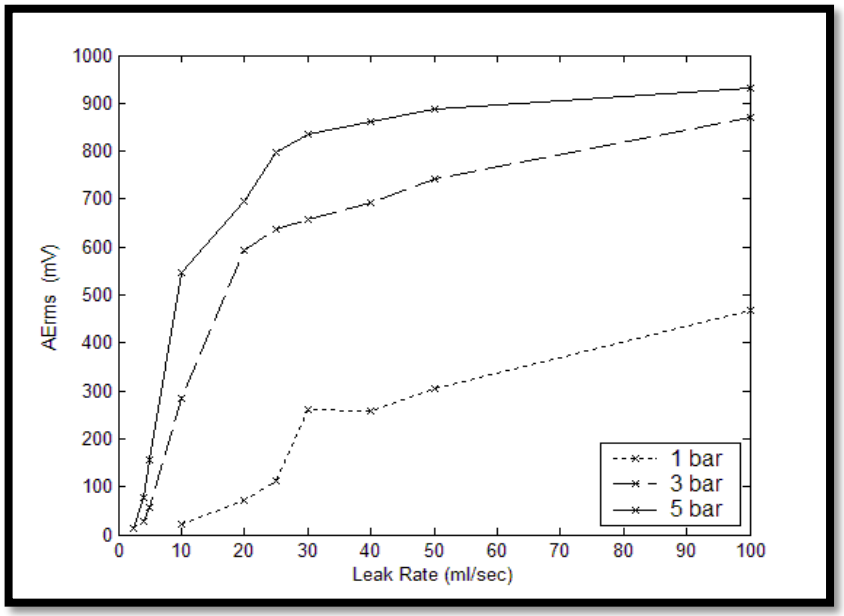
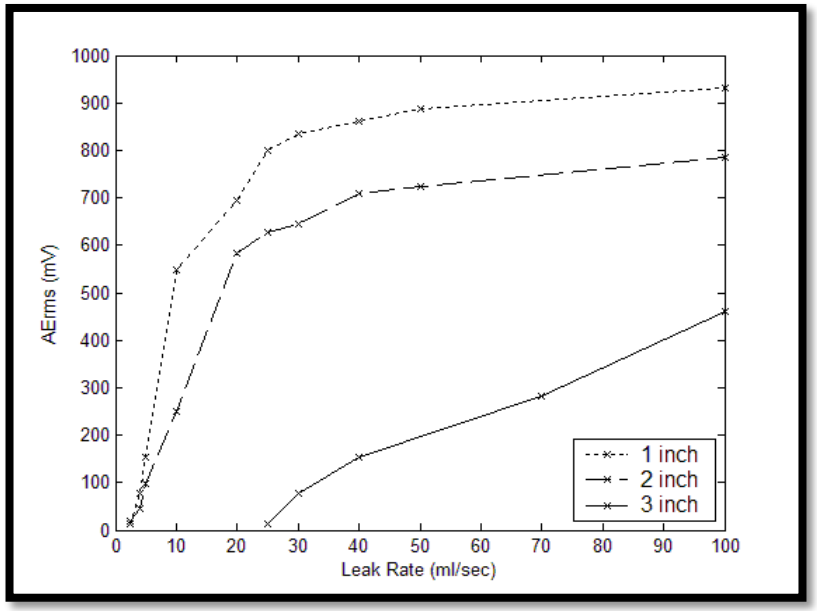


Diagram of experimental set-up



Relationship between AErms and leakage rates of 1 inch ball valve at different pressures.

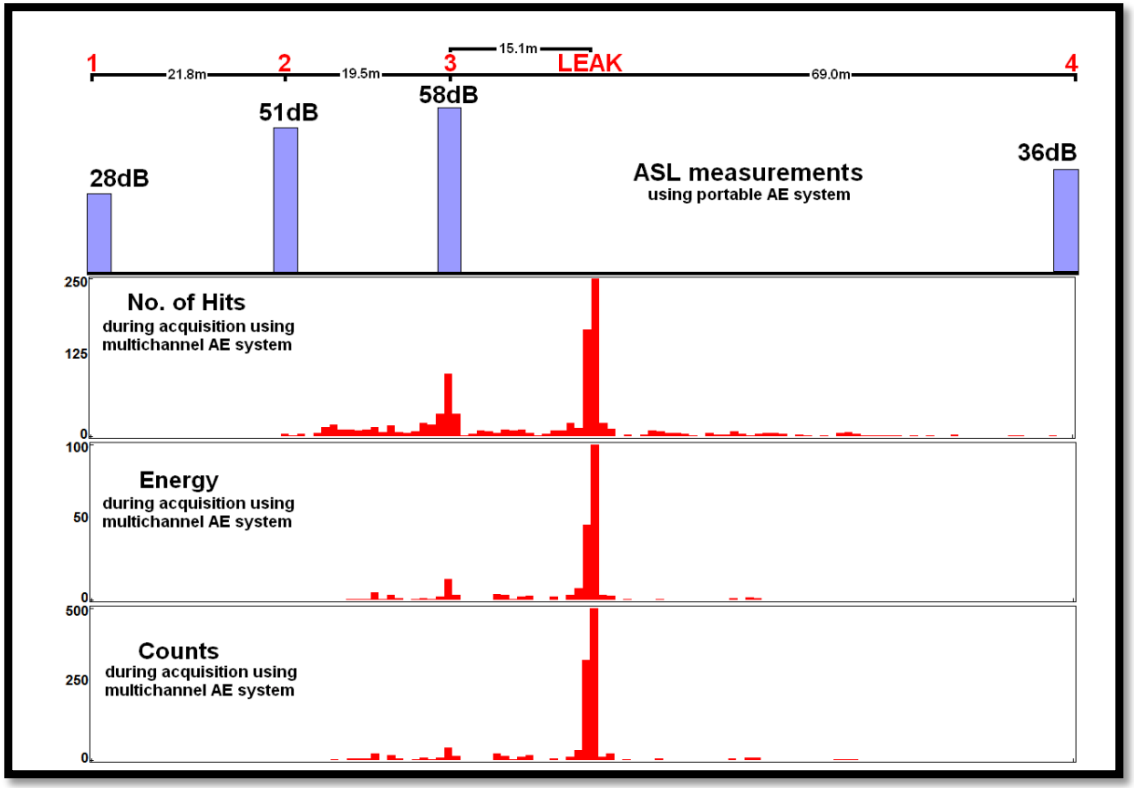


Relationship between AErms and leakage rates of different valve sizes at P = 5 bar

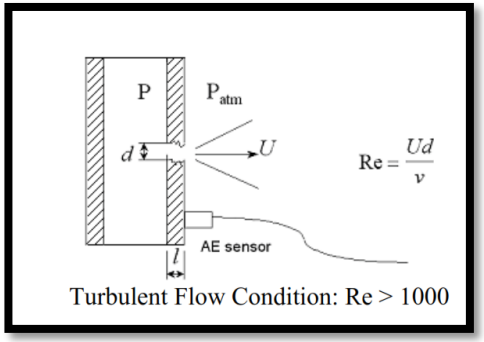
Previous studies

Acoustic emission leak detection of liquid filled buried pipeline [7]

Athanasios anastasopoulos, dimitrios kourousis and konstantinos bollas 2009



ASL vs linear location indicating the leak point



Leaking flow features

U Mean fluid velocity through orifice

d Mean orifice diameter

l Orifice length

v Kinematic viscosity of fluid

P Pressure inside the pipeline

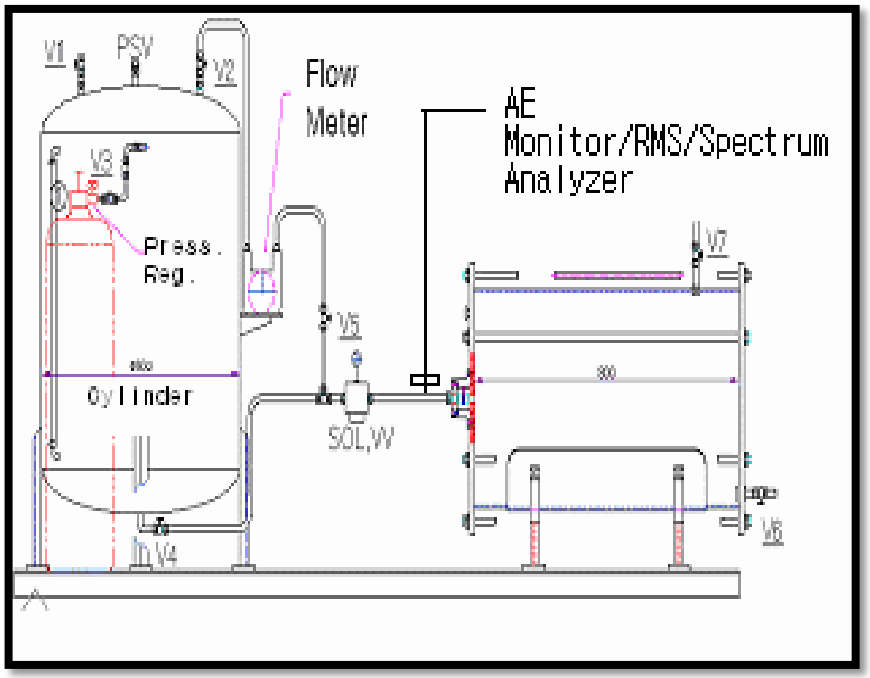
$\mathbf{P_{atm}}$ Atmospheric Pressure

Re Reynolds number

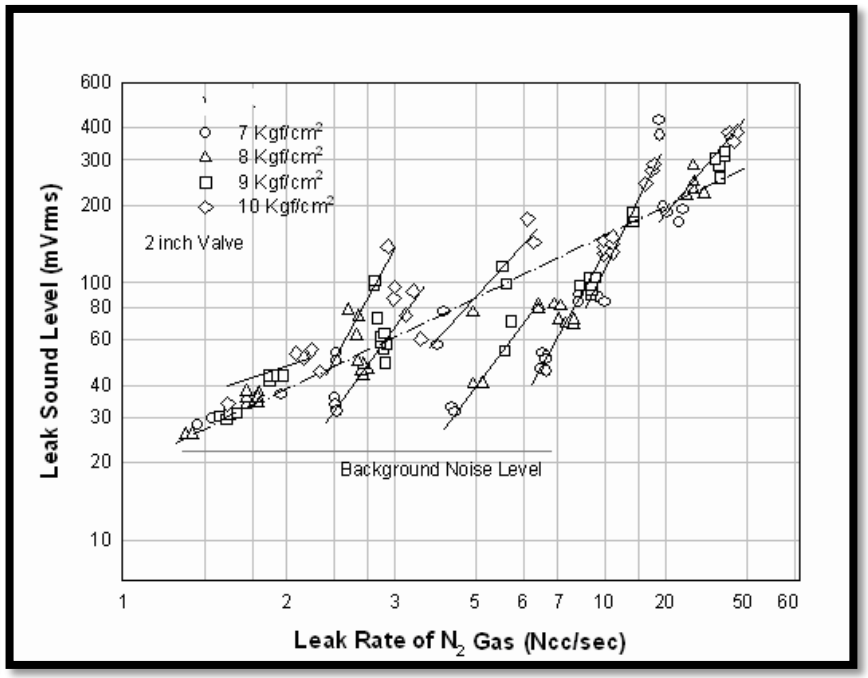
Previous studies

Field Application Study for Leak Detection Using Acoustic Emission Technology [8]

Sang-Guk Lee; Sung-Keun Park; Young-Bum Kim 2007



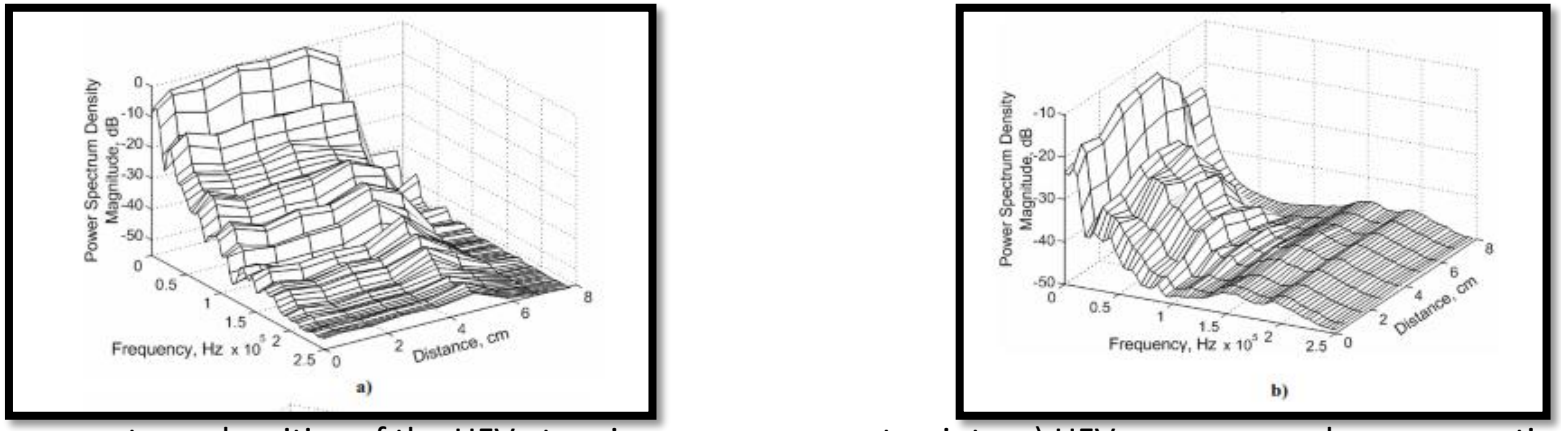
Experimental set-up for leak detection



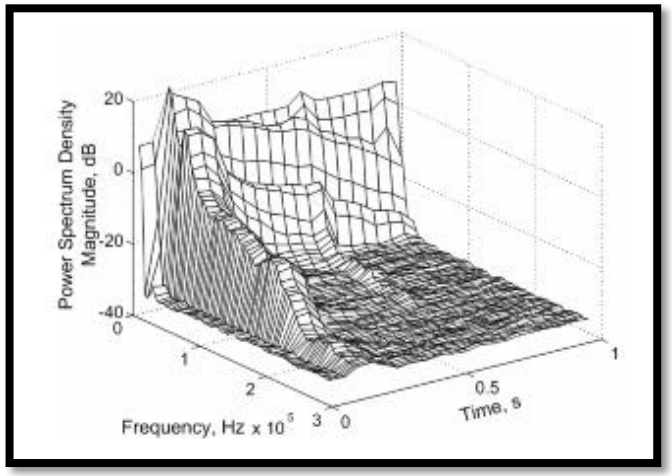
Plot of leak rate vs. acoustic signal amplitude detected by S1 sensor for four different pressure levels

Previous studies

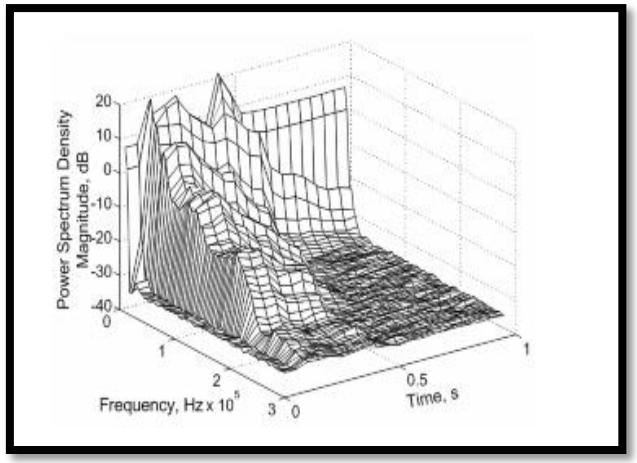
Investigation of high frequency vibrations of pneumatic cylinders [9]
Augutis; Saunoris 2004



Power spectrum densities of the HFV at various measurement points: a) HFV are measured on pneumatic cylinder housing; b) HFV are measured inside pneumatic cylinder



Power spectrum density of the HFV of the new pneumatic cylinder

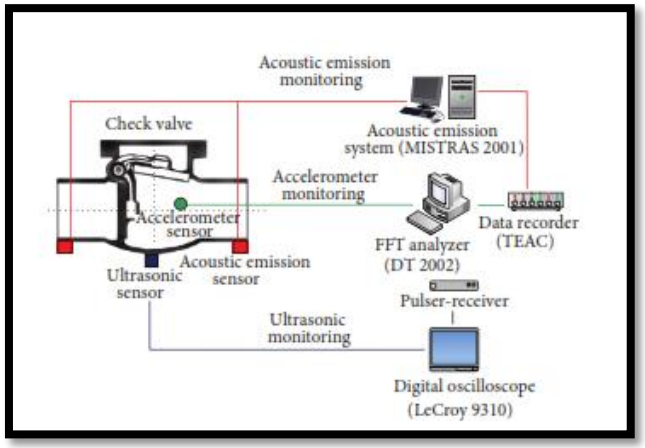


Power spectrum density of the HFV in the worn pneumatic cylinder

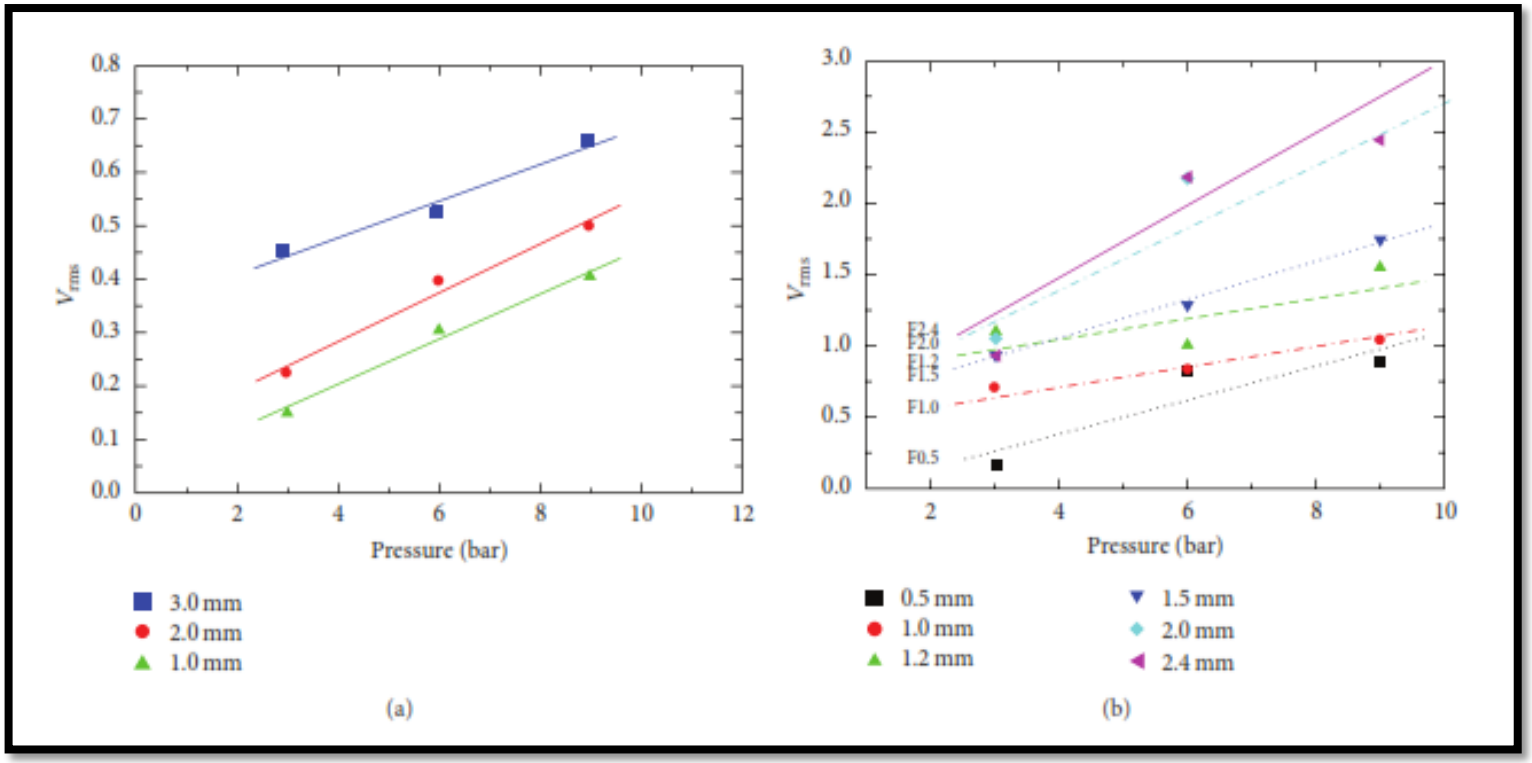
Previous studies

Nondestructive Detection of Valves Using Acoustic Emission Technique [10]

YAN, Jin, Yang HENG-HU, Yang HONG, Zhang FENG, Liu ZHEN, Wang PING a Yang YAN 2015



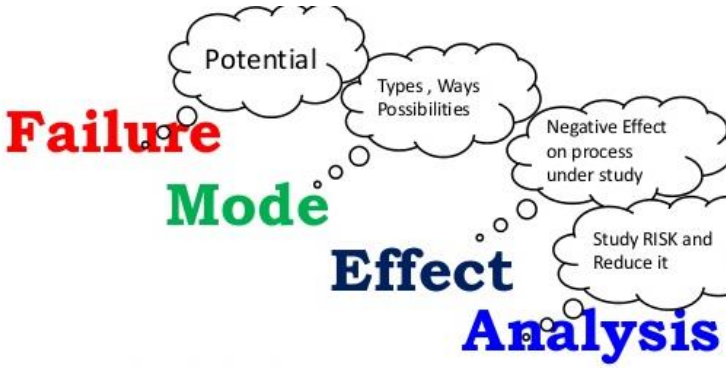
Schematic diagram for condition monitoring test of the check valve



RMS values of the acoustic signals: (a) disk wear and (b) foreign objects

Analysis and evaluation of Previous studies

- The coefficients of Severity , Detection.
- Comparing between Ultrasonic and Acoustic emission.
- AE activities during the leak.
- Typical AE for detect the location.
- The most important parameters signal of AE.



Analysis and evaluation of references

The problems that I have faced in the work (disadvantages)

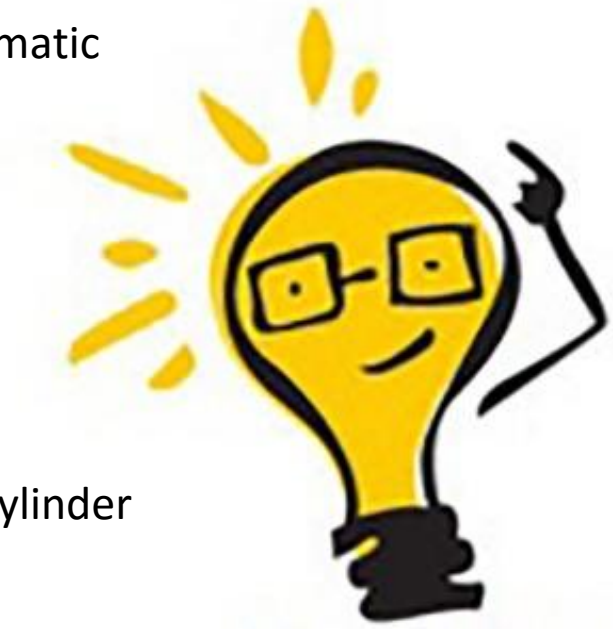
- Signal in the same undamaged cylinders is not the same.
- Sensor fastener and calibration.
- The noise in the signal is mixing signals.
- Friction and lubrication.

Hypotheses

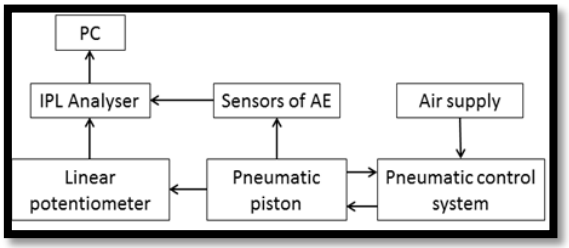
- Changing of signal according to the movement of piston.
- Relation between AE and the leak.
- Allowance of leakage ΔP/t value is 6 Pa/s.

The Objectives of the research

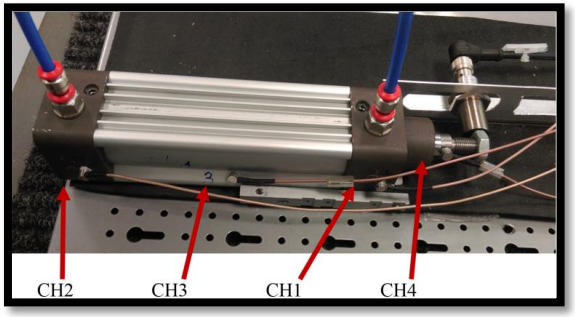
- Comparing between undamaged and damaged pneumatic cylinders.
- Determine the relation between AE and the leakage.
- Determine the quality of cylinders after production.
- Predicting the defect during actual operation of the cylinder online and determining the level of danger.
- Determine the type of defect according to Acoustic emission.



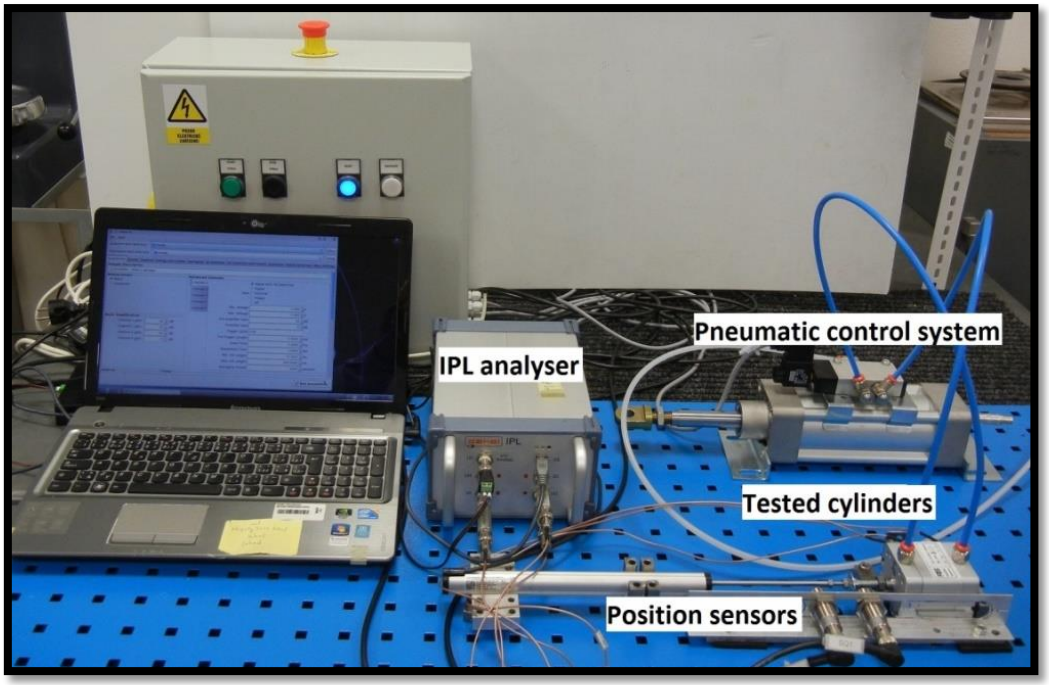
Current state solution dissertation



Schema of the experimental stand for testing of pneumatic cylinders

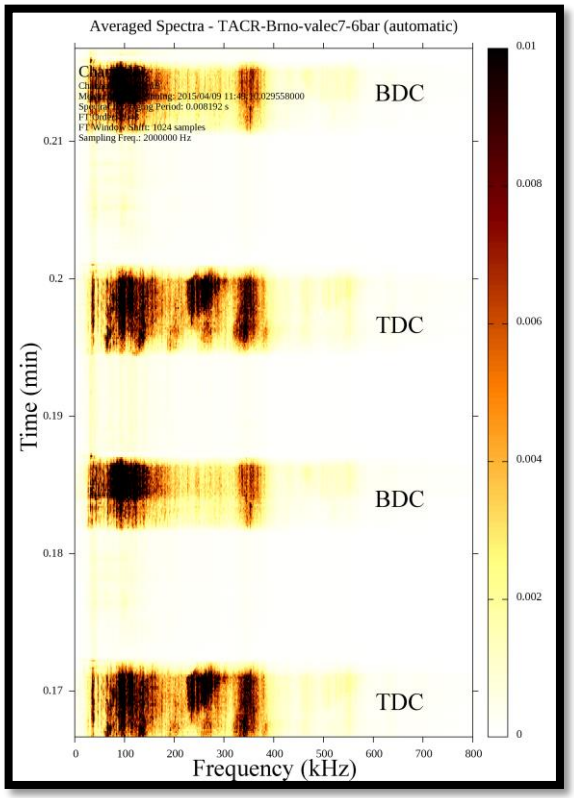


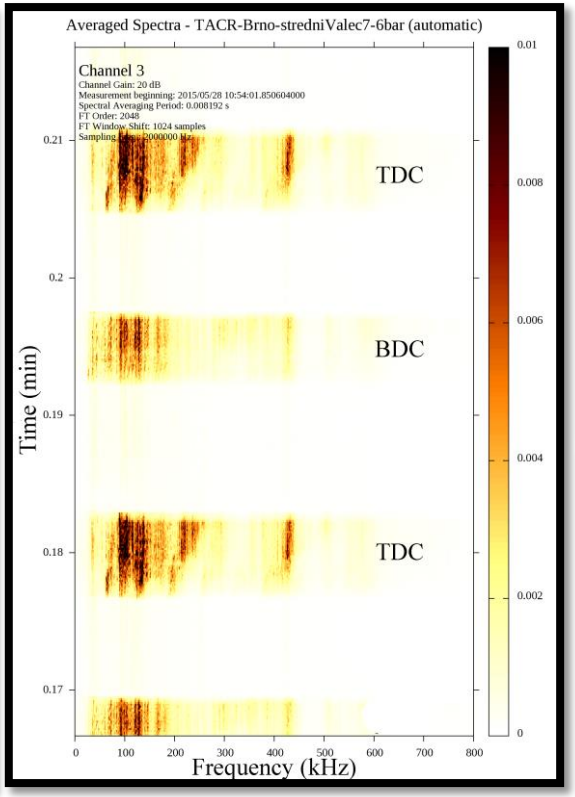
Position of AE sensors on the pneumatic cylinder (PS).

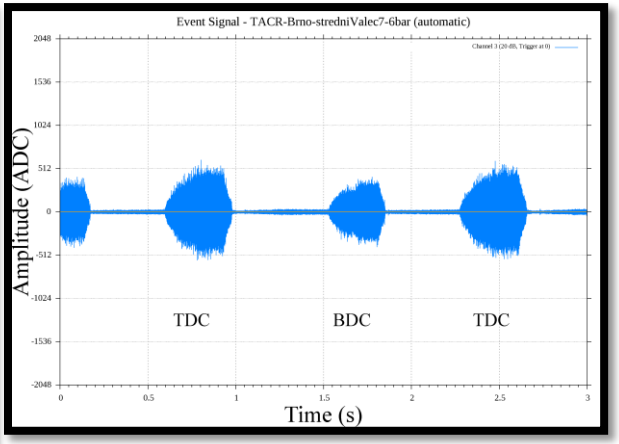


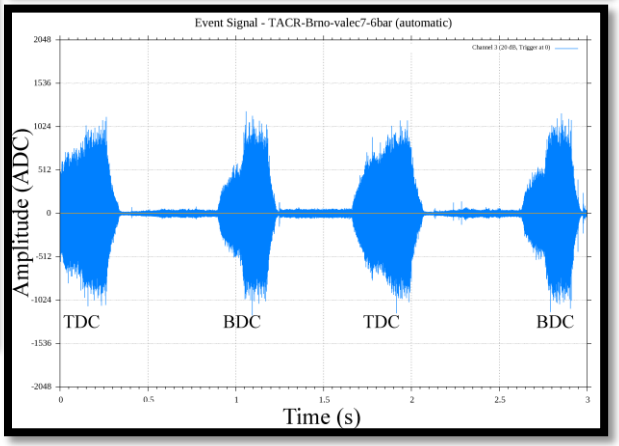
Assembly of experimental equipment

Current state solution of dissertation







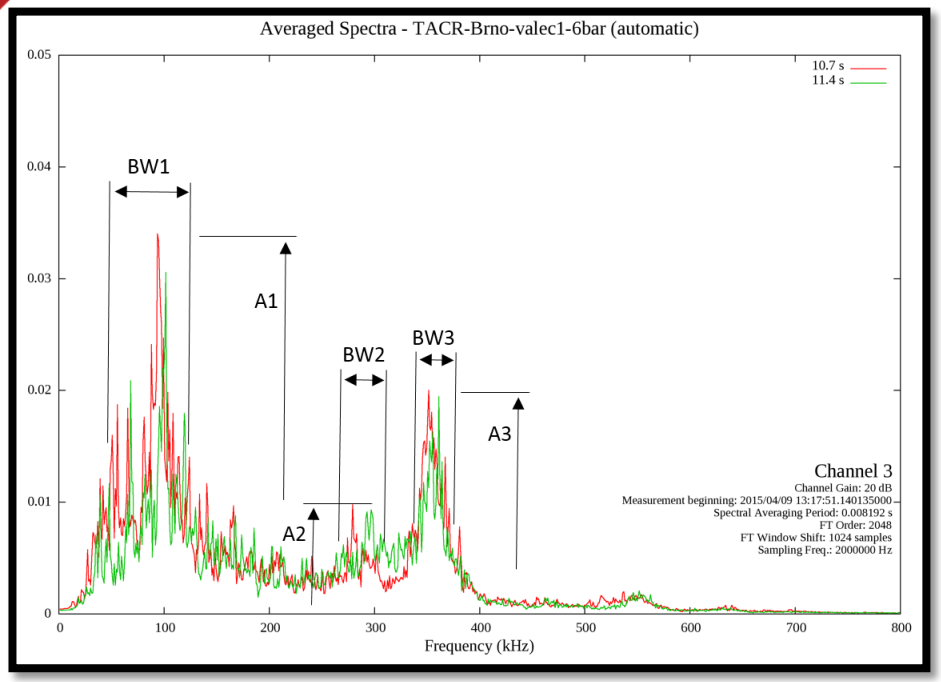


Spectral analysis in particular time - differences between signal spectrums obtained from cylinder without defect (a) and with defect (b).

TDC: when the piston impacts head cap cushion
BDC: when the piston impacts rear cap cushion

Comparison of the waveforms for the undamaged and damaged cylinder “PS” for 3s

Current state solution of dissertation



$$Avg = \frac{dBW_1 + dBW_2 + dBW_3}{3} + 1000 * \frac{dA_1 + dA_2 + dA_3}{3}$$

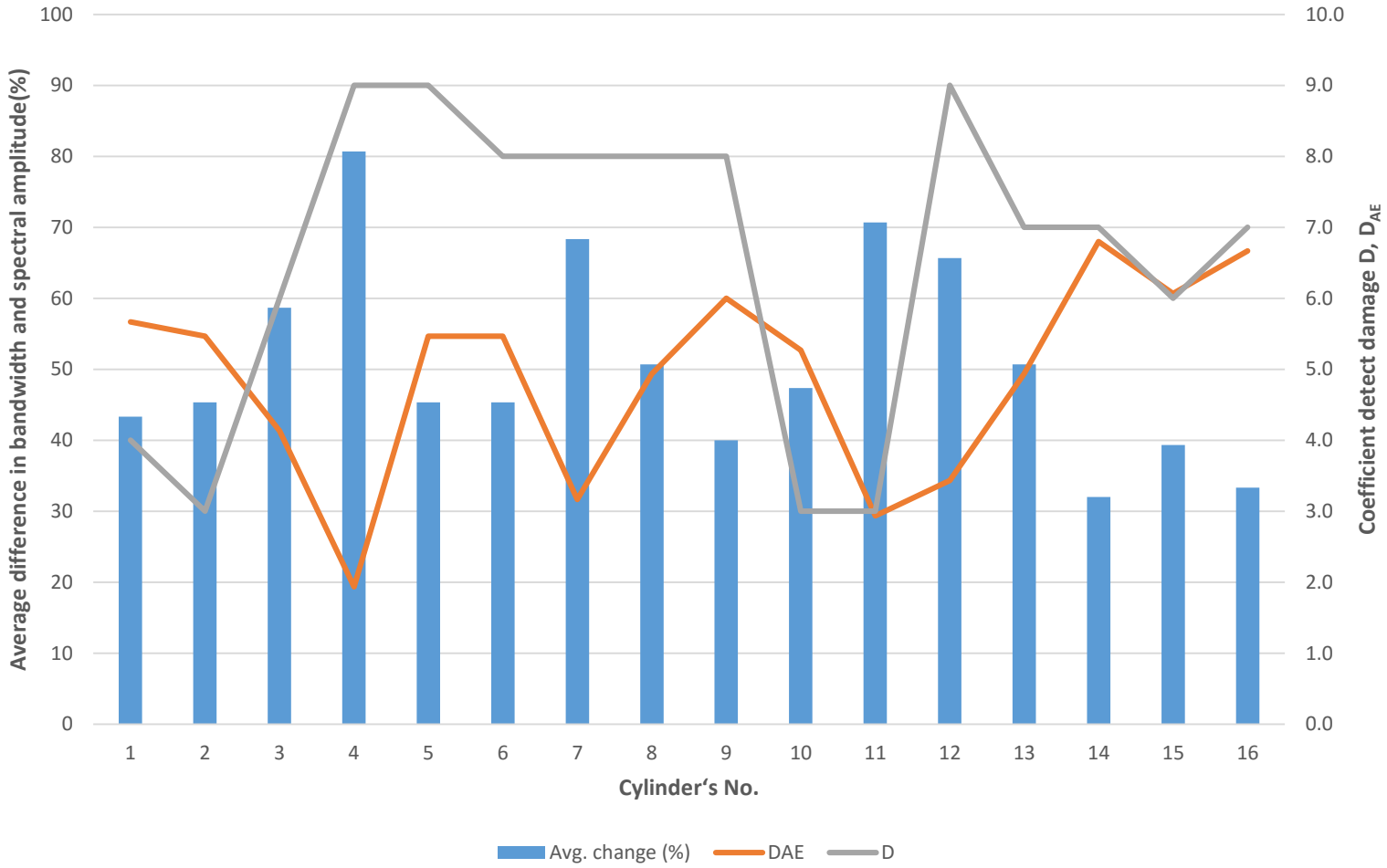
$$D_{AE} = \frac{100 - 2 * Avg}{10}$$

$$maxAvg = 50 \; minAvg = 0$$

Sample determination bandwidth max. Amplitude at undamaged cylinders PS

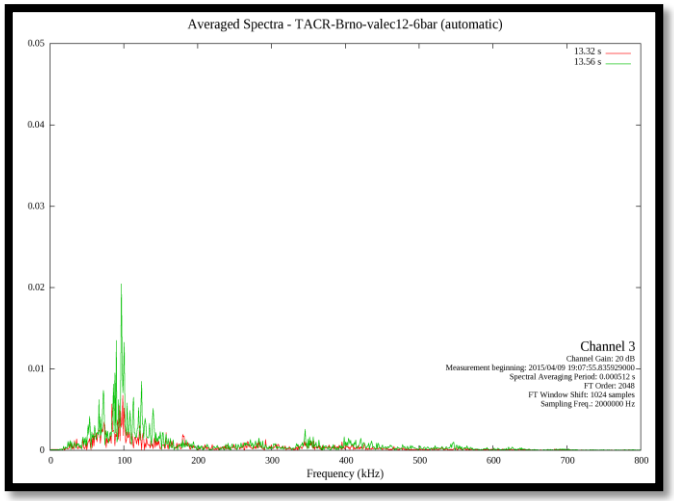
No. Cylinder	Type of defect	Description of the defect	Change BW (%)	Amplitude change (%)	The average change (%)	S1	S2	D	D_{AE}
4	BP 03	Missing O-ring on the piston rod	28	12,3	40,3	3	10	9	1,9
	BP 04					3	10	9	
12	TP 07	Cutting the O-ring on the piston rod	27,6	5,1	32,8	3	10	9	3,4
	TP 08					3	10	9	
14	M 03	Loosening 4 screws under the piston	9,3	6,6	16	3	10	7	6,8

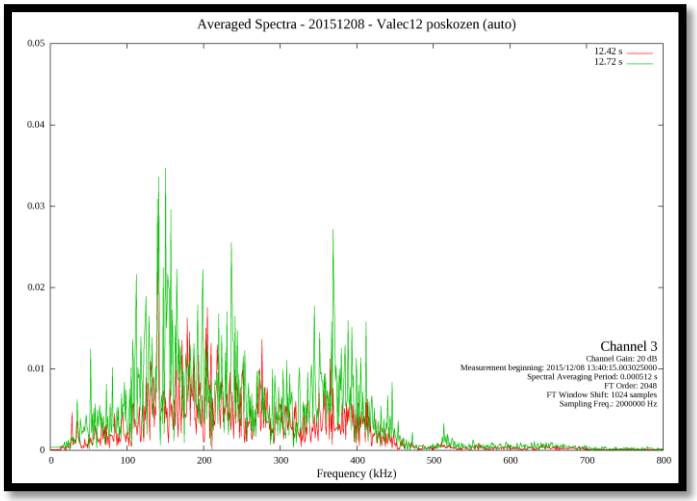
Current state solution of dissertation



Rate of change and revealing comparison of coefficients D, DAE cylinders PS 1-16

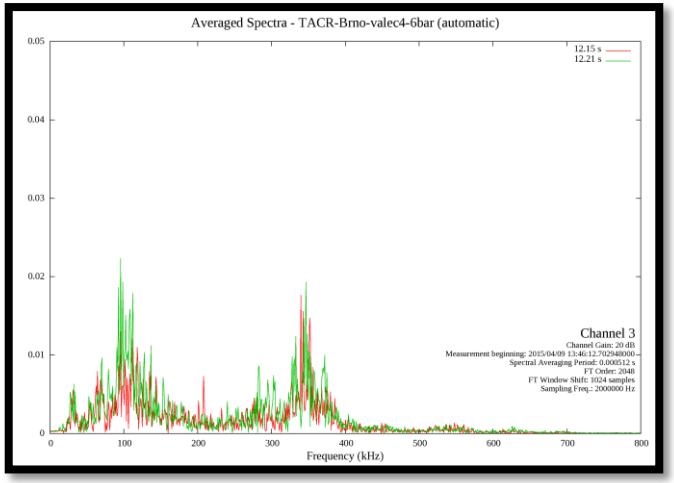
Current state solution of dissertation

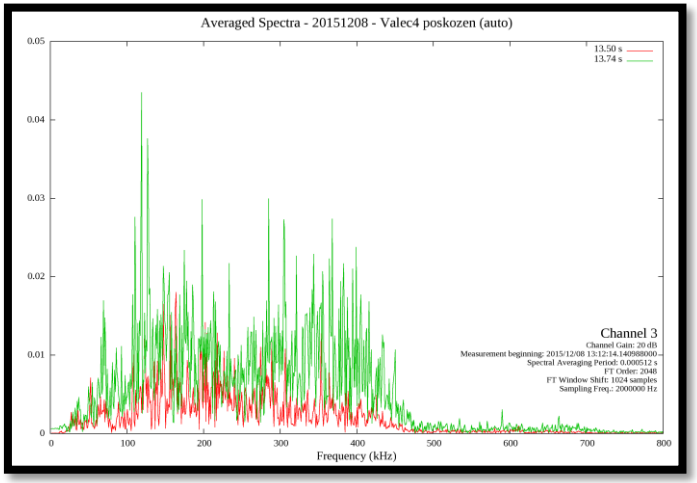




Amplitude

Signal spectrum of cylinder No. 12





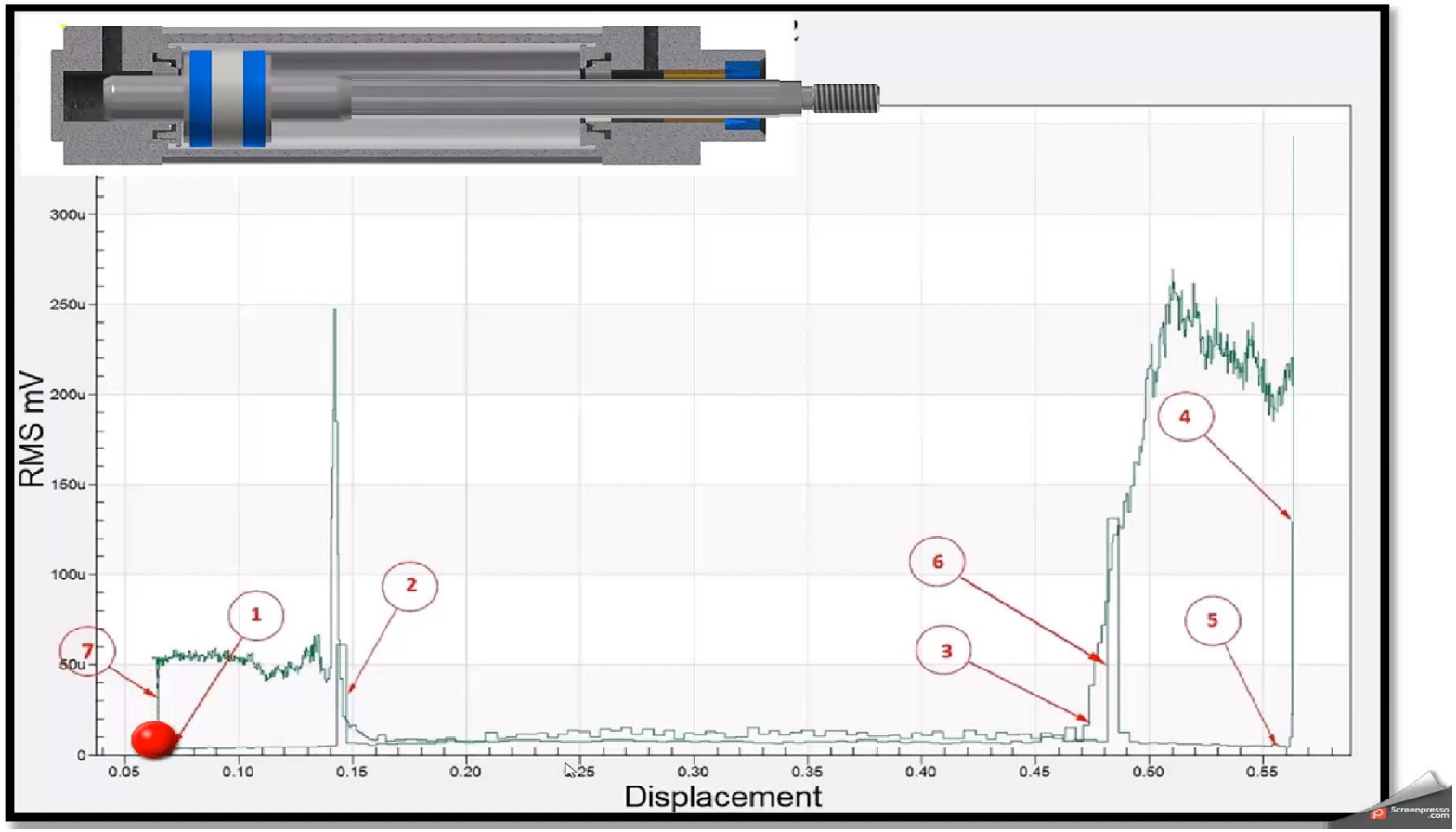
Amplitude

Signal spectrum of cylinder No. 4

(a) Intact cylinder

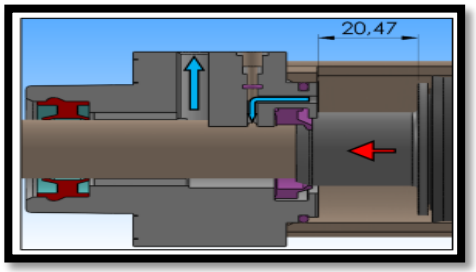
(b) Damaged cylinder

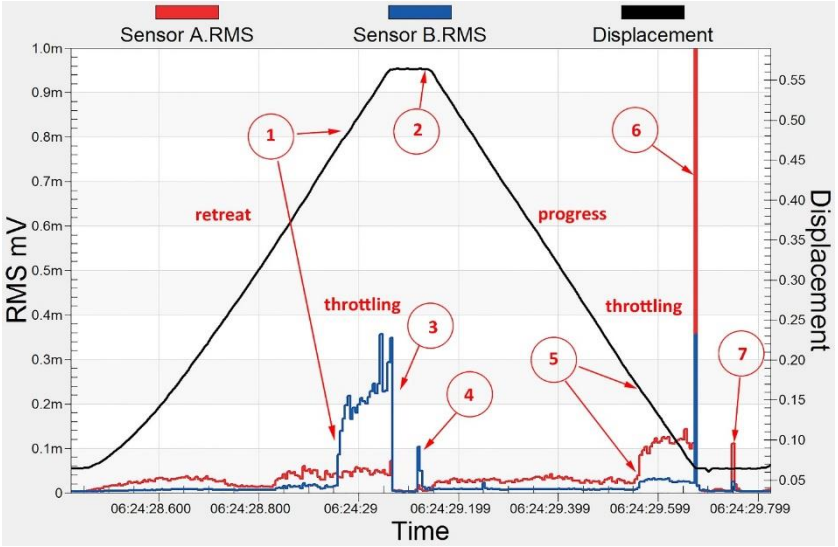
Current state solution of dissertation



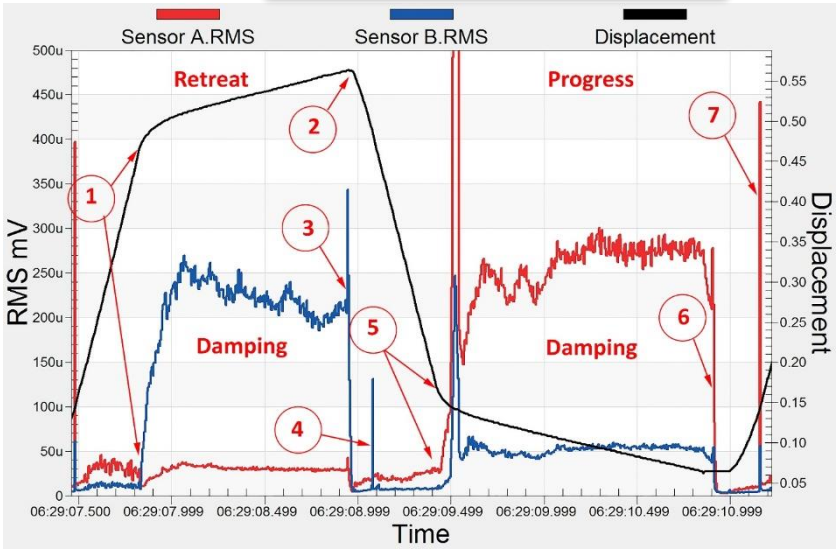
(1). Initiation of progress stroke, (2). When the piston leave the throttling zone in progress stroke, (3). Initiation of throttling (damping) in progress stroke, (4). End of throttling in progress stroke, (5). Initiation of retreat stroke, (6). When the piston leave the throttling zone in retreat stroke, (7). End of throttling in retreat stroke.

Current state solution of dissertation





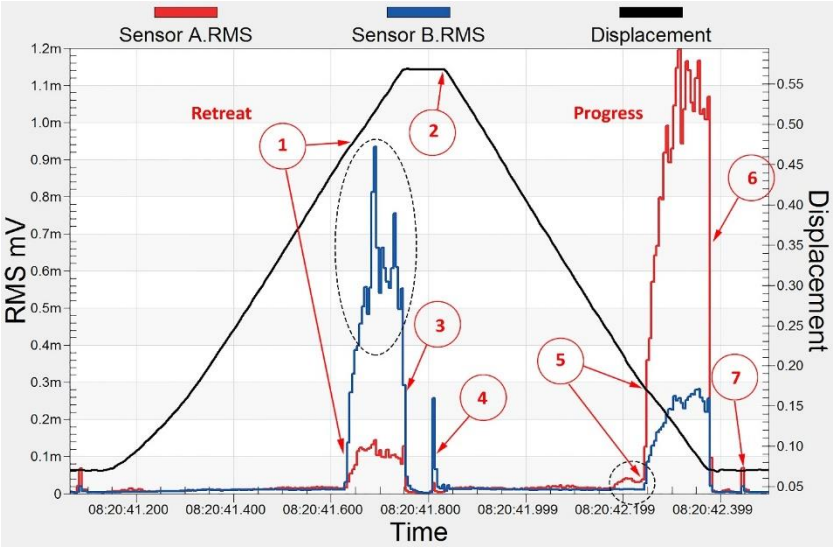
Undamaged cylinder No.2 after 101500 cycles without damping



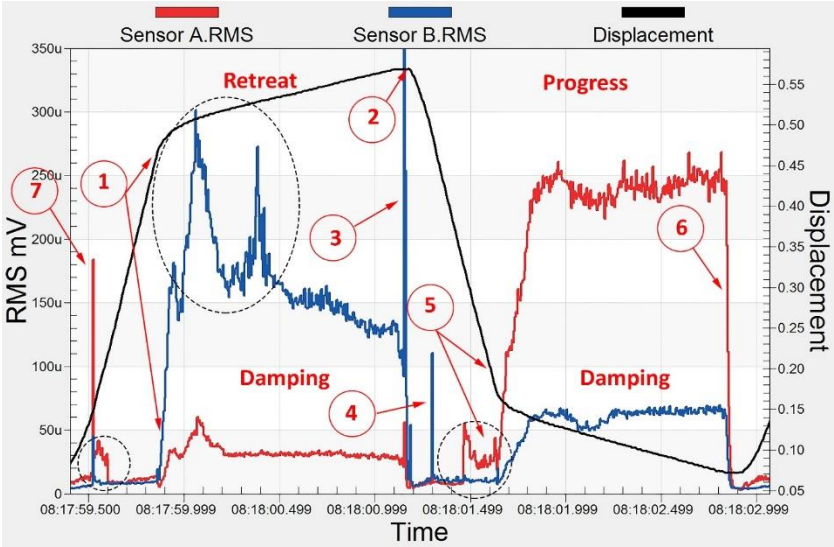
Undamaged cylinder No.2 after 101500 cycles with damping

(1). Initiation of throttling (damping) in retreat stroke, (2). Stop time and return to progress stroke, (3). End of retreat stroke, (4). End of throttling in progress stroke, (5). Initiation of throttling (damping) in progress stroke, (6). End of progress stroke, (7). End of throttling in retreat stroke.

Current state solution of dissertation



Damaged cylinder No.8 after 51100 cycles without damping

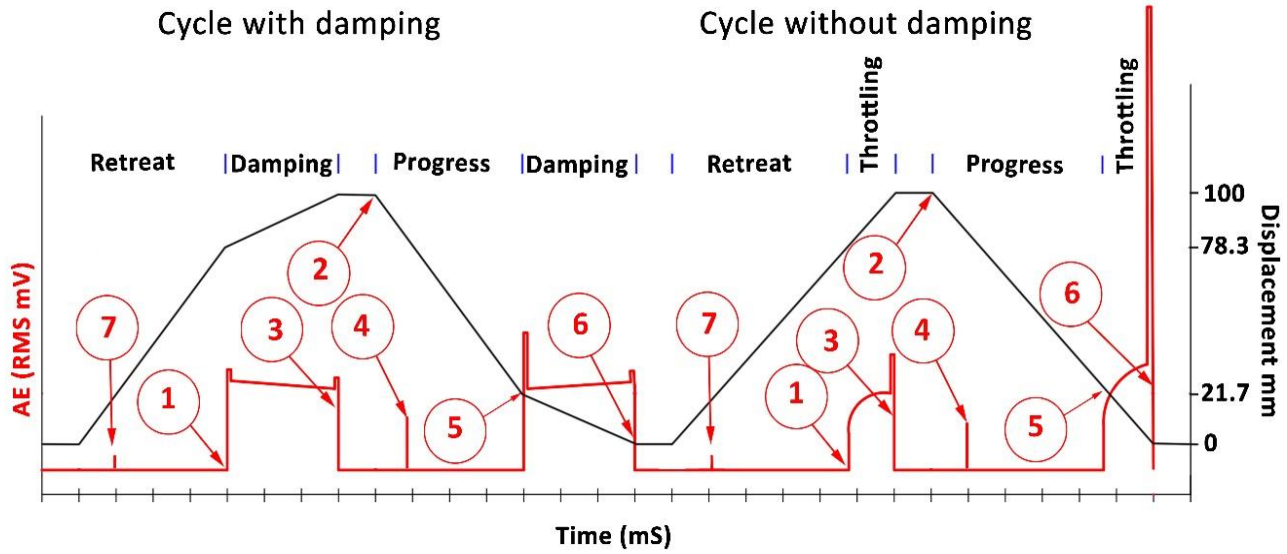


Damaged cylinder No.8 after 51100 cycles with damping

(1). Initiation of throttling (damping) in retreat stroke, (2). Stop time and return to progress stroke, (3). End of retreat stroke, (4). End of throttling in progress stroke, (5). Initiation of throttling (damping) in progress stroke, (6). End of progress stroke, (7). End of throttling in retreat stroke.

Solution suggestion and future work

Simulation of movement and treatment the signal

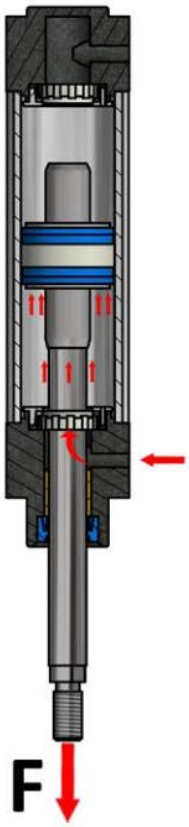


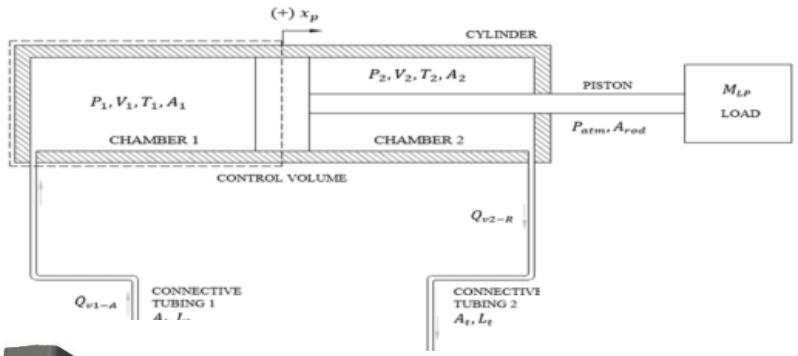
Kinematic scheme of intact cylinder shows us the progress and retreat stroke and response of AErms to this movement.

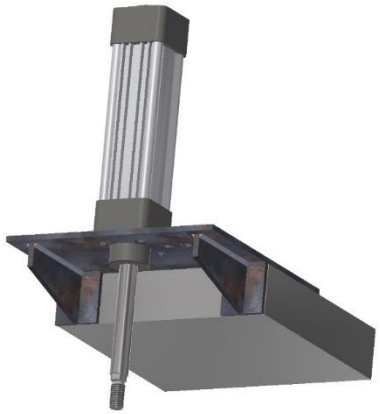
(1). Initiation of throttling (damping) in retreat stroke, (2). Stop time and return to progress stroke, (3). End of retreat stroke, (4). End of throttling in progress stroke, (5). Initiation of throttling (damping) in progress stroke, (6). End of progress stroke, (7). End of throttling in retreat stroke.

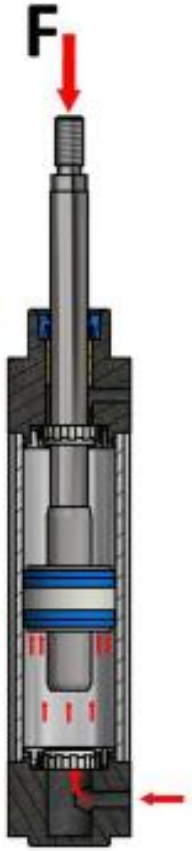
Solution suggestion and future work

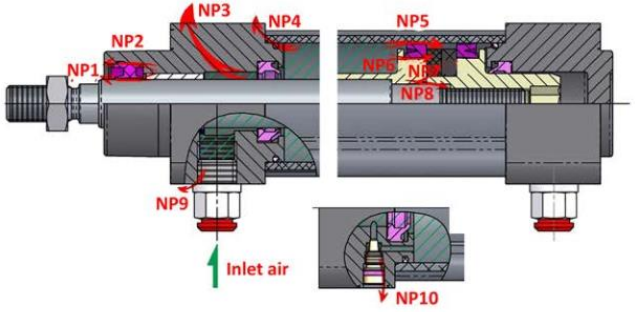
Loads on cylinder.

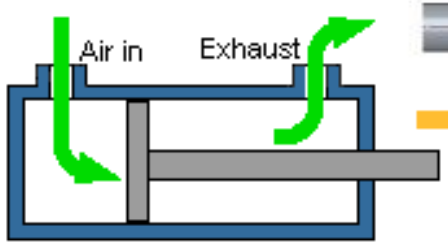


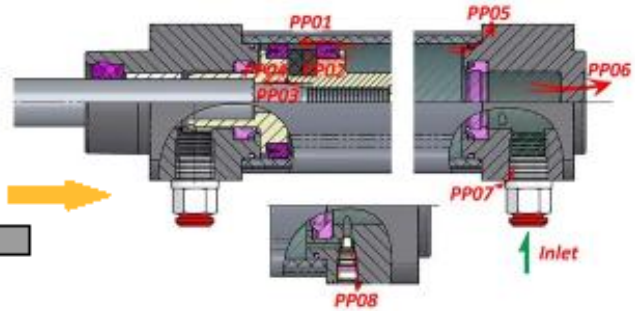






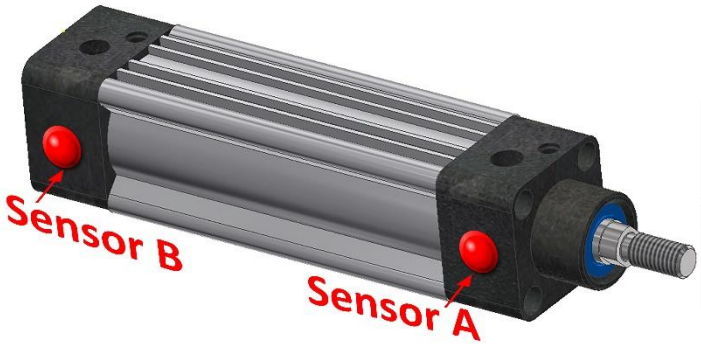


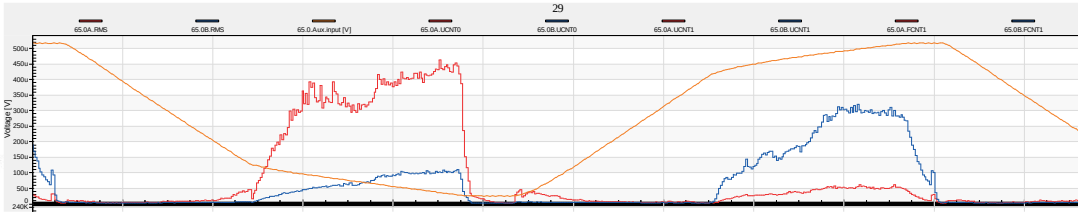


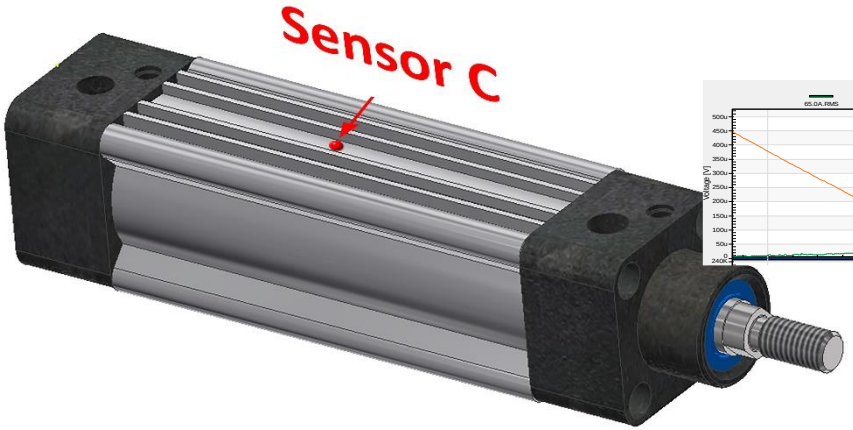


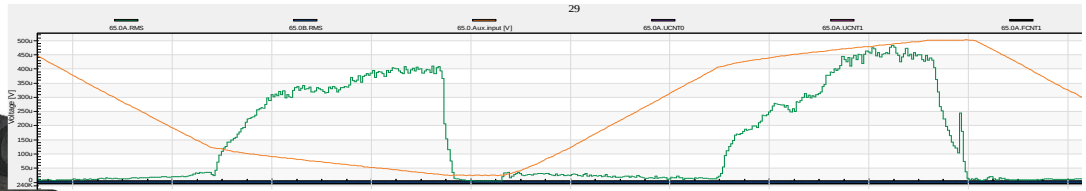
Sensor fastener and calibration

Sensor fastener and calibration









Conclusion

- Current results show good reliability, repeatability and conformity signal of AE.
- Coefficient detection DAE is lower than D.
- Most serious defects of cylinders are those that have a large degree of severity S2.
- Average energy of acoustic emission signal RMS is one of the most important parameters.
- Frequency spectrum analysis is inappropriate parameter which used in pneumatic cylinder.

Author or co-author of publications from the area of Ph.D

1. Pavel MAZAL, Houssam MAHMOUD, Miroslav JÁNA, Vladimír BUKÁČEK, František VLAŠIC: Use of Acoustic Emission Method to Identify Damage of Pneumatic Cylinders, In NDE for Safety / Defektoskopie 2015, Brno 2015, p 81 - 90, ISBN978-80-214-5280-0.
2. Pavel MAZAL, Frantisek VLASIC, Houssam MAHMOUD, Miroslav JANA: The Use of Acoustic Emission Method for Diagnosis of Damage of Pneumatic Valves, In XIXth World Conference on NDT, Munchen, Germany 2016, ISBN 978-3-940283-78-8, USB edition, 10 pages.
3. Pavel MAZAL, František VLAŠIC, Houssam MAHMOUD Možnosti hodnocení pneumatických prvků metodou akustické emise, Defektoskopia 2016, Vysoké Tatry, Slovakia, 26.-28.4.2016, prezentace.
4. Houssam MAHMOUD, Frantisek VLASIC, Pavel MAZAL: Simulation of Operational Loading of Pressure Equipment by Means of Non-Destructive Testing. In Metal 2015, Brno 2015.
5. Houssam MAHMOUD, Pavel MAZAL, Miroslav JANA, Frantisek VLASIC: Damage Identification of Pneumatic Components by Acoustic Emission. In European Conference on AE Testing (EWGAE 2016), Prague, Sept. 2016.
6. Pavel MAZAL[1], Houssam MAHMOUD[1], Petr DOSTAL[2], Michal CERNÝ[2], Michal SUSTR[2], Jaroslav ZACAL[2]: Cooperation Of Mendel University And Brno University Of Technology In The Field Of Biological Applications Of Ae Method. . In European Conference on AE Testing (EWGAE 2016), Prague, Sept. 2016.
7. Houssam MAHMOUD[1], Frantisek VLASIC[2], Pavel MAZAL[1], Miroslav JANA[3]: Leakage Analysis of Pneumatic Cylinders Using Acoustic Emission. Insight journal it will be published.
8. Houssam MAHMOUD, Frantisek VLASIC, Pavel MAZAL, Miroslav JANA: Application of Acoustic Emission Method to Diagnose Damage in Pneumatic Cylinders. Conference in London WCCM17, It will be published
9. Houssam Mahmoud, Pavel Mazal, Frantisek Vlasic, Miroslav Jana : Condition Monitoring Of Pneumatic Cylinders By Acoustic Emission. ICNDT2017 in Slovenia. It will be published.

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http://www.ndt.net/article/v05n09/berke/berke2.htm

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http://www.ecti-thailand.org/assets/papers/195_pub_16.pdf

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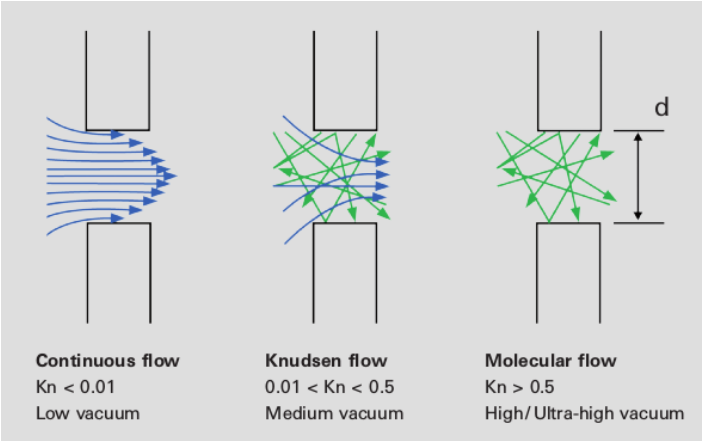
http://www.hindawi.com/journals/amse/2015/749371/

Answers of the questions

Question 1

v kap. 6.2, str. 20 se říká, že podmínka pro detekci v potrubí uloženém v zemi je Reynoldsovo číslo > 1000, aby bylo zajištěno turbulentní proudění. Je toto číslo skutečně hodnota zaručující turbulentní proudění? Re číslo se určuje nejenom rychlostí proudění, ale zejména charakteristickým rozměrem. Jaký by byl v případě úniku tekutiny z potrubí charakteristický rozměr? A dá se u pneumatických válců také použít korelace s turbulentním prouděním?



Profiles of the various types of flow regimes

https://www.pfeiffer-vacuum.com/en/know-how/introduction-to-vacuum-technology/fundamentals/types-of-flow/

Answer 1

When the leak occurs, the turbulence is caused by the flow of a pressurized fluid, that produces energy waves of frequencies. When the flowing of gas is enough to make stress waves, reaching the surface, the wave can be measured. The range of frequencies is (50-400 KHz) to obtain the signal of acoustic emission.

In the article they have made an artificial orifice to obtain the signal and according to this signal they determine the value of Reynold‘s number.

In our research we cannot determine the geometry of leak, we cannot use Reynold‘s number.

Answers of the questions

Question 2

Kap. 7. Analysis… , str. 25, bod ad) 11: Píšete, že metoda AE má výhodu v tom, že snadno detekuje místo netěsnosti. Kde všude u válců lze očekávat netěsnost, a jak v provozu zjistím, které to je právě místo? To budu muset každý válec osadit několika sensory podobně jako v laboratoři? To by asi bylo dost drahé?

Answer 2

In our task we determine the leak in the cylinder if it is exist or not, so it is possible to determine the location of leak in the cylinder, using 2 sensor.

In practice the tube of gas or liquid, pressure vessel, the signal is burst or discrete so it is easy to determine positions.
For 100 m tube of flowing gas from metal 2 sensors are sufficient.

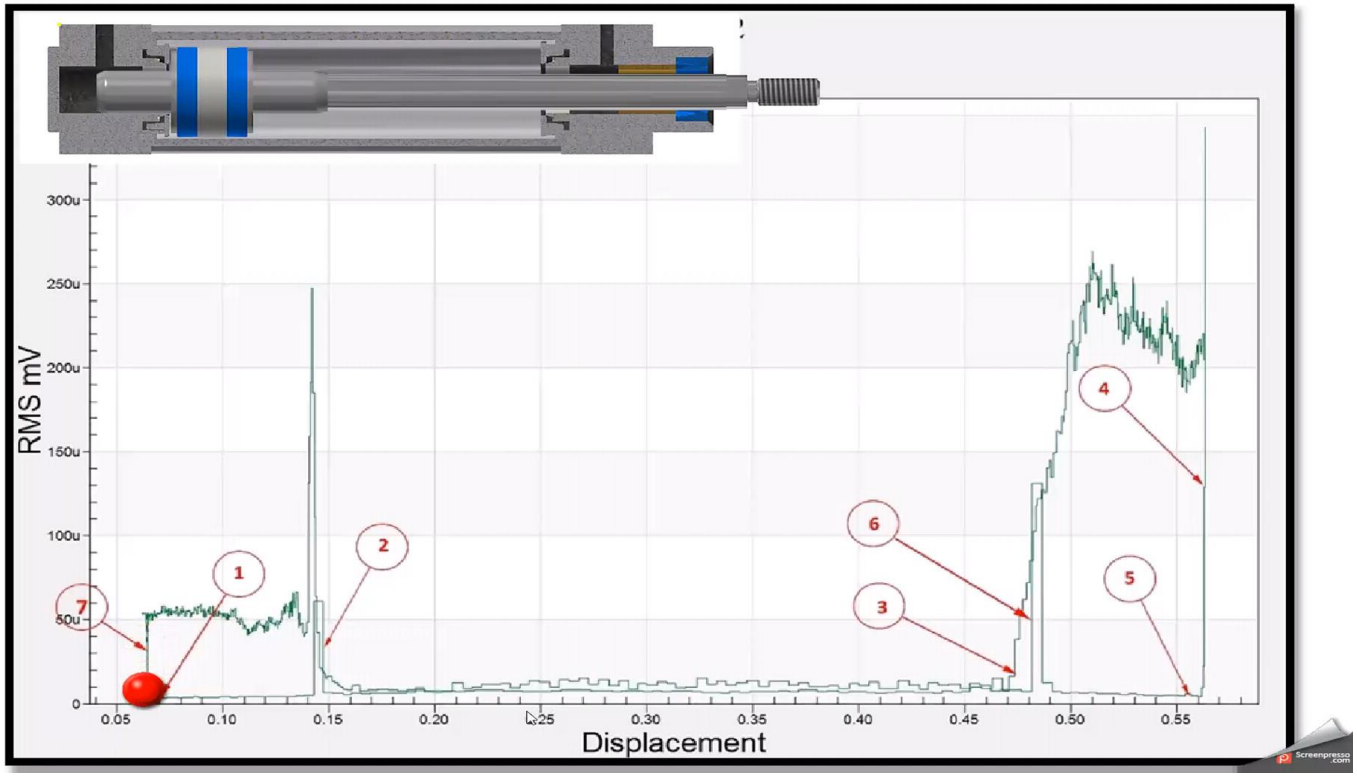
A portable apparatus will made to measure online the leaks, if it acceptable or not. and the inappropriate cylinder will be taken to another apparatus to detect the type of defects and its locations

Answers of the questions

Question 3

První větě hypotézy, str. 26, nerozumím. Pokuste se mi ji vysvětlit při obhajobě.

Answer 3



(1). Initiation of progress stroke, (2). When the piston leave the throttling zone in progress stroke, (3). Initiation of throttling (damping) in progress stroke, (4). End of throttling in progress stroke, (5). Initiation of retreat stroke, (6). When the piston leave the throttling zone in retreat stroke, (7). End of throttling in retreat stroke.

Answers of the questions

Question 4-5

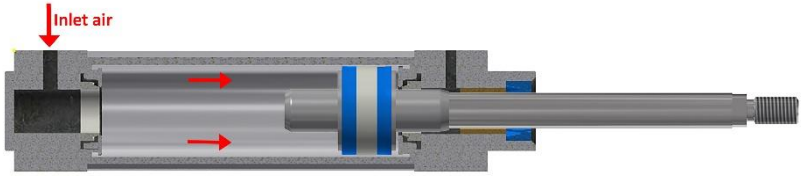
V druhé větě hypotézy je pravděpodobně chyba, asi má být správně When the value of the leak…… Otázka:
a. Co si mám představit pod pojmem Value of the leak? Je to hodnota v Pascalech/s?
b. A jak budu v provozu zjišťovat tuto hodnotu?
5. V třetí větě hypotézy je - zřejmě max. hodnota, viz „nomore“- leakage value 6Pa/s.
Proč tato hodnota? Když bude hodnota nižší, co to znamená? A když bude vyšší, co to také znamená?

Answer 4-5

The allowance of leakage, ΔP/t value in the cylinder is no more than 6 Pa/s

Test modes :
Δ P
ΔP/t Pa/s
Flow units mm^3/s
Blockage test
Additional ones depending on your applications

ATEQ 520 Leak Testers



This value is an internal standard of Polička company based on ISO standard. when the ΔP/t is less than 6 Pa/s it means, that the cylinder has no inner leaks.

Thank you for attention

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http://uk.fme.vutbr.cz/