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Statistics on the real lifetime of DH tubes. Investigation of pipelines' material mechanical properties degradation depending on operation time

Prof. dr. Jolanta Janutėnienė

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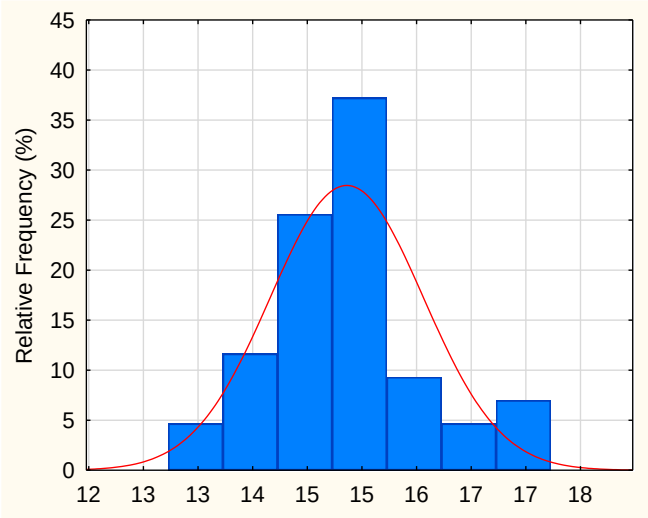

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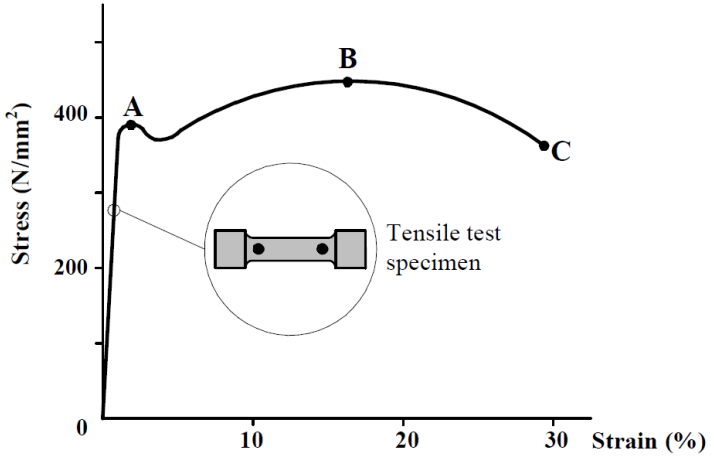
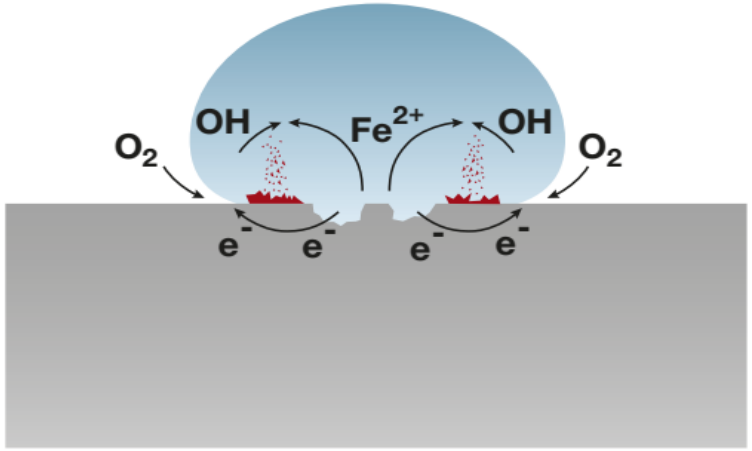




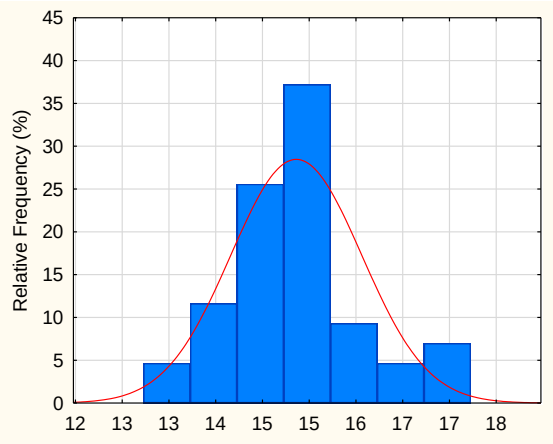
STATISTICAL ANALYSIS OF PIPELINE FAILURES (1/3)

By monitoring of random events we can observe their stability.

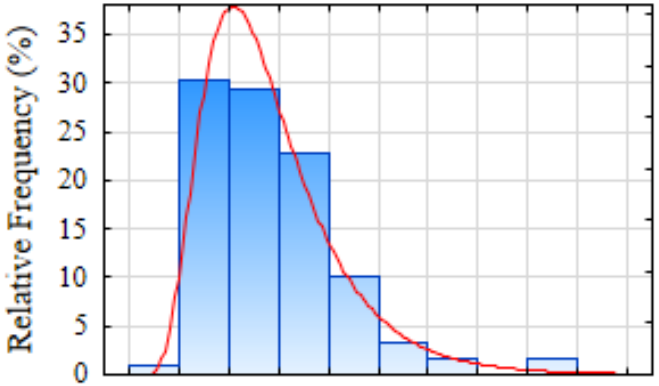
With a sufficient number of random events, statistical estimates of their distribution can be deducted:

Mean, variance, standard, coefficient of variation, coefficient of correlation, law of distribution.

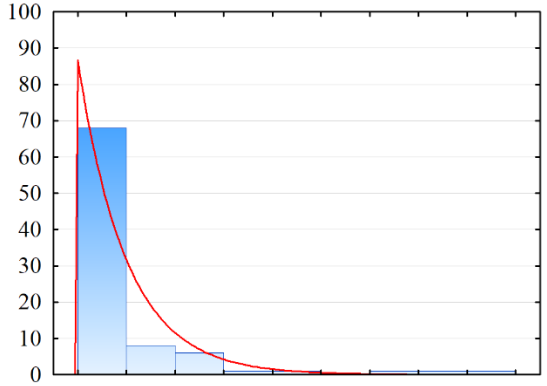
The observations and calculations show:



continuous random events are distributed according to the **Normal** law



vibration and cyclic loads or random events are distributed according to the L**ognormal** law

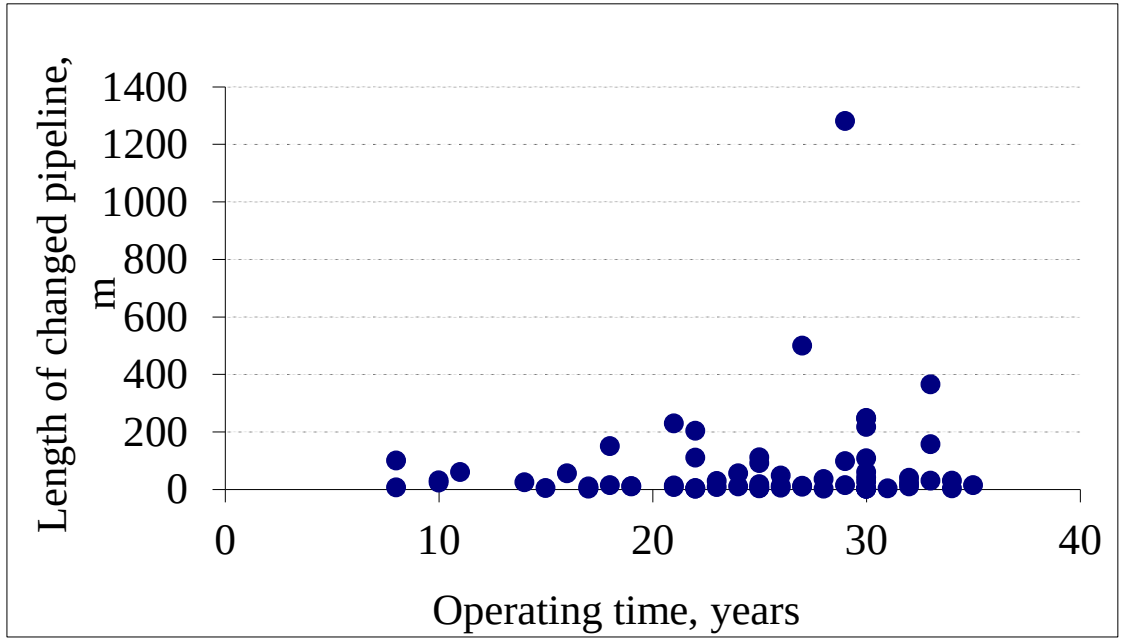


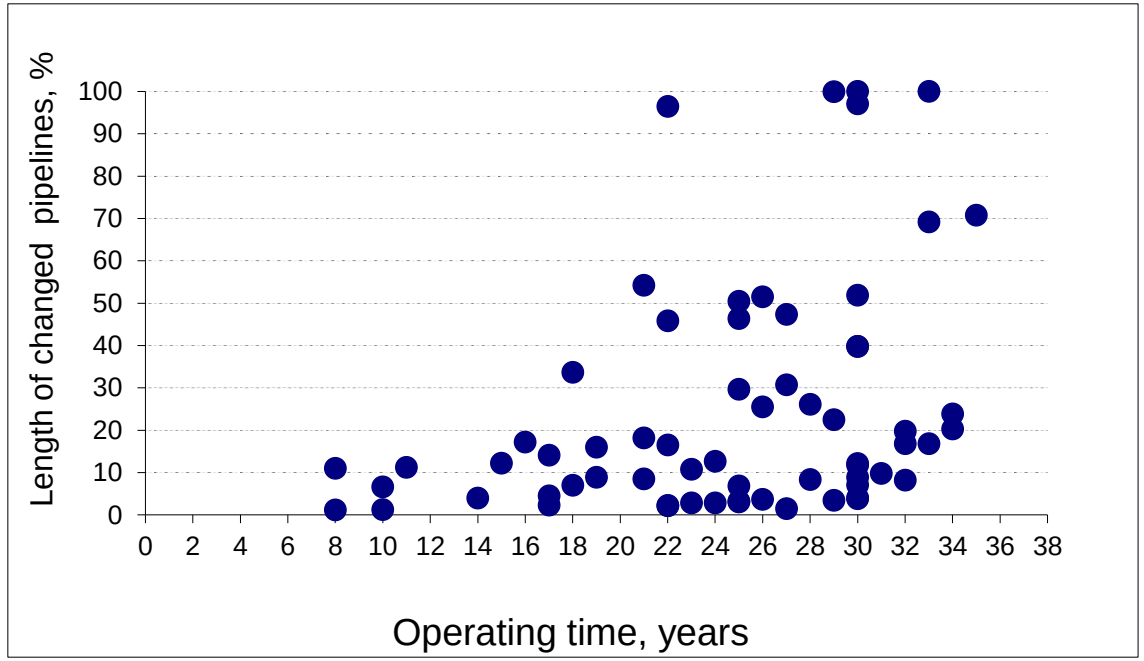
episodic and temporary short - term loads according to the **Weibull or Exponential** law

STATISTICAL ANALYSIS OF PIPELINE FAILURES (2/3)

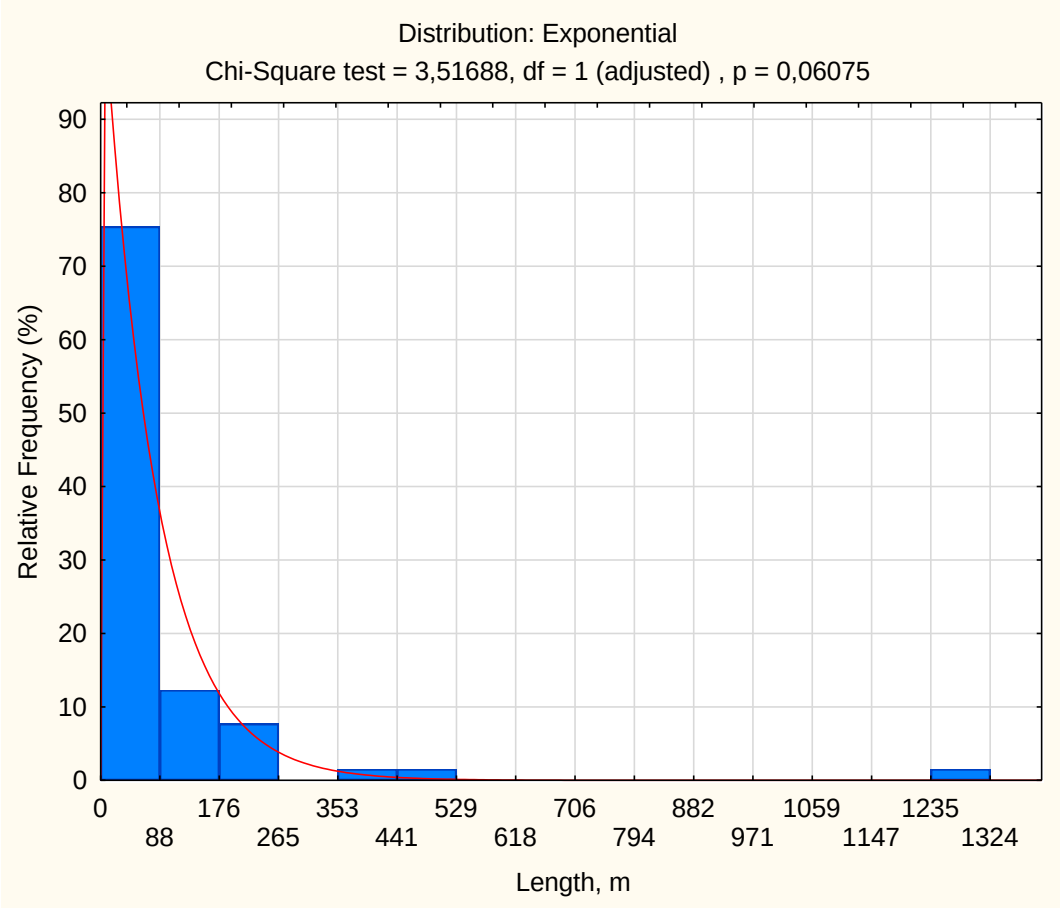
Real data of hot water pipelines were collected and analysed. The following information was selected from the pipeline route data:

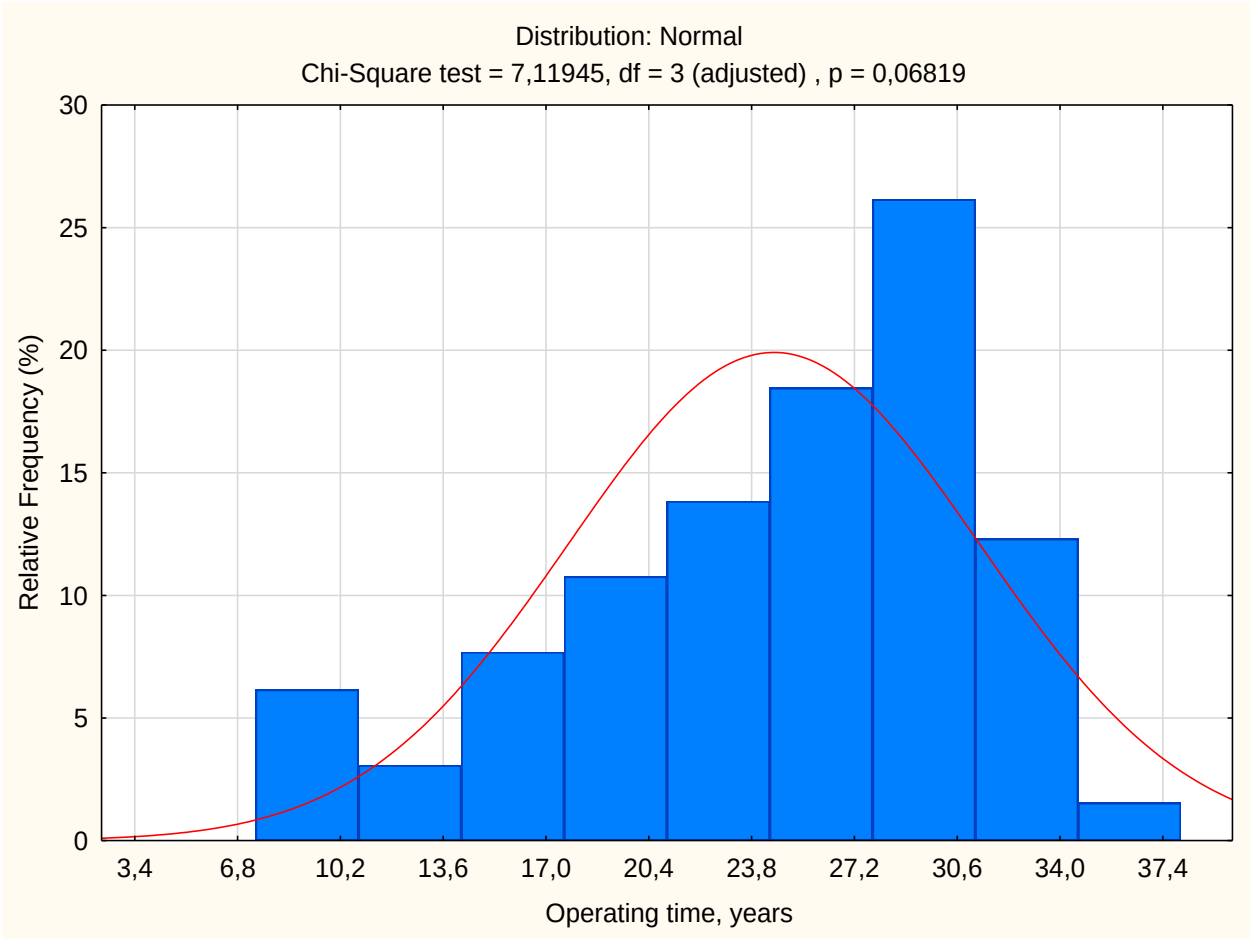
- years of operation before pipeline failure,
- length of damaged part and replaced with a new one.





STATISTICAL ANALYSIS OF PIPELINE FAILURES (3/3)





ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (1/6)

A long-term operating influence on mechanical properties variation of constructional materials were analysed.

Research object hot-water pipelines was chosen.

There are three external factors which influence the pipelines: water temperature, external environmental and pressure.

Each of these factors has an influence on aging process.

Parameters of hot water supplied by pipes: hardness of water up to 0.2 mg/eqv/l, there are no oxygen and carbon dioxide, salts. The temperature of water is 70-150oC, operating pressure – 1.6 MPa (during hydraulic test reaches 2.0 MPa).

Aim of this research is to identify relation between operating time and mechanical properties of material.

Experimental researches of hot-water pipelines material. From 20-40 years exploited pipelines specimens were cut and tension test was fulfilled.

ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (2/6)

The specimens from hot water pipeline material with different time of operating were chosen for the determination of materials mechanical characteristic variation.

Spectral analysis results of pipelines samplers of hot-water supply was done.

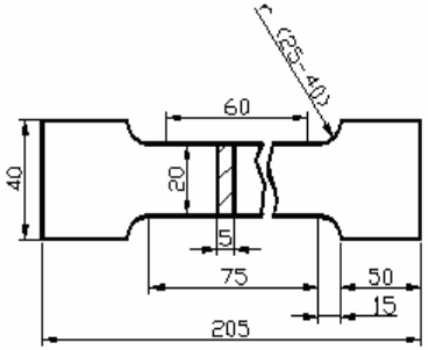
Diameter of pipe, m	Chemical elements, percent							
	C	S	P	Si	Mn	Cr	Ni	Cu
0.220	0.09	0.016	0.018	0.19	0.50	0.10	0.07	0.17
0.220	0.14	0.016	0.016	0.24	0.52	0.07	0.06	0.20
0.220	0.13	0.016	0.015	0.24	0.57	0.13	0.10	0.12
0.635	0.12	0.016	0.017	0.10	0.46	0.05	0.03	0.07
0.220	0.10	0.016	0.017	0.19	0.47	0.06	0.04	0.04

ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (3/6)

TENSILE TEST

Tension test was performed with specimens from these samplers. During tension test mechanical characteristics of steel was determined: yield stress σy, ultimate stress σu.

For tensile test performing specimens were machined according to standard



Strength force, kN	Yield force, kN	Ultimate stress, MPa	Yield stress, MPa	Relative elon-gation, %	Relative cross sectional area,%
40.3	30.7	400.1	304.9	13.0	54.0
46.6	34.7	444.0	330.7	8.5	47.3
42.6	29.5	413.9	286.7	9.1	44.5
42.7	28.6	404.9	271.9	8.3	44.5
26.9	18.9	422.6	297.2	15.6	42.7

ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (4/6)

According to geometrical parameters of specimens the main criterions, which characterize plasticity features of materials, were defined:

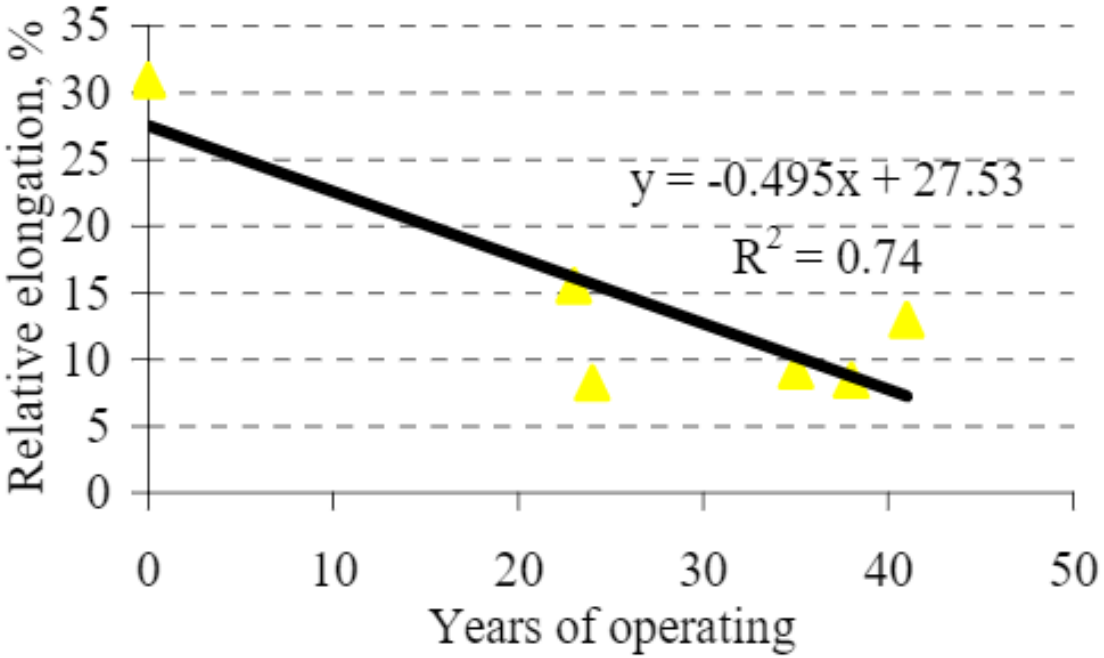
- the relative residual elongation of specimens

$$\delta = \frac{l_1 - l_0}{l_0} \cdot 100\%$$

- the relative cross-sectional area

$$\psi = \frac{A_0 - A_{fr}}{A_0} \cdot 100\%$$

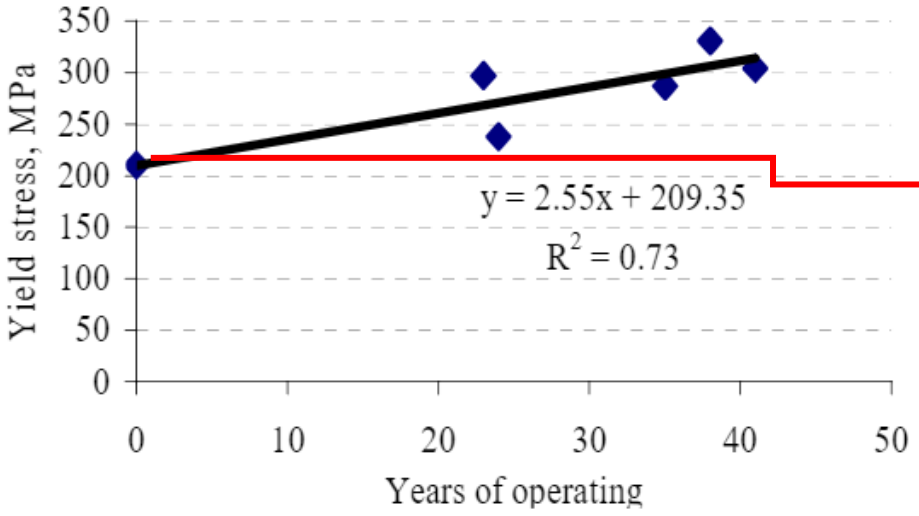
Materials plasticity features in the best way shows relative extension parameter of a specimen.

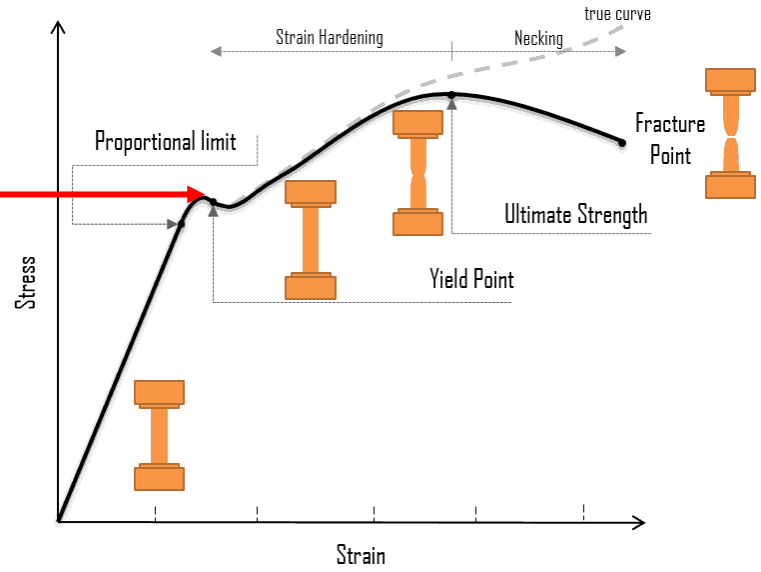


The relationship between relative residual length variation of specimen and materials service duration.

ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (5/6)

Results of the tests showed, that strength stress value grew up negligibly if compare with the strength stress value of the new material. In practical calculations concerned with design of new structures and elements materials yield stress is used as extreme boundary, because above it the irreversible plastic deformations start. Recording of yield stress in some case was unsuccessful.



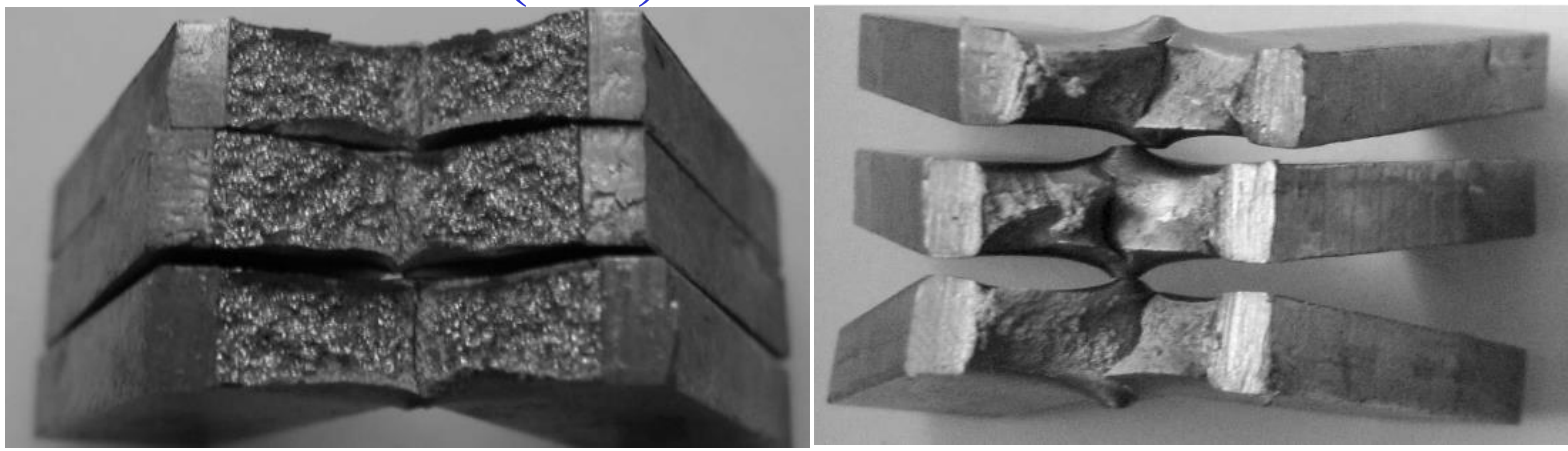


Relationship between materials mechanical characteristics and operating time

ANALYSIS OF METALS MECHANICAL PROPERTIES DEPENDING ON OPERATION TIME (6/6)

It was defined that plasticity features of the materials are changed and also Charpy V-notch impact test was performed.

Nonstandard (ten millimeters width and five millimeters thickness) specimens were tested.

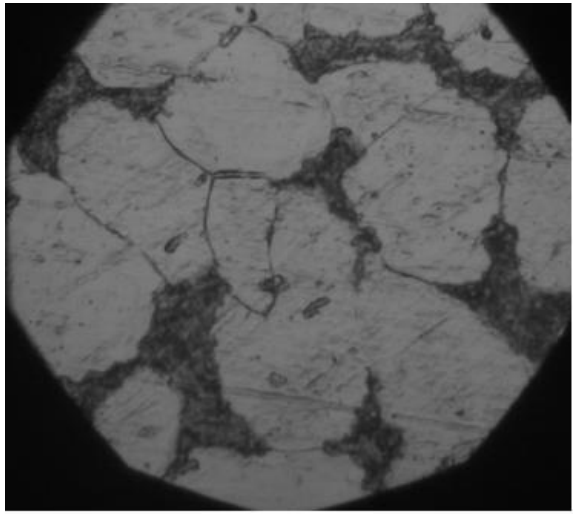


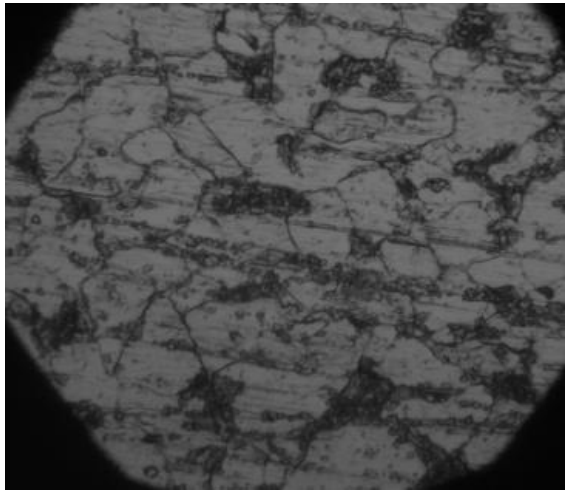
Specimens after impact test

brittle fracture

plastic fracture

Microstructure researches confirmed that bigger grains are one of the factors which make an influence on brittle fracture. The size of the grains was measured. Correlation coefficient shows inverse dependence -0,9.





An enlarged view (400 times) of materials micro-structure

CORROSION OF STAINLESS STEEL (1/4)

The pipe used for the mill is made of AISI 316L stainless steel with an outside diameter of 88.9 mm and a wall thickness of 3 mm.

The pipe is connected by welding to a pipe of the same material, the welded joint being made according to the usual rules.

The holes do not appear in the area of these welded joints.

The water of the Curonian Lagoon has a conductivity of 1000 to 15000 mS, which is typical for brackish water in the Curonian Lagoon.

The exact salt composition is unknown, but NaCl is present.

The natural pH is in the range from 5.7 to 7.

Material	Chemical composition
AISI 316	Cr (16.5-18.5%) Ni (10-13%) Mn (<= 2%) Mo (2-2.5%) Si (<= 1%) N (0.11%) P (0.045%) C (<=0.07%) S (0.03%)

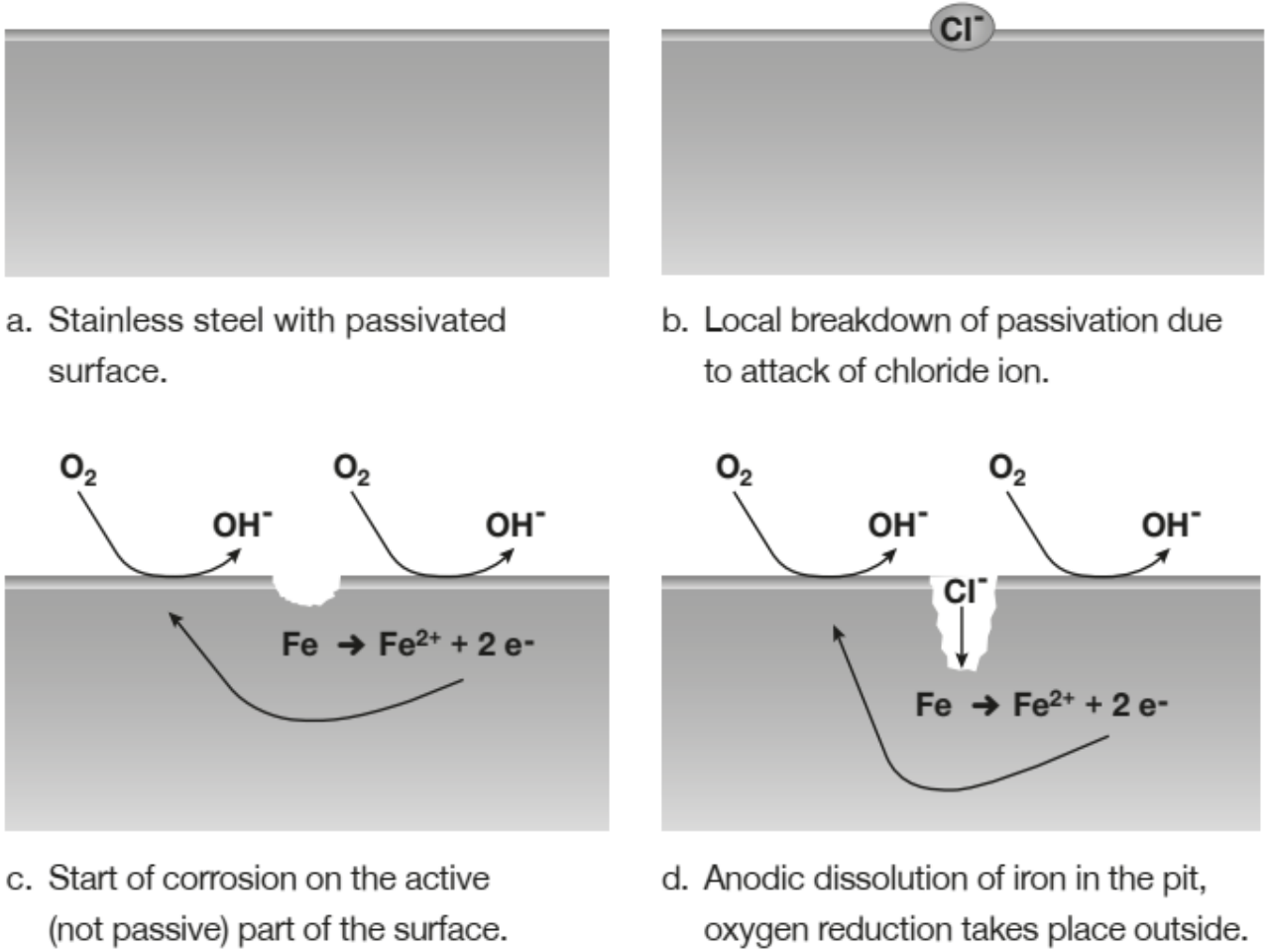
The pits in the straight sections of the pipe appear about 30 to 40 days after the start of operating.

CORROSION OF STAINLESS STEEL (2/4)

Electrochemical corosion

The mechanism and the electrochemical nature of the corrosion reaction defne the necessary requirements for corrosion to take place:

- a conducting metal
- an electrolyte (a thin moisture flm on the surface is already suffcient)
- oxygen for the cathodic reaction



a. Stainless steel with passivated surface.

b. Local breakdown of passivation due to attack of chloride ion.

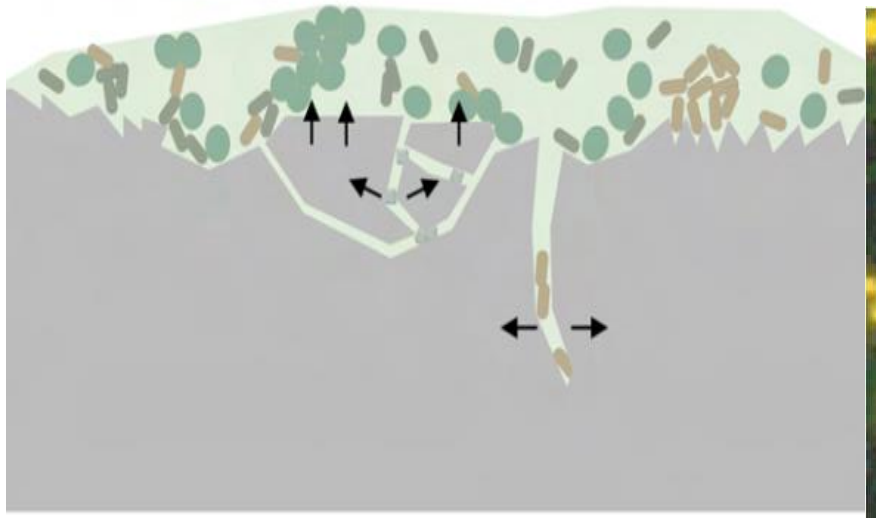
c. Start of corrosion on the active (not passive) part of the surface.

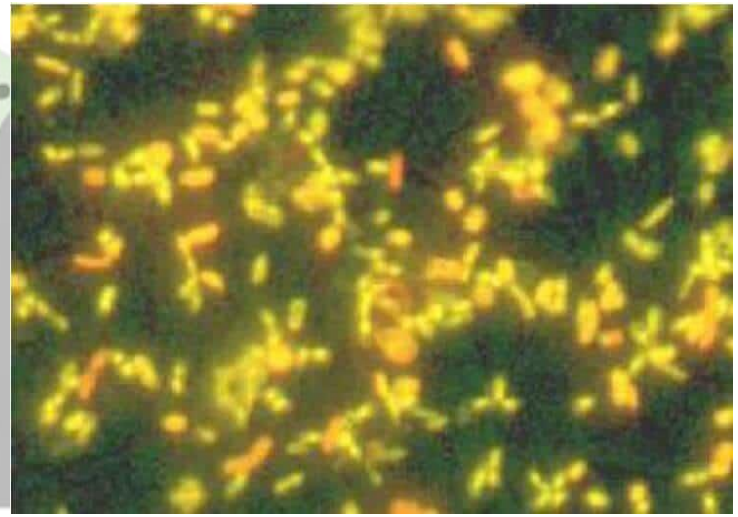
d. Anodic dissolution of iron in the pit, oxygen reduction takes place outside.

Phases of pitting corrosion on stainless steel.

CORROSION OF STAINLESS STEEL (3/4)

The non-reddish-brown coatings inside the pipes are a typical consequence of microbial growth.
This is also supported by the fact that holes in the wall only appear in these areas.





Schematic of a biofilm with metal eaters (brown rods) and sulphate-reducing microbes (green spots) in the upper part of the biofilm.

CORROSION OF STAINLESS STEEL (4/4)

Pitting corrosion is a localized form of corrosion that leads to the creation of small holes or “pits” in the metal. This form of corrosion is mainly found on passive metals as stainless stell. Passive metals owe their corrosion resistance to a thin oxide layer on the surface with a thickness of only a few nanometers. The corrosion initiating process starts with a local break-down of the passive layer like a crack.

Local corrosive attack can be initiated on stainless steels, for example, by **chloride ions** which forms better soluble metal chlorides.

Microbes are able to influence their environment. Microbes can shift the pH value in such a way that the passivating top layer of the stainless steel is dissolved (Thuy et al., 2020); (Imo et al., 2016).

Furthermore, they can shift the electrochemical potential so that stainless steel becomes non-noble and corrodes like low-alloyed steel (Venzlaff et al., 2013); (Machuca, 2019).

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