Sketch of the proof: Let x_0 be a fixed initial state. Then control sequence $U_q = Q_q^{-1}E_{(\alpha,\alpha)}(Ah^{\alpha}, q) + \eta(x_0, 0)$, where $\eta(x_0, 0) \in \mathcal{H}(2p, qm)$, transfers in q steps system (1) to the origin, see [3]. Since this sequence is uniquely determined in a neighborhood of the origin and origin is the equilibrium of (3) then using reasoning based on higher order functions (see [1]) we obtain thesis.

Remark: The approach to stabilization of nonlinear control systems with Grünwald-Letnikov h-difference fractional operator given in Theorem 2 is a consequence of controllability results presented in [3]. Its idea is different from the idea of approach to the similar problem presented in [5].

References

1. L. Chen, K. Narendra, Identification and control of a nonlinear discrete-time system based on its linearization: A unified framework. *IEEE Transactions on Neural Networks, 15*(3) 2004, p. 663–673
2. T.Kaczorek, Selected Problems of Fractional Systems Theory, Springer-Verlag, Berlin 2011
3. D.Mozyrska, E.Pawluszewicz, M.Wyrwas, Local observability and controllability of nonlinear discrete-time fractional order systems based on their linearization, *International Journal of Systems Science*, 48(4) 2017, 788-794
4. D.Mozyrska, M.Wyrwas, E.Pawluszewicz, Stabilization of linear multi-parameter fractional difference control systems, *Proc. of the Int. Conf. on Methods and Models in Automation and Robotics MMAR 2015*, Międzyzdroje, Poland 2015
5. D.Mozyrska, M.Wyrwas, Stability by linear approximation and the relation between the stability of difference and differential fractional systems, *Mathematical methods in Applied Siences,* 40(11) 2017, 4080-4091

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THE METHOD OF THE PIPELINE DAMAGE DETECTION USING THE ADDITIONAL INSTRUMENTATION - CORRECTORS

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Pipelines are difficult to service due to their large size and complex construction. Comprehensive diagnosis of leakages from long pipelines consists of several activities: leak detection, estimation of its size, searching for the location where the leak occurred, deduct the intentional leak (gas collection) from the damage. There are a number of methods to detect leaks (from monitoring pipelines using trained dogs, monitoring pressure and flows, to methods using neural networks), but each of these methods has its weak and strong sides. Due to the possible catastrophic consequences of misdiagnosis, several methods of detecting and locating leakages from pipelines are often used in parallel.

The article presents the basics of the method that can be used as a supplementary method. It is based on standard signals taken from the pipeline (it can be pressure, mass flow) and signals from the additional accessories - correctors attached to the pipeline.

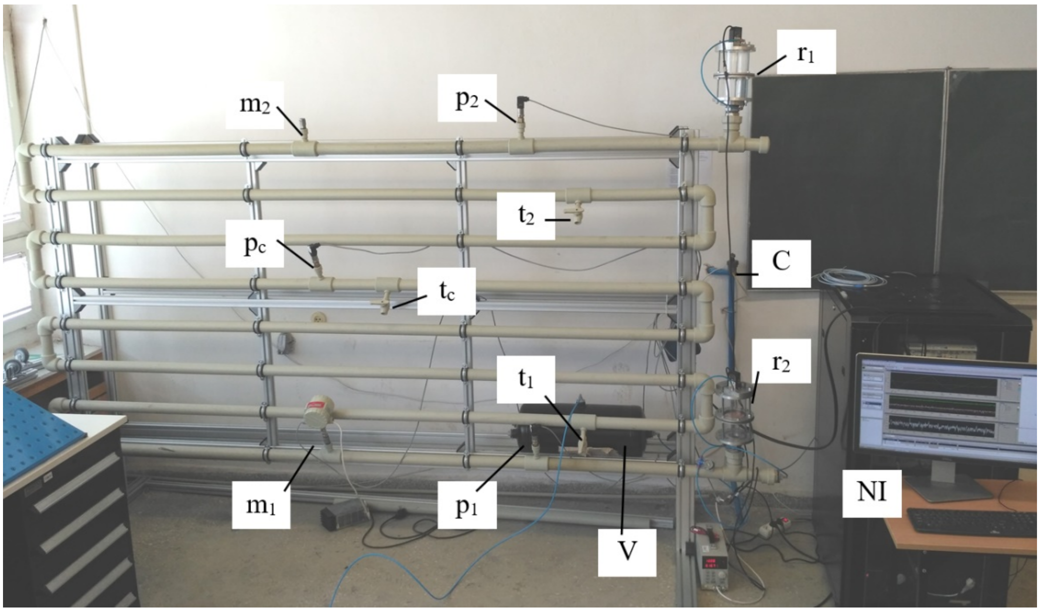

Fig 1. Stand for leak detection from pipelines; where:
C - connection to the compressor, V- pressure vessel, r_1, r_2 –correctors,
p_1, p_c, p_2 – pressure sensors, m_1 - mass flowmeter, m_2 - place for mounting second flow sensor, t_1, t_c, t_2 - valves, NI - measuring equipment [2].

In order to obtain the signals needed to verify the method, a test stand was constructed (Fig. 1). The stand consists of 27 m PPR pipes (internal diameter 45mm), three pressure sensors - p_1, p_c, p_2, three valves used to simulate gas leaks from the pipeline - t_1, t_c, t_2, correctors r_1, r_2, mass flow sensors m_1, m_2, and the pressure vessel *V*. The data are acquired by NI - National Instruments equipment [2].

The construction of correctors is shown in Figure 2 [1].
In concealers mounted to the pipeline as an additional equipment, there are two chambers separated by a membrane. In the upper chamber there is a sensor measuring pressure changes or a sensor measuring the vibrations of the membrane (depending on the construction version of the corrector). They provides an additional diagnostic information, the use of which will supplement the methods used to detect leaks from pipelines.

Correctors are easy to mount and do not affect the static and dynamic quality of the tested pipelines.

Fig 3. shows examples of leakage simulation results from the faucet on the pipelines (t_2), the signal of pressure changes, and correctors membrane dislocations.

Using the standard measured p_1 and p_2 signals, gas flow can be detected without any difficulty, but this is only possible with significant leaks. In order to detect small leaks and to enable the location and estimation of the outflow rate, it may be necessary to use additional diagnostic signals provided by correctors (r_1 and r_2).

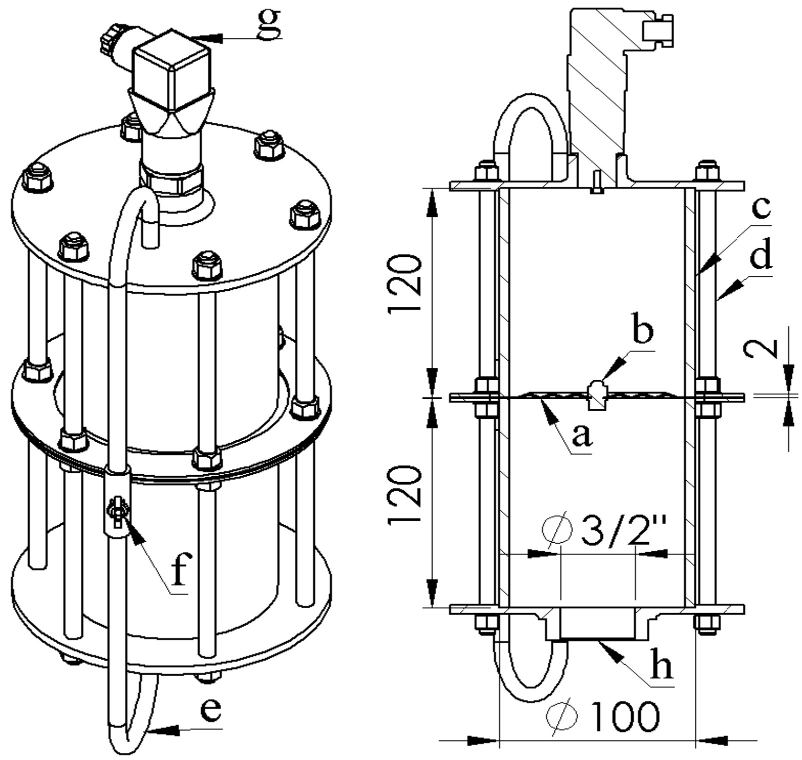

Fig. 2. Construction of an corrector for the diagnosis of leakage from gas pipelines, where: a - removable membrane, b – adjustable mass, c - tube walls, d - the pivots, e - the pressure equalizing tube, f - valve on the equalizing tube, g - differential pressure sensor or laser linear position sensor , h - connection to the pipeline. [1]

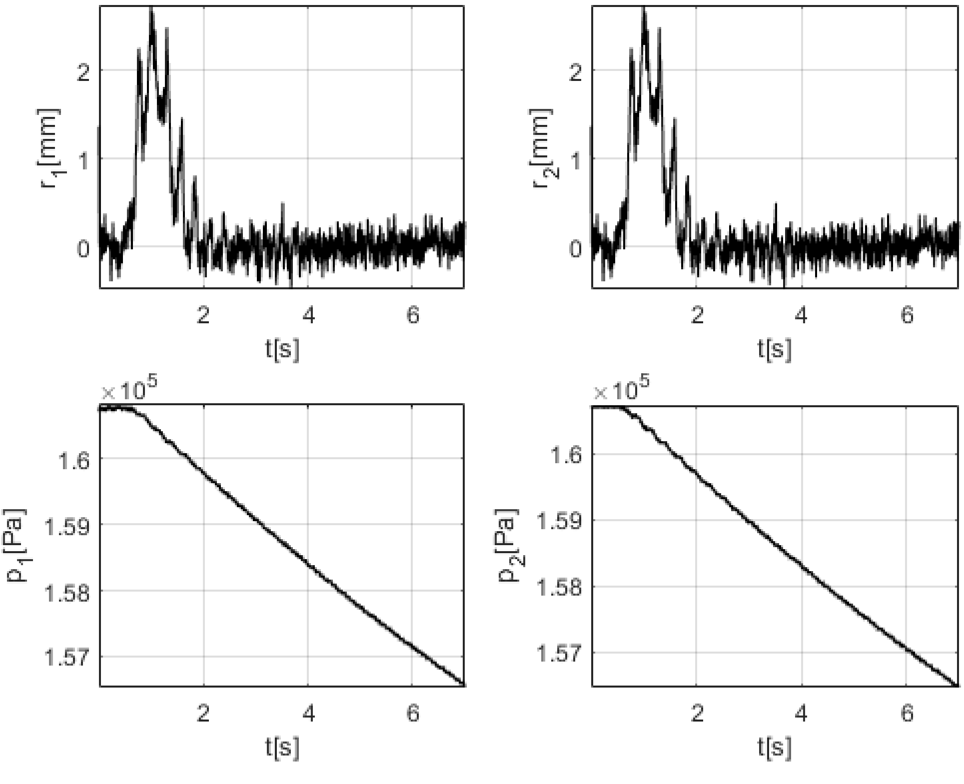

Fig. 3. Membrane dislocation signals r_1 and r_2; pressure signals p_1 and p_2 for outflow from valve t_2 (on the end of test pipeline).

In order to mathematically link the above signals, may be used the model in the form amplitude gain (A^2) [3]. This model use S_{yy} – the auto power spectral density of signals for changing the signals from time domain (t) to frequency domain (ω) [3]

$$A_{ry}^2 = \frac{S_{rr}}{S_{yy}} \tag{1}$$

A given model can also be written in the parameterized form [3]

$$A^2 = \frac{M_0 + M_1 s + M_2 s^2 + \ldots + M_n s^n}{L_0 + L_1 s + L_2 s^2 + \ldots + L_n s^n} \tag{2}$$

The analysis of the model parameters changes (M_0-M_n *and* L_0-L_n) should enable the detection of small leaks, their location, size estimation. Indirectly thanks to the analysis of the leakage location size it will be possible to infer whether it is the result of intentional leak (gas collection) or it is caused by pipelines damage.

The transition from signal diagnostics to parametric gives further significantly greater signal analysis capabilities.

References

1. Grądzki R., Golak K., Lindstedt P., Bartoszewicz B., Reasons for the experimental research of gas outflows based on the signals of weak interactions between the tested model of the gas pipeline, and tested equalizer, J. KONBiN, Nr 2 (2015), s. 39-48
3. Grądzki R, Golak K, Lindstedt P. Basics of the Corrective - Resonant Spectral Method of Gas Flow Identification from the Damaged Pipeline and its Experimental Verification, Journal of KONBiN, vol. 44 (2017), pp. 159-175.
2. Lindstedt P., Grądzki R., Model for blade diagnosis in a working rotor machine employing the method of virtual elimination of stochastic environment. Archive of Mechanical Engineering, Vol. 58, nr 3 (2011), pp. 305-318.

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МИНИМИЗАЦИЯ ТРАЕКТОРИИ ДВИЖЕНИЯ МОБИЛЬНОГО РОБОТА

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Мобильные роботы широко применяются в промышленности. Известны различные системы навигации и способы управления движением данных роботов. Однако они, либо отличаются высокой сложностью, либо обеспечивают невысокую точность управления. Поэтому проблема создания эффективных систем управления движением мобильных роботов по-прежнему остается актуальной.

Известны алгоритмы [1,2], которые обеспечивают попадание робота в целевую точку под заданным углом с требуемой точностью, однако траектория движения при этом является достаточно выпуклой. Цель работы – создание алгоритма, обеспечивающего построение траектории минимальной протяженно-