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The concept of the technological process control using a distributed industrial tomography system

Abstract. *The article presents the idea of a system enabling effective control of production processes. A high level of automation and control of production processes plays a key role in maintaining a high level of competitiveness of each enterprise. The proposed system concept consists of a network of distributed sensors that enable the measurement of many process parameters, manufacturing resources and the state of the machine park. The described control system uses both wired and wireless communication. The implemented communication systems will enable obtaining data from various sensors and other subsystems installed in enterprises, as well as obtaining data from new systems and sensors used to measure all types of processes, from production set-up to the final product. The described solution includes the use of process tomography sensors based on electrical tomography. The conducted research shows that the use of tomographic methods enables effective management of the intelligent structure of companies in the scope of manufacturing processes control.*

Streszczenie. *W artykule przedstawiono ideę systemu umożliwiającego efektywną kontrolę procesów produkcyjnych. Wysoki poziom automatyzacji i kontroli procesów produkcyjnych odgrywa kluczową rolę w utrzymaniu wysokiego poziomu konkurencyjności każdego przedsiębiorstwa. Proponowana koncepcja systemu składa się z sieci rozproszonych czujników, które umożliwiają pomiar wielu parametrów procesu, zasobów produkcyjnych i stanu parku maszynowego. Opisany system sterowania wykorzystuje zarówno komunikację przewodową, jak i bezprzewodową. Zaimplementowane systemy komunikacyjne umożliwią pozyskiwanie danych z różnych czujników i z innych podsystemów zainstalowanych w przedsiębiorstwach, a także uzyskiwanie danych z nowoopracowanych systemów i czujników używanych do pomiaru wszystkich typów procesów, począwszy od przygotowania produkcji aż do produktu końcowego. Opisane rozwiązanie obejmuje wykorzystanie czujników tomografii procesowej w oparciu o tomografię elektryczną. Przeprowadzone badania dowodzą, że zastosowanie metod tomograficznych umożliwia efektywne zarządzanie inteligentną strukturą firmy w zakresie sterowania procesami produkcyjnymi. (**Koncepcja sterowanie procesem technologicznym z wykorzystaniem rozproszonego systemu tomografii przemysłowej)**.

Keywords: electrical impedance tomography, elastic net, inverse problem.
Słowa kluczowe: elektryczna tomografia impedancyjna, elastic net, problem odwrotny..

Introduction

Industrial tomography enables non-invasive, dynamic observation of physical and chemical phenomena without the need of mechanical interference into the interior of the investigated object [1-14,16,19-22]. Thanks to the features mentioned above, this type of tomography is ideal for automatic optimization of design and production processes. Process tomography systems can operate autonomously in the field of monitoring, measurement and control of the correct functioning of industrial processes. A network of sensors connected to the system provides a constant data flow enabling tracking of technological processes even in closed technical facilities, such as fermenters. Process tomography is also used to acquire data on the flow of fluids and loose components in pipelines that act as transport media [24-29, 31-37]. The data obtained from the sensors are delivered to the data warehouse, where they are further processed. As a consequence, data warehouses enable building a knowledge base on operating systems and processes. Data analysis results can be displayed in a suitable form on the monitor screen. In semi-automatic systems they can be used by the operator as elements of supporting decision-making processes, and in automatic systems, decisions are made by IT systems, and the information about the history of these decisions is a log file. The production process control tasks carried out in this way allow increasing the efficiency and quality of products, as well as increasing the company's competitiveness level. Methods of analysis and control of processes include issues related to the processing of data obtained from various sensors located in remote nodes. Monitoring is based on acquired and processed data due to appropriately elaborated algorithms for parameter automation [15,17,18,23,30,38].

This paper concerns the issues of processes control in a cyber-physical system based on the concept of a production process management system equipped with tomographic sensors. Due to the reduction of the risk of failure, the launch of applications for processing data obtained from various sensors located in the installation of key nodes will increase the level of production protection in the sphere of health and safety as well as in terms of maintaining production continuity. The effectiveness of supervision and control over manufacturing processes depends on the scope of obtained and processed data and on the parameters of devices performing automation. Thanks to the conducted research, it will be possible to define a new mathematical basis with formalisms for defining, analyzing, verifying and checking systems that monitor and control physical objects. The model of the new system includes new measurement techniques and projects of innovative, intelligent measuring devices. The software structure includes a communication interface, original optimization algorithms and data analysis algorithms for reconstruction of tomographic images and monitoring of industrial processes.

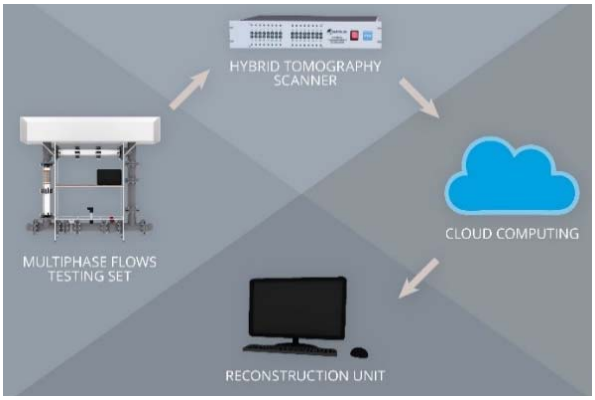


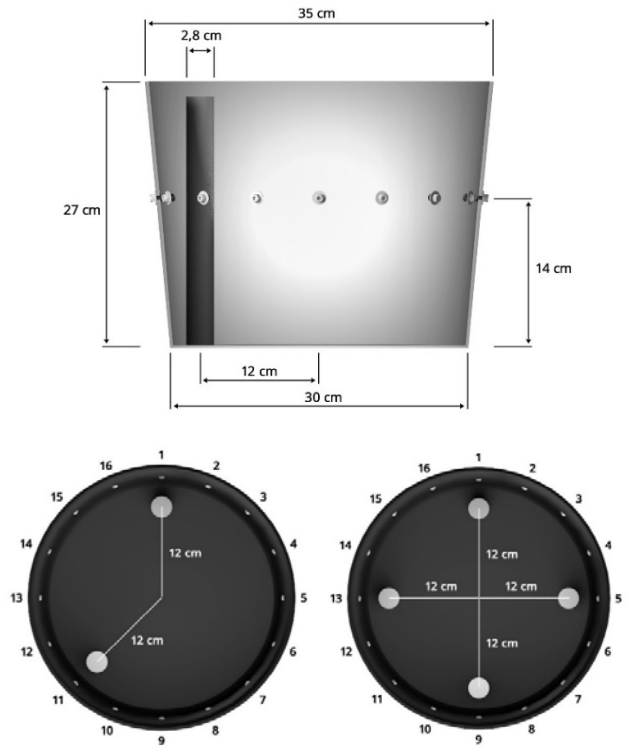
Fig. 1. Idea of distributed industrial tomography system.

Model of the system

This chapter presents the idea of an integrated IT industrial system whose task is to intelligently deliver flexible and reliable monitoring methods based on tomography. In Fig. 1, we can see a scheme of the industrial system mentioned. The proposed system model can be divided into the following subsystems: measuring devices, sensors, tested objects, applications for cloud computing and data analysis applications.

Model and experiment

Fig. 2 presents a measurement system based on electrical tomography installed on a real object. Around the bucket, in the middle of the height, a series of measuring electrodes were installed, to which the wires connecting them with the tomograph were connected. Inside the bucket there are objects immersed in water. Thanks to the specially designed frame (upper part of the bucket), the objects can be moved relative to each other and to the bucket, and their number can be changed. This allows measurements to be made for a variety of cases.



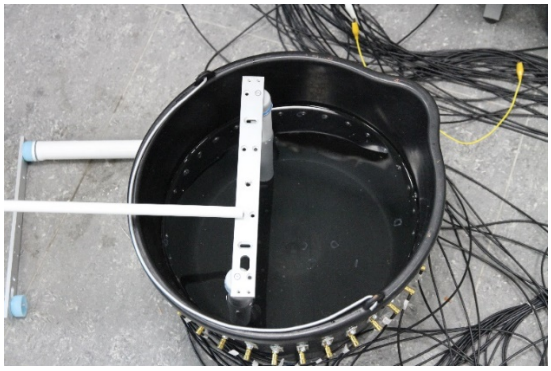
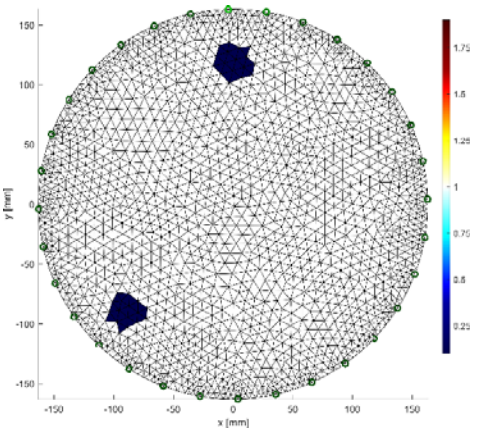


Fig. 2. Model of the measurement system.

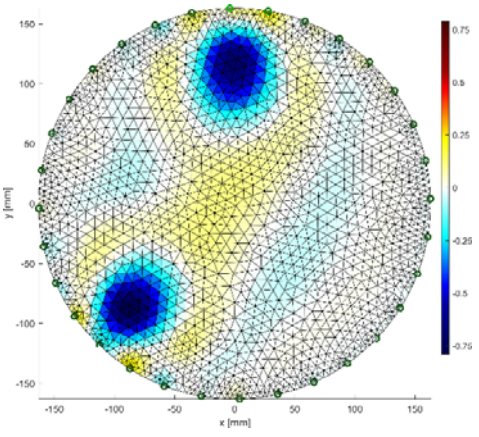
Image reconstruction

Computer tomography basses on the analysis of the reverse problem, which is difficult to investigate. This type of problem usually has no unambiguous solution and is poorly conditioned. The reasons for this are, for example, too little or too much information, which in addition may be contradictory or linearly dependent. The above problem can be analyzed by numerical methods, including also using the finite element method or the boundary element method. In a situation where data is too little we talk about fixed problems, whereas when the data is too much, the problems are over-determined. Knowledge of the a priori process usually makes reconstruction of the image more resistant to incomplete or noisy data. Automatic data analysis is an important part of diagnostics of industrial processes. Figs. 3 and 4 present tomographic reconstructions of images using stochastic and deterministic methods using 32 measurement electrodes.

a)



b)



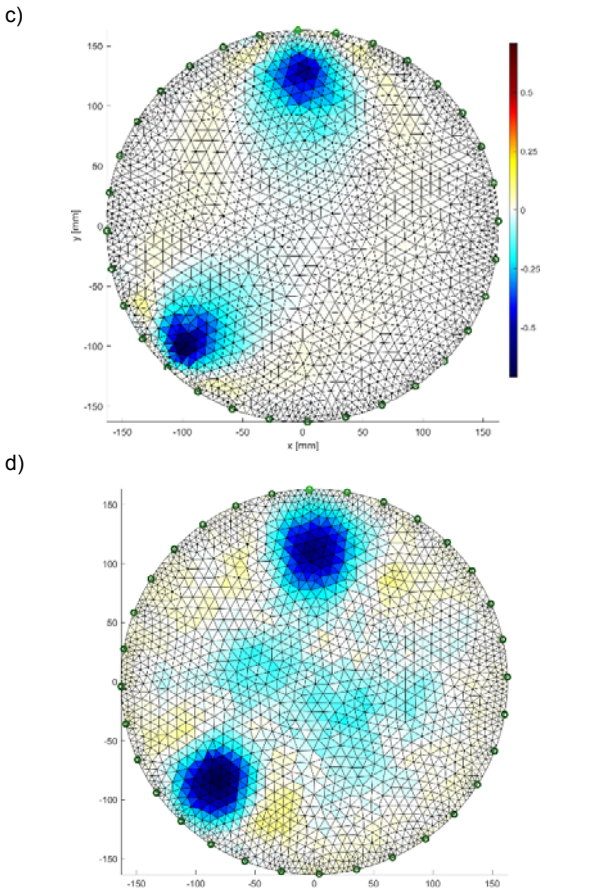


Fig. 3. Image reconstruction (32 electrodes): a) model, b) Gauss-Newton method with Laplace regularization, c) GN Tikhonov , d) Lars.

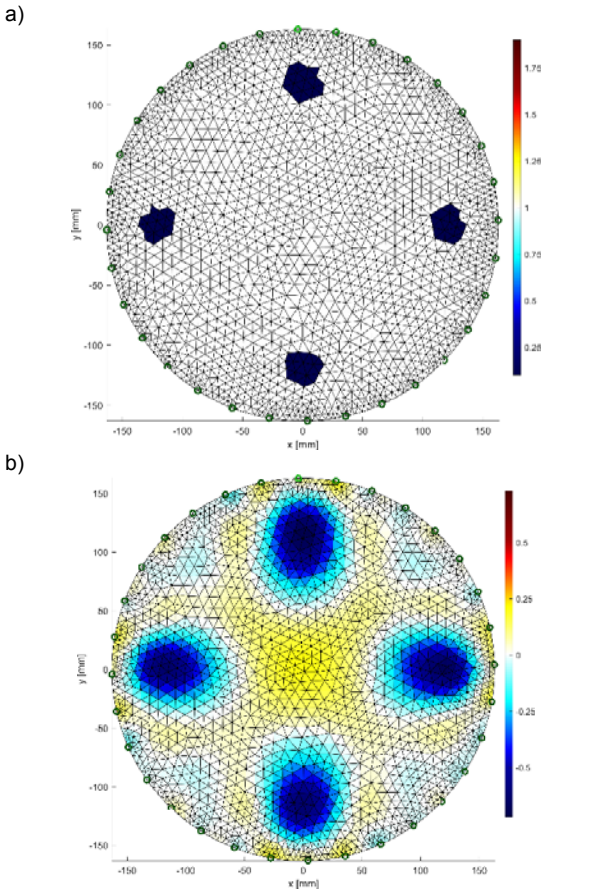


Fig. 4. Image reconstruction (32 electrodes): a) model, b) Gauss-Newton method with Laplace regularization, c) GN Tikhonov , d) Lars.

Conclusion

The article presents the real model of the measurement system in relation to a circular object, to which two methods of image reconstruction were applied: Gauss-Newton and Lars. The visual results of simulation experiments confirm the high quality of the reconstructed tomographic reconstructions. Computed tomography and electrical tomography can be successfully used for tasks related to the control of dynamic production processes. A high degree of automation increases the level of control of manufacturing and logistics processes, which in turn play a key role in maintaining high competitiveness of the company. An important element of the presented solution is a network of sensors for measuring process parameters. The surveillance system uses wired and wireless communication, which allows the delivery of data from installed sensors located in different places in the production system. Due to the specificity of the model used, the conducted research refers directly to manufacturing and logistics of a process nature, such as control of liquid flow in pipelines, chemical reactions in reactors, biogas manufacturing, etc.

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