Industrial Internet of Things concept and energy efficient technologies implementation at a fish drying unit

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Abstract. Modern trends in the availability of information and the widespread use of information and communication technologies not only in everyday life, but also in industry, make it clear that society is on the threshold of a fourth industrial revolution. Such terms as Information Society, Internet of Things, and Digital Economy are understood today as the main focus of state development on which the competitiveness of the national economy depends. The digital economy is primarily defined as a system of economic, social and cultural relations based on the use of digital information and communication technologies. The aim of the presented work is to develop the concept of the Industrial Internet of Things (IIoT) based on an experiment conducted at Murmansk State Technical University. The concept of the Internet of Things was implemented using a small-sized drying unit designed for carrying out the processes of drying and smoking fish and fish products. The proposed method of dewatering reduces the cost of electricity in the production of dried products, extends the life of smoking and drying facilities at the expense of more efficient use of coolant, and improves product quality by reducing the effects of deformation in fish tissues as a result of relaxation.

1. The fishing industry is a leading industry sector in the Murmansk region

In the Murmansk Region, fishing industry is not only the most traditional, but also the leading industry sector. According to the Federal State Statistics Service, the Murmansk Region occupies the third honorary place among the fish-processing regions, giving way only to Kamchatka Region (780.6 thousand tons) and Primorsky Krai (699.1 thousand tons). Our region provides almost half of the production of the North-Western Federal District (42 percent), where 1222.20 thousand tons of fish and fish products were produced in the year 2017, figure 1. The dynamics of fish production in the Northwest federal District and in the Murmansk region is presented in the figure 2. (Russian statistical compilation: Fisheries Industry of Murmansk region / Murmanskstat, 2017 45 p.). However, production dynamics of fish and fish products in the Murmansk region has slowed down in the recent years. For example, in 2017 there was a decrease in production compared with the peak year 2014, from 563.8 thousand tons of fish and fish products to 519.2 thousand tons. In other words, fisheries in the Russian Federation is a difficult sector for forecasting, whose development depends on many aspects, including the production factor, its material and technical base.
2. Current trends of society informatization

Current trends in the informatization of society, the development and widespread use of information and communication technologies not only in everyday life, but also in the industry make it clear that the society is on the threshold of the fourth industrial revolution [2]. Today such terms as Information Society, Internet of Things, and Digital Economy are considered to be the main vector of state development on which the competitiveness of the national economy depends. According to the definition of the World Bank, digital economy is primarily understood as a system of relations based on the use of digital information and communication technologies.

There is no doubt that digital economy should affect all areas of governmental activity, but the manufacturing sector as the driving engine of economic growth should undergo digital transformation in the first place [3].

Today in the Murmansk region, there is a tendency of transition of enterprises to smart production, and the use of digital information and communication technologies. Continuous product life cycle support systems are being implemented, such as: customer relationship management systems (CRM),
enterprise resource planning systems (ERP), and supply chain management systems (SCM) [4, 5]. Unfortunately, according to Rosstat, their share is not large. So far, it makes 15 percent of the total number of surveyed enterprises (Russian statistical compilation), Figure 3.

Figure 3. Percentage share of surveyed companies using software

3. Industrial Internet of Things concept implementation at a drying unit
That is why innovational and technological development of the fishing industry is so important. Consequently, the purpose of our work is to show how to develop the concept of Industrial Internet of Things (IIoT) on the basis of a small-sized drying unit designed for carrying out the processes of drying, air-drying, and smoking fish and fish products. The installation is used in the fish processing enterprise of Murmansk State Technical University. At the same time, our concept of building IIoT was developed from scratch and did not involve the use of ready-made solutions. The developed information system includes a human-machine interface made in the form of a Web application [6]. It implements the functions of remote access and mobile control, and also allows remote control of the process taking place in the drying unit, as well as checking the information and the status of all sensors in the system. The web interface makes it possible to significantly expand the boundaries of the workplace arrangement for the drying unit operator and increase the efficiency of the workshop. It is worth mentioning that the web application receives a video stream from the web camera, which enables the user (operator) to visually monitor the technological process in the small-sized drying unit. The core of the information system is the MS SQL Server MSU Data database, which is designed to synchronize the work of all applications. Multi-user mode database reduces errors when connecting to single resources while using them, Figure 4.

The basic principle of the information system is as follows: The system core collects information from sensors, actuators, controllers, and human-machine interface. The information obtained allows acquiring objective and accurate data on the course of the technological process, its features, and equipment operation time. The information obtained can be used to prevent unplanned downtime, equipment breakdowns, and to reduce unscheduled maintenance and supply chain management disruptions, thereby allowing the enterprise to function more efficiently. The development of our own software makes it possible to further transform the data exchange pool for connecting other installations and technological equipment of our workshop to the system. In this context, the correct presentation of information in the form understandable to the user is of particular importance. In this regard, we are working to modify the data sets of the core information system in the exchange formats XML, CSV, and others. Industrial Internet of Things enables to make organizational and technological transformation of production. At the management level, it integrates real production, transport, human, engineering, and other resources into almost unlimitedly scalable program-controlled virtual resource pools and the results of their use.
As a result, large-scale introduction of the Internet of Things was launched on the basis of a small-sized drying unit. Computer networks and production facilities were connected with embedded sensors, software, and the pool for data collection and exchange. The compact drying unit received information equipment that ensures remote control of the technological process, its visualization, and, if necessary, remote interference with the operation of the system. The compact drying unit operates taking into account the basic patterns of external and internal mass transfer of moisture in capillary-porous colloidal bodies. The installation implements a multi-level control of technological parameters of the processed raw materials [8]. The practice of developing the IIoT concept is positive. Already now, the economic effect is obvious and allows to make plans of improving our production line. We are planning to build a self-optimizing commodity turnover chain from enterprises supplying fish raw materials to companies - final consumers of fish products. Thus, transition to the principles of lifecycle information support (CALS-technology / Continuous Acquisition and Lifecycle Support) of fishery products and creation of a virtual enterprise on the basis of the production hall will be carried out. Since most of the information is transmitted through open communication channels, digital systems are associated with risk factors for the security of the data processed in them. Therefore, our project pays special attention to information security issues. To protect the big data (BIG DATA) [7] transmitted within the information system via the Internet, SSL (Secure Socket Layer) data transfer protocol is used to connect to the automation system server through the user authentication, Figure 5.

Figure 4. The structural scheme of the information system.
4. **Intensification of fish dehydration processes due to recovery of processing object's moisture conductivity properties**

The physical essence of the dehydration processes consists of following. On the curves of the kinetics of fish dehydration there are critical points $K_1$ and $K_2$ [8], figure 6.

The critical point $K_1$ characterizes the ending of moisture removing that is hold on fish surface by surface tense forces and moisture of macro capillaries and osmotically-bound moisture. These types of moisture have the lowest binding energy with the material, that’s why they removed first. Usually the second critical point in the capillary-porous colloidal solids appears by the transition from the removal of micro capillary moisture to adsorption connected one.

During the studying of the radius of micro capillaries in the dehydration process it was established that radius of capillaries may be reduced by 5-7 times as dehydration goes [8]. The smaller the radius means the higher binding energy with material. That’s why by reaching in the point $K_2$ the critical moistness $\omega_{k_2}$ the product hardens and, therefore, the sizes of micro capillaries decrease, especially in the surface layers of the product. In this case, $\tau_{k_2}$ shows the changing of the inner structure of material, its internal properties. This change influences the deceleration of the dehydration process.
5. The energy-efficient method of convective dehydration

The proposed method is designed for convective dehydration processes of drying fish [9, 10]. Dehydration process of the proposed method is intermittent implementation. Dewatering process consists of a continuous phase of the initial and subsequent periods combination consisting of the phases of drying and relaxation. During the relaxation, an exposure to a drying agent for dewatering is provided for a certain time. During relaxation, the supply of electric power to the heating elements is stopped. The rate of circulation of the drying agent is reduced. In the drying installation is supplied with air of lower temperature and higher relative humidity than the drying agent. In drier, conditions are created that constrain external mass transfer and promotes relaxation of moisture, that is, to its redistribution in the thickness of the fish. During the relaxation of the moisture is gradually shifting from the central layers where dehydration has not yet come to the dehydrated surface layers. The appearance of moisture inside the dehydrated surface area leads to putting up and expansion of capillaries. At the next interval change, product moisture re-enters the dehydration process, the high conductive properties throughout its volume.

The comparison of given method of convective dehydration with the classic technology (without relaxation). The electric energy savings in comparison with the classic technology amounted to 15 %. Dehydration kinetics curves of blue whiting's back presented in figure 7. The change of temperature of the heat transfer agent in the drying camera during the process of dehydration presented in figure 8.

![Dehydration kinetics curves of blue whiting's back.](image)

**Figure 7.** Dehydration kinetics curves of blue whiting's back.

Dehydration kinetics curves of blue whiting's back of the classic technology (continuous dehydration) and the technology with relaxation usage almost coincide. The dehydration rate with relaxation regime usage is comparable to the rate of the classic technology. Actuating mechanism of the drying installation function in a more sparing regime when using the new technology, thereby the service life of drying equipment increases.

A visual comparison of end product (blue whiting's dried back) produced by the classic technology and by the energy-efficient technologic regimes of fish dehydration (using the relaxation of fish' tissues) is done in figure 9. While using the energy-efficient dehydration technology, the fact of fish' tissues deformation reduces significantly, which causes the better appearance of the end product.
Figure 8. The change of temperature of the heat transfer agent in the drying camera during the process of dehydration.

Figure 9. End product (blue whiting's dried back) produced by the classic technology and end product (blue whiting's dried back) produced by the energy-efficient technologic regimes of fish dehydration (using the relaxation of fish' tissues).

6. Conclusions
Energy efficient convective dewatering method implemented on a drying unit allows:
- reducing electric energy costs in production of smoked production by 10-15 % without increasing the duration of drying process in comparison with the classic technology;
- increasing the resource of smoking-and-drying installations due to more rational heat transfer agent usage;
- raising the quality of the released production (it's appearance) due to reduction of the fact of deformation in fish' tissues as a result of using the relaxation regime (creating the conditions of redistribution of moisture in tissues of fish).

The proposed method of dewatering reduces the cost of electricity in the production of dried products, extends the life of smoking and drying facilities at the expense of more efficient use of coolant, and improve product quality by reducing the effects of deformation in fish tissues as a result of relaxation.

Acknowledgements
The project has been completed within the State Target of the Ministry of Education and Science of the Russian Federation, project no. 15.11460.2017/8.9.

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