Applied Aspects of Using OSTIS Technology in Information Support of Digitalisation of Water Use Processes of Dairy Processing Enterprises

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***Abstract*—The conceptual approaches of digitalisation of manufactures based on the e-Manufacturing ideology are evaluated, which are proposed to be used for modelling the processes of water use of milk processing enterprises; the organisational and technological processes of formation of pollutants in their wastewater are analysed. In IDEF0 methodology functional modelling of water use of such productions is carried out, that allowed to reveal complexity and multidirectionality of interrelations of parameters and to justify the use of OSTIS technology for tasks of formation of intellectual information and reference system. On the example of a biological pond as a node of wastewater treatment, an element of the proposed approach of practical implementation of OSTIS-solutions in the segments of digital modelling of the dairy industry and environmental management is implemented.**

***Keywords*—Digitalisation, water management, milk processing, information and reference system**

I. Introduction

The term Digitale Fabrik (digital factory) is used to describe production in the context of informatisation, but today the essence of Digitale Fabrik is more often expressed by the term e-Manufacturing. At the heart of the idea of e-Manufacturing is the continuous application of digital models in the design and operation of production systems. Not only the products themselves are modelled, but also production equipment, material flows, as well as production and logistics processes, taking ergonomics and human factors into account. The goal of e-Manufacturing is to achieve such a level of object and process modelling that the real manufacturing process starts only after all its elements have been studied and optimised with the help of models [1].

Digital manufacturing is one of the components of product lifecycle management (PLM) technology, its main task is to improve complex manufacturing processes. A set of digital manufacturing solutions belongs to the class of MRM-systems (Manufacturing Process Management) [2].

If in CAD/CAM/CAE-systems in most cases the application of a particular software tool is associated with obtaining a digital layout of the product and the distribution of roles is clearly deterministic by the content of the work performed (surface designer, layout designer, solid geometry designer, etc.), in MRM-systems this dependence is much more flexible [3]. This is due to the fact that technological processes in different industries can differ significantly, even enterprises of the same industry can have different technological processes. Such operations include the functioning of complexes ensuring the fulfilment of environmental requirements, including the removal (treatment, discharge) of industrial wastewater (WW) [4], [5].

This problem is especially acute for enterprises of milk processing industry.

II. Technological problems of formation and treatment of wastewater of milk processing enterprises

Contaminated wastewater of milk processing plants is a product formed after washing of equipment, technological piping system, transport tanks of different volumes, including road and railway tanks, flasks and other containers [6], [7]. Also the sources of pollutants formation include effluents after cleaning of production facilities, washing of panels and floors. The amount of polluted wastewater is 20% — 50% of the total volume of water use. Wastewaters of milk processing enterprises belong to the category of highly concentrated organic pollutants: they contain significant concentrations of organic pollutants (fat, protein, lactose), polluted also with inorganic compounds (including acids and alkalis) and synthetic surface active substances (detergents). Their composition and concentration of pollutants depend on the profile and productivity of enterprises [7], [8].

Analysis of literature sources [4]–[8] has shown that there is an intensive search for rational and highly efficient methods and technologies of wastewater treatment for food industry enterprises (including dairy industry). The most common solution in this area is the combination of classical treatment methods with new methods [8], while an adequate choice of equipment for a particular enterprise is impossible without a high-quality design task and the preparation of appropriate models (first of all, water technological passport), including those based on digital technologies [9].

III. Problem formulation for an intelligent information and reference system water use by dairy processing enterprises

To solve the problem, we initially perform functional modelling in IDEF0 methodology (Fig. III).

The following categories of parameters (according to IDEF0 terminology) are selected on the basis of technological analysis:

- **input factors**
  - coming from measuring instruments in operational mode:
    * actual flow rate of process water (PW):;
    * about 2-3 process water quality indicators (e.g., pH, electrical conductivity);
    * actual wastewater flow rate;
    * about 3-5 quality indicators of WW: pH, temperature, redox potential (ORP), chemical oxygen demand (COD), electrical conductivity;
    * information on equipment status (based on the production scheme and operating SCADA).
  - measurements of water quality parameters from the laboratory:
    * information on PW quality;
    * information on WW quality.
  - from expert technologists and expert technicians:
    * information on the planned demand for PW per shift;
    * information on the planned demand for ingredients per shift;
    * information on the state of technological equipment.
- **control factors**: requirements for the quality of PW, characteristics of the equipment (under which it operates according to its passport parameters), requirements for technological processes (under which the requirements for their regulatory flow are met), regulatory requirements for the quality of wastewater, cost of resources;
- **mechanisms**: electrical equipment that ensures the operation of the information system as a whole;
- **results**:
  - dynamic balance of water use (based on planned shift production tasks, as well as with the function of calculating financial costs for the period from the beginning of the shift to the current point in time - potentially a forecast is also necessary based on the current state, for example, until the end of the shift);
  - operational forecast of the quality of WW (based on planned shift tasks, as well as with a forecast correction function based on real indicators of production and quality of PW and WW at the current time (with various forecast projections);
  - dynamic recommendations for organizational, technical and technological actions in order to reduce financial costs for water use (based on the current situation and forecast);
  - dynamic costs for minimizing waste pollution (based on the current situation and forecast).

Performing a decomposition of the first level diagram (see Fig. 1) allows you to detail the tasks of digital modeling (Fig. III).

Analysis of the diagram of the first level of decomposition (see Fig. III):

- here the key will be the multi-level decomposition of the block "Systematization of data on water disposal parameters", it will include production subsystems and units that use "process water", polluting it and transforming it into "waste water" - with the main module "Intelligent information and reference system" (IIRS), which will analyze the situation and "consult" process and technical specialists: what operating modes they should choose initially, how to relate to the state of this or that equipment (the flow of production processes), what variants of the assortment task will lead to what resource costs and environmental risks, regarding the resource cost of a specific assortment task, regarding the acceptability of the functioning of a specific unit or the use of an ingredient, etc. (based on a retrospective production analysis);
- at the same time, the "Intelligent Information and Reference System" must, of course, work with the integrating technology support block "Analysis and forecasting of the efficiency of use of water resources of an enterprise."

The "intelligent information and reference system", in fact, should become an adaptive (interactive) technological regulation for water use of an enterprise, largely ensuring the interoperability of the entire system as a whole, with potential transformation along the chain: "decision support system – automated process control system for water use — digital MES (MIS, LIMS, EMI) resources — ERP."

Then the intelligent information and reference system for supporting specialists of milk processing enterprises in the water use segment is a software product (SP) intended for storage in a structured electronic form and prompt provision to other SPs and specialists of various technological information accumulated both in basic regulatory documents (BC ,SS R, BAT) and in specially created databases and knowledge. IISS will make it possible to create a unified information space of technological knowledge for prompt consultation on issues of interest to specialized specialists (managers, chief engineers, WW technologists, instrumentation and control engineers, designers) using data from regulatory documents and advanced solutions obtained, for example,

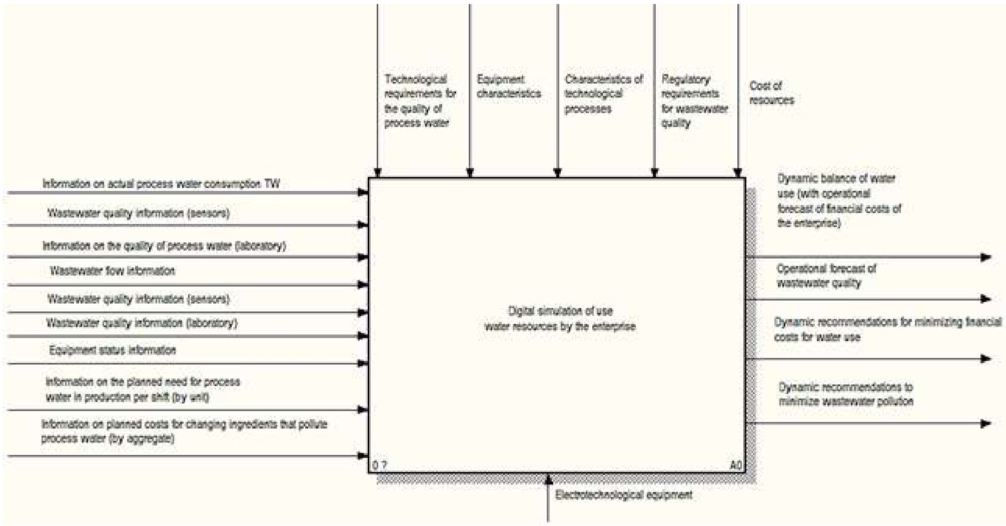

Figure 1. Context diagram for modeling water use of a milk processing plant

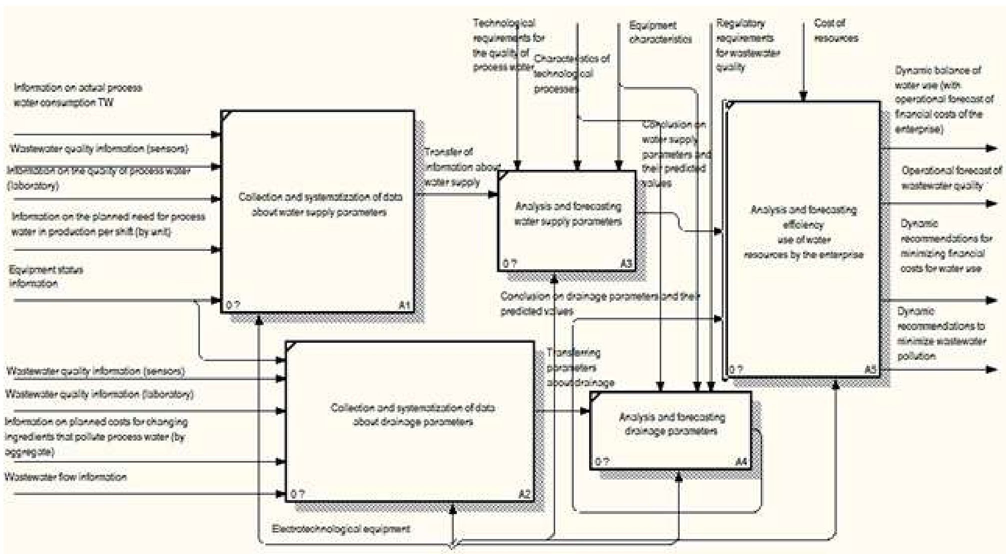

Figure 2. First level of context diagram decomposition

based on benchmarking and expert opinions.

Main planned products:

- software (SP), which can be used by all enterprises, including holding companies;
- educational and methodological materials for continuous improvement of qualifications and retraining of specialists in the field of digital technologies using the created product.

At the same time, it should be noted that water use processes, including the functioning of local treatment facilities, are characterized by nonlinearity, nonstationarity, multifactorial, multiprocess nature, constant changes in the structure of internal relationships, the presence of significant hidden mutual influences between technological parameters, the use of separately functioning ones when solving a single industrial problems of information systems (for example, 5-6 industrial SCADA) [4]–[9].

Accordingly, the proposed (reasonable) transformation ("intelligent decision support system – automated process control system for water use — digital MES (MIS, LIMS, EMI) resources — ERP") requires a specialized methodological apparatus of a new generation.

Such solutions include OSTIS Technology [10]. New generation intelligent computer systems developed on its basis are called OSTIS systems. The OSTIS Technology is based on a universal method of semantic representation (coding) of information in the memory of intelligent computer systems, called the SC code. SC code texts (sc-texts, sc-constructions) are unified semantic networks with a basic set-theoretic interpretation. Elements of such semantic networks are called sc-elements (sc-nodes and sc-connectors, which, in turn, depending on their orientation, can be sc-arcs or sc-edges). The universality and unification of the SC code makes it possible to describe on its basis any type of knowledge and any methods for solving problems, which, in turn, greatly simplifies their integration both within one system and within a group of such systems.

The basis of the knowledge base developed using the OSTIS Technology is a hierarchical system of semantic models of subject areas and ontologies, among which stands out the universal Core of semantic models of knowledge bases and the methodology for developing semantic models of knowledge bases, ensuring semantic compatibility of the developed knowledge bases [10]. The basis of the OSTIS -system problem solver is a set of agents that interact exclusively through the specification of the information processes they perform in semantic memory (sc-agents). All of these principles together make it possible to ensure semantic compatibility and simplify the integration of both various components of computer systems and such systems themselves. Within the framework of the OSTIS Technology, several universal options for visualizing SC code structures are proposed. Within the framework of this work, examples will be used in SCg-code - a graphical version of visualization of SC-code constructions and SCn-code — a structured hypertext version of visualization of SC-code constructions.

IV. Practical implementation of IIRS based on OSTIS Technology (using the example of a unit for post-treatment of wastewater from dairies — biological ponds)

In biological ponds for post-treatment, contaminants are removed by aerobic microorganisms, which enter them with purified liquid from secondary settling tanks (after aeration tanks and/or biological filters), and also develop directly in the ponds themselves. Higher aquatic vegetation (algae) plays an important role. The rate of the biochemical process of extraction and oxidation of organic pollutants in ponds with natural aeration is limited by the low rates of atmospheric reaeration and mass transfer processes. In ponds with artificial aeration, as a result of supplying the required amount of air with intensive mixing of the liquid, the speed of the biochemical process is 5–7 times greater.

The feasibility of their use at dairy processing enterprises is largely due to the fact that many harmful organic substances are not completely oxidized at biological wastewater treatment facilities; they remain stable in water for a long time and can have a toxic effect on living organisms. In addition, intensive technologies have significant disadvantages: high energy costs for aeration and problems associated with the processing and disposal of large amounts of excess sludge formed, its swelling and foaming.

The characteristics of the life cycles of biological ponds fully include: nonlinearity, nonstationarity, multifactoriality, multiprocessivity, constant changes in the structure of internal relationships, the presence of significant hidden mutual influences between technological parameters. Accordingly, it is justified to apply OSTIS Technology to the creation of a knowledge base of their processes with further synthesis of an intelligent information and reference system.

The formation of the IIRS knowledge base was based on the national regulatory document - BS 4.04.02-2019 "Building standards of the Republic of Belarus Sewerage. External networks and structures." Let's consider a fragment of the ontology that describes the concept of "biological pond" and the parameters specified on it in the SCn code [10].

biological pond
⇒ *explanation**:
  [Used for purification and post-treatment of municipal, domestic, industrial and surface wastewater containing organic substances.]
⇒ *subdividing**:
  {• *biopond with artificial aeration*
  • *biopond with natural aeration*
  }
⇒ *parameters**:
  {• *waste water flow*
    ∈ *measurable parameter*
    ⇒ *designation**:
      [Qw]
    ⇒ *measurement unit**:
      1 m^3/day
  }

waste water
:= *explanation**:
  [surface, domestic and industrial waters discharged into sewers]
⇒ *parameters**:
  {• *TBOD*
    ∈ *biochemical indicator*
  • *average monthly temperature in winter*
  • *average monthly temperature in summer*
  }

TBOD
:= [total biological oxygen demand]
⇒ *explanation**:
  [reflects the amount of oxygen required for the biochemical oxidation of organic wastewater contaminants in 20 days]
∈ *measurable parameter*

⇒ *designation**:
  [L]
⇒ *measurement unit**:
  1 mg/l

Consider for an example of using the developed ontology to describe a specific technological task. A biological pond with a flow rate of Q_w = 5640 m^3/day was taken as a technological prototype. Biochemical indicators of the processed WW: biological oxygen demand (TBOD) L_{en} = 18 mg/l; The technological task is to provide a TBOD of treated wastewater L_{ex} = 5 mg/l. At the same time, the average monthly temperature of PW for the summer period is T_w = 22 °C; average monthly temperature for the winter period T_w = 15 °C. The indicated parameters correspond to the use of a biological pond after a fairly well-functioning biological and physico-chemical wastewater treatment of a large milk processing plant.

Figures IV–IV show an example of a problem condition and related parameters, formalized in the SCg-code [10].

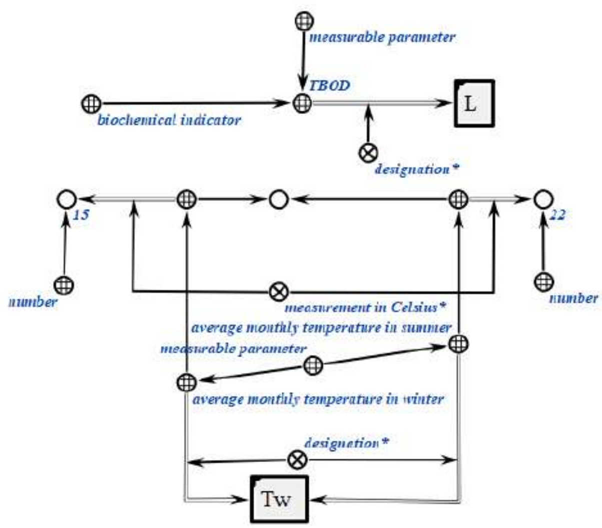

Figure 4. Formulation of the problem conditions (fragment 2)

V. Conclusion

The use of OSTIS Technology and the development of the corresponding ISRS in the analysis and formation of new production knowledge in the water use segment of dairy processing enterprises will allow:

- increase the efficiency and versatility of decision-making, including cases of complex production situations;
- improve administration flexibility, even when expanding technological lines;
- increase the level of qualifications of employees, since the OSTIS Technology represents a knowledge system in natural language and corresponds to modern ideas about the organization of human long-term memory.

Taken together, the creation of such products based on the OSTIS Technology will form an ontological basis for digital modeling of resource use processes (water, electricity, heat, steam, reagents) in dairies.

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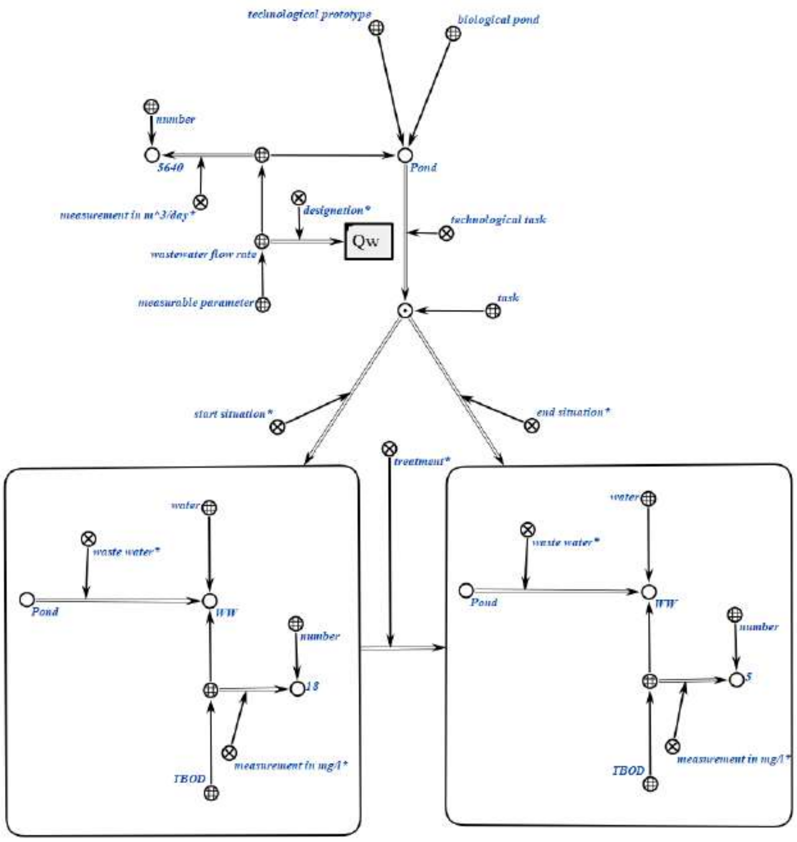

Figure 3. Formulation of the problem conditions (fragment 1)

ПРИКЛАДНЫЕ АСПЕКТЫ ИСПОЛЬЗОВАНИЯ ТЕХНОЛОГИИ OSTIS ПРИ ИНФОРМАЦИОННОМ ОБЕСПЕЧЕНИИ ЦИФРОВИЗАЦИИ ПРОЦЕССОВ ВОДОПОЛЬЗОВАНИЯ МОЛОКОПЕРЕРАБАТЫВАЮЩИХ ПРЕДПРИЯТИЙ

Штепа В. Н., Муслимов Э. Н.

Оценены концептуальные подходы цифровизации производств на основе идеологии e-Manufacturing, которые предложено использовать для моделирования процессов водопользования предприятий по переработке молока, проанализированы организационно-технологические процессы формирования загрязнителей их сточных вод. В методологии IDEF0 выполнено функциональное моделирование водопользования таких производств, что позволило выявить сложность и многонаправленность взаимосвязей параметров и обосновать использование технологии OSTIS для задач формирования интеллектуальной информационно-справочной системы. На примере биологического пруда, как узла очистки сточных вод, реализован элемент предложенного подхода.

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