MATHEMATICAL DESCRIPTION
OF TECHNOLOGICAL PROCESS
FOR PRIMARY FISH PROCESSING

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Abstract. The paper discusses an approach to the question of the possibility of a mathematical description of discrete processes. On the basis of these processes a large class of manufacturing equipment – production lines and systems for the processing of fish was generated. The use of mathematical models in the early stages of the design will improve the efficiency and quality of the produced equipment and reduce the risks and costs during the design work. We propose to describe the processes of fish processing by topological models that are presented in the form of functional graphs. Overall, the proposed approach will develop new design methods of fish processing equipment.

Key words: technological process, operation and kinds of operations of technological process, topological model, functional graphs

Introduction

Presently, technological equipment for the primary processing of fish faces the proper change of equipment generations. This is due to the fact that leading world manufacturers use achievements of science – technical process for increasing quality, effectiveness and competitiveness of their innovative products. Such machinery perfection gives the possibility of creating a new class of technical systems – mechatronic complexes with the intelligent control systems.

Creating such new machinery makes it necessary to develop a new research basis and use of fundamentally new approaches to designing and construction of technological equipment.

Fish processing enterprises need the machinery now which was built on the modular aggregating principle and which gives the possibility of production of various kinds of fish products with the minimum equipment readjustment.

It is impossible now to create a modern fish processing equipment without new methods, and mathematic models describing technological lines and complexes.

The process itself of designing technological line for primary fish processing has always been a process of solving a whole set of interdependent complex tasks, namely:
– creating a technological process of processing fish;
– creating mechanisms and devices for a chosen technological process of fish processing;
– creating automatic control system for a technological line.

The basis of graph theory in primary fish processing

Development of a new technological line is always started with making up a new technological process. Success of solving this problem always predetermines the whole process of designing and quality of new machinery being developed. The price of designing error at this stage is very high. This is the reason why scientifically founded approaches and new research methods which would allow to avoid subjectivity at taking decisions at this stage of work are necessary.

For this reason the use of graph theory methods, linear and dynamic programming is suggested in order to update quality of designing itself and fish processing equipment being developed.

The graph theory may be used for solving a very broad set of tasks, e.g.;
– for defining optimal or rational structure of a technological process and technological system as a whole;
– analysis and synthesis of control systems;
– investigations and calculation of mechanisms and devices dynamics;
– calculation of machines effectiveness and reliability;
– definition of rational equipment layout in production shops.

Mathematical models presented as graphs possess special advantages in comparison to traditional models – clarity which provides convenience when working with them in the process of their construction and investigation.

The graph theory is felxible, and it allows taking into account both direct connections and feedback, evaluating influence of one variable or component upon another one in any point of the system. The more complex is the investigated system the greater are advantages of the graph theory for constructing and analyzing mathematical models of technological process.

After all, the essence of primary fish processing constitutes the process of dismantling primary raw fish into component parts. Thus, technological process of processing fish constitutes directed transformation of conditions and properties of the object being processed. That is for every single fish transformation a characteristic pair of states corresponds: a primary – an initial one x_i and a secondary – an output one x_j.
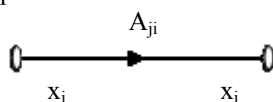
Such single transformation may be described in the following way:
– as algebraic expression

$$x_j = A_{ji}x_i ,$$

where
 A_{ji}　　– operator (coefficient) expressing transformation;
– as a functionally directed graph

$$A_{ji}$$

$$x_i \qquad x_j$$

where
 A_{ji}　　– is an operator (function of a graph are),
 x_i, x_j　– graphs nodes, describing initial and output conditions of raw.

That is technological process of processing fish in the simplest case is the chain of directed transformations – operations forming such sequence of raw conditions in which one intermediate condition is at the same time a primary and secondary one.

Topological models in fish processing

On the whole such technological process constitutes a total sum of operations and conditions of raw and its parts when they are being processed.

When constructing topological models of fish processing, the topological processes operations of technological process and their kinds are important elements.

Any technological process is always composed of some basic and auxiliary operations.

Basic operations are the ones in the result of which the changes of chemical and physics – mechanical properties of fish take place.

Auxiliary operations are the ones where we do not face any changes in the object being transformed. Such operations are usually the ones connected with orientation in space.
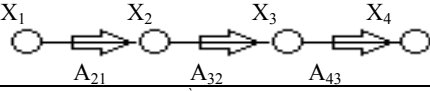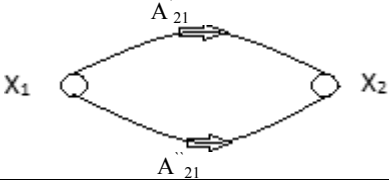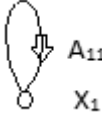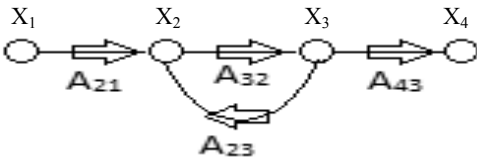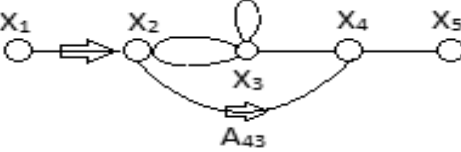
The kinds of operations in the technological process are determined by the way the technological system elements are associated with each other and how they constitute combinations of typical connections.

In real conditions the most characteristic technological and functional connections are determining the transformations flow as parallel, reverse, parallel-bypass and loop connections.

Total sum of such ties between conditions of object transformation constitutes technological topology determining technological structure of the primary fish processing process.

Being presented graphically such structure is described by a functionally directed graph. Such graph constitutes a mathematical model, which always reflects a diagram of realizing a technological process of raw processing by means of mechanization and automation.

Table 1

Presents kinds of technological process operations for primary fish processing

№	Operations name	Kind	Operations denotation
1	segmental		A_{21} ; A_{32} ; A_{43}
2	parallel		A'_{21} ; A''_{21}
3	loop		A_{11}
4	reverse		A_{23}
5	parallel-bypass		A_{43}

The flow of transformation raw in the technological process constitutes a direct way of model graph characterized by a directed object transformation.

For constructing a model of a discrete technological process of the primary fish processing it is necessary and sufficient:

1. to separate a resulting transformation (technological process) into the finished (elementally) operations, every one of which is realized by a corresponding operator (functional device, mechanism);
2. to show graphically all initial objects being processed and operations resulting into a corresponding object transformation;
3. to show graphically position of operations in their relations to the realization of the transportation flow which corresponds to their feed backs in a functional graph.

An example of developing a topological model of a technological process of portioning fish filets is presented in fig.1. Table 2 represents description of operations of a given topological model.
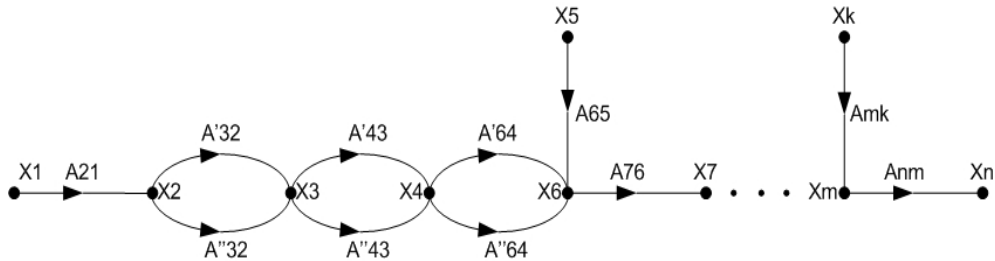
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Figure 1. Topological model of portioning fish filet technological process

Such topological model allows to investigate more thoroughly a filet portioning process, to find out its "drawbacks", to determine directions of a further modernization process, to formulate demands for creating new mechanisms and devices which will carry out operations of a given technological process, to develop requirements for an automated system of a technological line control.

For convenience of the technological process research its characteristics and analysis oriented functional graph of the process may be given algebraically by means of adjacent matrix. The adjacent matrix corresponding to the investigated graph with the nodes member p is the square matrix $M_c = [m_{ij}]$ of the order $p \times p$ with elements:

$$m_{ij} = \begin{cases} 1, \text{ if node } x_i \text{ is arch linked with node } x_j ; \\ 0, \text{ if node } x_i \text{ is not arch linked with node } x_j . \end{cases}$$

When constructing adjacent matrix its lines *i* and *j* are numerated according to numeration of matrix nodes. Functional graph may be also described as resolved by Kramer method, Gauss method or by iterative method.

Table 2
Description of topological model

Denotation	Operation name	Raw condition		Functional parameters	
		initial	final		
A_{21}	Move over in plane XOY	X=0 Y=0 Z=0	X=L1 Y=0 Z=0	Speed of raw shift	m·s⁻¹
				Force necessary for raw shift	H
				Position on plane XOY along a direct line	mm
$A_{32'}$	To shift in plane XOY	X=0 Y=0 Z=0	X=L2 Y=0 Z=0	Speed of shifting raw; Force necessary for shifting raw; Position on plane XOY along a direct line	m/s H mm
$A_{32''}$	Weighing	-	m	Raw mass	kg
$A_{43'}$	To shift in plane XOY	X=0 Y=0 Z=0	X=L3 Y=0 Z=0	Speed of shifting raw	m·s⁻¹

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Denotation	Operation name	Raw condition		Functional parameters	
		initial	final		
$A_{43"}$	To measure (to get raw parameters)	-	Ai, Bi, Hi	Raw dimensions	m
$A_{64'}$	To shift in plane XOY	X=0 Y=0 Z=0	X=L4 Y=0 Z=0	Speed of shifting raw	$m \cdot s^{-1}$
$A_{64"}$	To hold at movement line			Force necessary for holding raw	H
A_{65}	To cut	m=M	m=M1+M2	Force for raw parting	H
				Parting time	s
A_{76}	To shift in plane XOY	X=0 Y=0 Z=0	X=L5 Y=0 Z=0	Speed of shifting raw	m/s
Amk	To cut (to part)	m=M	m=ΣMi	Force for cutting	H
				Parting time	s
Anm	To shift in plane XOY	X=0 Y=0 Z=0	X=Lj Y=0 Z=0	Speed of shifting raw	$m \cdot s^{-1}$

When constructing any mathematical model describing an object or research process there always emerges a question of its adequacy. When checking correctness of technological process description some properties of adjacent matrix are used.

1. Adjacent matrix contains unities (or other positive members other than zero) along the main diagonal and only when graph has loops. When the main matrix diagonal possesses only zeroes it bears evidence to the absence of loops.
2. Raising adjacent matrix to power determines length of all ways in graph.
3. Relation of adjacent matrix elements member located under the main diagonal to the elements member above the main diagonal characterizes the graph symmetry.
4. Matrix elements located above the main diagonal reflect arches of straight forward direction.
5. Matrix elements located under the main diagonal reflect arches of reverse direction.

After the topological model of technological process is constructed and correctness of its construction is checked a possibility of its investigation and analysis appears there.

The model investigation is carried out with the purpose of determining places of technological process which are liable to changes in order to make the whole process better.

Conclusions

Comparative analysis of the model with already existing technological process allows to determinate how much the process being developed is better or worse. Such kind of analysis is offered for carrying out the methods of linear or dynamic programming. Construction of topological models of technological processes of the primary fish processing allows to make the basis for solving many design tasks being solved at creating new machinery. With their aid the mechatronic complex for the primary fish processing may be manufactured as well as automatic manufacture control systems and computer aided devices for designing new machinery.

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MATEMATYCZNY OPIS PROCESU TECHNOLOGICZNEGO OBRÓBKI WSTĘPNEJ RYB

Streszczenie. W pracy omówiono podejście do kwestii możliwości matematycznego opisu dyskret-nych procesów. Na podstawie tych procesów tworzona jest szeroka gama urządzeń przemysłowych - linie produkcyjne i systemy do przetwarzania ryb. Wykorzystanie modeli matematycznych we wcze-snych etapach tworzenia może poprawić wydajność i jakość wytwarzanych maszyn i zmniejszenia ryzyka oraz koszty podczas prac projektowych. Zaproponowano opis procesów przetwórstwa ryb z wykorzystaniem modeli topologicznych, które są prezentowane w postaci wykresów funkcjonal-nych. Ogólnie rzecz biorąc, proponowane podejście umożliwi opracowanie nowych metod projekto-wania urządzeń przetwórstwa rybnego.

Słowa kluczowe: proces technologiczny, rodzaje operacji technologicznych, model topologiczny, graf funkcjonalny

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