

About the graphical modeling of production systems in metallurgy

S M Kulakov, A I Musatova, V N Kadykov, V I Bazaykin and A G Nikitin

Siberian State Industrial University, 42 Kirova street, Novokuznetsk, 654007, Russia

E-mail: kulakov-ais@mail.ru

Abstract. To create a regulatory basis for technical and economic indicators in situational planning and forecasting the operation of the production system, it is offered to use a set of interrelated graphic and mathematical models. Mathematical models include: formula-algorithmic normative models of time characteristics of production processes; table models of situational standards of process time characteristics by product types and mathematical normative models of situational technical and economic indicators of production systems. The main attention in this article is given to the task of constructing graphic models that visually reflect the spatial organization of material flows, the operational structure of production processes and the decomposition of production operations. The necessary stages for construction of a graphic model of spatial organization of material flows are determined. The technique for constructing a graphic model of production operations is given, which includes the decomposition of complex operations into elements and microelements. Each graphic model is accompanied by the description, purpose, justification and specific examples.

1. Introduction

For the adoption of rational management decisions in the conditions of operating automated production systems, regulatory models of their functioning are needed that can be presented in the form of a set of interrelated graphical and mathematical models that includes the following components:

1. Graphic models of production systems functioning, including the models of spatial organization of material flows, operational structure of production processes, decomposition models of production operations.

2. Structured multifactorial mathematical models of production systems functioning, to which the following are assigned:

- formula-algorithmic normative models of production process time characteristics (including the duration of technological, transport, labour, control operations, cycles);
- table models of situational standards of process time characteristics of by product types (assortment), for example [1, 2].
- mathematical models of technological processes, for example [3].

3. Graphical aggregate-temporal normative models of production systems functioning (complex graphs reflecting the sequence and parallel operation of equipment, labour actions of personnel, organization of material flows) [2].

4. Mathematical normative models of situational technical and economic indicators of production systems (PS), including: assessment of the PS performance per unit of time, taking into account the



assortment, the model of the PS work time fund, the standard production volumes, profit forecasts, profitability, etc., and also table models of normative technical and economic indicators.

In this paper, the main attention is paid to the procedure of constructing graphic models that are necessary for the development of normative mathematical models used for planning and forecasting the technical and economic indicators of PS operation.

There are known graphic models of different purposes, containing a set of interrelated elements [5 - 8]. The graphic model of the spatial organization of PS material flows is a conditionally graphic representation of the flow of materials (raw materials, semi-finished products, products), combined with a schematic layout of the equipment (units, machines, vehicles) of the specific PS (technological complex, shop, divisions, technological line).

The graphical model presented in the form of a scheme of material flows organization is necessary for the construction and rationale of a rational production structure with a different specification degree of the system (enterprise, subdivisions, units of subdivision) at all stages of its life cycle.

2. Stages of the graphic model construction

The construction of the graphic model includes the following steps:

a) preparation of background information:

- determination of the boundaries of the considered (investigated, simulated) PS; study of the PS plan (drawing) with the specification of equipment and technological instructions;
- PS decomposition into specialized divisions (departments, lines, sections, sites), taking into account their role in the production process, types and amount of equipment used (the example is given in the form of table 1);
- analysis of the range of products (planned products), indicating the share of each type for a certain period of time (year, quarter or month); study of technological routes (maps) for manufacturing all types of products by aggregates.

Table 1. The list and characteristics of PS production sections (fragment).

Name of sections	Purposes of sections	Equipment of sections	
		name	quantity
1. Warehouse of workpieces	Receiving, unloading, storage, control, preparation and supply of blanks for heating	1. Electric overhead type crane	2
		2. Transfer trolley	2
		3. Racks for inspection and stripping blanks	4
		4. Table	2
2. Heating section	Heating of workpieces to the rolling temperature	1. Continuous furnace with walking beams	3
		2. Loading grate	3
		3. Furnace table	1
.....
8. Finished goods warehouse

b) development of the main components of the organization scheme of PS material flows:

- construction of the enlarged diagram of interconnections of sections and PS units;
- performance of visual (monitoring) observations over the flow of materials at specific facilities (sections, PS units);
- verbal description of structural features and purpose of the main, auxiliary and transport equipment of PS and technological routes for all types of products;
- formation of the material flow scheme [4, 9] by integrating the technological routes by units taking into account the assortment (examples are shown in figures 1, 2);

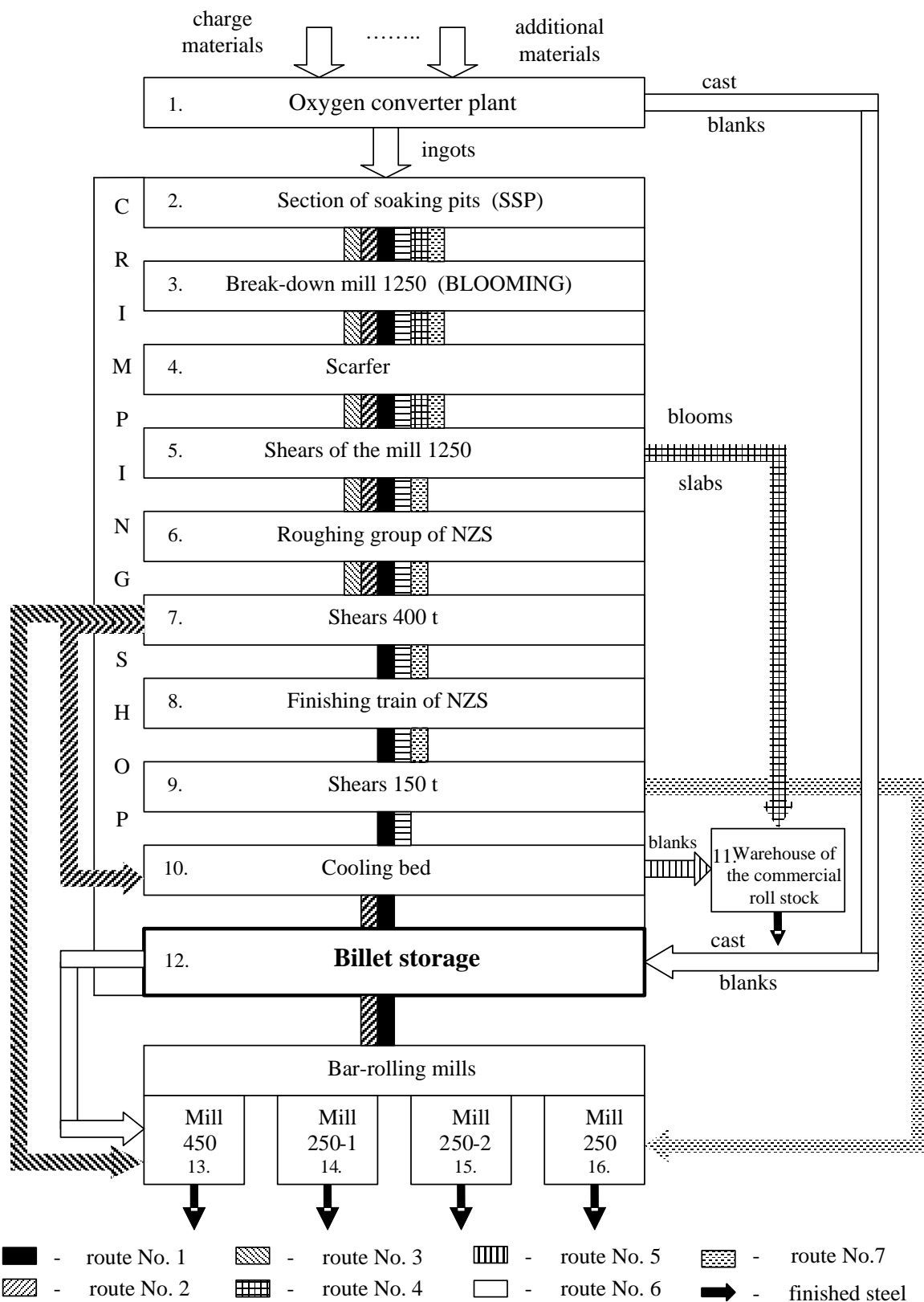


Figure 1. Integrated scheme of technological routes in rolling production.

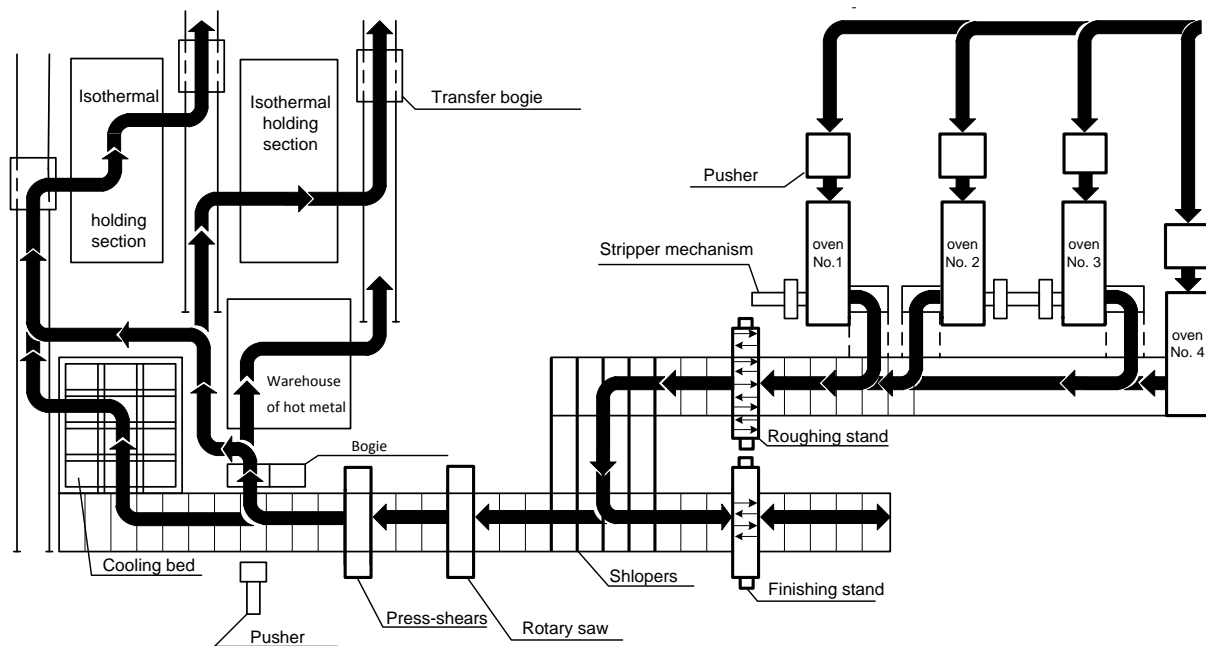


Figure 2. Scheme of the organization of material flows in the rolling shop (fragment).

3. Graphical model of the operational structure processes of PS

The graphical model of processes is a schematic representation of consecutive and parallel production operations and their connections on the basis of technological production routes and the model of organization of material flows. In accordance with the theory of graphs, this model can be called a directional production graph. For its construction, it is necessary to perform passive experiments (observations) in advance in order to study and represent the operations of the production process by sections and system units in the form of a tabular classification model of a set of operations, the example is presented in table 2.


Table 2. Classification of production operations by PS sections (fragment).


Index of operation ^a	The name of the operation	Type of the equipment	Borders of operation (moment)	Unit flow	Character of operation ^b
<i>M</i>	Stripping of the wire end	Wire pointer	The moment of turning on the machine – The moment of turning it off	Wire bundle	<i>A</i>
<i>Ma</i>	Preparation of a new coil for drawing	–	Starting time of restringing - The moment of its end	Wire	<i>A</i>
.....
<i>M</i>	Drawing	Drawing station	The moment of turning on the machine – The moment of turning it off	Coiled wire	<i>T</i>


^a*M* – mechanical, *M-Ma* – mechanical-manual, *Ma* – manual


^b*A* – auxiliary, *T* – technological, *TP* – transportation, *K* – control

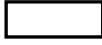
In the schematic representation of the operational graphic model, the following symbols of production operations are proposed:

 – *the main technological operation*, which is the main part of the production process, carried out in the leading unit, associated with the transformation of the raw materials (raw materials) into a semi-product (or product) with the required properties and characteristics (chemical composition, mechanical parameters, internal structure, shape, etc.). For example: *rolling a workpiece* in the work stand to produce a roll of a given cross-sectional shape; *melting of charge materials* in the furnace (converter) for the production of cast iron, steel or other alloy.

 – *auxiliary technological operation*, preceding or following the main operation. For example, preheating of billets in the furnace before rolling and operations following rolling: *cooling, cutting, baling*; preparation of charge materials for steel smelting in the converter and subsequent operations: *out-of-furnace processing of steel* (purging of argon steel in a special installation), *casting of steel* in a continuous casting machine for obtaining blanks, *slow cooling in chambers*.

 – *transport operation* associated with the movement of raw materials (materials, semi-finished products, packages, packs) inside the system, in particular: *unloading, loading, feeding, transfer* by electric bridge crane, conveyor, shleper, roller conveyor, transfer devices.

 – *control operation*, which includes an assessment of the characteristics of materials, semi-finished products, finished products and their verification for compliance with standards.

 – *element of the operation (refueling, preparation, installation, etc.)*.

Each symbol contains: the name of the operation, reflecting the process (heating, rolling, smelting), type of the material (billet, ingot, cast iron, alloy), the name of the equipment used (methodic furnace with walking beams, continuous steel casting machine). For the transport operation the symbol indicates: the type of operation, the equipment used, the transportation object, the departure and destination points.

Solving problems of rating characteristics (indicators) of the production process requires a multilevel graphic description of each operation, based on its decomposition into elements and trace elements.

4. Decomposition graphical model of production operations

PS is a symbolic representation of the components of operations and their relationships. The decomposition makes it possible to investigate and describe the internal structure of operations, that is, to define and classify its elements and microelements, the sequence and parallelness of their fulfillment, to establish spatio-temporal *fixation points* corresponding to the moments of the beginning and ending of each element and microelement (actions, movements) and visualize the whole process as a whole. Examples of graphical models (the operational organization of PS production processes) in combination with the decomposition of operations are presented fragmentarily in figures 3 - 5, [1].

In the decomposition depiction of operations, additional symbols can be included that reflect the nature of their execution (the actions of the mechanisms, the workers – executors), figure 5. A table model is compiled that characterizes the elements and microelements of the PS operations, which in its form corresponds to table 2.

It should be noted that the decomposition of the operation is carried out on the basis of detailed timing (monitoring) observations with the obligatory fixation of the interaction of three components: the operation of the equipment (including individual mechanisms), the processing of materials (flow), the actions of the working personnel. For example, the study of the stroke of the break-down mill was carried out using the decomposition of technological operations of the rolling process.

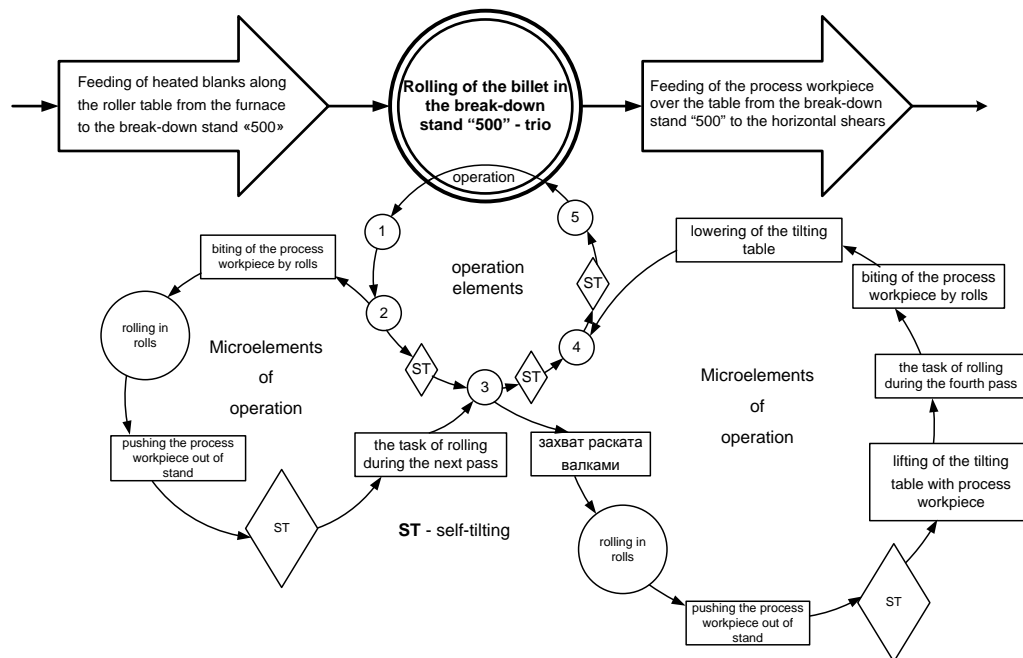


Figure 3. Decomposition of the production operation in the rolling shop.

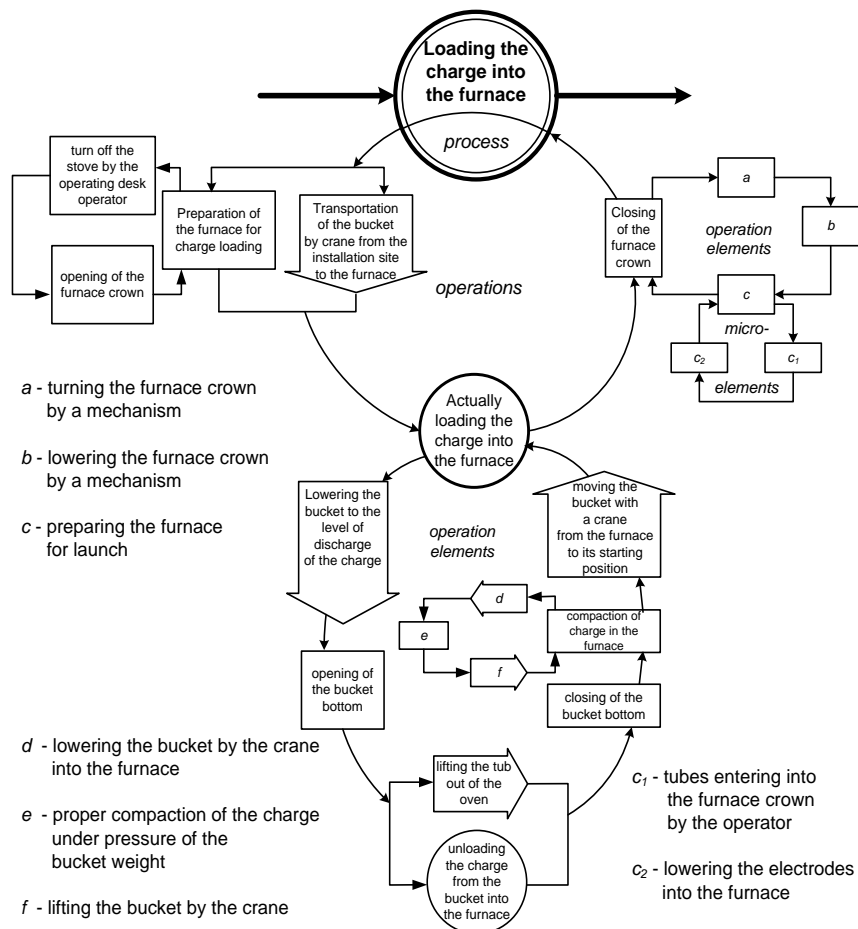


Figure 4. Decomposition of the process of charge loading into the arc steelmaking furnace.

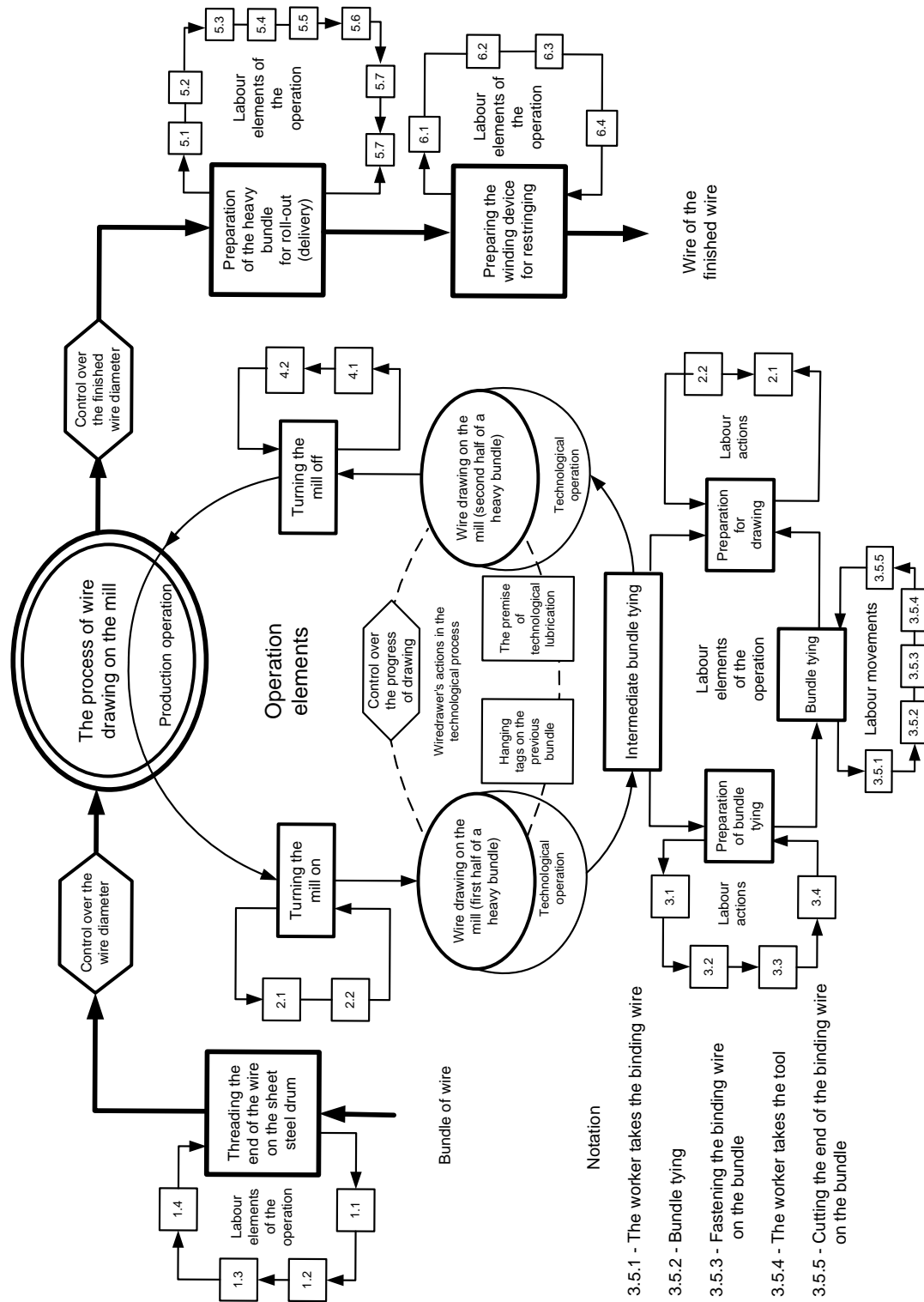


Figure 5. Decomposition of production operations of a drawing mill.

Fixation points were established in advance to visually determine the moments of beginning and end of the elements and microelements of operations. The two-variant definition of the *fixation points* of the elements of operations is presented in table 3.

Based on the decomposition (figure 6) and the selected methods for estimating the duration of the elements of operations, a model for the functioning of crimping stand was formed, then the regulatory durations of operations were determined, and the algorithm and calculations are given in [3].

Table 3. Determination of the fixation points of the operation elements.

For a unit of material flow			For a unit of equipment		
Name of operation elements	Fixation points of operation elements (moments)		Name of operation elements	Fixation points of operation elements (moments)	
	initial	final		initial	final
Initial pause	Stopping of the ingot before the stand	Beginning of the ingot biting by rolls	Stopping the ingot in before the stand. The time to prepare the work stand for rolling the ingot	Beginning of lifting of the upper stand roll	Setting the gap between the rollers for the first feed of the ingot (pass 1)
Deformation time of the ingot or rolling	Biting the front end of the ingot (rolling) with rolls	Exit of the rear end of the rolling from the rolls	Machine time (skipping)	The beginning of the acceleration of the rolls' rotation during ingot capture (rolling)	End of deceleration of rolls after the release of the rolling stock
Pause between passes	Exit of the rear end of the rolling from the rolls	Biting the rear end of the roll with rolls after reverse	The preparation time the mechanisms for the next pass (the establishment of a given gap between the rollers)	Start slowing engine speed after the release of the rolling	The beginning of acceleration of rolls revolutions at capture of roll
The time for the tilting of the roll before the next pass	Contacting the roll with tilting finger	The end of the roll installation on the table	Running time of the tilting device	Beginning of the tilting device lifting from initial position	Start of the rotation of the working table rollers

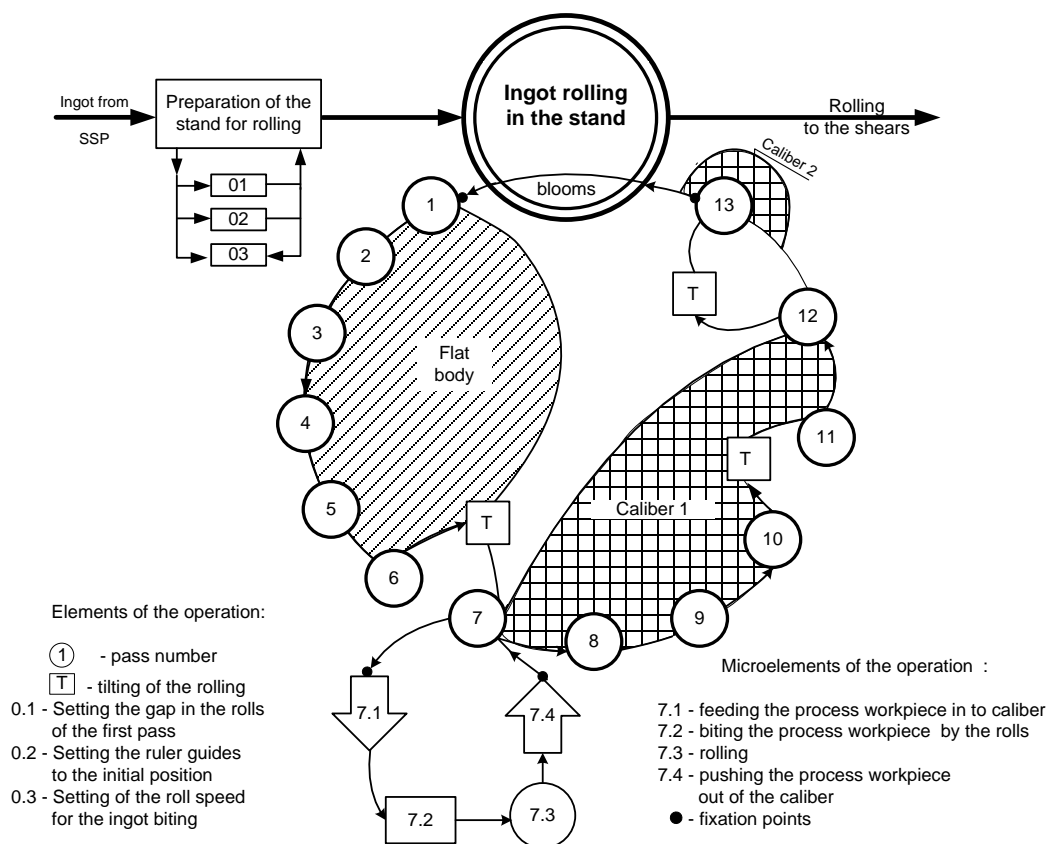


Figure 6. Decomposition scheme of the ingot rolling process.

5. Conclusion

In order to create a regulatory basis for technical and economic indicators for situational planning and forecasting the PS work, it was offered to use a set of interrelated graphic and mathematical models. In the paper the technique of formation of graphic models is described. It should be noted that the normative multivariant mathematical models for the PS functioning developed by the authors are applied in the management systems of objects of metallurgical enterprises and are published in papers [1 - 3, etc.]. Graphic models, which are the basis for creating the corresponding PS mathematical models, are not sufficiently described. Therefore, in this paper a step-by-step procedure for constructing graphic models, illustrated by concrete examples, is considered separately.

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