

Determination of system connections of hot rolled steel sheet manufacturing process

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Abstract. System analysis is used to state links between input and output parameters of any technical system taking into consideration flows of material, energy, and information. This approach makes it possible to find effective ways for improvement of technical system parameters. The paper presents results of system analysis application for multioperational technological process steel sheet of hot rolling. Structural scheme of metal sheet hot rolling process is presented based on principles of system analysis. Hot rolling technological operations such as workpiece heating, hot rolling, cooling, and coiling are presented as subsystems. Due to the obtained schemes metal sheet parameters are stated which have to be controlled during each technological operation of hot rolling technological process. The obtained results can be used as the basics for mathematical modeling of steel sheet hot rolling operation in order to get the final product with the required set of properties.

1 Introduction

It is known, that system analysis is the group of scientific methods for cognition to establish structural connections between separate elements of the analyzed system [1-3]. Using of system analysis is effective for complicated problems solving when decision-making process depends on many factors under uncertainty conditions [5-7]. The simplest and abstract level for system description is the “black box” model. The input parameters are presented a set of resources for system and its limitations when output parameters describe the results of system operation. It is implied that there is no information about the internal content of the system. The description of system using combination of necessary and sufficient relations between elements prerequisite for ensuring system properties is defined as the system structural model. System analysis is the way to establish links between different parts of any technical object. In the process of system analysis the abstract conceptual model of the technical system is created. It can be presented as the definite structural and logical scheme. It represents unambiguous relations between elements of the technical system and can be used as the basics for description of the technical system by mathematical models without conducting experiments [8, 9].

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At present time there exist many definitions of the concept “technical system” depending on the contest and investigation area where it is used. In general, technical system is the constructive entity of interacted and connected objects which is necessary for the targeted actions in order to get the desired result during its functioning. Technological manufacturing process is considered to be a kind of technical systems. Technological process can be presented as a chain of technological operations based on matter transformations.

The desired result of every technological process is to get the definite level of the manufactured product quality in order to ensure its customer properties [10, 11]. Dependability of technological processes can be characterized by high level of product quality level during long period of time. During each technological operation the input material properties change consequently under the external impacts of different physical nature. The reason to use system analysis of technological process is the complexity of material response to the variability of operational manufacturing parameters.

The aim of this study is to use system analysis for steel sheet hot rolling process in order to determine technological connections between different operations [12]. The urgency of this investigation is caused by numerous quantities of factors, both external and internal, which affect on hot rolled steel sheet quality and properties. That is why to establish system connection between technological parameters of different operations is the required condition for the effective quality management. This approach can be estimated as the basics for increasing the dependability of such kinds of technical systems.

2 Methods

Effectiveness of each technical system is defined by its dependability, efficiency, and safety (Fig. 1).

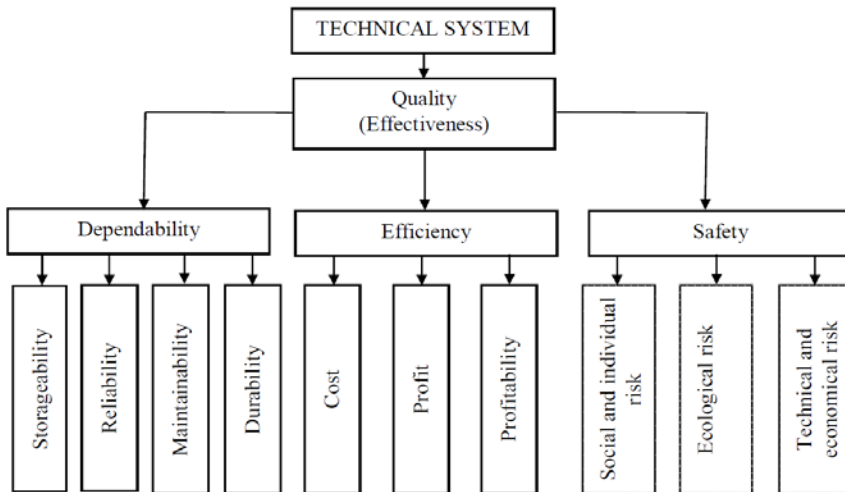


Fig. 1. Technical system effectiveness.

One of the basic and important sign of any technical system is its dependability [13]. It is the characteristics of the system to save its structural organization even after destruction of any separate element by its substitution or overlapping.

In order to manufacture the product with desired quality level it is necessary to find the interaction between technological parameters and response of the material to their change.

The description of any technological operation mathematically is a rather complicated problem. The complexity of interactions between technological operations and their unpredictable effect on product properties need the application of new approaches which can give the accurate information about the dependence of product properties on change of technological parameters.

As a rule, for the design of metal ware manufacturing processes the interactions and interdependences between preceding and subsequent operations are not taken into consideration. It complicates the decision-making process especially in the manufacturing conditions. System analysis makes it possible to analyze the technological process as a complicated technical system which at the same time is the subsystem in the frame of the whole industrial enterprise.

3 Results and Discussion

Steel sheet hot rolling process was chosen as the object for investigation. Hot rolling process consists from operations which are realized consequently. Application of system analysis to the steel sheet hot rolling process makes it possible to present both its input and output parameters, and determine energy and information flows which are necessary to get steel sheet with the desired level of properties (Fig. 2).

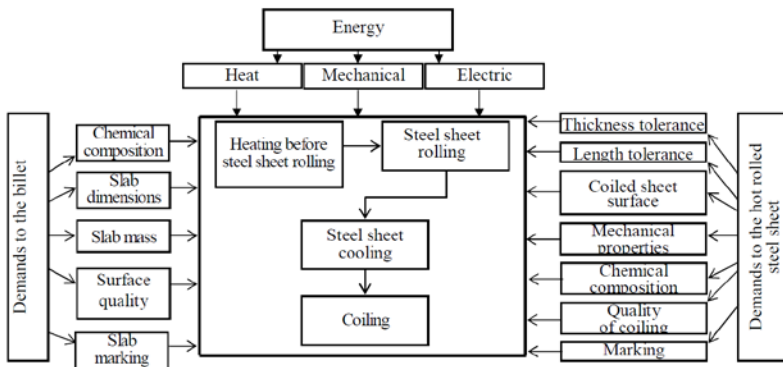


Fig. 2. Conditional scheme of steel sheet hot rolling process.

Both characteristics of slab and steel chemical composition which are regulated by normative and technological documentation are the input parameters of the process. Customer demands to the end product are considered to be the output parameters. It is necessary to note that hot rolled steel sheet can be used as the semi-product for further cold rolling process. From this point of view, properties of hot rolled steel sheet as the output parameters of the process have to be similar to the technological demands of cold rolling process. In other words cold rolling process can be estimated as the customer of hot rolling process. Material properties transformation at hot rolling occurs under energy exposure. Due to system analysis it is necessary to ensure the end-to-end flow of heat, mechanical, and electric kinds of energy through all elements of this system in order to get the hot rolled steel sheet. Flows of information are formed by controlled parameters of the process and demands to properties of the semi-product and final hot rolled steel sheet. Besides, demands to both ecological and industrial safety should be taken into consideration as the information flow.

On the basis of system analysis every technological process is estimated as the entire set of elements with assemble of connections and relations between them. Hot rolling technological process is the chain of consecutive operations of input workpiece (slab)

transformation into steel sheet with given properties. During system analysis it is necessary to divide the whole hot rolled process into separate operations. Each technological operation is considered to be the subsystem in the frame of the technological process. Hence, it is necessary to apply system analysis to each operation of hot rolling. As a result of system decomposition it is evident that hot rolling technological process consists of following subsystems: workpiece heating, hot rolling, cooling, and coiling.

Slabs with definite steel chemical composition and dimensions after continuous casting machine are used as the workpiece for hot rolling. Before hot rolling the slab is heated in gas furnaces. Result of subsystem “workpiece heating” system analysis is presented in Fig. 3.

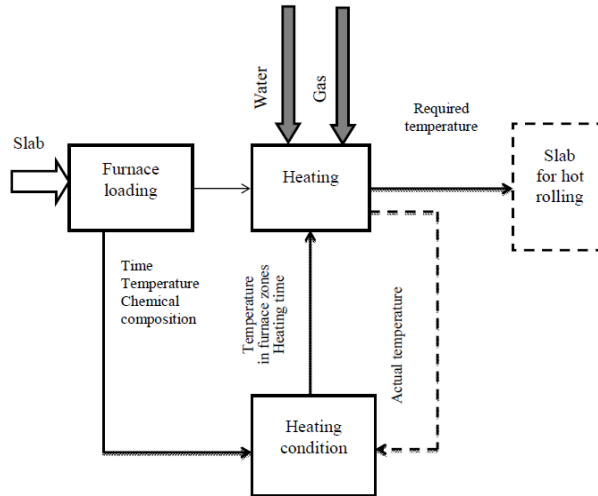


Fig. 3. Workpiece heating as the subsystem of hot rolling technological process.

Due to documentation metal charging in furnace and its delivering to rolling are carried out in accordance with technological peculiarities of metal heating in furnaces. Heated slabs are unloaded from furnace and are transported to roughing mill group along conveyor rolls.

The scheme of subsystem “hot rolling” system analysis is presented in Fig. 4.

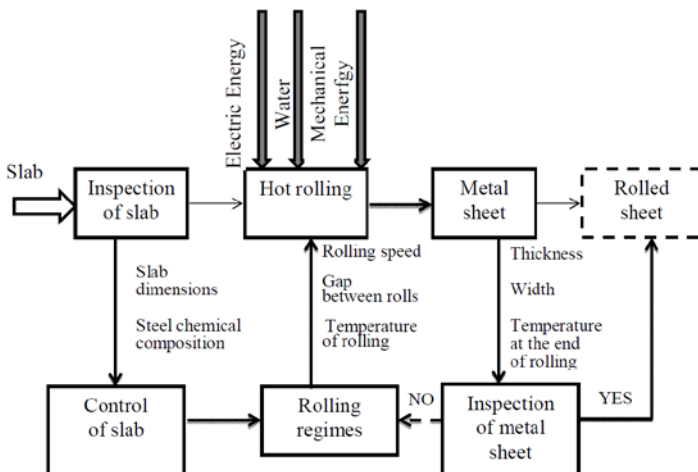


Fig. 4. Scheme of subsystem “hot rolling” system analysis.

Roughing mill stands are universal. It means that there are vertical rolls to squeezing slabs sides besides horizontal ones. Hot rolling is guided by operational schemes depending on production range and rolling energy consumption. After roughing mill stands hot-rolled breakdown is transported along rolls equipped with guide racking-type strips which are adjusted to workpiece width and ensure the correct tracking between rolls' gap. Before finishing rolling group both pipe and butt ends of the hot-rolled breakdown are cut. The scale is removed by descale sprays. Rolling rate and sheet reduction regimes in finishing mill group have to ensure the necessary deformation energy, temperature at rolling end, and given steel sheet geometrical dimensions.

Cooling as the subsystem of hot rolling process (Fig. 5). Cooling temperature depends on steel sheet thickness and steel chemical composition. In order to get necessary steel sheet properties the rolling rate is matched with cooling rate.

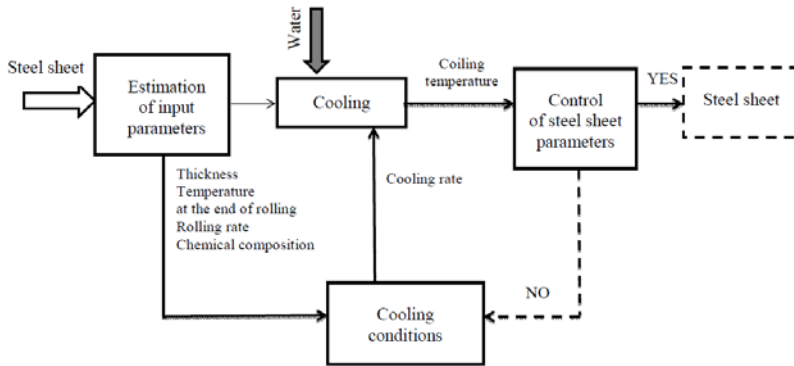


Fig. 5. Steel sheet cooling as the subsystem of hot rolling process.

Coiling is the final operation at hot rolling process. Rolling rate, cooling temperature, steel sheet chemical composition, its thickness and width are the input parameters for coiling (Fig. 6).

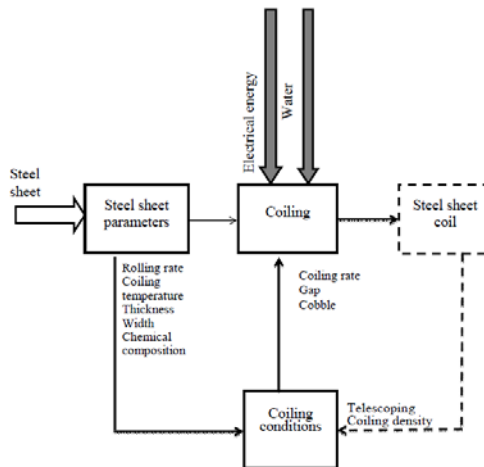


Fig. 6. Scheme of subsystem “coiling” of hot rolling process.

Cooling rate as well as coiling temperature have great influence on steel sheet structure and, consequently, mechanical properties of the final product. That is why application of system analysis is the effective method for estimation connections between technological parameters of these operations.

4 Conclusions

System analysis was used for metal sheet hot rolling process. The scheme of hot rolling allowed to graph the relations between technological parameters and establish their effect on metal sheet characteristics. It was shown the application of system analysis for vacuum ion-plasma coating process. It allowed to choose such technological parameters which made it possible to achieve the coating with that level of properties which is necessary for definite exploitation conditions.

At hot rolling manufacturing decision-making process is carried out under uncertainty conditions which occur due to the existence of many factors difficult to be estimated numerically [14, 15]. From this point of view application of system analysis is the effective way to establish the interconnection between different elements of the whole system. Stated in a such way notional factors form the basics for stating actual tasks of the manufacturing process which can be formalized mathematically depicting interconnections between customer properties of the product and process controlled parameters. Because of existence of operated, noncontrolled, and indignant parameters of any technological process the application of system analysis is the effective way for structural analysis. The obtained data can be used as the theoretical basics for mathematical modeling and optimization of technological processes in order to predict material properties after different kinds of processing and obtain the product with necessary quality and properties levels.

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