Increasing the speed of information transfer and operational decision-making in metallurgical industry through an industrial bot

V. Yu. Bazhin, Professor, Head of the Metallurgy Department1, e-mail: bazhin-alfoil@mail.ru
O. N. Masko, Post-Graduate Student1
Huy H. Nguyen, Post-Graduate Student1

1Saint-Petersburg Mining University, Saint-Petersburg, Russia.

In the production of non-ferrous metals, it is difficult to monitor technological parameters and to account for the material balance of the main and auxiliary components which leads to significant losses of raw materials and electricity. The metals industry is characterised by the need to account for, reduce and recycle large volumes of technogenic emissions. With global digitalisation and increased automation, the lack of a dedicated system for analysing and controlling shop floor data reduces the efficiency of environmentally hazardous operations with large quantities of material flows making them uncompetitive and environmentally damaging. Existing software-based material flow monitoring and control systems have a large import dependency. In pyrometallurgical and electrochemical production with multiple material streams the issue of data systematisation for effective control via a process control system needs to be addressed. As an adaptable example, this paper considers the feasibility of dedicated automated systems for accounting for material balances and generating appropriate process control actions through chatbots in metallurgical silicon production. Given the acute shortage of digital platforms for the implementation of MES-like production management systems, the use of application software interfaces chat-bots gaining popularity in services and education is promising. The paper presents a generic architecture of an industrial chatbot developed for the production of metallurgical silicon, describes the interaction of the application with the process control system, as well as an analysis of the results obtained and expected from the implementation. The system can be adapted to similar production facilities of non-ferrous metallurgy.

Key words: metallurgical silicon, automated control, material balance, ore-thermal furnace, ICS, chatbot, MES system.
DOI: 10.17580/nfm.2023.01.10

Introduction

The issues of energy and resource saving in mineral resource complex are of priority importance for modern economy. In this regard, effective management of technological processes by means of high-tech instrumentation equipment with domestic software defines further development of Russian economy [1, 2]. In non-ferrous metals production effective automatic control of multistage processes and flow lines have certain difficulties [3]. For example, in aluminum and copper electrolytic production several dozens of identical equipment are used for which it is necessary to use sequential control of technological parameters of each cell or furnace [4, 5]. Thus, in production with several sources of raw materials processed under conditions of high-temperature, aggressive chemical environment it is very difficult to control technological parameters and take into account material balance that is why there are significant losses of raw materials and electric power [6].

For instance, in silicon production quartz with different chemical compositions is used as raw material which leads to appearance of uncontrollable impurities in the final product. The quartz raw material contains a number of elements which unsatisfactorily affect the performance and efficiency of melting including fine particles. In addition, there are significant direct losses in the form of gas-fume emissions which can amount to more than 40% of the initial charge consumption. Some of the process parameters are not monitored and not predicted due to imperfect operability of the control system [7].

In order to increase resource and energy saving it is urgent to implement an information management system for metallurgical silicon production which along with streamlining of control processes of material and energy balances provides real-time collection of current data for database — BigData, documentation from the beginning of the process to the output of finished products.

To implement such a system in the current geopolitical environment, where the use of specialised digital platforms is not available or is subject to sanctions a radically new solution is needed. One way out in this environment is the implementation of a MES (manufacturing execution system) based on a chatbot which allows efficient and cost-effective solution to the tasks at hand [8, 9].

The concept of an industrial chatbot

A MES-system is required for the efficient control of production processes and for the organisation of stable functional relationships over time. In order to improve these connections, it is rational to use a communication interface (chatbot) which is tailored to the metallurgical production and which directly clarifies the needs of the maintenance personnel and the operators of the process control system. The proposed system (industrial chatbot)
helps to meet these requirements according to the set
communication in the production system through automatic
commands to the controller via text or voice.

At present, a selector communication is usually used to
switch to manual control of the furnace from automatic
mode and occasionally a telecommunication top-level
SCADA transmission system disconnecting the industrial
facility from the regulation [10]. In the case of metallur-
gical production, the chatbot conducts communication
from the technologist or the control system operator
in order to simplify and speed up decision making through
online communication, i.e. provide relevant information
in the fastest time after processing the data received from
the lower level SCADA system. For metallurgical produc-
tion it is used as an alternative to correspondence with the
operator and workshop technologist [11, 12].

A chatbot is a software application that interacts with
users in natural language. They are useful in areas such as
education, information retrieval, logistics and manage-
ment. The widespread use of chatbots is due to a number
of advantages, such as:
- accessibility to the user regardless of platform;
- ability to integrate the data generated by one chatbot
into other systems;
- reliability of ongoing communication;
- simplicity of development and rapid adaptation along
with universal application in any industrial environment.

Metallurgical manufacturing is a new area of applica-
tion for chatbots, whose use in related areas of the econo-
my has already proven effective [13].

An industrial bot is an ideal tool for optimising standard
repetitive tasks, such as the compilation and maintenance
of report documentation, extraction and collation of necessary
information, bypassing several stages of control action on
the control system. Such operations do not require creative
solutions and follow a strictly defined algorithm. As a result,
the influence of the human factor on process control is
reduced in all its simplicity of implementation [14].

Thus, the industrial bot provides the simplest and most
straightforward way to interact between the process/pro-
duction and the customer with instant feedback and no
human error-prone feedback. The bot will accept the
information, check for errors and store it in the database.

The design and development of a chatbot involves many
techniques. Understanding what a chatbot will offer and
what category it falls into helps software developers choose
the algorithms or platforms and tools to build it. At the same
time, it also helps end users understand what to expect from
the system in the event of an emergency or abrupt deviations
in metallurgical process parameters [15–17].

In terms of business classification, the production bot
fulfils the role of an assistant (assistant to the ICS opera-
tor (integrated control system)) configured to solve spec-
cific tasks. As for technical classification, it is rule-
based with a tree-like dialog structure. The dialog between the
user and the system follows a path predetermined by the
developer. The user or technologist, as the main chat man-
ger, makes decisions but cannot deviate from a predefined
production task. In order to avoid failures in the dialogue
structure this kind of chatbots must contain a large number
of voice control buttons instead of free-form questions.

According to the regulated tolerances provided by the
development platform, an open-source platform is pre-
ferred for a production chatbot to be better adapted to
specific tasks and the main requirement for its design is an
accurate representation of information and response gen-
eration strategy [18, 19].

Chatbot structure for metallurgical production

The structure of a chatbot for metallurgical silicon pro-
duction was developed using Aveva’s upgraded digital MES
platform in the form of the following modules (Fig. 1):
- Short downtime per process operation;
- Accidents or temporary shutdowns of equipment;
- Preventive maintenance.

The system automatically generates records for periods
of extremely slow process operation or complete shutdown.
The records generated in this module contain the informa-
tion required to prioritise maintenance, order equipment
and improve operational and process procedures. The module
provides an easy-to-use interface for furnace operators to
analyse the causes of production downtime.
- Product quality control

Analysis, reporting and quality management at all
stages of the process. At this stage process parameters
affecting product quality are collected against defined
tolerance intervals, process regimes, which provides ample
opportunity for analysis (Figs. 3, 4).
- Findings and knowledge

Maintaining logs (shift, repair crews, etc.), storing and
providing access to various documentation. This is a tool
for managing ongoing changes, keeping notes/comments
by technologists.
- Process and power consumption

For efficient production management it is necessary
to identify the periods of excessive energy consumption
and determine the causes (kWh, rub.) as well as to ana-
yse the schedule of energy consumption [20–22].
- Balance of raw material flows (material balance
control)

This module is responsible for raw material inventories
with product genealogy (production traceability) and for
the Actual Material Balance of metallurgical silicon by
the furnace that allows decision makers to analyse the
impact of quartz raw material quality on metallurgical sili-
con production quality parameters.

The material balance module is a key module in the met-
allurgical silicon production control system. By combining
the traditional calculation of material balance, taking into
account the influence of temperature in the furnace and
physical and chemical properties of quartz the balance mod-
ule provides the following functions: collecting data from the
ICS, data processing to display the composition and amount
of the formed silica fume depending on the key parameters (temperature in the furnace, particle size distribution and chemical composition of quartz raw materials) in the form of tables and graphical relationships. The module evaluates the preparation of charge materials and transmits information on changes in their composition for quick decision-making on changing technological parameters [23].

“Production_silicon_bot” generates an up-to-date and near-real-time picture of exactly what is happening in the production process based on the records of input and output flows of the plant including: materials, consumables, energy, waste, emissions and product output with regard to quality parameters. The chatbot provides an easy-to-use interface for operators analysing production data. Telegram channel was chosen as a working platform for operator-system interaction due to simplicity of implementation and free access in the Russian Federation (Fig. 5). To ensure information security (cybersecurity) user restriction is implemented through access list — telegram user id [24, 25].

“Production_silicon_bot” works with data coming from the SCADA system or Historian server. This data is

---

**Fig. 1.** Structure of a PMIS for metallurgical silicon production based on the chatbot “Production_silicon_bot”

**Fig. 2.** Table of downtime for the current month in the MS SQL server “Production_silicon_bot” database
stored in a relational database hosted on Microsoft SQL Server (Fig. 2). The Yandex.Cloud platform is used to avoid the limitation on the volume of files sent to Telegram where reports are stored and supplemented while the bot itself provides the user with data in the form of a link to a cloud storage document [26–28]. The use of highly rated software of the Russian company allows solving a number of problems simultaneously, such as guaranteeing data security (servers are located in Russia), storage, processing and visualisation of any type and volume of data, organisation of work with the system by the service personnel.

In the production of metallurgical silicon with complexity of material flows, a large number of uncontrollable parameters and emissions require a solution to the issue of systematization of data for effective management through the ICS. This could be solved using a Telegram bot interface. The use of bots in “dirty” production facilities with a large number of material flows contributes to the implementation of a closed cycle enterprise and a reduction of the carbon footprint.

“Production_silicon_bot” is a limited type of MES system with a simplified interface. However, given the fact that access to quality foreign digital platforms is difficult the use of a chatbot user interface is an optimal alternative.

The advantages of this solution include:
• low implementation cost;
• convenience and simplicity of use;
• quick response;
• no requirements for the power of the device involved;
• sufficient level of security;
• no need to initialise additional software to run the “helper” in question.

<table>
<thead>
<tr>
<th>Name</th>
<th>Measurement unit</th>
<th>Scheduled</th>
<th>Furnaces</th>
<th>Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-load voltage</td>
<td>V</td>
<td>210</td>
<td>189.72</td>
<td>191.21</td>
</tr>
<tr>
<td>current intensity</td>
<td>kA</td>
<td>45</td>
<td>42.46</td>
<td>41.44</td>
</tr>
<tr>
<td>Electrical power</td>
<td>MW</td>
<td>6.6</td>
<td>6.57</td>
<td>6.50</td>
</tr>
<tr>
<td>Ratio I/U</td>
<td></td>
<td>0.214</td>
<td>0.22</td>
<td>0.22</td>
</tr>
<tr>
<td>Load MW per hour</td>
<td>kg</td>
<td>214</td>
<td>216.07</td>
<td>212.94</td>
</tr>
<tr>
<td>Average hourly output</td>
<td>kg</td>
<td>550</td>
<td>499.27</td>
<td>484.03</td>
</tr>
<tr>
<td>Average hourly output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>since the beginning of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Current month’s report of the quality module in the electrothermal workshop “Production_silicon_bot”

Fig. 2. Table of downtime for the current month in the MS SQL server “Production_silicon_bot” database
As for direct loses, in metallurgical production they are related to a long delay in decision-making, when a machine or metallurgical furnace is in an unbalanced state for a long time resulting in direct losses of raw material and energy.

In the current geopolitical realities, the developed system of production data recording and analysis is a profitable solution for the metallurgical industry.

**Conclusion**

With global digitalisation and increased automation, the lack of a dedicated system for analysing and controlling shop floor data makes silicon production, as well as other multi-stage industries, uncompetitive in the global market. The concept of using an industrial chatbot (BOT) within the framework of an existing system of detailed operational planning of production process management in metallurgy allows to solve this problem bypassing the functional levels of the overall management system. Thus, it is possible to formulate character features and advantages of an industrial BOT:

- increased speed of information transfer from the upper to the lower level of the ICS;
- forecasting of technological situation through two-way communication;
- reduction in the number of transfer functions in the ICS;
- transfer influence on control systems through PI or PID controllers;
- increasing the level of information security.

The disadvantages of bots include some problems with supporting telecommunication communication in industrial interference conditions, which is solved quite easily with the help of wireless signal repeaters from the base station. In addition, the operators’ workplaces are far enough away from the sources of interference (electric arc furnaces). There are also wired shielded internet connections in addition to the wireless types, which are minimally susceptible to interference.

The introduction of this system in non-ferrous metals and their alloys production environments can significantly improve the efficiency of process control with domestic automation systems and software.

**Acknowledgments**

*This research was funded by Russian Science Foundation grant No. 22-29-00397.*
References


