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Generalized Net Model of the Processing of Copper Concentrates

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Abstract: The generalized network is used to construct a model describing the processing of copper concentrates. The model can be used to simulate the processes associated with the production of anodes, cathodes, sulfuric acid and fayalites. The possibility of using GN as a tool for modeling such processes is also analyzed.
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AMS Classification: 68Q85, 90B30.

1 Introduction

In the paper we consider one Bulgarian company, which is called «Aurubis Bulgaria». The copper production plant of the company is in Srednogorie region, Bulgaria. The plant was built in 1958 and it consists of four main production units: Smelter, Refinery, Acid plant and Flotation plant.

The products of this company are widely used for copper applications in industries such as the electrical, electronics, chemical, construction and automotive industries. Production at the plant in Pirdop covers the following units: Smelter, Refinery, Acid Plant and Flotation Plant. The main activity of the company is copper concentrate processing, production of copper anodes and copper cathodes, and by-products such as sulfuric acid and fayalite.

Today, Aurubis is the leading integrated copper group and the world's largest copper recycler. They produce some 1 million t of copper cathodes each year and from them a variety of copper products.

Aurubis has more than 6,400 employees, production sites in Europe and the USA and an extensive service and sales system for copper products in Europe, Asia and North America.

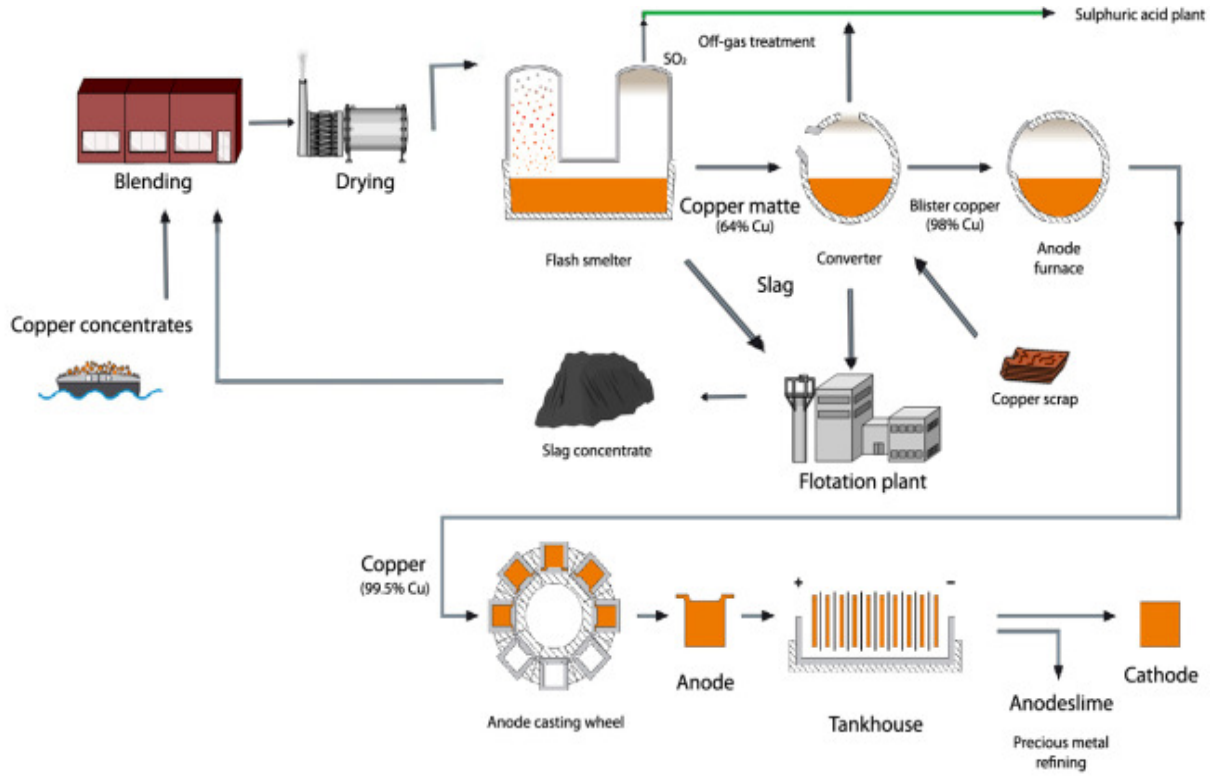

Figure 1. Diagram of the process

2 A GN-model

The GN-model for this section (Figure 2) contains 7 transitions and 18 places. Initially, there is one α-token that is located in place l_1 with initial characteristic: "*Cooper concentrates*".

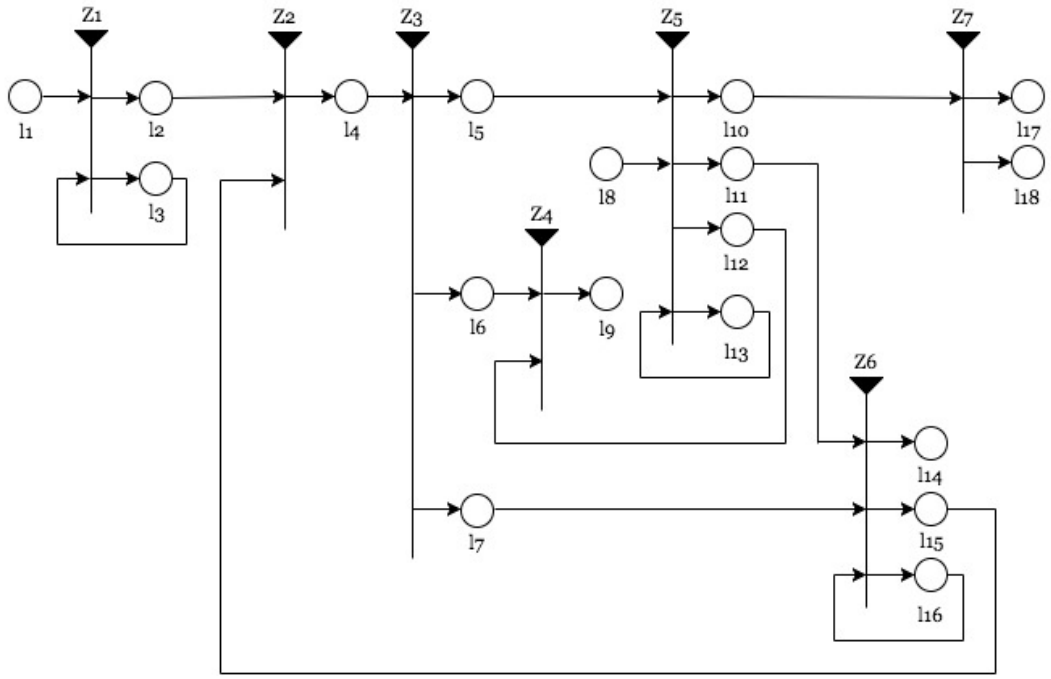

Figure 2. GN model of process

The transitions of GN–model have the following description.

Transition Z_1 in the model represents the supply of copper concentrates with ships from Port of Burgas, originating from North and South America, the Black Sea region and Bulgaria. The imported copper concentrates are delivered by bulk vessels to the Port of Burgas and railed to the Aurubis plant in Pirdop. Aurubis maintains weighing and sampling control operations at the Port of Burgas for establishing weight and sampling of the copper concentrates. Quality is controlled by company's certified laboratory.

$$Z_1 = \langle \{ l_1, l_3 \}, \{ l_2, l_3 \}, r_1, V_1 \rangle$$

$$r_1 = \begin{array}{c|cc} & l_2 & l_3 \\ \hline l_1 & false & true \\ l_3 & W_{3,2} & true \end{array}$$

where:

$W_{3,2}$ = "Incoming raw materials have been inspected by the accredited laboratory of the company".

The condition for the transition is $V_1 = \wedge(l_1, l_3)$.

After activating of the transition Z_1 in place l_2 enters α-token with a characteristic: "*The Copper Concentrators checked by the laboratory*" and in place l_3 there is α-token with a characteristic: *"Controlling of the copper concentrates"*.

Transition Z_1 in the model represents mixture and drying division – Copper concentrates are received and blended (Cu~20 %). The mixture is dried in two steam drying ovens in order to reduce the moisture.

$$Z_2 = \langle \{ l_2, l_{15} \}, \{ l_4 \}, r_2, V_2 \rangle$$

$$r_2 = \begin{array}{c|c} & l_4 \\ \hline l_2 & W_{2,4} \\ l_{15} & W_{15,4} \end{array}$$

where:

$W_{2,4}$ = *"The copper concentrates are dried and processed into the mixture"*.

$W_{2,4} = W_{15,4}$

The condition for the transition is $V_2 = \vee(l_2, l_{15})$.

After activating of the transition in place l_4 enters α–token with a characteristic: *"Mixture of the copper concentrates"*.

Transition Z_3 in the model represents smelting division – the mixture is smelted in a flash smelter in order to achieve partial oxidation and smelt the mixture. As a result of chemical reactions, matte (Cu~65 %) and slag are formed. The technological gases pass from the smelting furnace into a boiler in order to use the energy from the heat.

$$Z_3 = \langle \{ l_4 \}, \{ l_5, l_6, l_7 \}, r_3, V_3 \rangle$$

$$r_3 = \begin{array}{c|ccc} & l_5 & l_6 & l_7 \\ \hline l_4 & W_{4,5} & W_{4,6} & W_{4,7} \end{array}$$

where $W_{4,5} = W_{4,6} = W_{4,7}$= *"Melting in a furnace"*.

The condition for the transition is $V_3 = \vee(l_4)$.
The α-tokens obtain characteristic respectively:

- in place l_5: *"Matte from the smelting furnace",*
- in place l_6: *"The technological gases",*
- in place l_7: *"Slag from a melting furnace".*

Transition Z_4 in the model represents processing sulfur technological gases formed in pyro-smelting copper concentrate processing in a smelting furnace and the converters in metallurgical production results in sulfuric acid production.

$$Z_4 = \langle \{ l_6, l_{12} \}, \{ l_9 \}, r_4, V_4 \rangle$$

$$r_4 = \begin{array}{c|c} & l_9 \\ \hline l_6 & W_{6,9} \\ l_{12} & W_{12,9} \end{array}$$

where $W_{6,9} = W_{12,9}$= *"obtained sulfur technological gas".*
The condition for the transition is $V_4 = \vee(l_6, l_{12})$.
After activating of the transition in place l_9 enters α –token with a characteristic: *"sulfuric acid".*

Transition Z_5 in the model represents converter division – the matte is transported from the smelting furnuce to converters. Black copper with a concentration of 98-99 % and slag are formed in the conversion process. The slag obtained from the converters and from the smelting furnace is transported to a flotation plant. The sulfuric gases from the smelting furnace and the converters are passed on to produce sulfuric acid.

$$Z_5 = \langle \{ l_5 , l_8, l_{13} \}, \{ l_{10}, l_{11}, l_{12}, l_{13} \}, r_5, V_5 \rangle$$

$$r_5 = \begin{array}{c|cccc} & l_{10} & l_{11} & l_{12} & l_{13} \\ \hline l_5 & false & false & false & true \\ l_8 & false & false & false & true \\ l_{13} & W_{13,10} & W_{13,11} & W_{13,12} & true \end{array}$$

where:

$W_{13,10}$ = *"Black copper with a concentration of 98-99 % from the conversion process",*
$W_{13,11}$ = *"Slag from the conversion process was obtained",*
$W_{13,12}$ = *"The sulfur gases from the conversion process were obtained",*

The condition for the transition is $V_5 = \vee(l_5, l_8, l_{13})$.
After activating of the transition:

- in place l_{13} enters α-token with a characteristic: *"Processed matte from the smelting furnace with a copper scrap";*
- in place l_{10} enters α-token with a characteristic: *"Black copper with a concentration of 98-99 %";*
- in place l_{11} enters α-token with a characteristic: *"Slag from the conversion process"*
- in place l_{12} enters α-token with a characteristic: *"The sulfur gases from the conversion process".*

Transition Z_6 - the sludge from the smelting plant and the converters formed as a result of the smelting process are processed in a flotation plant in order to extract the remaining copper.

The flotation method of enrichment is used, where two products are obtained: concentrate, which is returned back to the smelting production process and Iron-Silicate fines.

$$Z_6 = \langle \{ l_{10}, l_7 \}, \{ l_{14}, l_{15} \}, r_6, V_6 \rangle$$

$$r_6 = \begin{array}{c|ccc} & l_{14} & l_{15} & l_{16} \\ \hline l_{11} & false & false & false \\ l_7 & false & false & false \\ l_{16} & W_{16,14} & W_{16,15} & true \end{array}$$

where $W_{16,14} = W_{16,15}$= *"slags from the smelting furnace and converter are processed"*.
The condition for the transition is $V_6 = \wedge(\vee(l_{11}, l_7), l_{16})$.
After activating of the transition:

- in place l_{16} enters α -token with a characteristic: *"Slags from the smelting furnace and converter";*
- in place l_{14} enters α -token with a characteristic:*"Iron-Silicate fines";*
- in place l_{15} enters α -token with a characteristic *"Cooper concentrate"*.

Transition Z_7 - Anode division and Refinery - Here the black copper is refined in two anode furnaces in order to increase the purity of the copper above 99.5 %. Anodes are cast according to the specifications of the internal and external clients. After that about 2/3 of the anodes produced in the Smelter are sent to the Refinery. The electrolysis process produces cathodes with a copper concentration of 99.99 %.

$$Z_7 = \langle \{ l_{10} \}, \{ l_{17}, l_{18} \}, r_7, V_7 \rangle$$

$$r_7 = \begin{array}{c|cc} & l_{17} & l_{18} \\ \hline l_{10} & l_{10,17} & l_{10,18} \end{array}$$

where $W_{10,17} = W_{10,18}$.= "Black cooper is received".
The condition for the transition is $V_7 = \vee(l_{10})$.
After activating of the transition:

- in place l_{17} enters α –token with a characteristic: *"anodes";*
- in place l_{18} enters α –token with a characteristic: *"cathodes"*.

3 Conclusion

The paper examines the different stages of the copper concentrate process, as well as its simulation and behavior in the future. The model shows the realization of the final products: cathodes, anodes, sulfuric acid, iron-silicate (phialite). The GN-model shows the connections, the way of interaction and the processes between the different components in the factory operation. Various processes are monitored: raw material supply, metallurgical production, refinery, flotation plant, production of sulfuric acid.

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