**2022 May Day MCM**

Problem B. Quality control of mineral processing

Improving the quality of mineral processing can directly or indirectly save non-renewable mineral resources and the energy needed for mineral processing, thus is helpful for promoting energy conservation, emission reduction, and achieving the goal of "carbon peaking and carbon neutrality". During mineral processing, voltage, water pressure, and temperature are important factors that directly affect the qualities of mineral products. The process of mineral processing is shown in Figure 1. A production workshop processes a batch of raw minerals. Several parameters related to raw minerals are shown in attachments 1 and 2. For the convenience of description, it is assumed that the mineral processing process needs to go through two stages, systems I and II, in no particular order, and other conditions (voltage, water pressure, etc.) remain unchanged. Production technicians can change product quality by introducing temperature control instructions and adjusting the temperature. The temperature data of systems I and II are listed in attachments 1 and 2. It takes exact 2 hours for the mineral processing, i.e., the corresponding mineral product quality evaluation index (A, B, C, D) can be detected after 2 hours of the temperature adjustment. It is assumed that other new temperature control instructions will not be given within 2 hours after a temperature control instruction is given. The real-time temperatures of each system are recorded in attachments 1 and 2, and the set temperatures are almost consistent with the system temperatures, but there are slight fluctuations. Note: In attachments 1 and 2, the specific names of raw mineral parameters and process data are not given. Different types of data have different collection intervals.

System I

Minerals

System II

Mineral products

Process parameters

Figure 1 Mineral processing

**Question 1:** Attachment 1 provides the mineral processing data of the workshop from 2022-01-13 to 2022-01-22. Please apply the data in attachment 1 to establish a mathematical model and give the method of predicting product qualities by system temperatures. Under the given 2022-01-23 raw mineral parameters (see attachment 1) and the system temperatures (see Table 1, assuming that the system temperatures are the same as the temperatures set by the temperature control instructions), give the product quality prediction results. Note: in the provided data, due to other uncertainties, the quality of products under the same (or similar) system temperatures may vary greatly. In this case, please predict the most likely indicators and fill the results in Table 1.

Table 1 Results for Question 1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | Temperature of the system I | Temperature of the system II | Index A | Index B | Index C | Index D |
| 2022-01-23 | 1404.89 | 859.77 |  |  |  |  |
| 2022-01-23 | 1151.75 | 859.77 |  |  |  |  |

**Question 2:** Based on the results of Question 1, using the data in attachment 1 and assuming that the mineral parameters and product target qualities are known (the system temperatures are unknown), please establish a mathematical model to estimate the system temperatures corresponding to the given product target qualities. Given the mineral parameters of 2022-01-24 (see attachment 1) and product target qualities (see Table 2), estimate the set temperatures (assuming that the temperatures set by the temperature control instructions are the same as the system temperatures). Note that the qualities of the same group of products may be obtained by multiple temperature adjustment methods. Please give the most likely system setting temperatures and fill the results in Table 2.

Table 2 Results for Question 2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | Index A | Index B | Index C | Index D | Temperature of the system I | Temperature of the system II |
| 2022-01-24 | 79.17 | 22.72 | 10.51 | 17.05 |  |  |
| 2022-01-24 | 80.10 | 23.34 | 11.03 | 13.29 |  |  |

**Question 3:** The process parameters are detected during mineral processing (see Figure 1) and can reflect the quality of the raw mineral. Due to the same batch (day) of raw mineral quality being different, it may also cause a difference in the quality of the products under the same (or similar) temperature control instructions. Attachment 2 gives the mineral processing data and process parameters of the workshop from 2022-01-25 to 2022-04-07. Table 3 shows the sale conditions of mineral products. Products that meet the sale conditions are regarded as qualified products; otherwise, they are considered unqualified. Assuming that the number of products produced per unit time is the same, the qualified rate = the number of qualified products / the total number of products. Please establish a mathematical model and give a method to predict the qualified rates of mineral products by specifying the temperatures set by temperature control instructions. Under the given mineral parameters of 2022-04-08 and 2022-04-09, process parameters (see attachment 2), and the set temperatures (see Table 4, assuming that the system temperatures are the same as the temperatures set by the temperature control instructions), please predict the prediction results of the qualified rate. Fill the results in Table 4, and establish a mathematical model to evaluate the accuracy of the given qualified rate.

Table 3 Product sale conditions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Index | Index A | Index B | Index C | Index D |
| Sale conditions | 77.78 - 80.33 | <24.15 | <17.15 | <15.62 |

Table 4 Results for Question 3

|  |  |  |  |
| --- | --- | --- | --- |
| Time | Temperature of  the system I | Temperature of  the system II | Qualified rate |
| 2022-04-08 | 341.40 | 665.04 |  |
| 2022-04-09 | 1010.32 | 874.47 |  |

**Question 4:** According to the results in question 3 and the data in attachment 2, establish a mathematical model to analyze how to set the system temperature under the condition of the specified qualified rate. You have the following tasks: (1) appropriate sensitivity analysis; (2) analysis of the accuracy of the results; (3) according to the qualified rate requirements for the products in Table 5 of 2022-04-10 and 2022-04-11 (see attachment 2 for mineral parameters and process parameters), judge whether the requirements can be met. If the requirements can be met, give the set temperatures of the systems (assuming that the system temperatures are the same as that set by the temperature control instructions), and fill the results in Table 5.

Table 5 Results for Question 4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Qualified rate | Whether the qualified rate can be achieved? | Temperature of  the system I | Temperature of  the system II |
| 2022-04-10 | 80% |  |  |  |
| 2022-04-11 | 99% |  |  |  |