Using the LABVIEW software package to automate production and research tasks

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Abstract. Currently, improving the quality indicators of mass production and consumer goods is impossible without the use of modern software systems, means and methods of automation. The main systems capable of satisfying the tasks of modern enterprises and scientific organizations include Scada-systems, which provide the necessary control accuracy and versatility in conditions of low costs for additional staff training. Consider the prospects for improving the technical and economic indicators of metallurgical and chemical enterprises through the introduction of automation, on the example of the operation of concentration plants. Obviously, the main tool to increase the economic efficiency of production is to reduce various types of costs. Among the main cost items, fuel, feedstock and chemical reagents are distinguished, however, the undisputed leader is the cost of electricity, the work of the mills needed to grind the feedstock. On the other hand, the problem of timely and quick diagnosis of the internal components of the mills and the ability to choose the optimal mode of operation are also relevant tasks. These reasons significantly affect such process indicators as the quality of the crushed raw materials, the energy efficiency of the grinding process, reducing the cost of the production cycle, etc. To control the processes of grinding, loading of raw materials, monitoring the filling of the drum, the use of vibroacoustic primary transducers installed on the housing of the axle bearing of the drum mill is promising.

1. Introduction

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a major National Instruments product. It is used in data collection and processing systems, as well as for the management of technical objects and technological processes. Ideologically, LabVIEW is very close to SCADA-systems, but in contrast to them, it is more focused on solving problems not so much in the field of automated process control systems (APCS), but in the field of an automated research system. However, the functionality of this product seems to be broader.

National Instruments' primary focus was measurement and automation tools. Although the LabView complex is closely related to National Instruments hardware, it is nonetheless not related to specific hardware and can be used with devices running Windows, Linux, MacOS, etc., which makes the environment universal and can be used on most enterprises and in research projects.

Automation of technological processes is a necessary element of improving the production of modern enterprises to increase the efficiency of processes in all areas of industry [1, 2], where a large number of primary converters (sensors) and various devices are used, the metrological characteristics...
and indications of which must be continuously monitored. Their characteristics are greatly influenced by the input signal power parameters, the increase of which is an urgent automation task [3, 4].

Due to the features of the LabView software package, it can be used in production processes, not only for automation, but also for quality control of materials. For example, laboratory methods for studying the tribological characteristics of metals from works [5–11] based on the use of the LabView software package are used at enterprises for sampling and also monitoring production processes in the production of standardized products. The method consists in measuring the tribological characteristics of metal-oil systems using a laboratory bench, improved by a software package based on LabView, which allows you to speed up and simplify work at times. An advanced installation can be used at any enterprise by unskilled personnel, since LabView has a graphical interface and intuitive controls.

At the enterprises of the mineral resource complex, the stage of grinding the source material to a large extent affects the subsequent stages of processing, affecting the quality of the finished product. The methods of automatic regulation and manual regulation by the grinding complex used at existing enrichment factories, preserved at some plants, do not guarantee the stability of the process, and are not able to ensure the constancy of the parameters of the products obtained. Automation of the grinding stage allows you to comply with the required process criteria, including taking into account the variability factor of the properties of the feedstock, and quickly carry out readjustment of the equipment used. As an example, which allows production to respond quickly to constantly changing properties of the feedstock, which entails the adjustment of individual operations of the process chain, automated control over the volume of filling, for example, grinding mills, can be used.

The grinding process is carried out using mills containing, in addition to the charge, solids made of materials such as steel or aluminum. Grinding bodies and crushed material significantly affect the integrity of the lining, intensifying wear, as a result of which a set of measures is used to increase the life of the mills: the use of combined linings, the use of DEM modeling to predict places of increased wear, and others [12–15].

The process of quality control of the mills is a non-trivial task. This is primarily due to the different duration of the grinding processes, which depends on the properties of the feedstock and the required qualitative characteristics of the material at the end of the process. Also, parameters of grinding media, a protective inner coating of the drum, occupancy rate, etc., have a great influence. Maximum productivity is achieved by optimizing the entire set of parameters, including taking into account the number of grinding elements, since their disadvantage is characterized by an insufficient degree of grinding of the material due to the "filtering" of grinding elements to the walls. The parameters of the crushed bulk material significantly affect subsequent redistribution, which is explained by the fact that if the required fineness was not obtained at the grinding stage, the required value of mineral disclosure was not achieved, and, therefore, it is necessary to make additional adjustments to the parameters of the production process at the following stages of production.

Therefore, the competent organization of the grinding process: monitoring the degree of filling of the equipment, the state of interior decoration, the number and distribution of grinding media, can reduce the energy consumption of the enterprise, the number of unexpected stops of the equipment, increase the service life of the lining of the mill and the unit as a whole, thereby increasing its efficiency.

2. Proposed Methodology
To solve certain production problems, it is necessary to use various types of mills. The grinding process is so important in the further enrichment of raw materials, since it is in it that minerals are discovered due to the destruction of bonds between useful components and waste rock. Therefore, the goal of this process can be considered to be optimal for further enrichment procedures of dimensional parameters or size required by the customer, as, for example, when sorting coal.

There are five of the most common automated control methods for grinding process parameters. The first method is based on the fact that it is necessary to adhere to the required percentage ratio between the flow rate of the water used in the mill and the noise indicators in the zone where slag formation
occurs. This is due to an automated device that analyzes the supplied signals and changes, if necessary, the amount of water supplied. The second method is to automatically adjust the mill loading level based on an analysis of the vibrational characteristics of the process. The influence of changes in the viscosity of the crushed product on the flow of water formed the basis of the third method. The fourth method involves the study and adjustment of the composition of the resulting waste after the grinding process using special expensive equipment for express analysis. After receiving the data, the program can make a download adjustment. The fifth option is based on the relationship between the noise emitted by the grinding equipment and the required amount of feedstock loaded. The efficiency of the last disassembled method can be greatly negatively affected by units located in the immediate vicinity of the sensor mounting point, which registers the received data.

The most rational option for adjusting the grinding process indicators is to study the volumetric filling of the grinding equipment, the amount of raw material loaded, the number of grinding media used for the subsequent automated process of loading the raw materials and grinding media.

In most enterprises, processes, especially those associated with heat treatment, play a significant role in the processing of heat transfer processes, due to the fact that modern science and technology require a reliable forecast of such processes, the experimental study of which in laboratory or field conditions is very difficult and expensive, and in some cases, it is simply impossible [16]. This requires considerable calculations and labor, but the use of Scada-systems and LabView complexes allows you to speed up the calculations, thereby reducing the risks of production errors that affect the quality of products, which is the main goal of modern production. For the effective application of the calculated data of heat transfer processes, it is necessary to provide the necessary accuracy, without which it is impossible to achieve the required metrological parameters, which affects the built-in product quality [17].

Fig. 1. Block diagram of a device for automatic control of the degree of filling of a ball mill with ground material
3. Results and Discussion
A block diagram of a device that implements a method for automatically controlling the degree of filling of a ball mill with crushed material [18] is presented in Figure 2.

The considered option [18, 19] of automated control of the volumetric filling of grinding equipment and the size of grinding bodies is based on the study of vibroacoustic vibrations of the mill body at a characteristic frequency, which is the disturbing frequency of the shock pulses of grinding bodies against the mill drum body.

The frequency of shock pulses is significantly affected by such characteristics as the size and composition of grinding bodies, the frequency of rotation of the drum, the diameter of the mill, etc.

The period of revolution of the grinding bodies of the ball load can be found from the expression (1):

\[ T_{shz} = \frac{T_{md}}{n(1 - K^2)} , \]

where

\[ K = \frac{R_2}{R_1} , \]

- \( R_1 \) - the radius of the grind equipment, m;
- \( R_2 \) - internal radius of the load, m;
- \( \phi \) - fill factor of grind in equipment;
- \( n \) - rotational speed of the mill drum, 1/s;
- \( T_{shz} \) - period of circulation of grinding bodies, s;
- \( T_{md} \) - rotation period of the grinding equipment case, s;
- \( \mathcal{U}_n \) - the circulation coefficient of the load of grinding equipment.

The number of grinding media concentrated at the upper level can be calculated using the following formula:

\[ M = \frac{\pi R_1^2 L \rho_{sh}}{m_{sh}} , \]

where

- \( M \) - is the number of grinding media at the upper level;
- \( L \) - chamber length, m;
- \( \rho_{sh} \) - bulk density of grinding media, kg / m³;
- \( m_{sh} \) - the mass of the grinding body of medium diameter, kg.

Knowing the period of circulation of the grinding media and the number of grinding media at the upper level, it is possible to determine the frequency of collisions of the outer layer of grinding media against the mill body:

\[ f = \frac{M}{T_{shz}} = 0.1 n L \frac{\rho_{sh}}{\rho_m} \left( \frac{2R_1 - d_{sh}}{d_{sh}^2} \right) , \]

where \( d_{sh} \) - is the average diameter of the grinding media, m;
- \( \rho_m \) - steel density (material density of grinding media), kg / m³.

The presented expression (3) determines the characteristic frequency of disturbing impulses of the impact of grinding media on the inner surface of the drum of grinding media (maximum acoustic noise of the mill).

Taking \( a = 0.1 \rho_{sh} / \rho_m \), you can adjust (3), which determines the frequency of impact of grinding media on the mill drum housing:

\[ f = a n L \frac{(2R_1 - d_{sh})}{d_{sh}^2} , \]

By changing the expression (4), the relation is obtained for determining the diameter of the grinding media:

\[ d_{sh} = \frac{1}{2} \sqrt{\frac{a L n \left( \frac{a L n}{f} + 4D \right)}{f} - \frac{a L n}{f}} . \]

With constant monitoring of the collision frequency of grinding media, the frequency of rotation of the grinding equipment in automatic mode, you can get the average size of the grinding media.
4. Conclusion
Using LabView software package helps to achieve the necessary results, such as automation of production, acceleration of production processes, ensuring the required metrological characteristics and specified accuracy, as well as quality control of products and raw materials used. As shown in the article, these tasks are relevant, since at present there are more and more new methods for using the LabView software package, using examples of enterprises and research organizations.

The method considered is based on the study of vibro-acoustic signals of grinding media, therefore, if an object with large dimensional parameters gets into the grinding process, then an analysis of the oscillations, namely, sharp amplitude jumps, will allow us to fix and evaluate the complications that have arisen. Therefore, it will be possible to correctly assess the level of workload of the units, automatically carry out its control, and quickly respond to the ingress of foreign bodies into the crushed material, preventing equipment breakdown, thereby increasing its service life and reducing operating costs, to improve the quality of the finished product.

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