Automation of project activities in modernization of drive of operating cement mill

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Abstract. The article presents an approach to automation of modernization project for cement mill drives with replacement of the gearbox for which its service life has expired. The parameters of quality assessment of the chosen solution in the modernization project have been determined. It is mentioned that one of the problems of this stage of modernization is to offer the option of arrangement of the new drive on existing site. The paper offers the variant of the software structure that allows one to automate the considered process.

1. Introduction

Cement industry is the base in a complex of industries that produce construction materials. A cement manufacturing process requires a combination of many machines and devices in one line. The most important stage of the manufacturing process is a grinding process in a cement mill. There are more than 50 cement plants in Russia and more than 700 cement and raw mills with power from 500 to 10000 kW [1]. However, the plant and equipment of the Russian cement industry are characterized by high progressive wear that exceeds 70% at the moment [1]. It is obvious that repair and / or replacement of many cement mills and their drives are necessary to maintain cement production at the current technical level.

The proportion of energy resources in the cost structure of cement production is higher than the average one in the domestic industry as a whole, and significantly higher than the world level. Nowadays, the development of the industry is aimed at the increase of the energy efficiency of production. It requires from the cement plants not only to maintain existing production capacities but also to change thoroughly the manufacturing processes in order to reduce energy losses.

Therefore, the authors can assert that the ordinary replacement of the worn equipment by the similar one can be considered as sustainable because of some reasons: low technical and economic efficiency of out-of-date production capabilities, high weight and size of the equipment in operation, problems with the supply of spare parts for repair of the equipment. So taking into account the current situation, cement plants need to carry out a deep renovation of their technological equipment.

2. Parameters for estimation of the quality of the cement mill drive modernization project

A key and critical stage in the cement production from the point of view of the reliability of the entire production line is the stage of grinding the clinker in a cement mill. In this regard, manufacturer staff needs to keep constantly the workability of the drive of the cement mill. In case of a mill stop due to a breakdown in the drive group, losses due to non-production during one or two weeks of downtime are comparable with the full cost of the new drive replacement kit [2].
About 90% of operating cement mills have a horizontal layout with steel balls as milling bodies [3]. The main drive of the mill consists normally of an electric motor, a gearbox, couplings, an auxiliary drive and accessories. It is possible to use different drive arrangements depending on the location of the drive components relative to the cement mills and the different types of the gearboxes. One of the basic arrangements of the drive of a horizontal cement mill is shown in Figure 1.

![Figure 1. The example of the horizontal cement mill layout](image)

It is necessary to determine the type of the existing and replacing drive while modernizing. Horizontal mill drives can be divided into following types according to mutual arrangement of the components [3, 4]:

1) with sequential arrangement of the drive components:
   - with central arrangement of the drive (the whole drive group is along one axis):
     a) direct drive (without a gearbox);
     b) drive with Symetro-type gearboxes;
     c) drive with a planetary gearbox [5];
   - with shift (left, right) of the electric motor axis related to the mill axis:
     a) drive with planetary gearboxes with a shifting stage;
     b) drive with cylindrical gearboxes with a shifting stage [6];

2) lateral drives:
   a) with one drive;
   b) with two drives.

The process of modernization of the cement mill drive requires solving the problem of multicriteria optimization. To develop the drive modernization project, one needs to take into account the criteria of energy efficiency and reliability of the drive, economic criteria as well as some limits that arise from the financial abilities of the enterprise and the actual conditions of the existing plant site, e.g.: a type of the cement mill, an existing drive type, a foundation layout etc.

The main criteria influencing the quality of the modernization can be presented as the “fishbone” diagram (Figure 2). There are 3 main groups of parameters that affect the quality of the modernization project of the cement mill drive: technical parameters, economic parameters and parameters related to maintenance [2]. It is necessary to study the design parameters of the drive in more detail.

The following main design parameters of the cement mill drive can be distinguished: T1 - mutual arrangement of the mill and the gearbox; T2 - arrangement of the main electric motor; T3 - mutual arrangement of the main electric motor and the auxiliary drive; T4 - number of gearbox stages; T5 - type of gearbox stages; T6 - type of gearing; T7 - type of tooth profile; T8 - type of the bearings; T9 - design of the gearbox casing; T10 - gearbox input coupling type; T11 - gearbox output coupling type; T12 - lubrication system; T13 - type of auxiliary drive; T14 - set of sensors; T15 - replacement options for the gearbox input coupling; T16 - replacement options for the gearbox output coupling; T17 - replacement options for the auxiliary drive.
For each of the mentioned parameters a set of alternatives should be formed. For example, gears can be cylindrical, conical, chevron, etc. Based on the generated alternatives, it is possible to create a morphological table [7] for evaluating the efficiency of the modernization process. In this case, the parameters T1-T3 must be specified for both the operating gearbox and the new gearbox. It is caused because of limits in the process of creating the possible solutions using a morphological table. The solutions generated this way can be analyzed for different technical and economic criteria.

Speaking about the influence of design decisions on economic parameters, it is necessary to emphasize the costs of preparatory works for modernization. These costs imply the preparation of a production site for the installation of a new drive, namely the preparation of foundations, the movement of the electric motor, the laying of communications for the lubrication system etc. Consequently, a problem of finding a solution with minimal changes of the existing infrastructure arises.

Therefore, taking into account above mentioned limits, a cardinal change in the drive type during modernization is not usually carried out. For example, the lateral drive is not replaced by a central one. However, modernization even within one group of drives may require a significant change of the production site. There are 5 principal variants of drive modernization from the point of view the change of location of the components on the production site (gearbox, main electric motor) and changes in foundations [8]:

1) Type 1 (Figure 3.a): the main electric motor does not change its location on site. The drive axis is not changed. It is possible to install the gearbox with the existing anchor bolts. The drive type can be changed within its sub-group.

2) Type 2 (Figure 3.b): the main electric motor does not change its location on site. The drive axis is not changed. It is possible to install the gearbox with the existing anchor bolts through the intermediate frame. The drive type can be changed within its sub-group.

3) Type 3 (Figure 3.c): the main electric motor changes its location on site. The drive axis can be changed. It is possible to install the gearbox with the existing anchor bolts. The drive type can be changed within its group.

4) Type 4 (Figure 3.d): the main electric motor changes its location on site. The drive axis can be changed. It is possible to install the gearbox with the existing anchor bolts through the intermediate frame. The drive type can be changed within its group.

5) Type 5 (Figure 3.e.): the main electric motor changes its location on site. The drive axis can be changed. It is possible to install the gearbox on the existing foundation, so it is necessary to create the
new one or to make significant changes of the existing one. The first option implies adding some layer
of concrete for foundation and boring the new holes for anchor bolts. The second one requires the
preparation of the new foundation.

Figure 3. Options of foundation modifications

Reasonable choice of the option of the foundation modernization requires to determine the relations
between installation parameters of the new drive and the existing production site parameters as well as
special requirements of the cement plant. The last ones can be considered as the rules in one of the
knowledge representation language. The possibility to use one of the mentioned types of foundation
modernization can be estimated with the following conditions.

To install the gearbox on the existing foundation, the following condition should be fulfilled:
To install the gearbox with the existing anchor bolts, the following condition should be fulfilled:

\[ g_{aw\text{ min}} \leq w \leq g_{aw\text{ max}}; \]
\[ g_{al\text{ min}} \leq g_i \leq g_{al\text{ max}}; \]
\[ l_{ls\text{ min}} \leq l_{ls} \leq l_{ls\text{ max}}; \]
\[ l_{hs\text{ min}} \leq l_{hs} \leq l_{hs\text{ max}}. \]  

(1)

If these conditions could not be fulfilled, the check of the condition (3) is necessary. It shows if the gearbox can be installed on the existing foundation with the existing anchor bolts with the intermediate frame.

\[ l_{hs} + l_{ls} + g_j = L; \]
\[ a_1 + a_2 = l_{ls} + g_{lls} + g_{aw}; \]
\[ a_1 = l_{ls} + g_{lls}; \]
\[ w > w_{h1}; \]

or

\[ l_{hs} + l_{ls} + g_j = L; \]
\[ a_1 + a_2 + a_3 = l_{ls} + g_{lls} + g_{aw}; \]
\[ a_1 + a_2 = l_{ls} + g_{lls}; \]
\[ w > w_{h2}; \]

(2)

In formula 1-3: \( L \) – the total lengths of the drive from the electric motor shaft end to the mill flange; \( g_{aw\text{ min}}, g_{aw\text{ max}}, g_{aw} \) and \( g_{al\text{ min}}, g_{al\text{ max}}, g_{al} \) – minimum, maximum and calculated installation dimensions of the gearbox (width and length); \( g_i \) – overall dimensions of the gearbox; \( g_{lls} \) and \( g_{llt} \) – lengths of the high-speed and low-speed shaft ends of the gearbox; \( l_{hs\text{ min}}, l_{hs}, l_{ls\text{ min}}, l_{ls}, l_{hs\text{ max}}, l_{hs}, l_{ls\text{ max}}, l_{ls} \) – minimum, maximum and calculated lengths of high-speed and low-speed couplings of the gearbox respectively; \( w_{h1}, w_{h2} \) – width of the foundation holes 1 and 2 (from the mill side); \( a_1, a_2 \) and \( a_3 \) – location of the anchor bolts; \( w \) – distance between anchor bolts.

3. Automation of the assessment of the modernization project

The development and evaluation of the drive modernization project can be automated. For this purpose, the determined design parameters of the drives should be presented together with a variety of alternatives and criteria for their evaluation, as well as limits of their use are recorded in the system. The system should generate various options for modernization of the drive, evaluate them, offer the options for upgrading foundations in accordance with the formulas and application logic described above. The automated system should choose the most appropriate option for the user using the optimization unit.

The structure of the software of this computer system consists of a databank of the possible solutions; a linguistic module; an editing module; a recommendation development module; a calculation module; an optimization module and a user interface. Figure 4 shows the scheme of interconnections of the modules.

The linguistic module and the editing unit should be mentioned separately. The linguistic module is designed to facilitate communication between the user and the system. The variety of possible alternatives for the modernization quality parameters are linguistic constants. A one-to-one correspondence between the linguistic constants and the numerical values of the quality criteria is set. Thus the unit of the linguistic data conversion checks correctness of the inputted data (numeric or string). Translating unit sets the correspondence between linguistic data and quality criteria values. The unit for numeric assessment of linguistic data binds the actual numeric values for the modernization project.

The translating unit and the unit for linguistic data conversion are connected with the editing module of the system. It helps to change the weight coefficients of the quality criteria, introduce new
linguistic constants used to describe the project to modernization of the cement mill drive, change the values of quality parameters for alternative variants of drive modernization projects for an actual cement mill.

This approach provides the possibility of updating the automated system and changes the target function and limits for the problem of optimal modernization project of the drive.

Figure 4. Structure of automated system

4. Conclusion
The article analyzes the main parameters of the operating cement mill drive which influence the process of its modernization. Terms of application of various options for using the existing production site for the installation of a new drive are presented. A structure of the software is proposed to automate the preparation and evaluation of the project. The use of automation tools not only reduces the time of project preparation, but also improves its quality. The proposed methods were tested with the company-manufacturer of the drive solutions for cement mills.

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