ELABORATION OF THE ENERGY BALANCE FOR MACHINE TOOLS

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Abstract - When managers of industrial enterprises are unable to purchase new equipment, there is the possibility upgrade or remanufacture equipment supplied. For the action to be efficient it is necessary to draw up the calculation of economic efficiency of repair activities and for it must be drawn energy balance of the machine. For the balance sheet it is envisaged the principle of energy conservation. For this is defined the set of input quantities (given quantity measured, calculated indirectly)is calculated the losses of balance sheet account, are established the efficiencies values and are highlight the outputs values. Either open or closed, electricity balance elaboration must begin with determining working regimes of all facilities falling into the system analysis. The program aims to simulate ways to reduce energy consumption and increase technical and economic efficiency of a machine for mechanical processing. The program is based algorithms known from the literature, and includes balances that are common for DC and asynchronous electric motors and has a friendly interface.

Key words: energy balance, DC and asynchronous motors, energy losses.

1. INTRODUCTION

Due to the current economic stagnation, many companies are reluctant to purchase new equipments. One possible solution is remanufacturing the old ones with a certain factor of usage. Often even this solution is not successful in the company board.

The paper aims to support the energy manager in industrial enterprises, which are in a position to support these proposals. Thus, the general model of energy and economic analysis is presented for various mechanical processing equipment industry. The proposed model has a high general applicability and can be customized and could be applied to other machines who not necessarily perform mechanical processing.

2. THE MODEL OF ENERGY ANALYSIS

Principle considered in the energy analysis was that of considering energy equipment as a system where inputs and outputs are present, as shown in Figure 1. To achieve energy balance is envisaged principle of energy conservation [1]. For this, is define the set of input quantities (given quantity, measured and indirectly calculated), are calculate the loss of balance sheet accounts, are established yields values and are shown the outputs values [5]. If the energy in the system is equal to the useful energy added to the energy losses, then balance sheet is defined as electricity closed one, if not, the balance sheet is called open electricity. Either open or closed, electricity balance development must begin with determining working arrangements of all facilities falling into the analysis system. Installed electric power of the machine is determined by the rated output power of all receivers that goes into it.

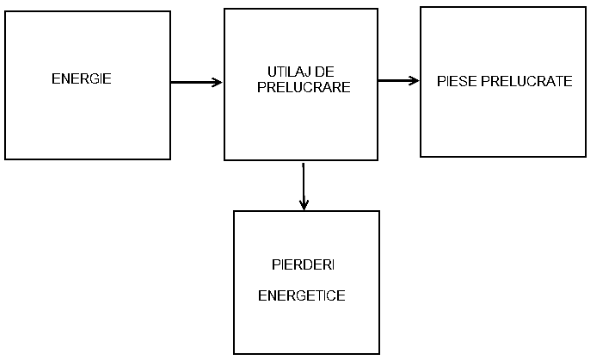

Fig. 1 Inflows and outflows - for a processing equipment

To develop real power balance there are some necessary steps to be taken as [6]: obtain and process technology knowledge that occur in the production department where there is the equipment, electrical equipment acquisition schemes, establish the necessary measuring equipment to these schemes, checking the equipments for measuring current, power and energy, doing measurements in a usual day of production, determination of electricity in the system analyzed, calculating energy losses of all consumers in the balance sheet, determine the useful energy in the energy equipment, making electricity balance and calculating efficiency indicators, analyze the obtained results by comparing the performance of similar equipment, establish appropriate technical and organizational measures to improve the operating mode of the machine etc.

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Closed electricity balance sheet is performed directly for the productive machines. These require measuring the quantities of electricity in the contour for a certain period, determining the energy losses within the system and determine the quantities of useful energy as difference of the two values. Electricity balance sheet is done only for active energy. Energy in (W_c) is that one absorbed from the power grid, and the useful one is that required energy from the cutting process.

General balance equation expresses that energy in the energy center (processing equipment) directly usable energy production is equal to the energy leaving the center (the energy required for chip separation and for movement) plus the amount of electricity losses into the process.

The proposed model enables the ongoing monitoring of electricity consumption for all machines. After analyzing the results of monitoring datas and calculations, can draw energy audit reports, which establish the most effective measures, which if are applied, are going to obtain the desired efficiency result, consisting in particular in reducing energy consumption, increasing productivity, and increase profits. Measures to increase energy efficiency are among others: increasing the share of products that require lower power consumption, upgrading manufacturing technologies, reduce energy losses occurring in distribution network, using appropriate electric motors installed power needed improvement power factor, installing automatic symmetrization tasks, installing harmonic filters, flattening the load curve, bad wiring upgrade, using modern measuring and control devices [3].

In analyzing the efficiency upgrade, it will be take into account the energy balance sheet for the remanufactured equipment. In this sense, it can use an algorithm for calculating of the energy consumption for all the motor drive based on their load [7]. Therefore we can use an index based on measuring the absorbed current, *load factor* who is the ratio of the current regime and the nominal:

$$\beta_I = \frac{I}{I_n} \tag{1}$$

For current measurement is not necessary to interrupt the operation of the machine. So following relationships are established by using the indicator β_I :

$$\eta \approx \frac{\beta_I - A_\eta}{B_\eta \beta_I} \tag{2}$$

$$\cos\varphi \approx \frac{\beta_I}{A_\varphi + B_\varphi \beta_I} \tag{3}$$

Active power absorbed by the motor system is calculated by the formula:

$$P_A = \sqrt{3}\, UI\cos\varphi \cdot 10^{-3} \quad [kW] \tag{4}$$

Shaft power is determined by the relation:

$$P_a = \eta P_A \tag{5}$$

Active power losses in the motor:

$$\Delta P = (1 - \eta)\, P_A \tag{6}$$

The regime reactive power absorbed is:

$$Q_A = \frac{\sqrt{1-\cos^2\varphi}}{\cos\varphi} \cdot P_A \tag{7}$$

The coefficients A^η, B^η, A^φ, B^φ are experimental and depend on the nominal efficiency value, i.e. the nominal power factor.

Useful energy is given by the *cutting power*. The latter one can be calculated [8] by using simple methods but effective in the same time, generally based on experimental measurements. Given that the main job of developing cutting forces are considered worthy of turning, milling, planning and boring that share processing margins removed with a knife. Considering the specific cutting resistance, k_c, as reported cutting force per unit area and thickness dependent cutting h_D, we can write a formula for power cutting experiment:

$$P_a = \frac{k_c \cdot v_a \cdot a \cdot t}{60 \cdot 10^3} \tag{8}$$

Were a is depth of cut, t – advance, v_a - cutting speed.

Main axis torque [2] :

$$M = F_a \frac{d}{2} \tag{9}$$

and linear velocity depending on speed:

$$v_a = \pi d n \tag{10}$$

And the angular velocity:

$$\Omega = \frac{v_a}{60} \tag{11}$$

Were d is the processing diameter.

Cutting power with global efficiency of the machine, η_u, causes the machine shaft power and the absorbed power from the network:

$$P_{arb} = \frac{P_a}{\eta_u} \tag{12}$$

Note:

P_c power consumed by the equipment;

P_{tm} total power loss of engine;

P_a output power used for cutting.

The energy losses during a day become:

$$\Delta W_p = t\, P_{tm} \ [\,kWh] \qquad (13)$$

Energy balance of the machine becomes:

$$W_c = W_a + \Delta W_p \qquad (14)$$

where W_c is the total energy consumed by the equipment, and W_a is the useful energy required in the process of cutting .

$$W_a = P_a\, t \qquad (15)$$

3. THE SOFTWARE USED FOR ANALYSIS

The program aims is to simulate ways to reduce energy consumption and to increase technical and economic efficiency of a analized machine for mechanical processing, based on the algorithms described in the previous chapter. The program is a simulation application that enables energy audit and a technical and economic analysis of the energy efficiency. One of the objectives of the program is to achieve a high degree of generality applications, enabling the analysis of a variety of specific equipment engineering industry. Another objective of the program is to create a database who will allowing enterprise to do periodical electric balance by providing responsable energy policy makers as an easy to handle, with reduced consumption of working. So, the technical characteristics of the machinery and electric motor drives are entered only once.

In terms of information, the application includes a database modules for computing the energy balance sheet indicators and a user interface. The user interface consists of input interface and one for the use of computing facilities and data display output. Each function is implemented in a separate user dialog units. So, we meet separation of input and update data on its engines drive the machine with the functions of audit and review. The solution is to develop an application with a programming language Java [4]. Running the application is optimum done on a screen display resolution with minimum of 1920 x 1080 pixels. Computer program requires the existence of a family of operating systems Windows 7, Windows XP. Hard disk space required is minimum about 15 MB. The program runs successfully on any PC computer with processor performance than 486. Recommended minimum configuration: Intel (R) Pentium (R) Dual CPU E2180, 20GHz and 1GB RAM. The program is based on some algorithms known from the literature, and includes balances that are usual done for DC electric motors and asynchronous motors. All auxiliary engines on equipment (pumps, fans) are treated as a single equivalent motor. Figure 3 presents the development of application to the study of Vertical lathe, SC27.

It can be observed the structure of the program:

- An overview of the machine and its features with the ability to supplement or delete this information;
- A database divided into several Divisions comprising data of different types of actuators of the machine;
- Engine computer for each balance sheet management, according to the presented algorithms;
- Computer cutting power, according to the algorithm;
- Computer of the energy efficiency;

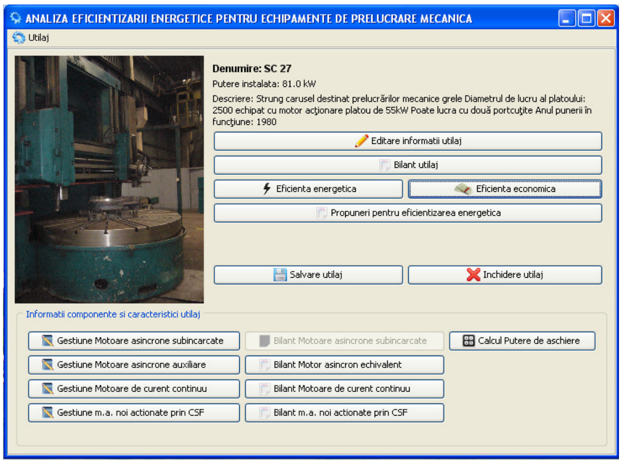

Fig. 3 Main window of the program

- Area for inclusion of proposals for energy efficiency where indicated modifications will be subject to modernize equipment,
- Computer energy efficiency which are evaluated during recovery and profitability of the project.

Functionalities are available through a user interface. Graphical interfaces are Windows type and provide an interactive environment.

Dialog boxes contain active buttons that allow the exit of the function, save and close the dialog. Dialog box has a title bar that also serves to activate the box. Button is displayed on its surface a label indicating the function to be executed. To operate a button graphic cursor is positioned (by moving the mouse) button and clicking the left button of the mouse.

Given the general nature of the application, you can use your input to a machine in order to open the application to another. For this purpose it uses input operations, deleting and modifying engines, keeping drives are shown (Figure 4).

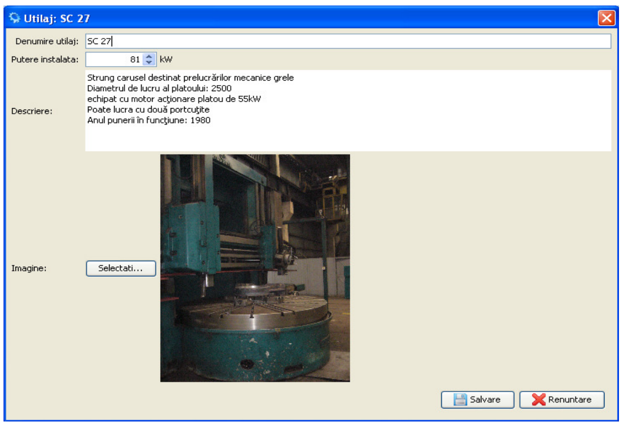

Fig. 4. Possibilities of changing the data base

Change operations are done by changing the value of attributes displayed, as shown in Figure 5.

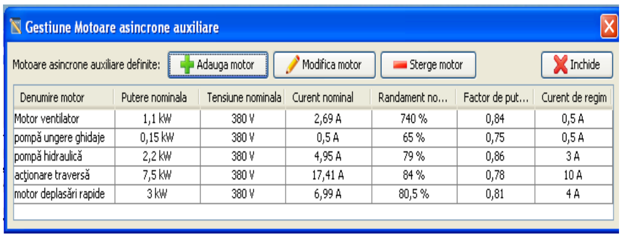

Fig. 5 Changing the attributes listed

Changes are the same in all databases to even process that generates user-friendliness. White space remaining on the windows is necessary in the event that the machine is equipped with a number of engines; it decreased as the extent of filling.

Once complete database, the program automatically calculates the respective engine energy balance individually and in groups. Pressing the energy balance can be seen entering the calculation engine parameters as in Figure 6. There appear beside coefficients calculated according to the algorithm and the engine operating parameters (efficiency, power factor, power consumption mode, an output shaft, active power losses and power consumption mode).

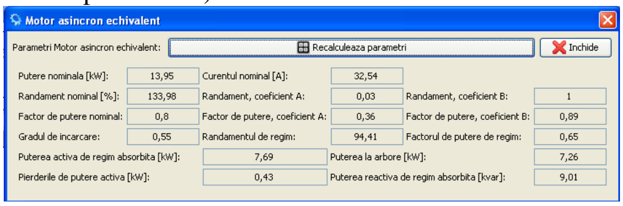

Fig. 6 Calculation of equivalent induction motor parameters necessary balance

The program can now proceed to calculate the energy balance across the machine, case in which appear the window as in Figure 7.

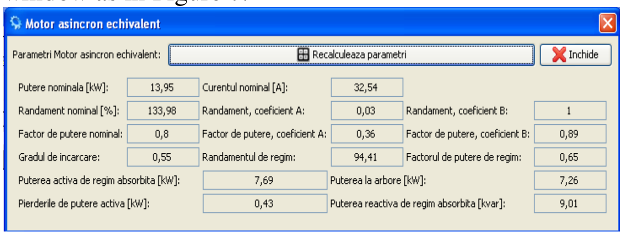

Fig. 7 Window for energy balance calculation sheet for the machine

As shown here are past data sheet: engine operating losses that occur in the process, the power used in cutting total losses engines. Are also displayed on, the time of use of the machine, which can put the user in the top right box, useful energy required in the process of cutting energy losses during a working day, the total energy consumed. The program is a checking account balance by calculating the absolute and relative error according to the algorithm and make a written display if the energy balance is correct.

Push the button "*proposals for energy efficiency*" it will opens a display as in figure 8, which is an area that can be inscribed proposals for modernization of equipment. These proposals are taking into account and they are the basis for calculating the energy efficiency and economic equipment upgraded .

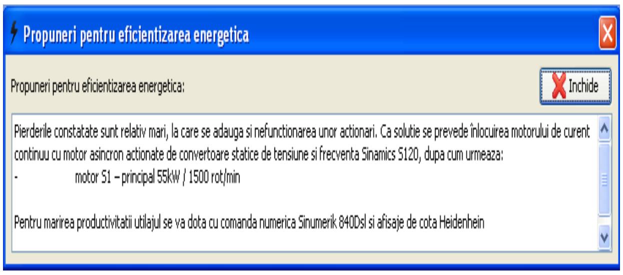

Fig.8 Window where the modernization proposals are introduced

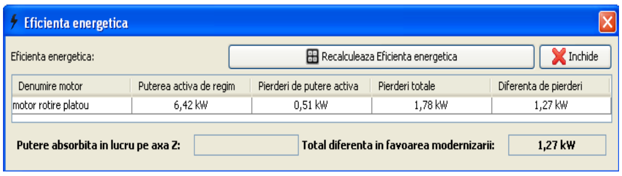

Fig. 9 Window indicating the energy efficiency of the equipment modernization

When push the "*energy efficiency*" there are shown in the window (figure9) active power mode engines that equip machines after upgrading, their losses, losses of old engines and the difference that exists between the loss of old engines and new engines. If the result is negative it can be concluded that modernization is no longer necessary for the purpose of replacement engines. Similarly, there may be negative gap losses. This means that the replacement drive is pointless.

There is also a calculator that displays the economic efficiency, who shown the recovery time of the investment and if it is considered cost effective (Figure 10).

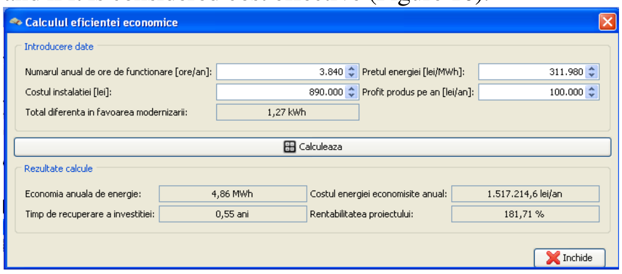

Fig. 10 Window indicating the economic efficiency of equipment modernization

4. CONCLUSIONS

An energy audit it is necessary to be made and for the machine tools, especially when is under discussion a program of modernization for industrial enterprises. The investments depends on the analysis made following the balance sheet, investments that are important to be made.

The procedure presented in the paper makes it possible to analyze the possibility of equipment modernization even during the working sessions of the Administration Board of the companies.

One important aspect is that both the technical and economic, actuators with DC motors need to be replaced sooner or later with asynchronous motors actuators for which speed is controlled by static frequency converters.

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