

EVALUATING THE EFFICIENCY OF CONTINUOUS HANDLING MEANS

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Abstract

The handling operations are the inseparable element of production processes. The percentage of this type of work, in reference to other production activities, can reach even high levels bringing the increase of expended costs. The capital consumption of handling works affects the improvement of a proper selection of means to assure the production profitability. An important issue of selecting the handling means is based on their work efficiency evaluation. The paper contains the description of the software (developed at The University of Life Sciences in Lublin), that would be helpful in solving the real problems associated with the selection of the continuous handling means used for works planned to do during a production process. The described software is an application consisting of forms that reflect divisions of means for continuous handling and connected databases for storing auxiliary information and results of calculations performed. The principle of the software is based on making calculations of the work efficiency as well as exploitation costs for continuous handling means. Additional values are: ease of data input and search for means characterized by possibly the lowest exploitation costs. Correctness of the software functioning was verified on an example related to comparison of three conveyor types.

Keywords: efficiency evaluation, continuous transport, exploitation costs

1. Introduction

Production processes require continuous translocation of different materials, both within a production facility, and out of it. Diverse solutions applied in enterprises are based on supplying the production components to the site, where the production is realized or translocation of a product between localities, where it is improved with particular elements. Regardless of the solutions selected for a given production process, handling devices aim at facilitating to create a product as profitable as possible. The percentage of handling works referring to other production activities, can reach different values. It can be assumed that the larger dimensions and weight of produced goods, the higher percentage of handling works during a process leading to their achievement. The significant capital consumption is usually assigned to the handling works; when their percentage in the whole production process is remarkable, they exert significant effects of the total costs. It indicates some significant role of selecting the means in assuring the profitable production. A proper selection of handling devices requires determining the efficiency of their work. The efficiency evaluation is based on making certain calculations according to particular method. Software that allow for fast, faultless, and complicated calculations plays an important role in making decisions. It can be of a special importance in situations, when calculations are very complicated and must be repeated in short time intervals [3].

The aim of study

The paper deals with presenting the software that aims at helping to select the continuous handling means to realize imposed tasks. The software will be developed, the function of which is

to make calculations of the work efficiency and exploitation costs of analyzed continuous handling means. Additional purpose of the application is to select devices (among analyzed previously) that are characterized by the highest possible work efficiency and the lowest possible exploitation costs.

2. Objects and methods

The efficiency of the continuous handling means was calculated on a base of formula appropriate for their types [1, 2, 5].

In the case of devices using the gravity, following formula should be applied:

$$q = S \sqrt{2gH(1 - \mu ctg\alpha)} \rho \psi, \quad (1)$$

where:

S - area cross-section of a device,

ρ - density of handled material,

ψ - fill factor of the device for continuous handling,

g - gravitational acceleration,

H - height of translocation,

μ - friction coefficient,

α - angle of the handling mean incline according to the level expressed in degrees.

Efficiency of belt conveyors can be estimated using a following formula:

$$q = S v \rho, \quad (2)$$

v - operating speed of a conveyor.

The area of transported material's cross-section depends on conveyor's construction, namely the way of rolls arrangement.

In the case of flat belt conveyor:

$$S = \frac{2}{3} \beta B h = \frac{1}{6} b^2 \operatorname{tg} \varphi, \quad (3)$$

φ - angle of repose for a material,

β - belt width use coefficient,

B - belt width.

In the case of belt supported by two rolls:

$$S = \frac{1}{6} (b \cdot \cos \gamma)^2 \operatorname{tg} \varphi + \frac{1}{4} b^2 \sin \gamma \cos \gamma, \quad (4)$$

b - section of the belt width in contact with transported material,

γ - angle of conveyor's rolls incline.

For belt conveyor supported by three rolls:

$$S = \frac{1}{6} (b \cos \gamma - l_1 \cdot \cos \gamma + l_1)^2 \cdot \operatorname{tg} \varphi + \frac{1}{4} (b_1^2 - l_1^2) \operatorname{tg} \varphi, \quad (5)$$

l_1 - horizontal fragment of a belt width.

Efficiency of drag conveyors can be determined using following formula:

$$q = S v \rho \psi c, \quad (6)$$

c - correction factor assuming the inclination of a conveyor.

To determine the work efficiency of bucket conveyor, below formula should be applied:

$$q = \frac{V}{a} v \rho \psi, \quad (7)$$

V - capacity of a single bucket,

a - distance between buckets.

The work efficiency of screw conveyor can be calculated from:

$$q = \frac{D^2 - d^2}{4} \omega s \rho \psi c, \quad (8)$$

where:

D - outer diameter of a screw,

d - diameter of screw's shaft,

s - screw's lead,

ω - angular velocity.

The costs for handling device exploitation were determined according to procedure proposed by Muzalewski [4].

Maintenance costs are defined as:

$$K_{utrz} = K_a + K_k + K_{ub}, \quad (9)$$

where:

K_a - amortization costs,

K_k - costs for storing and conservation,

K_{ub} - insurance costs.

$$K_a = \frac{C_m}{T}, \quad (10)$$

C_m - price for a device,

T - operation life.

$$K_k = 0,02C_m, \quad (11)$$

$$K_{ub} = U, \quad (12)$$

U - insurance amount.

Hourly maintenance costs can be determined by means of the formula:

$$K_{utrzj} = \frac{K_a + K_k + K_{ub}}{W_r}, \quad (13)$$

W_r - annual utilization.

Unit maintenance costs is described by the formula:

$$K_{uz} = K_N + K_{ee} + K_{mp}, \quad (14)$$

K_N - unit costs for recovery,

K_{ee} - unit costs for electric energy,

K_{mp} - unit costs for auxiliary materials.

$$K_N = \frac{k_n C_m}{T_h}, \quad (15)$$

k_n - recovery costs to device price ratio coefficient,

T_h - normative utilization of a device during working.

$$K_{ee} = Z_{ee} C_{kWh}, \quad (16)$$

Z_{ee} - use of electric energy,

C_{kWh} - price for electric energy.

$$K_{mp} = Z_{mp} C_{mp}, \quad (17)$$

where:

Z_{mp} - utilization of auxiliary materials,

C_{mp} - price for auxiliary materials.

Value of a unit exploitation costs is calculated on a base of the formula:

$$K_e = K_{utrzj} + K_{uz}, \quad (18)$$

3. Construing and verifying the software

An appropriate selection of a program, within which the application would be written, is crucial for creating the advisory systems. Both programming languages and programming environments have many unique features. These features may considerably affect the level of difficulty of particular purposes realization. Discussed software was construed within MS Access that is a part of MS Office package – one of the most common tools for creating the relation databases. Creator – as one of the most basic tool of the package – allows for quick and simple building the databases and forms used to make a clear user's interface. It is particularly important in the case of programming complicated systems, because it leads to reducing strenuous operations and substantial time saving. The executable code responsible for data collecting and processing, as well as displaying the results, was created with a help of Visual Basic for Applications language. The language is characterized by great opportunities and quite simple syntax, due to which it can be successfully applied to create application's elements that, cannot be built by means of any wizard.

The application in question was created in a form of “tree” consisted of connected forms, databases, reports, and queries. In order to make the software using easier and clearer, a starting window containing five buttons, was designed; press of any results in displaying forms assigned to particular types of continuous handling means (Fig. 1).

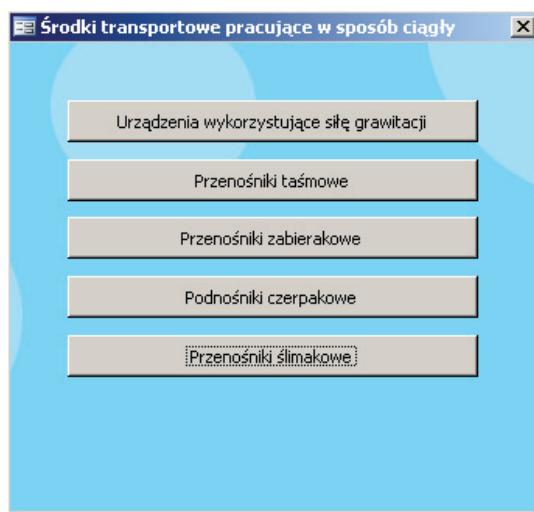


Fig. 1. Starting window

Forms assigned to the handling devices allow for making calculations of their work efficiency. Therefore, the text fields are incorporated, where data on the conditions of their work can be entered. The application was created with a view of users who have not wide knowledge upon the continuous handling. Thus, elements helping its utilization were designed; these are reports for display such information as densities of the most often handled materials, correction factors, permissible handling velocities for particular devices, etc. To make forms more clear, the text fields for data input and results output, were marked with some symbols. Due to a fact that using traditional legends containing excessive amount of described fields is difficult, the system was equipped with a property of the text fields named *Text formant labels*. This feature action is based on displaying a short explanation when the mouse cursor is moved over a given object, e.g. the text field. Such solution makes possible to efficient use of the application even by persons who work with it for the first time. Selected coefficients, the value of which are the same for majority of conditions, were placed in proper text fields as defaults, which allows for avoiding the necessity to input the same data every time when the calculations are to be made. Example of the calculation form is presented in Fig. 2.

Przenośniki taśmowe

Nazwa: Przenośnik PT-400-1

$$q = S \cdot v \cdot \rho \quad [\text{kg/s}]$$

Taśma oparta na jednej rolce Taśma oparta na dwóch rolkach Taśma oparta na trzech rolkach

B [m] 0,4 B [m] 0,4 B [m] 0,4
 β 0,65 β 0,65 β 0,65
 φ [stopnie] 16 φ [stopnie] 16 φ [stopnie] 16
 γ [stopnie] 16 γ [stopnie] 16 γ [stopnie]

v [m/s] 3 p [kg/m³] 670

Oblicz

S [m²] 0,003 q [kg/s] 6,03

Obliczenie kosztów eksploatacji

K_e [zł/godz] 3,47

Działania na rekordach

Fig. 2. Form assigned to belt conveyors

Previously mentioned reports are one of standard objects possible to apply within MS Access environment. Their action is based on displaying the data of interest grouped and divided in required manner. The tasks ordered to them consist in showing the user data contained in selected tables. Reports are generated automatically after pressing appropriate buttons and tables, the data are collected from, can be freely modified. The software allows for writing the results of operations made, which is an important value, because a user can compare the work parameters of newly analyzed devices with those of earlier browsed. Writing particular values is possible due to a constant connection among calculation forms with databases. These connections make that values entered to the text fields are automatically entered into the record fields of a table. It is an additional benefit, because data is not lost during accidental application exit. However, it is somehow inconvenient – entered data is remembered with no confirmation, thus randomly written value can lead to errors in calculations. There is another feature resulting from the connection between calculation forms with databases. It makes possible to view table records using form by

entering appropriate values to the text fields. Fast browsing the records is possible just by mouse scrolling. Slightly more complicated actions can be done using buttons in a window entitled *Actions on records* (Fig. 3). The window contains buttons for viewing the previous, subsequent, first, and last record of a table. There are also available buttons for deleting and searching within records of a result table according to ordered criteria.



Fig. 3. Actions on records window

Calculations of exploitation costs of particular devices are made using forms that are opened when button *Calculation of exploitation costs* localized on forms assigned to particular handling devices, is pressed. Placing the text fields used to make calculations of exploitation costs in separate forms aimed at achieving more clarity of the system, which in turn would result in a simple operating and lower probability of user's mistake.

C _m [zł]	2800	k _n	0,4
T [lat]	16	Z _p [kWh]	2,2
T _h [godz]	1500	C _p [zł/kWh]	0,24
o [%]	0		
Oblicz			
W _r [godz/rok]	93,75	K _{utrz} [zł/rok]	203
K _a [zł/rok]	175	K _{utrzj} [zł/godz]	2,17
K _K [zł/rok]	28	K _N [zł/godz]	0,75
K _o [zł/rok]	0	K _p [zł/godz]	0,55
K _{uż} [zł/godz]		1,3	
K _e [zł/godz]		3,47	

Fig. 4. Form for calculating the exploitation costs

Functioning of designed system was verified on an example of comparing the work efficiency of two belt conveyors, among which one has a belt supported by a single roll, while the other by two. Analyzed case referred to rye grain translocation. Belts width and its utilization coefficient, as well as the angle of repose and working velocity (specific for transported material) have the same values for both types of conveyors: 0.4 m; 0.65; 16°; 3 m/s, respectively. It was also assumed that the angle of roll's incline in two-roll conveyor was 20°. Moreover, it was assumed that the price of every device was 2800 PLN and that electric energy demand of the single-roll conveyor is 2.2 kWh, while the two-roll one is 2.6 kWh; other values required to make calculations of the exploitation costs were collected from tables included in [4]. Appropriately filled form is presented in Fig. 2. The efficiency of the belt conveyor, the belt of which is supported by one roll reached to

6.03 kg/s, whereas that of the two-roll conveyor 14.07 kg/s. The exploitation costs of the first discussed conveyor reached 3.47 zł/h, while these of the second 3.55 PLN/h.

Achieved results revealed that the efficiency of the two-roll conveyor greatly exceeds that of the single-roll one at assumed initial parameters. Minute differences of exploitation costs for both types of conveyors make that selecting such characterized by higher efficiency would be more beneficial.

4. Conclusions

Created software is an efficient tool helpful in selecting the continuous handling means for realization particular tasks. Solutions applied during the software programming make neither possibility of its use by persons who have not wide knowledge on the calculations nor properties of transported materials. Created queries allow for searching for devices according to ordered criteria, due to which making a binding decision on selecting particular handling mean becomes simpler and faster. Knowledge on costs for possessing and utilizing the handling devices allows for estimating the economic effects of the production process and planning any purchase, or acquiring an investment credit.

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