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INCREASE OF VENTILATION SYSTEMS PROCUREMENT AND INSTALLATION WORKS EFFICIENCY

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The article presents the results of theoretical research on obtaining of the maximum profit by the installation and procurement company in the manufacture and sale of pipe billets for the installation of ventilation systems in the production premise. Graphical and analytical dependences are given. The results of research substantiate the receipt of the maximum profit in the manufacture and sale of the ventilation pipe billets of the different diameters by the installation and procurement enterprise. The purpose of the work is to increase the efficiency of ventilation system installationin production facilities, to determine the maximum profit for the installation and procurement company in the manufacture and sale of pipe billets of the different diameters of ventilation system in the presence of several restrictions on materials and manpower, identify ways to improve installation of ventilation system in production facilities of small volume and justification of the calculation method. Quantitative characteristics of the objective function under given initial conditions are established. The calculated dependences for determining the parameters of the objective function are obtained. The obtained results allow to determine the optimal parameters of the values at the given restrictions on materials and labor intensity of production. The maximum profit in the manufacture and sale of ventilation pipe billets of different diameters by the procurement and installation company is determined. Using of the graphical method and the simplex method to determine the required parameters can significantly increase the efficiency criteria for procurement and installation work and thus reduce the amount of labor and material consumption for the manufacture and installation of ventilation systems.

Key words: procurement and installation work, ventilation system, material consumption, labor resources, profit, simplex method

Introduction

The physical state of the air space in the industrial rooms is characterized by different indoor climate characteristics that are maintained by system of ventilation (Gumen et al., 2016; Voznyak et al., 2005). Comfort conditions at first are determined by the air velocity and internal temperature (Dovhaliuk & Mileikovskyi, 2007; Voznyak et al., 2005). These values are supported by ventilation devices and depend on the designed structure both of air exchange and air distribution schemes (Dovhaliuk & Mileikovskyi, 2008; Voznyak et al., 2019). Normalized characteristics of indoor air must be provided in the working area of industrial premises, since the fact that the sanitary-hygienic characteristics of the room microclimate of the industrial rooms correspond to the physiological needs of a person depends, to a large extent, on its health and efficiency (Dovhaliuk & Mileikovskyi, 2013; Voznyak et al., 2005). In this case, the working area is situated both in the direct and in the return air stream of the incoming air flow. Combination of all factors determines the nature of the air flow at its leakage in a premise (Kapalo et al., 2018). CO_2 concentration in a premise also must be taken into account (Kapalo et al., 2019; Kapalo et al., 2014).

To implement these tasks there is a need to increase the efficiency of installation of ventilation in production facilities, increase profits for procurement and installation companies in the manufacture and sale of pipe billets of different diameters of ventilation, identify ways to improve the installation of ventilation in small production facilities and justification calculation.

Target of this article

The purpose of the work is to increase the efficiency of installation of ventilation in production facilities, determine the maximum profit for the procurement and installation company in the manufacture and sale of pipe billets of different diameters of ventilation system in the presence of several restrictions on materials and manpower, identify ways to improve small volume and justification of the calculation method.

Techniques used

The importance of providing normalized characteristics of the room microclimate due to low gabarites and presence of technological equipment as well maintenance personnel in the industrial premise on air velocity distribution and their features, is researched in (Gumen et al., 2016; Dovhaliuk & Mileikovskyi, 2007; Dovhaliuk & Mileikovskyi, 2008). It is known for example air distributors with a high intensity of the velocity and temperature extinguishing of the incoming air, that is, devices that provide an intense mixing of the tidal air with the environment (Dovhaliuk & Mileikovskyi, 2013; Voznyak et al., 2019). It is a great number of different designs of the air distribution devices and circuits of incoming air distribution, both in the upper and in the room serviced area, where the effect of the jets laying on the interior surfaces of walls or ceilings, which is a fairly wide spread phenomenon in ventilation technology (Voznyak et al., 2005).

All these devices, together with the piping, make up the ventilation system (Zhelykh et al., 2019).The ventilation system is located in the manufacturing premise (Fig. 1).

Fig. 1. Ventilation system in the production premise

Before installation of this system in the production room there is a process of its production at the assembly and procurement enterprise according to the specification (Zhelykh et al., 2019). It is clear that in the process of manufacturing a ventilation system there are production restrictions on materials and resources (Gass, 1961; Danzig, 1966; Lyashenko et al., 1975; Pupkov, 1974). This article offers tools and ways to optimize the production process to maximize profits and minimize production waste (Gass, 1961; Danzig, 1966; Lyashenko et al., 1975; Pupkov, 1974).

Consider the problem: the production of procurement and installation company (supply in the production room) products of two types – pipe billet ventilation system diameters d_1 and d_2 in the presence of restrictions on raw materials – (first equation of the system (1)) and labor – (second equation of the system (1)). Thus, the problem is two-dimensional and is as follows: to maximize the objective profit function $z = c_1x_1 + c_2x_2$ under constraints (1):

$$\begin{cases} a_1x_1 + a_2x_2 \le a_3 \\ b_1x_1 + b_2x_2 \le b_3 \end{cases} \tag{1}$$

Here x_1 means the number (running meter, for example in hundreds of meters) of the manufactured pipe billet with a diameter of d_1, and x_2, respectively – d_2, and $x_1 \ge 0$ and $x_2 \ge 0$. Suppose there are a_3 units of raw materials (for example, a_3 tens of running meters of metal) and b_3 units for labor resources (for example, b_3 man-days of labor). Define the solution space, which is located in a non-negative quadrant.

The first inequality $a_1x_1 + a_2x_2 \le a_3$ requires staying in that part of the non-negative quadrant, which consists of points (x_1, x_2) with coordinates that satisfy this inequality. The easiest way to determine such an area is to draw a boundary line $a_1x_1 + a_2x_2 = a_3$ at two points (one on the OX_1 axis and the other on the OX_2 axis). If $x_1 = 0$, then $x_2 = a_3/a_2$. If $x_2 = 0$, then $x_1 = a_3/a_1$. These two points $(a_3/a_1; 0)$ and $(0; a_3/a_2)$ lie on this boundary line. All points that lie in the shaded area and on the line that limits it, satisfy the inequalities $a_1x_1 + a_2x_2 \le a_3$ (Fig. 2).

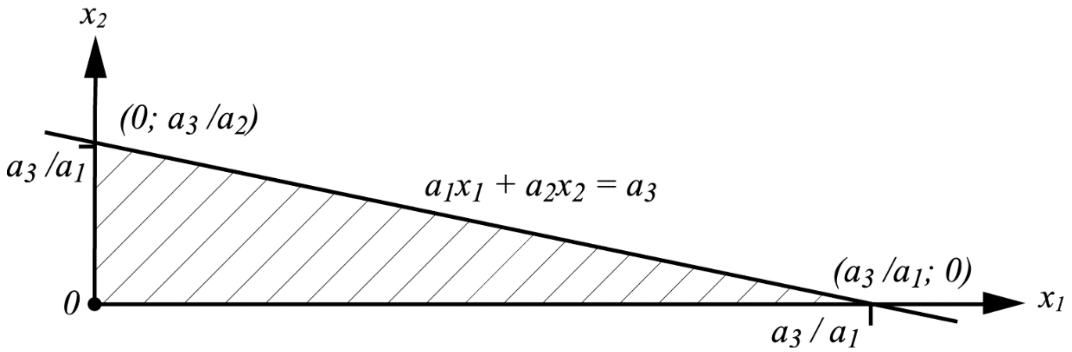

Fig. 2. Inequality solution $a_1x_1 + a_2x_2 \le a_3$

For the second inequality, the boundary line will be $b_1x_1 + b_2x_2 = b_3$, and its points of intersection with the coordinate axes – $(b_3/b_1; 0)$ and $(0; b_3/b_2)$, as shown in Fig. 3.

Any point of this convex set satisfies the inequality $b_1x_1 + b_2x_2 \le b_3$. We will find a solution that would satisfy both inequalities by combining the two shaded areas in one graph (Fig. 4) – their common part will be the desired space of solutions.

This combined solution space is all possible combinations of blanks d_1 and d_2, which can be made in the presence of a_3 running meters of metal and b_3 man-days, ie the constraint of the problem satisfies only the points belonging to the shaded area.

Until now, the problem of finding all the extreme points of the convex solution space, except for one point A, which is obtained at the intersection of two boundary lines, has been solved. This point is the case when all available resources are completely spent on the production of blanks d_1 and d_2. Any point of the line $a_1x_1 + a_2x_2 = a_3$, for example $(0; a_3/a_2)$, requires the use of a_3 running meters of metal without residue, similarly, any point of the line $b_1x_1 + b_2x_2 = b_3$ requires the full use of all available human -days. It is clear that both requirements are satisfied when we consider the point A of intersection of two lines with coordinates $A(i;\ j)$, which is obtained by solving a system of equations describing both lines. The coordinates i and j are determined from (2) and (3), respectively.

$$i = \frac{a_3 b_2 - a_2 b_3}{a_1 b_2 - a_2 b_1}; \tag{2}$$

$$j = \frac{a_1 b_3 - a_3 b_1}{a_1 b_2 - a_2 b_1}. \tag{3}$$

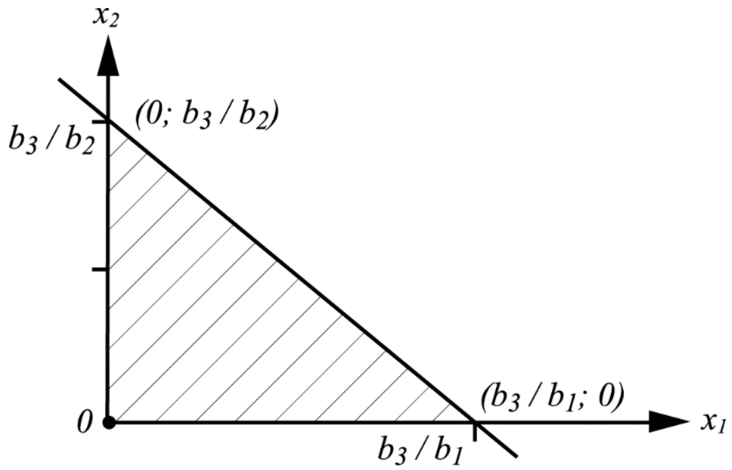

Fig. 3. Inequality solution $b_1x_1 + b_2x_2 \leq b_3$

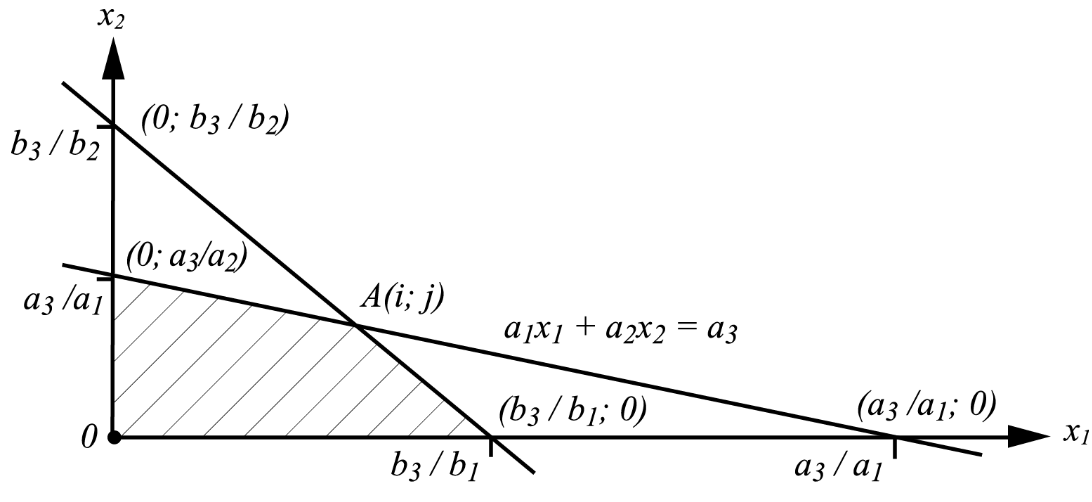

Fig. 4. Solution of the system of inequalities (1)

The next step is to determine which of the infinite number of points in the shaded area maximizes the target profit function $z = c_1x_1 + c_2x_2$. This expression is considered as the left part of some equation, which connects the variables x_1 and x_2. For example, the equation $c_1x_1 + c_2x_2 = 0$ is represented by the line shown in Fig. 5 by a dotted line. The equality of zero of the target function of profit z means that the procurement and assembly company does not produce any products, as evidenced by the direct $c_1x_1 + c_1x_2 = 0$. However, there is a need for the direct profit to shift in the direction of its growth, but without violating the conditions of restriction. associated with the availability of resources for both raw materials and labor intensity. It is necessary to move the direct profit only on the shaded area to a stop at the border, as it is no longer possible to look for a solution outside it.

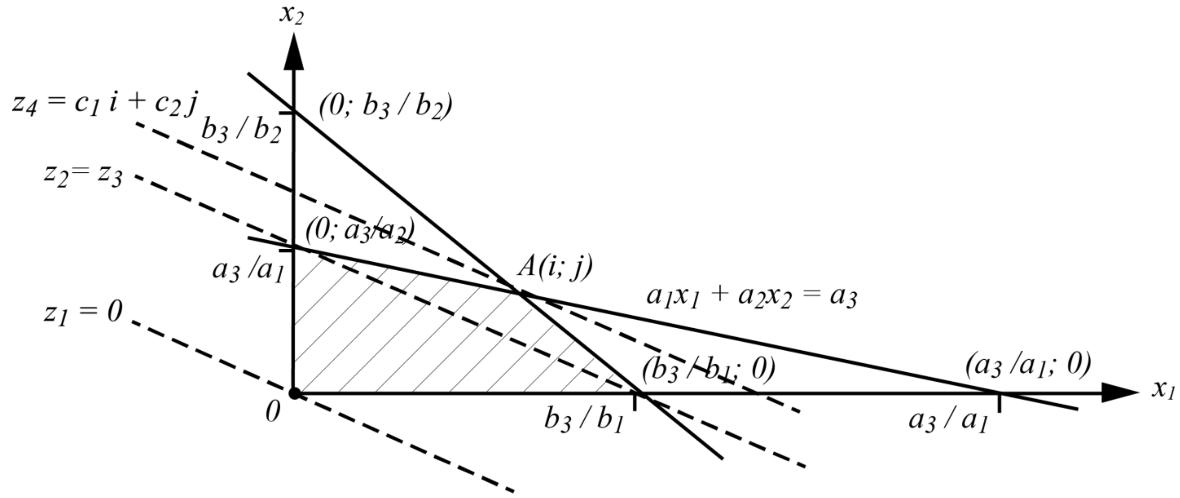

Fig. 5. Optimization of the objective function

We will demonstrate a geometric interpretation. This movement of the line of profit should be carried out by moving it up parallel to itself (Fig. 5), and the last valid position of this line will be its passage through point *A* (*i; j*). The objective function will have the maximum value $z_{\max}$ (4), (5):

$$z_{\max} = c_1 i + c_2 j\,, \tag{4}$$

$$z_{\max} = c_1 \frac{a_3 b_2 - a_2 b_3}{a_1 b_2 - a_2 b_1} + c_2 \frac{a_1 b_3 - a_3 b_1}{a_1 b_2 - a_2 b_1}\,. \tag{5}$$

The optimal production plan is to produce, respectively, $x_1 = i$ units, ie according to the condition $\frac{a_3 b_2 - a_2 b_3}{a_1 b_2 - a_2 b_1}$ meter pipe billet diameter d_1, and $x_2 = j$ units, ie $\frac{a_1 b_3 - a_3 b_1}{a_1 b_2 - a_2 b_1}$ meter diameter d_2. This will yield a profit of $z_{\max}$ units of value. Such a kind of "stretching" of the objective function through a convex set occurs precisely when special algebraic methods of the simplex method are used.

In the simplex method, the iterative process begins at any extreme point (as in this case $x_1 = 0$, $x_2 = 0$). Then it is determined which are the more favorable solutions located at the extreme points, and one of them is tested. This iterative process improves the solution in terms of optimizing the objective function, moving from some extreme point to a more favorable one, with a larger value of z. Iterations continue until an extreme point is found that no longer allows for further improvement ($x_1 = i$, $x_2 = j$, and $z_{\max}$).

The distinguishing feature of the simplex method, which makes it so economical, is that it determines the path from one extreme point to a more favorable neighboring one, sorting only a small subset of the set of all extreme points.

Point *A* (*i;j*) is the optimal production plan for a wide range of objective functions. If the profit from the sale of products d_1 or d_2 changes, then the angle of the direct profit will change – geometrically it will be the rotation of the direct profit around the point *A* (*i;j*). However, a significant change in the coefficients of profit can tilt our line so much that the optimum will be at another point. For any direct profit, the optimum is reached at one of the four extreme points. If the objective function occupies a boundary position that includes the boundary of the convex set, then the ambiguity of the optimal solution will arise. For an objective function with the same coefficients $z = cx_1 + cx_2$, the extreme points *A* (*i; j*) and *B* (b_3/b_1;0) will be optimal, as well as all points on the segment connecting them.

This approach can be used in solving any two-dimensional problem. In this case, you have to find only those points that are necessary for the boundary lines, as well as the extreme point at which the objective function last touches the convex set of solutions.

A similar general geometric interpretation is given for multidimensional problems of manufacturing a pipe billet not of two different diameters, but of a larger number of them according to the specification. A convex polyhedron is formed, defined by these constraints, and it remains to "pass" through it the objective function in the direction leading to the optimum. You can clearly imagine situations that arise in three-dimensional space, considering the room as a convex set, defined by the constraints of some linear program. However, problems with more than two variables are not solved graphically, but only using the simplex method.

Conclusions

On the basis of the obtained results we state:

– the quantitative description of the objective function characteristics is established;
– calculation dependences for determining of the objective function parameters are obtained;
– the maximum profit in the manufacture and sale of ventilation pipe billets of different diameters by the procurement and installation company is determined;
– the use of the graphical method and the simplex method of determining the parameters allows to significantly increase the efficiency criteria for procurement and installation work and thus reduce the number of labor resources and consumption of materials for the manufacture of ventilation systems.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ЗАГОТІВЕЛЬНО-МОНТАЖНИХ РОБІТ СИСТЕМ ВЕНТИЛЯЦІЇ

У статті представлені результати теоретичних досліджень отримання максимального прибутку монтажно-заготівельним підприємством в процесі виготовлення та реалізації трубної заготовки для монтажу системи вентиляції у виробничому приміщенні невеликого об'єму. Наведено графічні та аналітичні залежності процесу. Результатами досліджень обґрунтовано отримання максимального прибутку під час виготовлення та реалізації вентиляційної трубної заготовки цілого спектру діаметрів монтажно-заготівельним підприємством. Метою роботи є підвищити ефективність монтажу системи вентиляції у виробничих приміщеннях невеликого об'єму, визначити максимальний прибуток для монтажно-заготівельного підприємства в процесі виготовлення та реалізації трубної заготовки різних діаметрів вентиляційної системи за наявності декількох обмежень – за матеріалами та трудовими ресурсами, а також виявити шляхи підвищення ефективності монтажу системи вентиляції у виробничих приміщеннях невеликого об'єму та обґрунтувати методику їхнього розрахунку. Встановлено кількісні характеристики цільової функції при заданих вихідних умовах та отримано розрахункові залежності для визначення параметрів цільової функції. Отримані результати дають змогу визначити оптимальні параметри величин при заданих обмеженнях щодо матеріалів та трудоємності процесу виробництва. Застосування графічного методу та симплекс-методу для визначення необхідних параметрів заготовки дозволяє значно підвищити критерії ефективності проведення заготівельно-монтажних робіт і тим самим зменшити кількість трудових ресурсів та витрату матеріалів для виготовлення і монтажу вентиляційної системи загалом.

Ключові слова: заготівельно-монтажні роботи, система вентиляції, витрата матеріалів, трудові ресурси, прибуток, симплекс-метод.