UDC*: 621.512*

USE OF THERMAL ENERGY OF MINING COMPRESSOR UNITS

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Abstract. *Mining industry uses electricity as well as pneumatic power or compressed air power.*

Mining compressor equipment (KKU) that produces this energy is the highest power equipment. The share of the energy balance of mining enterprises with the underground method of extracting minerals is a large share and reaches 20-30% for ore mines.

Compressed air is transported from the compressor station to the pneumatic receivers of the mine through long air ducts. In this case, significant energy losses occur as a result of air cooling, as well as hydraulic resistance and pressure changes in the supply networks and compressed air leakage.

As can be seen from the above, the main energy and material costs in the use of pneumatic energy in mining enterprises are related to the production and transportation of compressed air.

Key words: *compressor, piston compressor, compressed air, energy, energy balance, cooling system, heat energy, heat carrier, temperature.*

UDC*: 621.512*

KON KOMPRESSOR QURILMALARINING ISSIQLIK ENERGIYASIDAN FOYDALANISHI

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Annotatsiya. *Konchilik sanoatida elektr energiyasi bilan bir qatorda pnevmatik energiya yoki siqilgan havo energiyasidan keng foydalanadi.*

Ushbu energiyani ishlab chiqaradigan kon kompressor uskunalari (KKU) eng yuqori elektr quvvatli uskunalar hisoblanadi. Foydali qazilmalarni qazib olishning yer osti usuli bilan kon korxonalarining energiya balansidagi ulushi katta ulushni tashkil etadi va ruda konlari uchun 20 – 30% ga yetadi.

Siqilgan havoni kompressor stantsiyasidan shaxtaning pnevmatik qabul qiluvchilariga tashish uzun havo kanallari orqali amalga oshiriladi. Bunday holda, havoning sovishi, shuningdek gidravlik qarshilik hamda ta'minot tarmoqlarida bosimning o'zgarishi va siqilgan havoning oqishi natijasida sezilarli darajada energiya yo'qotilishlari yuz beradi.

Yuqoridagilardan ko'rinib turibdiki, konchilik sanoati korxonalarida pnevmatik energiyadan foydalanishda asosiy energiya va moddiy xarajatlar siqilgan havoni ishlab chiqarish hamda tashish bilan bog'liq hisoblanadi.

Kalit so'zlar: *kompressor, porshenli kompressor, siqilgan havo, energiya, energiya balansi, sovutish tizimi, issiq energiyasi, issiqlik tashuvchi, harorat.*
UDC*: 621.512*

ИСПОЛЬЗОВАНИЕ ТЕПЛОВОЙ ЭНЕРГИИ ГОРНЫХ КОМПРЕССОРНЫХ УСТАНОВОК

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Аннотация. *Горнодобывающая промышленность использует электричество, а также пневматическую энергию или энергию сжатого воздуха.*

Карьерные компрессорные установки (ККУ), вырабатывающее эту энергию, является оборудованием наивысшей мощности. Доля энергетического баланса горнодобывающих предприятий с подземным способом добычи полезных ископаемых составляет большую долю и достигает для рудников 20-30%.

Сжатый воздух транспортируется от компрессорной станции к пневморесиверам шахты по длинным воздуховодам. При этом возникают значительные потери энергии в результате охлаждения воздуха, а также гидравлических сопротивлений и изменений давления в питающих сетях и утечек сжатого воздуха.

Как видно из вышеизложенного, основные энергетические и материальные затраты при использовании пневматической энергии на горнодобывающих предприятиях связаны с производством и транспортировкой сжатого воздуха.

Ключевые слова: *компрессор, поршневой компрессор, сжатый воздух, энергия, энергетический баланс, система охлаждения, тепловая энергия, теплоноситель, температура.*

Introduction

It is known that air compressors are generators of heat energy as well as compressed air production.

For the energy balance of a multi-stage reciprocating compressor, taking into account the energy equivalent to the heat released during air compression, the equation can be written as:

$$E = E_{п} + E_{и} + E_{ц} + E_{пх} + E_{кх} \quad (1)$$

where E is the total amount of energy supplied to the compressor motor; $E_{п}$ is the energy lost in the engine during the conversion and transmission of electrical energy into mechanical energy; $E_{и}$ - energy, equivalent to heat released by the compressor; $E_{ц}$ - energy, equivalent to the heat coming out of the compressor cylinders; $E_{пх}$ - energy, equivalent to the heat coming out of the intercooler; $E_{кх}$ is energy, equivalent to the heat coming out of the next cooler [5,6].

Style and materials. From the energy balance equation, the efficiency coefficient of the compressor machine is written as follows

$$\eta = \frac{E_{п}}{E} \quad (2)$$

All other components of the equation: $E_{и}$, $E_{ц}$, $E_{пх}$, $E_{кх}$ - represent the heat released during air compression, which is usually not taken into account when determining the useful work efficiency of the compressor. This heat is equal to the following for one-stage compression, J / s

$$Q = c_{р} \cdot M \cdot (T_2 - T_1) \quad (3)$$

For two-stage compression

$$Q = c_p \cdot M \cdot (T_2 - T_1) + Q = c_p \cdot M \cdot (T_2' - T_1') \quad (4)$$

For multi-stage compression

$$Q = \sum_{i=1}^{n} c_p \cdot M \cdot (T_{2i} - T_{1i}) \quad (5)$$

Here c_p is the constant pressure in the heat capacity of air J / (kg K); M - compressor efficiency, kg/s; T_1, T_1', T_{1i} - absolute air temperature at the beginning of compression in the first, second, i - stages of the compressor, K; T_2, $T_{2'}$, T_{2i} - the absolute air temperature at the end of compression in the first, second, and i stages of the compressor, K.

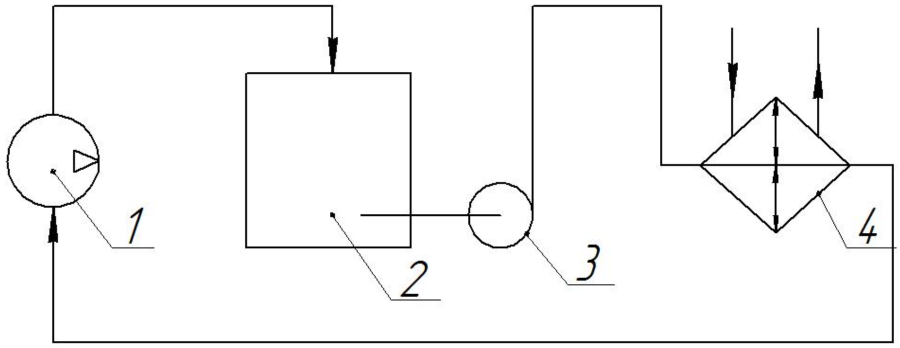
By reusing the heat released from the compressed air in the compressor, the overall FIK in pneumatic devices increases and can approach the FIK of electrified drives. In this case, pneumatic machines, while maintaining all other advantages, turn out to be less economical than electric devices.

Materials and Methods

Using a lot of information about the energy balance of compressors, for example [7], we analyze how much heat energy can be consumed in the operation of compressor devices. Thus, the thermal energy balance for a 2-stage piston compressor is as follows: 100 Joules for consuming electrical energy from the network, 9 Joules for the electric motor and transmission that converts electrical energy into mechanical energy, 6 Joules for cylinder coolant, intercooler and 33 Joules for cooling water and 32 Joules for the cooling water of the aftercooler. It can be seen that 71% of the consumed electricity can be used in the form of heat, in the form of hot water that can be used for various purposes, which leads to an increase in the efficiency of compressors. This is even more important because pneumatic energy produced by general purpose compressors is one of the most expensive forms of energy used in modern mining production industries. Thus, one kilojoule of energy obtained from the pneumatic drive of mining machines and mechanisms using compressed air is seven to ten times more expensive than the kilojoule obtained as a result of the operation of electric drive, so it is one of the important reserves for increasing the efficiency of pneumatic devices by reusing the thermal energy released from compressed air.

Due to the urgency of the problem of using compressed air thermal energy, a cooling and recycling device for the 4VM10 – 100/8 piston air compressor has been designed, installed and tested, which simultaneously removes the hot air from the main cooling system of the compressor. water acts as a primary heat carrier, and using the hot energy of this water by heating cold water is a secondary heat carrier [1,9].

This device works as follows (Figure 1). The water heated in the compressor 1 is poured from its cooling system into the discharge tank 2, from there it is supplied by a centrifugal pump 3 to a recuperative type heat exchanger 4, where the secondary cooling of the heat carrier (heat treatment water) circulates in the pipes, and the primary cooling of the heat carrier (in the cooling system of the compressor heated water) flows through these pipes from the outside, after which, having cooled to a certain temperature, it again enters the cooling system of the compressor.



1 – picture. Scheme of the cooling and processing unit of the compressor station:
1 – compressor, 2 – tank, 3 – pump, 4 – heat exchanger.

When moving through this heat exchanger, the heated water coming from the cooling system of the compressor absorbs its heat and cools when it interacts with the cold outer walls of the pipes, and the water flowing through the pipes absorbs this heat and heats up.

Results

The experimental operation of the cooling and processing device in the conditions of the mining compressor station gave the following average results (Table 1).

1 – table

Temperature change of heat carriers when passing through a heat exchanger

The temperature of the primary heat carrier is the water of the compressor cooling system		**The temperature of the secondary heat carrier is the water that uses the heat of the heated water in the compressor cooling system**	
Temperature at the inlet of the heat exchanger, t_1', °C	The temperature at the outlet of the heat exchanger, t_1'', °C	Temperature at the inlet of the heat exchanger, t_2', °C	Temperature at the outlet of the heat exchanger, t_2'', °C
25,5	20,0	5,0	15,0

The flow rate consumption of the secondary heat carrier was 20 m3/h or 5.5 kg/s. The thermal power processed in the experimental device can be determined from the heat balance equation as the heat flux received by the coolant of the secondary heat carrier:

$$Q_y = M_2 \cdot c_p \cdot (T_2'' - T_2') \qquad (6)$$

where M_2 is the mass consumption of the secondary heat carrier, kg/s; c_p is the average specific isobaric heat capacity of water, equal to $4.19 \cdot 10^3$ J/(kg·K); T_2', T_2'' is the temperature of the secondary heat carrier at the inlet and outlet of the heat exchanger.

Substituting the measured data, we get the value of the processed heat power equal to 230 kW.

The recycling coefficient can be calculated according to the following formula:

$$k_y = \frac{q_T \cdot \eta_э \cdot Q_y}{q_э \cdot N_k}, \qquad (7)$$

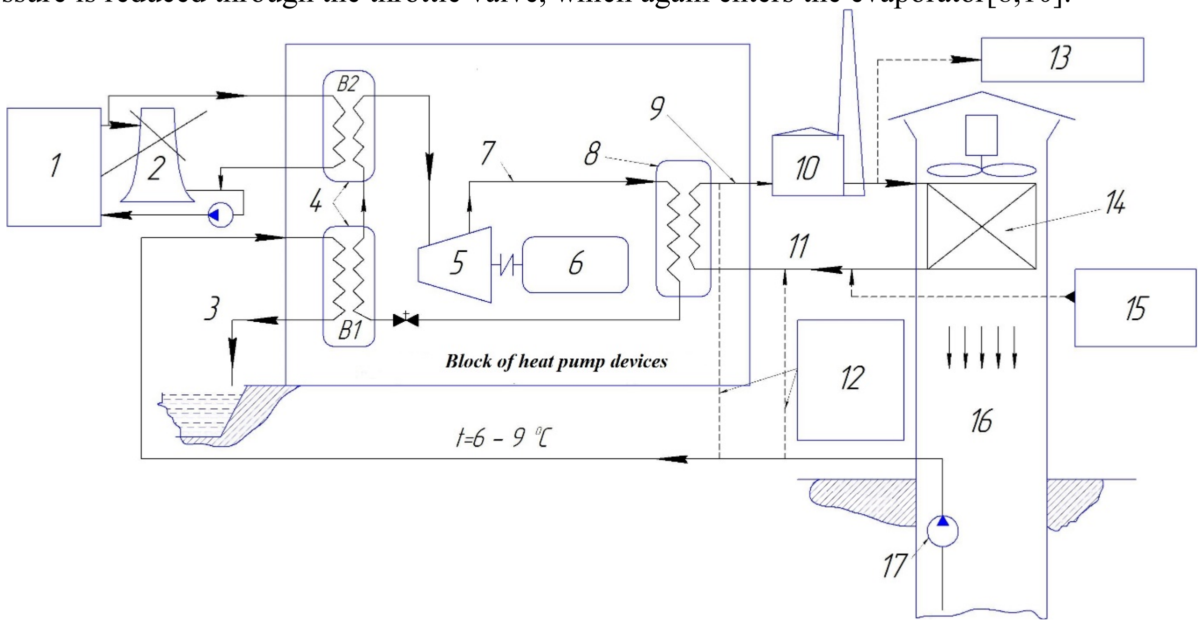
where q_T is the relative consumption of standard fuel for generating heat in mine boilers, kg/kJ; η_e – FIK of the power transmission line between the power station and the mine; q_e – comparative consumption of standard fuel for electricity production, kg/kJ; N_k is the power of the compressor engine, kW.

If the specific fuel consumption for heat production in mine boilers for mining conditions is $4.04 \cdot 10^{(-5)}$ kg/kJ and the specific fuel consumption for electricity production is $9.43 \cdot 10^{(-5)}$ kg/kJ, FIK Assuming that η_e=0.9, the power value of the processing energy calculated above and equal to 230 kW, the actual power consumed by the engine of the 4BM10-100/8 compressor from the network for its normal operation is 600 kW, were taking the value of the energy coefficient of operation equal to 0.15, that is, in this case, taking into account the recycling of the heat released from the heated water in the cooling system, the total FIK of the compressor unit increases by 15%.

Discussion

Due to the increase in energy prices, from the end of the last century, heat pumps (IN) began to be used, the principle of their operation is based on the conversion of heat from low-temperature sources to high temperature, and due to phase changes of the working substances, the heat consumer ozone R22, R134, R142 freons, as well as carbon dioxide (CO – R744), are used as refrigerants [3,4].

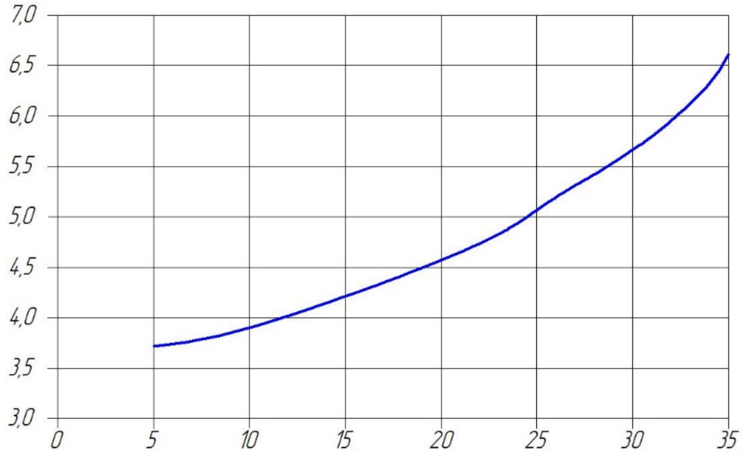
Figure 2 shows the scheme of comprehensive reuse of secondary energy in mines and mines using heat pumps. The evaporator of the heat pump consists of two circuits. Mine water with a temperature of t=6-9 °C is included in the 1-evaporator, and water heated in the KKU cooling system with a temperature of t=15-25 °C is included in the 2-evaporator. Due to the heating of this coolant, which is a low-temperature source, the refrigerant boils in the evaporator, that is, its temperature rises and the evaporation process occurs, after which the refrigerant vapor enters the compressor, where it is compressed. is compressed with, as a result of compression, the temperature increases further. Compressed vapors are condensed in a condenser at high temperature and pressure. Heat is supplied to the water of the heating or heat water supply system (t=65 °C), the refrigerant is cooled, and then its pressure is reduced through the throttle valve, which again enters the evaporator[8,10].



2 – picture. Principle scheme of comprehensive reuse of secondary energy resources in mines using heat pumps:

1. Mine compressor equipment, 2. Hot water cooling tower, 3. Mine water injection, 4. Evaporator, 5. Compressor, 6. Electric motor, 7. Freon, 8. Condenser, 9. Intermediate heater of heat carrier t= 650 C, 10-boiler room, 11-return of the heat carrier t=500 C, 12-seasonal changer of currents (instead of cooling tower allows to cool the circulating water of the enterprise in summer), 13-external consumer, 14-air heaters , 15-return from external consumer, 16-min hot air delivery, 17-min water discharge device.

The efficiency of the heat pump (IN) is evaluated by the coefficient of conversion (O'KB) [2], which shows the ratio of the amount of heat energy produced by the IN to the consumed 1 kW of electrical energy (Fig. 3).



3 – picture. Dependence of heat pump efficiency on low potential source temperature φ=f(T)

Conclusion

As can be seen from the graph, this coefficient varies in the range of 3.75 - 6.64, which is considered a low-level heat carrier - a cooled source, and in our case it depends on the water in the KKU cooling system and the temperature of the mine water. Since the temperature of the water in the KKU cooling system is higher than the temperature of the mine water, the conversion factor of using mine water is about 3.74 - 3.93, and it is 5.14 - 5.77 when using water in the KKU cooling system. it depends on many factors (season, condition of KKU cooling system, temperature of water entering the cooling system, etc.).

Therefore, since less work is required to compress the refrigerant, the efficiency of the IN increases, which means that the compressor, which is the main consumer of IN electricity, needs less power.

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