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NEW PRINCIPLE OF ORGANIZATION OF WORKING PROCESS OF AIR CONDITIONING SYSTEMS AT RAILWAY AND SEA TRANSPORT

Summary. An indispensable component of ensuring safe control of railway and sea transport in conditions of hot climate is maintenance of comfortable temperature of air in control cabins and living spaces. Now the interest is restored to use the Air Refrigerating Plants (ARP) as they have a wide potential of low-temperature cooling without use of ozone-destructive cooling agents prohibited by decision of the Montreal meeting. At the same time, air conditioning installations on the basis of turbo-expanders have low refrigerating factor, they are very expensive in manufacturing and require a high level of maintenance service.

Alternative trend of perfection of air refrigeration units is connected with a new principle of organization of working process, based on the use as expander and compressor of aggregates of cascade exchanger of pressure (CPE). Besides of unsurpassed efficiency of exchange processes, CPE is characterized by simplicity of design and high reliability, including, due to low frequency of rotation ($2000-3000 \text{ min}^{-1}$) with practically absence of consumption of mechanical energy on the drive of the rotor. The attractive aspect of application of equipment of conditioning with CPE is the opportunity of organization of working process only due to thermal energy including the utilization in the heat-power installation of transport vehicle.

НОВЫЙ ПРИНЦИП ОРГАНИЗАЦИИ РАБОЧЕГО ПРОЦЕССА СИСТЕМ КОНДИЦИОНИРОВАНИЯ ВОЗДУХА ЖЕЛЕЗНОДОРОЖНОГО И МОРСКОГО ТРАНСПОРТА

Аннотация. Необходимой составляющей обеспечения безопасного управления железнодорожного и морского транспорта в условиях жаркого климата является поддержание в кабинах управления и жилых помещениях комфортной температуры воздуха. В настоящее время возобновляется интерес к использованию воздушных холодильных установок, имеющих большой потенциал низкотемпературного охлаждения без использования запрещенных решением Монреальского совещания озоноразрушающих хладагентов. Вместе с тем воздушные кондиционные установки на базе турбодетандеров имеют невысокий холодильный коэффициент, дорогостоящи в изготовлении и требуют высокого уровня технического обслуживания.

Альтернативное направление совершенствования воздушных холодильных установок связывается с новым принципом организации рабочего процесса, основанным на использовании в качестве детандера и компрессора агрегатов

каскадного обменника давления (КОД). Помимо непревзойденной эффективности обменных процессов, КОД характеризуется простотой конструкции и высокой надежностью, в том числе, благодаря невысокой частоте вращения (2000-3000 мин⁻¹) с практически отсутствием затрат механической энергии на привод ротора. Привлекательным аспектом применения установок кондиционирования с КОД является возможность организации рабочего процесса только за счет тепловой энергии, включая утилизируемую в теплосиловой установке транспортного средства.

1. INTRODUCTION

The opportunity to reduce the price of ARP is connected with the use as the expander-compressor the Wave Pressure Exchanger (WPE) similar on a construction to the aggregate of air supply of the Internal Combustion Engine (ICE) "Comprex" supercharging system.

In a rotor of WPE, during immediate interchanging of energy between compressing and compressed mediums, alongside with cooling of a gas (air) stream, compression up to 25 ... 30 % of a coolant is carried out. The most part of a coolant is compressed in a separate, basic stage of the compressor actuated from an external power supply of mechanical energy.

Wave pressure exchangers alongside with attractive properties mainly associated with simplicity and reliability of a construction, have a number of disadvantages caused by a wave character of exchanged processes. The deviations of the operating mode of WPE from calculated conditions on a rotational speed of a rotor, consumption and temperature of the active medium are accompanied by sharp loss in performance of its operation as a result of both a mismatch of the moments of connection of a cell to the windows of a high pressure with phases of motion of primary waves, and owing to increase in a share of not displaced compressed air, remaining in a cell during the moment of its separation with the windows of high pressure. Besides the inevitable dissipative phenomena in processes of formation and interaction of strong shock waves limit the EFFICIENCY of the best specimens of wave exchangers of pressure on calculated conditions to values of 0,55 ... 0,56 [1].

To defects of WPE it is necessary to relate to the practical limitation of a degree of heightening of pressure in one step by values $\pi_k = 2,5 \dots 2,8$ according to criterion of efficiency of exchange processes.

Wider perspective of perfection of operating characteristics of ARP has use of a cascade pressure exchanger (CPE) as the expander and as well as the basic compressor of essentially new variety of energy-exchanging devices.

In the design of CPE which is developed in V.Dal EUNU an interchanging of energy is carried out in conditionally stationary static multistage processes of mass- exchange with forming waves of insignificant efficiency. Therefore the working process is characterized by a higher effectiveness and lesser sensitivity to the mismatch of a rotational speed of a rotor.

2. FEATURES OF WORKING PROCESS OF THE CPE

The principle of operation of the CPE is illustrated by figure 1 where monolayer scanning of cells of a rotor relatively to gas-distributing windows and mass-exchanging channels of a stator is schematized.

The active medium going from the window of gas of high pressure (GHP) in a cell of a rotor, «recompress» preliminary compressed air up to a level of resistance of a web and displaces it through the window of air of high pressure (AHP) to the consumer.

Potential energy of working mediums after disconnection with the windows of a high pressure it is usefully used for preliminary compression of fresh air during sequentially communication of a considered cell with the cells of compression section by means of head-exchanging channels. Thus, in

the process of cascade mass-exchange a pressure decreases stepwise in each of the cells during its moving on a site of expansion, and on a site of compression -raises stepwise.

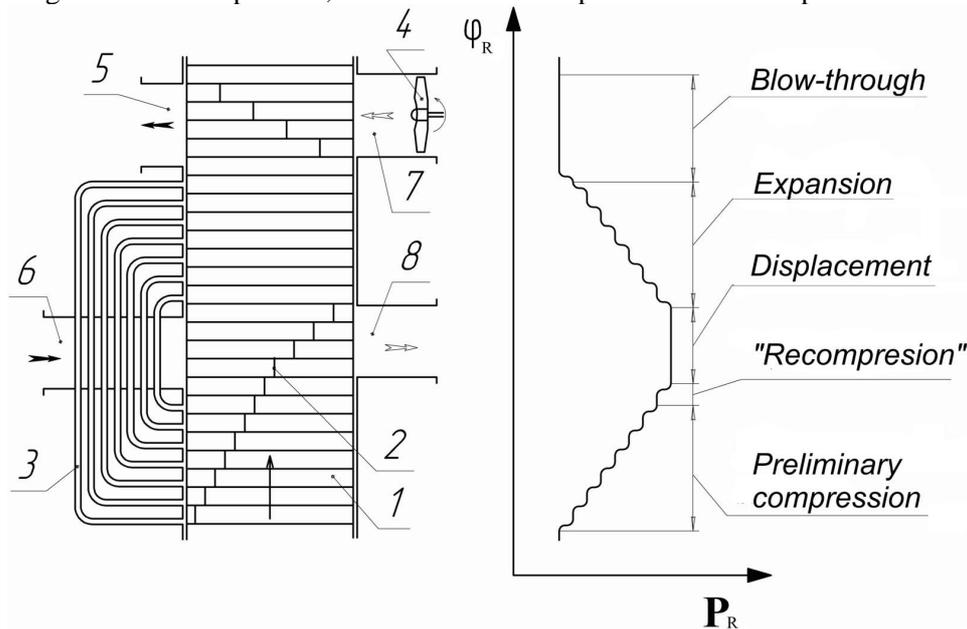


Fig. 1. The scheme of monolayer scanning of a rotor of the CPE relatively to the windows and channels of a stator: 1 - cells of a rotor; 2 - conditional contact boundary of compressing and compressed mediums; 3 - mass-exchanging channels of a stator; 4 - the blow-through ventilator; 5 - a window of Gases of Low Pressure (GLP); 6 - a window of Gases of a High Pressure (GHP); 7 - a window of Air of Low Pressure (ALP); 8 - a window of Air of a High Pressure (AHP)

Рис. 1. Схема развертки ротора КОД относительно окон и каналов статора: 1 – ячейки ротора; 2 – условная контактная граница сжимающей и сжимаемой сред; 3 – массообменные каналы статора; 4 – продувочный вентилятор; 5 – окно газов низкого давления (ГНД); 6 – окно газов высокого давления (ГВД); 7 – окно воздуха низкого давления (ВНД); 8 – окно воздуха высокого давления (ВВД)

At connection of a cell to windows of low pressure (GLP and ALP) forced purge is carried out with a fresh charge.

In the idealized cycle of the CPE, the exemplary equality of volumetric consumptions of compressed air and compressing gas takes place, therefore a relationship of mass consumptions of these mediums is close to inverse ratio of their temperatures. The noted one is direct affirming of higher EFFICIENCY of the CPE concerning the WPE, practically realizing the equality of mass consumptions of compressed and compressing mediums in structure of supercharging system of ICE.

The remarkable feature of the CPE duty cycle consists in insignificant influence of incompleteness of compressed air displacement from the rotor cells to the consumer ("dead" volume) on effective indexes of an exchanger. The reason of such insensitivity is quite explainable. Energy of the compressed air which was left in the cell after disconnection with the AHP window participates during cascade mass exchange and, hence, alongside with the energy of compressing gas in the cell is immediately consumed for the subsequent compression of the fresh charge.

The operating advantage of the CPE is also an opportunity of realization of working process at lower rotational speeds of a rotor ($1500 \dots 3000 \text{ min}^{-1}$) relatively a rotational speed of a rotor of WPE ($8000 \dots 12000 \text{ min}^{-1}$).

The design of the Cascade Pressure Exchanger is illustrated by figures 2, 3.

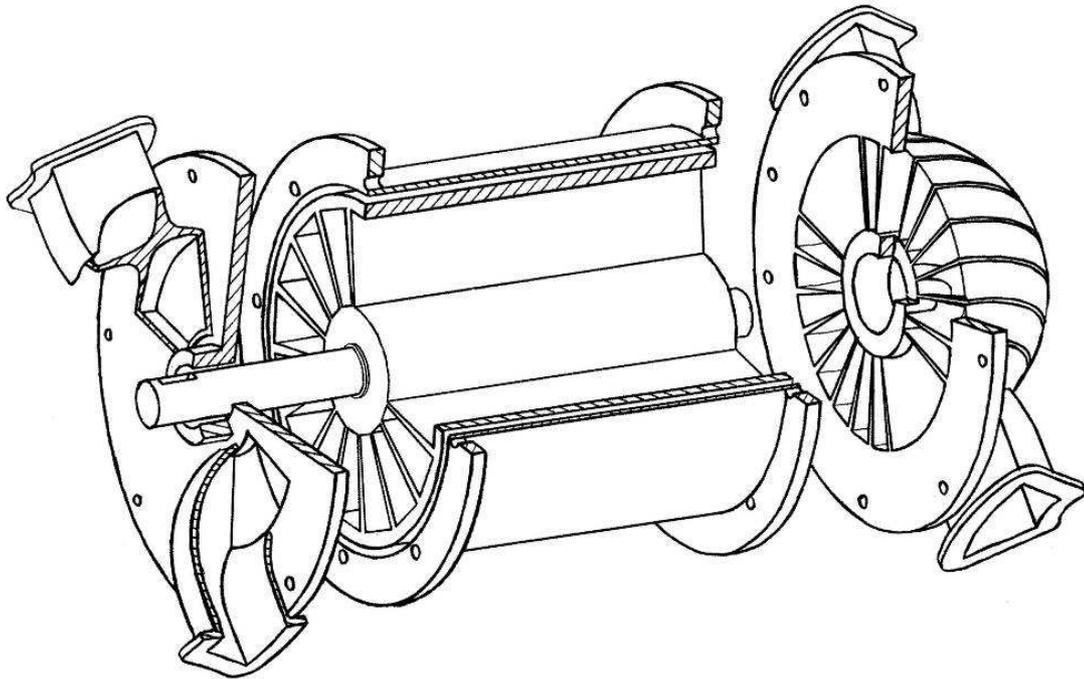


Fig. 2. A principal view of the Cascade Exchanger of Pressure (CPE)
Рис. 2. Конструктивная схема каскадного обменника давления

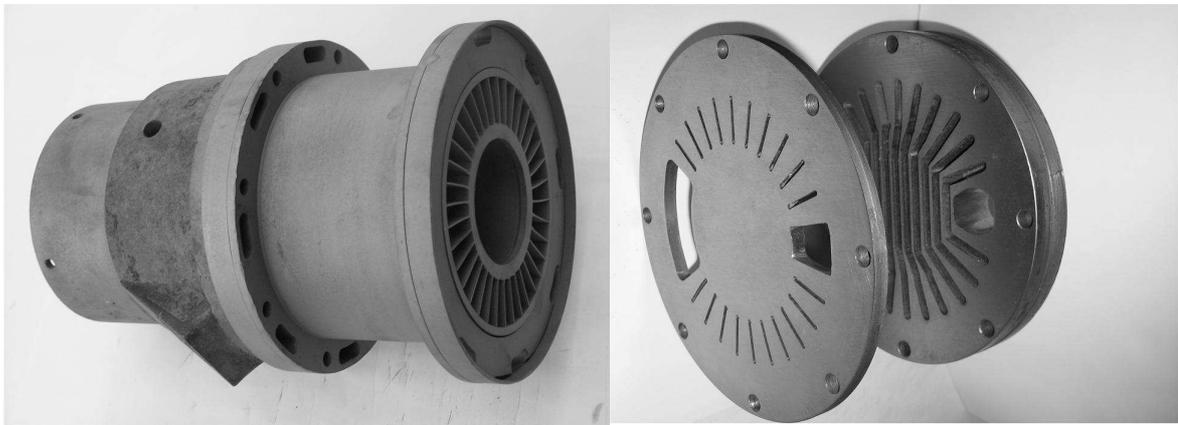


Fig. 3. The basic units of a Cascade Exchanger of Pressure
Рис. 3. Основные узлы каскадного обменника давления

The tests of some pre-production models {prototypes} have confirmed the efficiency of exchange processes in the CPE in a range of operating conditions up to $\pi_k = 4 \dots 4,2$. On the condition at $\pi_k = 2,5$ at a ratio of temperatures of compressing and compressed gases $\Theta = 1,82$ (a rotational speed of a rotor - 2750 min^{-1}) the efficiency of the CPE reaches values 0,82.

The noted above properties of the CPE allow to carry out a working cycle of an air (gas) refrigerator plant without use of the compressor of the basic compression step of a coolant agent.

3. OPERATING INDEXES OF ARP WITH THE CPE

On the basis of aggregates of the CPE the authors have developed the new design of no-compressor ARP with the CPE. In the design the thermal energy is the principal power source of

operation. In this device of ARP with the CPE mechanical energy is consumed only for a drive of the displacement ventilator of high-heading line and blow-through ventilators of lines of low pressure.

The tests of experimental installations of ARP with the CPE have shown the efficiency of its operation in a wide range of depth of cooling. At use of ARP with the CPE as the conditioner, working in heavy climatic and technological conditions with an ambient temperature above 45 ... 50°C, the expenditures for producing of cold output of 3,7 kW made: 0,85 kW of electric and 6,8 kW of thermal energy.

At comparative estimations of power perfection of ARP with the CPE should be taken into account the lower cost price of thermal energy concerning electric or mechanical energy, especially in conditions of autonomous navigation of a vessel (a condition of maintenance of a vehicle).

In an even greater degree the advantages of ARP with the CPE becomes apparent in conditions of production of deep cold (with temperature of a cooled object below -70 ... -150°C) where the use of traditional steam compression installations becomes problematic. At realization of a regenerative cycle, according to calculated investigations in the specified range of temperatures, the ARP with the CPE has considerably the best indexes of the cost price of production of a cold concerning the best specimens of air refrigerating machineries with turbo-expander.

Power efficiency of ARP with the CPE alongside with obvious simplicity of a construction and operating reliability open the perspectives of their wide application in various industrial spheres and on transport, including, as the refrigerating plants of railway mechanical sections, sea and automobile refrigerator containers.

More detailed information can be received at immediate contact to authors.

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