HEAT EXCHANGE APPARATUS

G.A. Dreitser
Department of Aviation Space Thermotechnics, Moscow Aviation Institute, Russia

Keywords: Heat transfer, heat exchangers, classification, thermal calculation, hydraulic calculation

Contents

1. Introduction

Heat exchangers are an integral part of the cooling systems of the elements of flying vehicles as well as of the cooling and thermostat systems of thermoelectronic equipment, and the conditioning systems of different heat exchangers. In order to select the most effective designs of different heat exchangers, it is necessary to have the data on the modern technological advances in the area of heat transfer enhancement as well as the information about the methods of choosing optimal parameters of heat exchangers and the methods of their calculation. Devices for heat transfer from one heat carrier to another are referred to as heat exchangers.

These are radiators, condensers, evaporators, recuperators, sublimers, heaters, boilers, different-type heaters and coolers of gases and liquids, etc. Heat exchangers find a wide use in power engineering; chemical, food, metallurgical, and petroleum refinery industries; on transport; in the engines of cars, tractors and combines; in the systems of heating and hot water-supply. Heat exchangers are also widely used in flying vehicles. The process of designing aviation heat exchangers occurs with an increase in the power stress and servicing energy systems that must be cooled.

UNESCO – EOLSS SAMPLE CHAPTERS

2. Purpose of Heat Exchangers

At moderate flight speeds the systems of aviation engines, lubricants, different equipment and optional energy systems can be cooled in heat exchangers using free air or other heat carriers. At supersonic flight speeds, due to the aerodynamic heating the free air in the air intakes has such a high temperature that it cannot be used for cooling. In addition, there arises the problem of special cooling of aircraft cabins, instrument compartments, chassis compartments and other elements of the aircraft design. For the cooling of these or those aircraft members, engines and power systems to be arranged, it is necessary to have special heat exchangers and coolants that have been supplied on the earth before flying or individual vehicle-borne refrigerating plants. In some cases heat is removed outward by radiation. The main coolant in vehicles is usually a fuel that passing from a tank to an engine cools the design members and can also cool the oil and compressor air. Water, alcohol, etc. serve as auxiliary coolants that being heated remove heat from a cooled surface. In future, when reaching hypersonic flight speeds it will become obligatorily to arrange cryogenic fuel cooling of all the engine members.

At high coolant resources it is possible to cool the air before the compressor or between the compressor stages. Consider the by-pass turbojet engine with reheat (TJER) for high flight speeds with the air cooling before the compressor of an inner loop. The schematic of such an engine is shown in Figure 1.

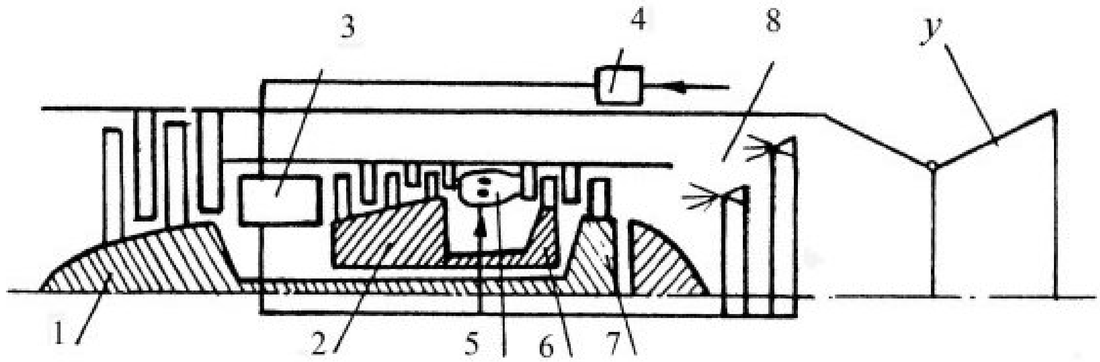

Figure 1. Schematic of the by-pass turbojet engine with reheat (TJER): 1 – fan; 2 –inner loop compressor; 3 – fuel-air heat exchanger; 4 – fuel pump; 5 – combustion chamber; 6 – compressor turbine; 7 – fan turbine; 8 – reheat chamber; 9 – propulsive nozzle.

The main distinctive feature of such an engine is the presence of a special heat exchanger for heat removal from the air before the compressor to the fuel. The air cooling enables one to increase the compression degree and to eliminate the necessity of cooling the compressor blades. The heated coolant (fuel) is supplied to the main combustion chamber of the inner loop and the reheat chamber.

In addition, it is possible to implement the schematic of the steam-hydrogen rocket-turbine engine where the compressor is driven by a superheated hydrogen turbine. Gasification and superheating of hydrogen occur in gas-hydrogen heat exchanger. After being expanded in the turbine, hydrogen is mixed with the compressor air and burns away in combustion chamber.

Figure 2 shows the schematic of the demonstrative variant of such an engine designed and tested by the firm "Pratt-Whitni." After being expanded in the turbine, hydrogen is directed to the combustion chamber and to the burning up chamber (behind a heat exchanger). The striving to improve the economy of aircraft gas-turbine engines has resulted in designing engines with heat regeneration. Also, the heat exchangers of the cooling systems of high-temperature turbines have received wide acceptance in aircraft engines. In the above engines, by the function, mass and size the heat exchangers are the main units of a propulsion system.

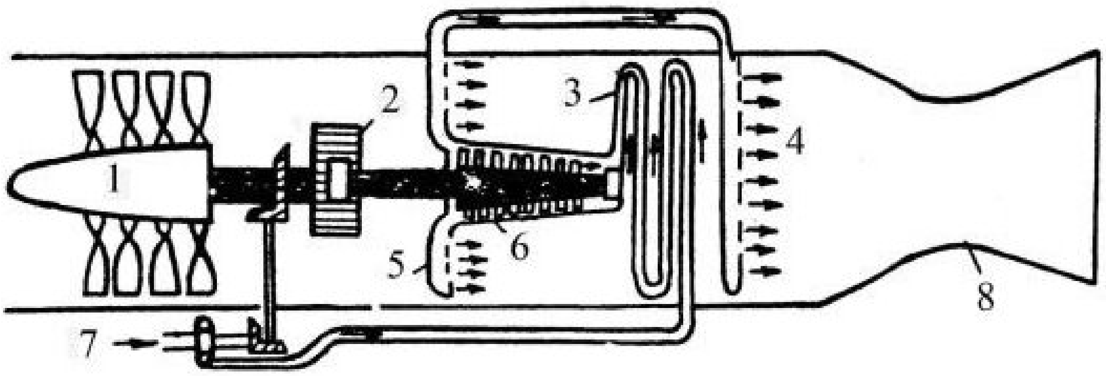

Figure 2. Schematic of the air-jet engine with the compressor drive from the superheated hydrogen turbine [8]: 1 – fan; 2 – reducer; 3 – heat exchanger; 4 – burning up chamber; 5 – turbine; 6 – main combustion; 7 – liquid hydrogen pump.

As a rule, the heat exchangers and radiators are some part of space power plants. For all these heat exchangers, of the most importance are the requirements on small size and mass. Heat transfer enhancement is an effective method to decrease them. This method is also beneficial for decreasing a temperature head and, hence, a wall temperature in the regenerative cooling systems of combustion chambers, engine nozzles and other members of the design.

The heat regeneration is also used in by-pass engines, turbojet engine with heat recovery (TJEHR). Air is compressed in fan and is divided into two flows. After being compressed in compressor, the first loop air is directed to heat exchanger where it is heated by hot gases. The final air heating occurs in combustion chamber. The combustion chamber gases enter the turbine of compressor, then that of fan and from there heat exchanger. In the heat exchanger the gases are heated by the first loop air before it is supplied to the combustion chamber and then enter nozzle where the gas is expanded to the atmospheric pressure. The second loop air is directed through a channel to nozzle. Unlike the turbo jet engines, where the gas is directed to the heat exchanger after being completely expanded in the turbine, in TJEHR it is only partially expanded in the turbine. Therefore, under the other conditions being equal the gas at the heat exchanger entrance of TJEHR will have a higher temperature. The thus increased temperature head yields the growth of the amount of the transferred heat and the economy of TJEHR. Heat exchangers as the main members are a part of the following systems of flying vehicles: fuel heating, lubricant cooling, air conditioning of cabins, thermal anti-icing over, fuel-tank pressurization by gas, hydraulic as well as cooling of instrument compartments, vehicle-borne compartments, etc.

UNESCO – EOLSS SAMPLE CHAPTERS

Despite a diversity of the used heat exchangers, in brief it is possible to place on them the essential thermal, hydrodynamic, constructional, operational and technological requirements.

1. The maximum compactness, i.e., a heat exchanger at the given values of heat power and power for heat carrier pumping must have small mass and volume, for which purpose it is necessary to achieve maximum possible heat transfer enhancement in the heat exchanger channels. If the sizes of the heat exchanger are assigned, then it is necessary that the heat exchanger must provide maximum heat power or minimum hydraulic resistance.

2. The stability of thermal and hydraulic characteristics of operating heat exchangers, i.e. the provision of their reliability during the assigned life service. To do this, the heat exchanger must obey such operating requirements as the small fouling of its heat exchange surface and the entire apparatus as a whole, the ease of cleaning, inspecting and repairing, the provision of the sealing of heat exchanger hot and cold cavities, the material resistance of heat exchange surfaces that is chosen with regard to the heat carrier properties, the retention of serviceability under considerable dynamic loads and different atmospheric conditions.

3. The simplicity, reliability and realizability of the design that provide, on the one hand, the satisfaction of such constructional requirements as the compensation of different thermal extensions of heat exchange surfaces and the body, the heat exchanger compactness and, on the other hand, the possibility of assembling heat exchangers with the use of the existing equipment and their reliable operation.

These requirements are often contradictory. That is why, when designing heat exchangers it is very important to determine the optimality criteria in each particular case.

3. Classification of Heat Exchangers

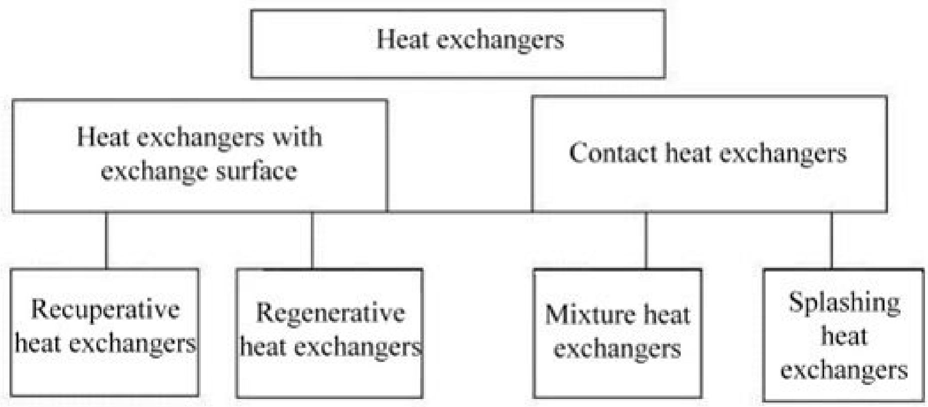

Figure 3. Classification of heat exchangers

Heat exchangers are used for heat transfer from one heat carrier to another. Heat carrier having a higher temperature and releasing heat is referred to as hot one while

©*Encyclopedia of Life Support Systems* (EOLSS)

heat carrier having a lower temperature and absorbing heat as cold one. According to the means of heat transfer, all heat exchangers can be divided into two large groups: surface and contact (Fig. 3). In surface heat exchangers heat carriers are either separated by a solid wall (such heat exchangers are referred to as recuperative ones) or they in turn contact one and the same wall (such heat exchangers are referred to as regenerative ones). This wall (surface) is referred to as a heat exchange surface.

In a recuperative heat exchanger one side of a heat exchange surface is all the time streamlined by a hot heat carrier and another, by a cold heat carrier. Heat is transferred from one heat carrier to another through a wall that separates them. The direction of the wall heat flux remains invariable (Figure 4).

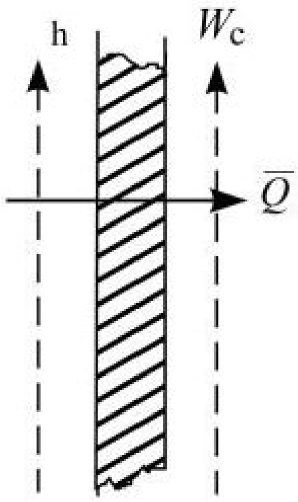

Figure 4. Schematic of the recuperative heat exchanger ($\overline{Q}$ is the heat flux direction).

In a regenerative heat exchanger the common heat exchange surface is by turns streamlined either by one or another heat carrier (Figure 5).

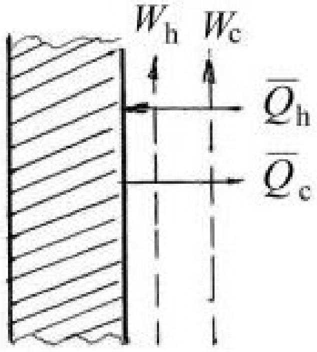

Figure 5. Schematic of the regenerative heat exchanger ($\overline{Q}_h$ is the direction of the heat flux from a hot heat exchanger; $\overline{Q}_c$ is the direction of the heat flux from a cold heat exchanger).

UNESCO – EOLSS SAMPLE CHAPTERS

During heating of a heat exchange surface called a regenerator nozzle it contacts a hot heat carrier and accumulates heat that during cooling is transferred to a cold heat carrier. The direction of the wall heat flux is reversed at regular intervals. Balls, rings, small pipes assembled into a close-packed bundle, sometimes brickwork (for example, in the regenerators of open-hearth furnaces) were used as nozzles in such heat exchangers. The advantages of such heat exchangers are the possibilities to locate a large surface per unit volume (large compactness) and to operate at high temperatures (when high-temperature materials serve as nozzles), the disadvantages are the bad sealing, the inevitability to mix heat carriers, the impossibility to operate at high pressures of working media.

In contact heat exchangers heat is transferred at the direct contact of hot and cold heat carriers, in this case heat transfer is accompanied by mass transfer. These heat exchangers are divided into mixture and splashing ones. In mixture heat exchangers the hot and cold heat carriers are mixed and form solutions or mixtures (these are scrubbers or mixers of hot and cold water used in water-supply systems. In splashing heat exchangers the heat carriers are in different phases and at contact they exchange heat, practically not mixing. For example, in tower-coolers the drops of sprayed water are cooled by the oncoming flow of the cold air while in sprayers the hot vapor is cooled, lifting through a cold liquid layer. Contact heat exchangers cannot be used if the working media have different pressures or in general cannot be mixed. Contact and regenerative heat exchangers have not found a wide use in practice. As before the recuperative heat exchangers that will be considered below remain the basic type of heat exchangers used in different branches of technology.

-
-
-

TO ACCESS ALL THE **22 PAGES** OF THIS CHAPTER,
Visit: http://www.eolss.net/Eolss-sampleAllChapter.aspx

Bibliography

Avduevsky, V.S., Galitseyskiy, B.M., Globov, G.A., et al., Eds. V.S. Avduevsky and V.K. Koshkin, (1992),.Fundamentals of heat transfer in aviation and rocket-space technologies. Handbook. Second edition. Mashinostroyeniye, Moscow, 528 p.

Bakylev, V.I., Golubev, V.A., Krylov, B.A., et al., Eds. V.A. Sosunov and V.M. Chepkin, (2003), Theory, calculation and design of aviation engines and energy plants. Handbook. Third edition. MAI Press, Moscow, 688 p.

Dreitser G.A., (1986), Compact heat exchangers. MAI Press, Moscow, 74 p.

Hesselgresves J.E., (2001), Compact heat exchangers: selection, design, and operation. Pergamon. An Imprint of Elsevier Science. Amsterdam, London, New York, Oxford, Paris, Shannon, Tokyo, 398 p.

Kakas S., (2002), Lin Hongtan. Heat exchangers: selection, rating, and thermal design. Second edition. CRC Press, Boce Raton, London, New York, Washington DC, 501p.

Kakas S., Burgles A.E., and Maginger F., Eds. (1981), Heat exchangers: thermal – hydraulic fundamentals and design. Hemisphere, Washington DC.

Kalinin E.K., Dreitser, G.A., and Yarkho S.A., (1990), Heat transfer enhancement in channels: Third edition. Mashinostroyeniye, Moscow, 200 p.

Rohsenow W.M., Hertrett J.P., and Ganic E.N. Eds., (1985), Handbook of heat transfer application. Second edition. McGraw-Hill, New York.

Biographical Sketch

Genrikh A. Dreitser. Moscow Aviation Institute – MAI. 4, Volokolamskoe shosse, Moscow, 125993, Russia

Date of birth- 14.06.1934. Engineer (Moscow Power Engineering Institute) - 1958. Doctor of Philosophy (Moscow Aviation Institute)- 1964. Doctor of Technical Sciences (Moscow Aviation Institute) - 1978. Titled Professor (Moscow Aviation Institute) - 1981. USSR State Prize Laureate -1985. Russian Federation State Prize Laureate - 1990. Honored Scientist of Russian Federation - 1996. Two Gold Medals of USSR State Industrial Exhibition-1983, 1985. Three Silver MAI Prize Laureate - 1996, 2000.

He is a well known specialist on heat and mass transfer and aerospace thermal techniques. He executed fundamental researches or unsteady heat transfer hydrodynamics in single-phase and two-phase cryogenic fluids in channels and tanks with reference to aerospace engines and power installations. His work has led to the development new engineering methods of calculation unsteady and emergency regimes in engines and power installations, methods of calculation of turbulent two phase flows. He developed and investigated an effective method of heat transfer enhancement in tubular heat exchangers. He for the first time found out the law of remarkable increase of heat transfer in channels with discrete turbulizers in comparison with similar smooth channels concerning increase of hydraulic resistance. This law was registered by USSR State Committee Inventions and Discoveries in 1981 as scientific discovery. Professor G.A. Dreitser – author more than 450 published works, including 24 monographs (Books), among which 6 were translated in the USA.

UNESCO – EOLSS
SAMPLE CHAPTERS