CYCLES OF GAS TURBINE ENGINES WITH GAS DYNAMIC REGENERATION

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One of shortcomings of the Carnot cycle is a considerable difference of specific volumes of a working fluid that results in a large size of the flow path of blade machines or a length of the cylinder in the piston machines. This shortcoming can be eliminated by replacement of adiabatic expansion and compression by isochoric (Stirling cycle) or isobaric (Eriksson cycle) ones with intermediate regeneration of heat. In this case, with the same efficiency as in the Carnot cycle, it is possible to essentially reduce sizes of the flow path of the thermal machine.

CYCLE OF A THERMAL MACHINE

Figure 1, a shows ideal gasdynamic cycle of a thermal machine without a compressor. After isothermal expansion of the working fluid in the cylinder (or blading of a gas turbine) (1-2), where all the heat Q_1 delivered will be converted to useful work, the gas enters in a subsonic channel,

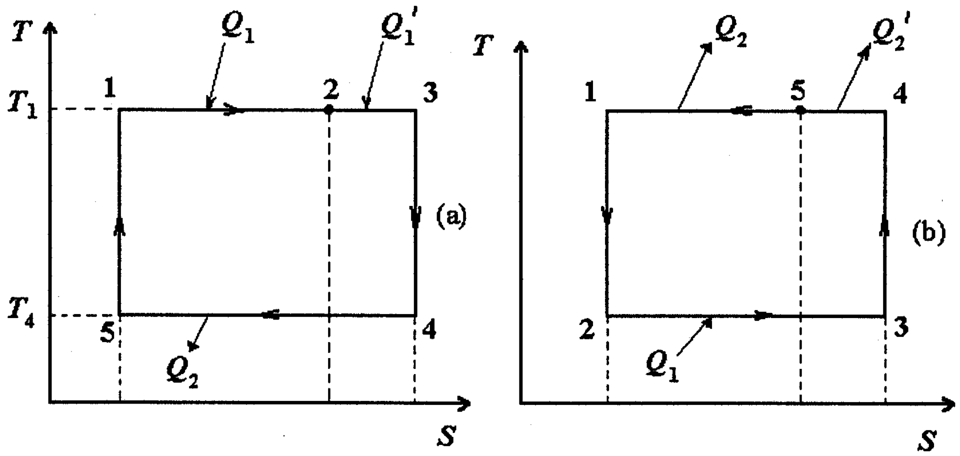

Figure 1. Gas dynamics cycles thermal (*a*) and refrigerating (*b*) machines without compressor and expander

where isothermal input of the additional heat Q_1' takes place. In this case, according to the theory of the thermal nozzle, a static pressure and a stagnation pressure decrease, whereas a stagnation temperature increases by Q_1'/C_p. The gas is accelerated up to a sound velocity in the point 3 and then further adiabatically expands (3-4) in a supersonic nozzle. The rejection of heat from the supersonic gas flow occurs in the isothermal process (4-5). For closing the cycle without using a compressor, it is necessary to meet the condition of $Q_2 = Q_1'$. Then the stagnation temperature of the gas in the point 5 will be equal to that in the a point 1 and the cycle becomes closed by the adiabat of compression (5-1) in a supersonic diffuser. It is possible to show, that the stagnation pressure in the point 5 under accepted conditions will be equal to that in the point 1.

This will result in irreversible energy losses in comparison with the ideal reversible processes. For reducing these irreversible losses it is necessary to decrease a temperature difference between the gas and the environment. In a limiting cycles, it can be achieved by decreasing of the recovery factors. As it was already pointed out, when using the gases as a working fluid, the recovery factor poorly differs from unit, however, for several mixtures of gases (He-Xe or H_2 - Xe), the Prandtl number and, consequently, the factor *r*, are essentially less than unit.

A creation of a positive pressure gradient along the gas flow gives another one opportunity of reduction of the recovery factor. As is known[1], very small, even negative values of the recovery factors were measured in an area of the boundary layer separation in a cross flow over the cylinder. Along the (4-5) line the supersonic gas flow takes place with a positive pressure gradient and we can expect favourable influence of this gradient on the recovery factor. However, it is necessary to note, that in the cycle of the refrigerating machine, the process of heat input (2-3, *Figure 1, b*) occurs with a negative gradient of pressure. The effect of the cross flow of the substance on the recovery factor is shown in[2-3], however, using of this effect is inconvenient, when realising thermodynamic cycles. An interesting opportunity reduction of the recovery factor gives on organisation of a condensation shock at an exit from the supersonic nozzle. In this case, the condensate can deposit on a wall of the channel and the recovery factor tends to zero, since a temperature of the liquid drops is close to the thermodynamic temperature of the gas. Using of this effect in the process (2-3, *Figure 1, b*) of the cycle of the refrigerating machine seems to be especially promising.

CONCLUSION

In this paper, ideal cycles of the thermal and the refrigerating machines are analysed, in which gasdynamic processes of the gas flow in channels with heat addition and heat rejection are used for closing the cycle. It is shown, that for ideal processes the efficiency of such cycles is equal to that of the Carnot cycles. At the same time, the basic shortcoming of the Carnot cycles, that is a high degree of the expansion in the turbine, is eliminated. Moreover, in the ideal cycle, the process of compression of the gas is accomplished in the cooled channel. Several questions should be solved, such as a start of machines, some problems of operation of these cycles, and also the problem of adjustment of a capacity. There is a lot of unresolved problems, which are connected with using of phase transitions (evaporation and condensation). For practical realisation of proposed cycles more thorough theoretical and experimental studies are necessary.

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