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FLOW THERMODYNAMICS. CHANGES IN THE KINETIC ENERGY OF THE CURRENT AND ITS MANIFESTATION IN NOZZLES AND DIFFUSERS

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Abstract
This article describes the theoretical foundations of flow thermodynamics, energy exchange processes in gas and liquid flows, and their practical importance. The connections between the kinetic energy of the current, internal energy and pressure energy are analyzed, the working principle of nozzles and diffusers, as well as the laws of work in isochoric, isothermal, isobaric and adiabatic processes are explained. The first law of thermodynamics for gas flow and its physical content are revealed. The article shows the role of flow thermodynamics in understanding and improving the efficiency of energy circulation processes in gas turbines, compressors, heat exchangers and jet engines.
The article analyzes the laws of thermodynamic change of flow kinetic energy, its role in gas and liquid movement processes, as well as energy exchange in nozzles and diffusers. It is justified that the kinetic energy of the current is important in creating useful work in heat machines and reactive devices.

Keywords: Flow thermodynamics, gas flow, kinetic energy, internal energy, pressure, nozzle, diffuser, isochoric process, isobaric process, isothermal process, adiabatic process, enthalpy, heat exchange, gas turbine, jet engine, heat exchange apparatus.

Introduction

Flow thermodynamics — is a branch of science that studies energy exchange, heat, and work processes in the state of motion of gases and liquids, and it is one of the important branches of thermodynamics. This direction is based on the use of kinetic energy of the working body-gas or steam‘ current in steam‘ and gas turbines, turbochargers, jet engines, modern machines.

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Within a fluid or gas stream in motion, energy is constantly transferred from one form to another: pressure energy can be converted into kinetic energy, and kinetic energy can be converted into heat or mechanical work.

Today, flow kinetic energy issues are central to improving the efficiency of devices such as gas turbines, jet engines, pumps, compressors, and heat exchangers.

The main task of the science of flow thermodynamics is to analyze the energy change of a gas or liquid in motion —. Current kinetic energy, that is, energy dependent on speed, is at the center of these changes. It is inextricably linked with pressure energy and heat, and determines the ability of the current to perform mechanical work.

Main part

1. The essence of flow thermodynamics

A current is a mass of a gas or liquid moving in a certain direction per unit of time. In a thermodynamic system, energy exchange occurs through a current: that is, the flow of gas or liquid carries energy in the forms of heat, work, kinetic and potential energy. Flow thermodynamics analyzes these energy changes and quantifies them.

The kinetic energy of a gas flow is proportional to the square of its flow rate, the higher the flow rate, the higher its performance. The channels that convert the internal energy of a gas into the kinetic energy of the movement are called soplos. When a gas moves along the nozzle, its pressure decreases, and its elasticity increases. If, as a result of the compression of the working body in the channel, its pressure increases and its speed decreases, such channels are called diffusers. In gas flow testing, it is generally assumed that steady flow is carried out without heat exchange (adiabatic). A flow process in which all parameters of a gas (v, w, p, T) in any section of a channel do not change over time is called a stable flow process.

2. The first law of thermodynamics for flow

Isochoric process (Greek "isos" – is the same, "horos" – volume) — is a process in which the volume of a gas occurs unchanged: $V=const$, So the volume of the gas does not change, but its pressure and temperature can change. The work done

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by the gas is always defined as follows: $A = \int_{V_1}^{V_2} pdV$. But in the isochoric process, $V_1=V_2$, that is, the volume does not change. Therefore, the integral limits are the same: $A = \int_{V_1}^{V_2} pdV = 0$.

Isothermal process (Greek "isos" – is the same, "thermos" – is the temperature) — is a process in which the temperature of a gas occurs unchanged (ie $T=const$). During the isothermal expansion or compression of an ideal gas, the temperature does not change, so the internal energy of the gas does not change ($\Delta U=0$). Therefore, the work done by the gas is equal to the amount of heat: $Q = A$.

Isobaric process (Greek "isos" – is the same, "baros" – is the pressure) — is a gas process in which the pressure occurs unchanged: $p=const$. That is, during gas expansion or compression, the pressure does not change, only the volume and temperature change. The work done by the gas is always determined as follows: $A = \int_{V_1}^{V_2} pdV$. If the pressure does not change (isobaric state), then we take p out of the integral:

$A = p\int_{V_1}^{V_2} dV = p(V_2 - V_1)$, physical meaning If $V_2>V_1$ → gas expands, $A>0$ — gas works. If the gas $V_2<V_1$ → is compressed, work is done on the gas $A<0$.

Binding with the ideal gas equation, for an ideal gas: $pV=nRT$, therefore: $V_2 - V_1 = \frac{nR(T_2-T_1)}{p}$, if we put this expression in the working formula: $A = p \cdot \frac{nR(T_2-T_1)}{p} = nR(T_2 - T_1),\ A = p(V_2 - V_1) = nR(T_2 - T_1)$.

Adiabatic process — in this process there is no heat exchange with the gas, that is: $Q=0$, Therefore, all energy given or obtained is manifested in the form of — work. $Q=\Delta U+A$, But in the adiabatic process $Q=0$, therefore: $A=-\Delta U$. that is, when the gas expands → $\Delta U<0,\ A>0$ (gas works), when the gas is compressed → $\Delta U>0 \quad A<0$ (work is done on the gas).

Adiabatic bonding for an ideal gas: $pV^{\gamma} = const,\ \gamma = \frac{c_p}{c_v}$ is an adiabatic metric (eg $\gamma\approx1.4$ for air). The work is by general formula: $A = \int_{V_1}^{V_2} pdV$, but $p=const$, $A = \int_{V_1}^{V_2} \frac{C}{V^{\gamma}} dV = C\int_{v_1}^{v_2} V^{\gamma} dV$, integrating: $A = \frac{C}{1-\gamma}(V_2^{1-\gamma} - p_1V_1)$, $C = p_1V_1^{\gamma} = p_2V_2^{\gamma}$ from the Adiabatic equation, hence: $A = \frac{p_2V_2 - p_1V_1}{\gamma-1}$.

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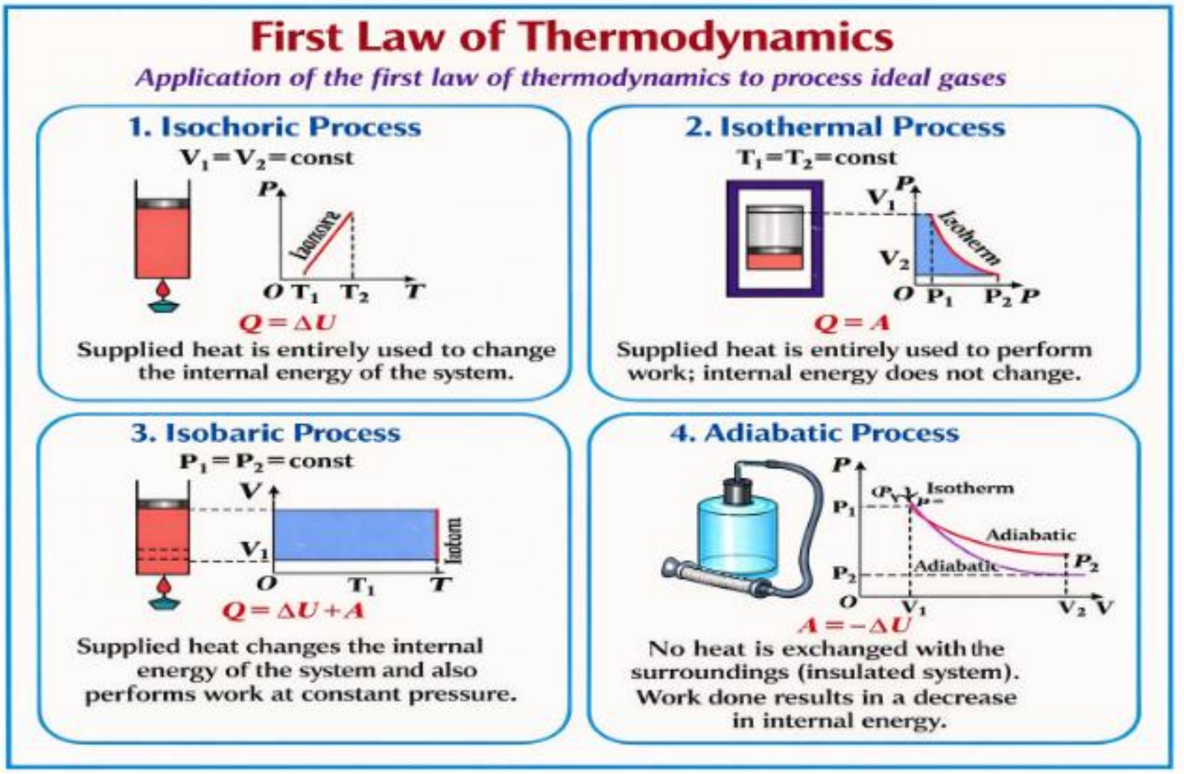
The first law of thermodynamics for a gas stream is defined by the following equation: $dq=du+d(u+pv)+\frac{dw^2}{2}$

in this case, the heat supplied to *dq*-1 kg of gas from an external heat source:
change in *du*-gas working energy;
d(pv)-work spent on moving 1 kg of gas along the channel (shifting work);
$\frac{dw^2}{2}$ – changes kinetic energy when a gas shifts.
(u+pv)-because the magnitude is enthalpy
$dq=dh+\frac{dw^2}{2}$ or $q=h_1-h_2+(w_2^2-w_1^2)/2$
when a gas moves along a channel without alternating with the external environment, its kinetic energy increases as a result of its decrease in enthalpy.
If the initial speed of the working body is zero, then the flow rate can be determined using the following formula:
$w=\sqrt{2(h_1-h_2)}$
If the enthalpy is measured in kJ/kg, then the last equation can be written as follows.
$w=44{,}72\sqrt{(h_1-h_2)}$



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3. Physical content of the law

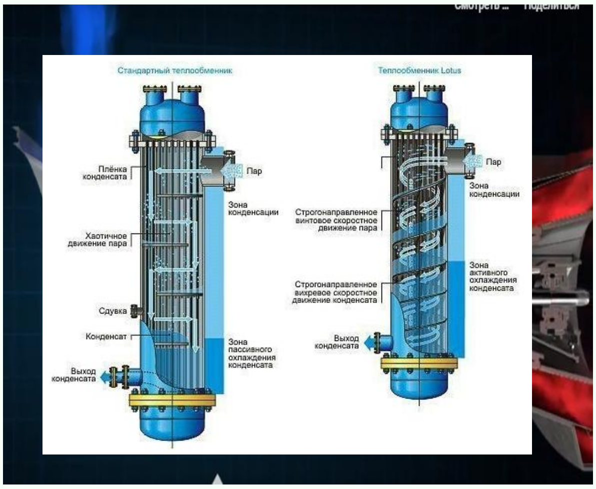
As a gas or liquid flow passes through the channel, it changes in temperature, pressure and speed. The amount of heat (dQ) given to the current is a common result of these changes.

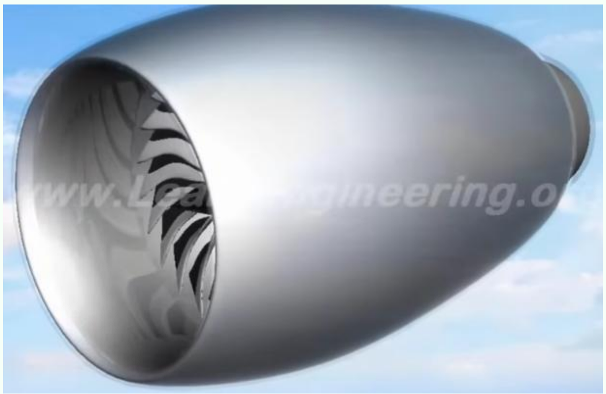
For example, in a bug‘ turbine, the kinetic energy of the current increases and the pressure decreases. In this case, part of the internal energy is spent on increasing the flow rate, as a result of which useful work is done.

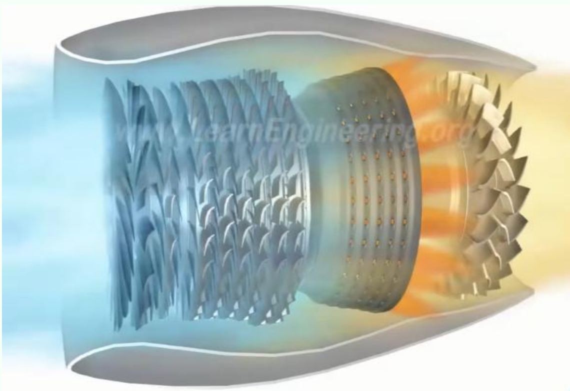
4. Practical application

Principles of flow thermodynamics:

in gas turbines, – is converting the kinetic form of energy into mechanical work
in jet engines, – is generating thrust by converting current pressure to strong speed
in heat exchange devices, – is used to analyze the process of transition of heat flow from one medium to another.







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5. Heat balance of flow

The difference between the amount of heat entering and leaving the system is spent on the work of the current or on energy changes. In these processes, enthalpy (h) is the main parameter, which represents the change in pressure and temperature in the flow in the form of a single energy. Therefore, the concept of "enthalpy flow" is widely used in current thermodynamics.

6. Physical essence of flow kinetic energy

Kinetic energy — is energy proportional to the square of the mass and speed of an object in motion: $E_k = \frac{mv^2}{2}$, if the mass consumption in the current is m icho-m (kg/s), the kinetic energy of the current passes in a unit of time as follows, $\dot{E}_k = \frac{\dot{m}v^2}{2}$

It can be seen from this equation that when the flow rate increases, the kinetic energy increases in square order. Therefore, increasing the flow rate means increasing the kinetic energy, transferring part of the potential or internal energy in the flow to the kinetic form.

7. The law of change of kinetic energy of flow

According to the first law of thermodynamics: $\delta Q = d(h + \frac{v^2}{2} + gz)$

h — enthalpy (internal energy + pressure work),
$v^2/2$ — kinetic energy,
gz — potential energy.
If the potential energy change is not taken into account, the energy change equation is simplified: $\delta Q = dh + d(\frac{v^2}{2})$

So, when enthalpy (heat or pressure energy) decreases in the current, kinetic energy increases — is the theoretical basis of this nozzle working principle. On the contrary, if the kinetic energy decreases and the pressure increases, this is a characteristic of the diffuser process.

8. Thermodynamic analysis of nozzles and diffusers

8.1. Soplo

Soplo — is a flow rate enhancer that has high pressure at the input and low pressure at the output. As the current narrows inside the nozzle, the pressure energy is converted into kinetic energy.

The energy balance for Soplo is written as follows:

$$h_1 = \frac{v_1^2}{2} = h_2 = \frac{v_2^2}{2}$$

If there is no heat exchange (*Q=0*), then the flow rate increases as enthalpy decreases. This process is called adiabatic expansion.

Practical application of Soplo:

Generation of thrust in gas turbines and jet engines. Accelerate bug‘ flow in Bug‘ turbines. Speed control in aerodynamic test stands and wind tunnels.

Kinetic energy at the Soplo output:

$$E_{k2} = \frac{mv_2^2}{2}$$

This energy is converted into useful work or repulsion in the engine.

8.2. Diffuser

Diffuser — is a device that reduces flow rate and increases pressure. It is in an expanding form and moves quickly at the flow inlet and slowly at the outlet. Thus, part of the kinetic energy is converted into pressure energy.

So is the energy equation for the diffuser:

$$h_1 = \frac{v_1^2}{2} = h_2 = \frac{v_2^2}{2}$$

but here $v_2 < v_1$ and $h_2 > h_1$.

This process is called adiabatic compression and the pressure of the current increases. Practical use of diffuser:

Restoring flow pressure at the outlet of gas turbines.

Increase the inlet pressure of fans and compressors.

Stabilization of pre-reactive current output pressure in aviation.

9. Interdependence of flow kinetic energy and enthalpy

In nozzles and diffusers, the exchange of energy occurs through the interplay between enthalpy and kinetic energy. Generally:

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$\Delta h = -\Delta(\frac{V^2}{2})$. that is, when enthalpy decreases, kinetic energy increases (soplo), and when enthalpy increases, kinetic energy decreases (diffuser).

Therefore, a nozzle — is a device that converts energy into a kinetic form, and a diffuser is a device that performs reverse processes that convert kinetic energy into pressure energy.

10.Causes of loss of flow kinetic energy

Under practical conditions, part of the kinetic energy of the current undergoes various losses:

Friction on pipe walls;
Formation of turbulent currents and eddies;
Lack of nozzle and diffuser smoothness;
Heat exchange and flow unevenness.

Such losses reduce the efficiency of the flow. Therefore, aerodynamic shapes, smooth walls, optimal angles and smooth narrowing/expansion profiles are selected.

Conclusion

Flow thermodynamics is the science that applies the laws of conservation and change of energy to a gas or liquid in a stream. It serves as a theoretical basis for improving the efficiency of heat machines, turbines, pumps and reactive devices. The first law for flow is used as the basic equation in the implementation of the energy analysis of any thermodynamic process.

Current kinetic energy is one of the main forms of energy circulation in thermodynamic systems. Soplo and diffusers are practical expressions of this energy change — they provide the interaction between pressure energy and kinetic energy.

If the nozzle increases the kinetic energy and creates useful work, the diffuser reduces it and restores the pressure. The in-depth study of these processes serves as an important scientific basis for improving the efficiency of turbines, engines, compressors and other thermal engineering devices.

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