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GRAPHICAL PRESENTATION OF LOSSES OF WORK IN T-s DIAGRAM

Pero PETROVIĆ, Gordana TICA, Milovan KOTUR

Mašinski fakultet, Banja Luka, BOSNIA & HERZEGOVINA

Abstract
One of the most widespread irreversible processes in technical engineering is transfer of heat from bodies of higher to bodies of lower temperature. This is a basic reason behind low efficiency of plants for transformation of thermal energy into work. In a system in which these processes occur, entropy increases and loss of work occurs. These may be shown in T-s diagram, which significantly makes understanding of the mentioned phenomena easier.
Modern technical plants in which in which transfer of heat energy into work is realized (engines, thermal power plants, etc.) still lag behind the ideal. The basic reason for that is the necessity of heat exchange with significant temperature difference in order to achieve satisfactory velocity of processes.
Keywords: T-s diagram, technical engineering, heat transfer, modern technical plants

1. GRAPHICAL PRESENTATION OF LOSSES OF WORK

Let us analyze exchange of heat between two flows of the same substance (of the same mass flows, $\dot{m}_1 = \dot{m}_2$), which change a phase in the heat exchanger, Fig. 1.

Condensation happens in the flow two (provider of heat)l while evaporation happens in the flow one (receiver of heat). Temperature difference due to different pressures is in the flows.

If in *T-s* diagram (Fig. 2.) a change of state of both flows is shown, at which $T_2>T_1>T_0$, and, on the basis of the aforementioned, it shows that the surface 2'2"a'b' presents heat taken from 1kg of flow two, while the surface 1'1"c'a' presents heat brought 1kg of flow one. Equality of the heats is followed by equality of surfaces, the surface 2'2"a'b'= surface 1'1"c'a'. Equality of these surfaces also comes from the applied construction of rectangle a'c'e2". The same construction shows equality of surfaces 2'2"1'd=surface d1"c'b'.

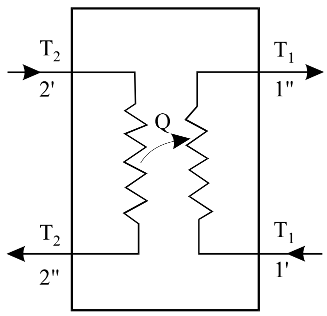

Fig. 1 Exchange of heat between flows of the same substance

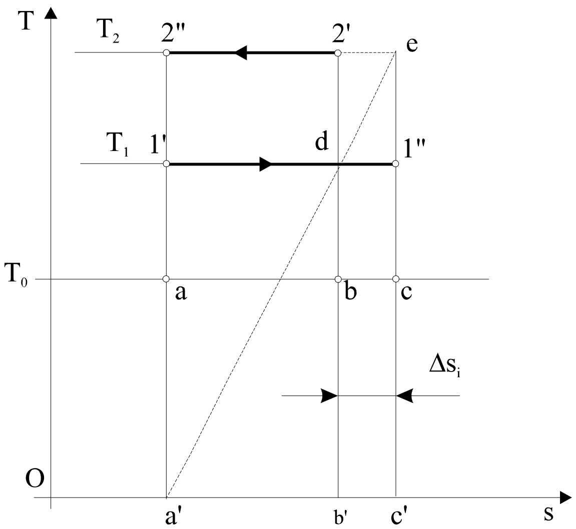

Fig. 2. *T-s* diagram of heat exchange of the same substance flows at $T_2>T_1>T_0$

If flow 2 would be taken in a reversible heat machine (RTM), (instead of into a heat exchanger), in which right-handed Carnot cycle process occurs with another working substance, the state of flow would be changed from 2' to 2". Work equal to surface 2'2"ab would be obtained from the heat taken from flow 2. As an analogue to that, if flow 1 in introduced into RTM with the state 1", so that at exit from RTM the state is 1', work equal to surface 1"1'ac would be obtained from the heat taken to RTM.

The loss of work in the process of transfer of heat energy from a body with higher to a body of a temperature level equal to difference of surfaces, the surface ab2'2" minus the surface ac1"1' equals the surface bcc'b'. Out of the construction applied in Fig. 2, it is also shown that the difference of these surfaces equals to the surface bcc′b′. It is seen from the same picture that this surface equals the product of surrounding temperature and increment of entropy in the system, which is the Goui-Stodola equation.

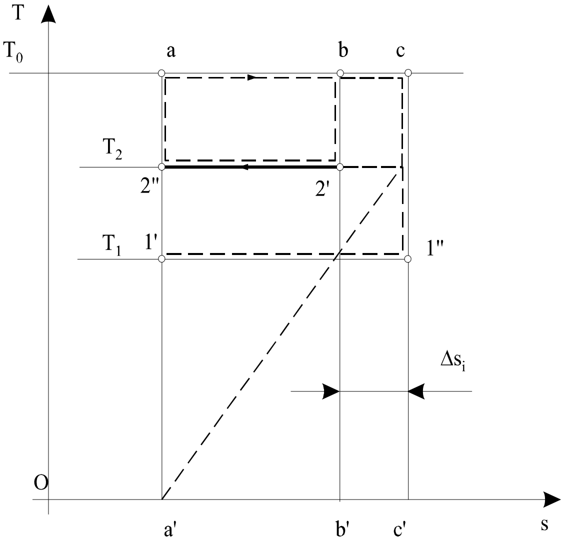

Fig. 3. *T*-*s* diagram of heat exchange of the same substance flows at $T_1<T_2<T_0$

If we apply the same analysis at exchange of heat at a temperature area below the temperature of surrounding area $T_1<T_2<T_0$, Fig. 3, we get analogous indicators. The heat taken from 1kg of flow 2 (surface 2'2"a'b'), at change of the state of the flow from 2' to 2" equals to the quantity of the heat that 1kg of flow 1 receives (surface 1'1"c'a').

If flow 2 at exit from the heat exchanger would be taken in RTM in which right-handed Carnot cycle process occurs with a working substance in which the heat is brought from the surrounding area, and taken to flow 2, at which it would change the state from 2" to 2' it would result in work equal to surface 2"ab2'.

In an analogue way, if flow 1 at the state 1' is taken in RTM in which Carnot's cycle process also occurs with a working agent to which the heat brought to from the surrounding area and taken from it to flow 1, whose state changes from 1' to 1", it would result in work equal to surface 1'ac1″.

The difference of these surfaces, surface 1'1"ca minus surface 2"2'ba equals to surface bcc'b', which presents the loss of work at the exchange of heat with temperature difference T_2-T_1 at temperature area below T_0.

The same analysis may be done for $\dot{m}$ kg/s in $T-\dot{S}$ diagram. In that case, appropriate surfaces would present heat flows and powers.

If on the basis of Fig. 2 and Fig. 3 a difference of work is determined, it results in a well-known expression for determination of losses of work due to irreversibility at exchange of heat with temperature differences:

$$\Delta W = T_0 \frac{T_2 - T_1}{T_1 T_2} Q = T_0 \Delta S_i \quad (1.)$$

Showing exchange of heat in graphical methods given in Fig. 2 and 3 provides comprehensive interpretation of this phenomenon. By bringing closer temperatures T_2 and T_1 to the absolute zero, losses of work are inclined to infinity.

2. CONCLUSION

Exchange of heat with temperature differences is a basic cause of the loss of work in the process of transformation of energy. That is why their efficiency may be improved with those indicators that provide exchange of heat with lower temperature differences.

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