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Eksergijska analiza prenosa in razdeljevanja toplote

Exergy Analysis of Heat Energy Transfer and Distribution

ALOJZ POREDOŠ — MIRAN ZAGER

Pravo vrednost toplotne energije dobimo s kakovostno ali eksergijsko analizo njene spremembe, prenosa in razdeljevanja. Eksergijska vrednost toplote ali njena zmožnost opravljanja dela je lahko dobra podlaga za postavitev poštene ekonomske cene.

V prispevku so podane osnovne zakonitosti, ki so potrebne za popis eksergijskih stanj toplovodnega sistema. Izvedena je analiza toplovodnega sistema Šaleške doline. Zbrani so potrebni parametri za določitev termodinamičnih stanj v posameznih pomembnih točkah. Za vse glavne veje sistema so izračunane izgube eksergije zaradi prenosa in razdeljevanja toplote pri stalni temperaturi okolice.

Analiza vpliva temperaturnega nivoja toplote kaže močno odvisnost eksergijskih izgub od temperature dovoda in povratka ter s tem povezanega masnega toka vode. Ob upoštevanju temperaturne odvisnosti še dodatnih toplotnih izgub cevnega omrežja za transport toplote se izkaže temperaturni nivo za najpomembnejši dejavnik racionalnega delovanja toplovodnega sistema.

Izvedena termodinamična analiza je podlaga za diferencirani tarifni pravilnik, ki bo, poleg količine, upošteval tudi temperaturni nivo porabljene toplote.

The real value of heat energy is obtained by a qualitative or exergy analysis of its conversion, transport and distribution. The exergy value of heat or its capability of performing work can be a sound basis for the formation of a fair purchase price.

The paper presents the fundamental laws which have to be known in order to describe the exergy conditions in a heating system. An analysis of the »Šalelška dolina« district-heating system is made. The parameters necessary for the determination of the thermodynamic conditions are gathered at each important point. For all the main branches of the system, exergy losses are calculated as a consequence of heat transport and distribution at a constant temperature of the environment.

The analysis of the influence of the heat temperature level shows a strong exergy loss dependence on the temperature of supply and return and mass flow of water related to the temperature level. Considering also the temperature dependence of additional heat losses in the heat transport pipeline, the analysis shows that the temperature level is one of the most important factors for rational operation of the heating system.

The performed thermodynamic analysis represents the basis for a differentiated tariff regulation which will, in addition to the quantity, also consider the temperature level of the consumed energy.

0 UVOD

Letos mineva 42 let od rojstnega leta pojma eksergija, ki je zamenjal nerodni izraz » tehnična dela zmožnost«. Uvedel in utemeljil jo je veliki slovenski termodinamik svetovnega slovesa prof. Zoran Rant. Ta pojem je bil v letih 1961 do 1966 v Nemčiji glavna tema različnih posvetovanj in srečanj termodinamikov. V tem času so bili o eksergiji objavljeni številni članki in razprave. Vendar vsi termodinamiki niso bili enotnega mnenja, zato so se aktivnosti na tem področju za nekaj časa upočasnile in celo zaustavile. Ponovni razcvet in upoštevanje temeljnih spoznanj prof. Zorana Ranta se je nadaljevalo z naftno krizo sredi sedemdesetih let.

Prof. Rant [1] je leta 1955 zapisal »Energija ima vrednost samo, kolikor se da prevajati iz ene svojih oblik v drugo«. Iz tega izhaja, da je več vredna tista energija, ki je bolje spremenljiva. Nekatere energije je mogoče v celoti spreminjati v delo, pri nekaterih pa tega ni mogoče doseči:

0 INTRODUCTION

Forty-two years have passed since the creation of the term »exergy« replacing a much more awkward expression »technical work capability«. The term was first introduced and explained by a renowned Slovenian scientist working in the field of thermodynamics, Professor Zoran Rant. In the years 1961 to 1966 exergy was often among the topical subjects discussed at various conferences and conventions on thermodynamics especially in Germany. During this time a number of papers and discussions were published about exergy. However, scientists did not all share the same opinion about the importance of exergy, therefore work in this area gradually slowed down and even stopped. A revival of the interest in exergy and its fundamental concepts, introduced by Professor Zoran Rant, came with the oil crisis in the mid-seventies.

In 1955, Professor Rant [1] wrote »Energy has its value only if it can be converted from one form into another«. From this it follows that the form of energy that is the most valuable is the one that is the most convertible. Some forms of energy can be fully converted into work while npr. pri toploti ali notranji energiji. Procesi sprememb energije so lahko povračljivi in dajejo največjo mogočo količino dela, ali pa so tudi iz različnih vzrokov nepovračljivi.

Temeljne trditve prof. Ranta so še:

— največje delo, ki ga lahko dobimo iz energije, imenujemo eksergija,

— eksergija je tisti del energije, ki ima vrednost,

— energija brez eksergije je brez vrednosti.

Iz spoznanj o eksergiji lahko ugotovimo, da je eksergija sistema enaka nič, kadar je ta v ravnovesju z okolico. V nasprotju z energijo velja za eksergijo, da ta ni neuničljiva, vsaka izguba eksergije pa je nepopravljiva.

Eksergijska analiza razdeljevanja in prenosa toplote, kar je primer pri vsakem toplovodnem sistemu, je narejena zato, da ugotovimo izgube eksergije, ki naj bodo osnova za oblikovanje diferenciranih cen toplotne energije.

1 EKSERGIJA IN ANERGIJA TOPLOTE

Eksergija je tisti del toplote, ki ga lahko spremenimo v katerokoli drugo obliko, tudi v mehansko delo. Za konstantni temperaturni nivo toplote in okolice velja:

others cannot, e.g. heat or inner energy. The processes of energy conversion can be reversible, giving a maximum amount of work, or they can be for different reasons irreversible.

Some other fundamental concepts of exergy established by Professor Rant are:

— maximum work that can be gained from energy is called exergy,

— exergy is that part of energy which has value,

— energy without exergy is without value.

From these fundamental statements on exergy, we can see that the exergy of a system is equal zero when the latter is in equilibrium with the environment. As oposed to energy, for exergy it holds that it is indestructible and each loss of exergy is incorrigible.

An exergy analysis of heat transport and distribution, which are part of any hot-water system, was made with the purpose of establishing the losses of exergy, which should serve as a basis for the formation of tariff prices of heat energy.

1 EXERGY AND ANERGY OF HEAT

Exergy is that part of heat which is convertible into any other form, including mechanical work. For a constant temperature level of heat and environment it holds that:

$$E_Q = \frac{T - T_{ok}}{T} Q \qquad (1).$$

Anergija je nespremenljiv del toplote, ki pa je lahko tudi koristna, če ji dodamo del eksergije. Izračunamo jo:

Anergy is the inconvertible part of heat which may become useful if a part of exergy is added to it. It can be calculated from:

$$B_Q = \frac{T_{ok}}{T} Q \qquad (2).$$

Iz zadnjih dveh enačb izhaja:

From the last two equations it follows that:

$$E_Q + B_Q = Q \qquad (3).$$

Eksergijska vrednost toplote bo tem večja, čim višji je temperaturni nivo toplote. Prvi mejni primer se pojavi, kadar je $T = \infty$ in $E_Q = Q (B_Q = 0)$, drugi mejni primer pa je pri $T = T_{ok}$ in $B_Q = Q (E_Q = 0)$. Prvi mejni primer ni dosegljiv, kar pomeni, da je toplota vedno zmes eksergije in anergije, drugi mejni primer pa je opažen v okolici, kajti njena toplota je čista anergija.

2 IZGUBE EKSERGIJE

Vsako spremembo eksergije v anergijo imamo za njeno izgubo, kajti nasproten proces ni mogoč. V obravnavanem toplovodnem sistemu se pojavijo izgube eksergije zaradi prenosa toplote iz primarnega na sekundarni medij in zaradi izgub toplote, ki vsebuje določen delež eksergije. Kot izgubo eksergije štejemo tudi v sistem vloženo električno energijo.

The exergy value of heat will be the higher, the higher is the temperature level of heat. The first limit example appears when $T = \infty$ and $E_Q = Q$ $(B_Q = 0)$, and the second limit example at $T = T_{ok}$ and $B_Q = Q$ $(E_Q = 0)$. The first limit example cannot be achieved, which means that heat is always a mixture of exergy and anergy, whereas the second limit example is present in the environment since its heat is pure anergy.

2 EXERGY LOSSES

Each conversion of exergy into anergy is considered as its loss since the process cannot be reversed. In the hot-water network discussed, exergy losses appear as a result of heat transfer from the primary into the secondary medium and because of loss of heat which contains a certain amount of exergy. What is also considered as an exergy loss is the electric energy put into the system.

a) *Izguba eksergije pri prenosu toplote*

Eksergijske izgube za primer spremenljive temperature vira in ponora toplote računamo po enačbi (2):

a) *Exergy loss in heat transfer*

The exergy losses for a case of variable temperature of the heat source and sink can be calculated according to equation (2):

$$E_{\mathrm{izga}} = T_{\mathrm{ok}} \frac{(T_{\mathrm{a}} - T_{\mathrm{b}})}{T_{\mathrm{a}}\, T_{\mathrm{b}}}\, Q \qquad (4),$$

kjer sta T_a in T_b temperaturi ponora in vira toplote, v našem primeru sekundarnega in primarnega dela sistema.

where T_a and T_b are the temperatures of the heat source and sink, in our case of the secondary and primary part of the system.

b) *Izgube eksergije zaradi izgube toplote*

V toploti, ki se izgublja iz toplovodnega sistema v okolico, je določen delež eksergije. Tega določimo glede na enačbo (1):

b) *Exergy losses due to heat losses*

In the heat which is given off from the hot water system into the environment there is an amount of exergy. This can be defined by equation (1):

$$E_{\mathrm{izgb}} = E_{\mathrm{Qizg}} \qquad (5).$$

Ta eksergija je povsem izgubljena, ker se temperaturni nivo izgubljene toplote popolnoma izenači z okolico.

This exergy is lost for ever since the temperature level of the lost heat is fully levelled with that of the environment.

c) *Izgube eksergije zaradi transporta toplote*

Toploto transportiramo od vira do porabnikov s toplo vodo določene entalpijske vrednosti. Za transport porabljamo električno energijo. Ta se porabi za premagovanje pretočnih uporov in opravljanje tehničnega dela pri transportu. Torej lahko pišemo:

c) *Exergy losses due to heat transport*

Heat is transported from its source to consumers via hot water possessing a certain enthalpy value. For the transport electric energy is used. This is consumed for overcoming flow resistances and for performing technical work in the transport. Thus we can write:

$$E_{\mathrm{izgc}} = W_{\mathrm{el}} \qquad (6).$$

3 EKSERGIJSKA ANALIZA TOPLOVODNEGA SISTEMA

Obravnavamo toplovodni sistem razvejanega cevnega omrežja za transport toplotne energije od vira do porabnikov. Bistveni element takšnega sistema je cevje, ki omogoča transport energije, pri tem pa se pojavljajo večje ali manjše toplotne in tudi eksergijske izgube. Pomembni deli sistema so tudi toplotne postaje, kjer se toplota prenaša iz višjega na nižji temperaturni nivo, kar prav tako zmanjšuje kakovost toplote ali njene eksergijske vrednosti.

3 EXERGY ANALYSIS OF THE HOT-WATER SYSTEM

The subject of our discussion is the hot-water system of a pipeline network for the transport of heat energy from its source to consumers. The central element of this system is the pipeline, enabling the energy transport, in which occur losses of heat and exergy either small or big. Important parts of the system are also heat stations in which the heat is transferred from a higher to a lower temperature level, also resulting in lower quality of the heat and its exergy value.

3.1 Opis obravnavanega toplovodnega sistema

Termoelektrarna Šoštanj (TEŠ) lahko dovaja v toplovodni sistem Šaleške doline največ 160 MW toplotnega toka z vodo temperature 160/80 °C in tlakom 19 bar pri zunanji temperaturi -21 °C. Ta toplotni tok se prilagaja potrebam glede na zunanjo temperaturo z zniževanjem masnega toka ali temperaturnega nivoja vode. Tok vode se razdeli po posameznih vejah, in sicer v Šoštanj, v Pesje, neposredno v Velenje in prek centralne energetske postaje (CEP) v Velenje. Z dovedeno

3.1 Description of the hot-water network system

The Šoštanj Thermal Power Plant (TEŠ) supplies the hot-water network of Šalelška dolina with a max. 160 MW heat flux, the water having a temperature of 160/80 °C and a pressure of 19 bar at an outdoor temperature of -21 °C. This heat flow is daily adjusted to the needs depending on the outdoor temperature by lowering the mass flow or water temperature level. The water flow is divided into several branches, i.e. Šoštanj, Pesje, directly into Velenje and via the central energy station (CES) into Velenje. The supplied heat raises toploto se dvigne temperaturni nivo sekundarne vode v toplotnih postajah s 70 °C na 90 °C, razen v CEP, kjer je ogretje na temperaturo 110 °C, s katero se šele nato dogreva voda za potrebe široke porabe Velenja. Temperatura povratne vode v TEŠ je 80 °C, temperatura povratne vode v CEP pa 75 °C.

Ker je največja vrednost masnega toka na primarni strani sistema 580 kg/s, moramo pri konstantni temperaturi dovoda toplote popraviti temperaturo povratka celotnega sistema.

Za obtok primarne vode skrbijo pretočne črpalke v toplotnih postajah v TEŠ s priključno močjo 1575 kW. V CEP so vgrajene črpalke z močjo 1333 kW. Tako v toplovodni sistem vlagamo skupno 2908 kW električne moči, ki je čista eksergija.

Za opisani sistem bomo določili eksergijske tokove po posameznih vejah sedanjega sistema pri spremenljivem temperaturnem nivoju dovoda in povratka toplote. Izračunali bomo eksergijske izgube, ki nastanejo pri prenosu toplote v toplotnih postajah in CEP.

the temperature level of the secondary water in the heat stations from 70 °C to 90 °C, except in the CES where heat is transferred onto a temperature of 110 °C, at which point the water is only reheated for the needs of wide consumption in Velenje. The return temperature of the water coming back to TEŠ is 80 °C, and the temperature of the water returning to CES is 75 °C.

Since the maximum value of the mass flow on the primary side of the system is 580 kg/s, for a constant temperature of heat supply the return temperature of the whole system has to be corrected.

The circulation of primary water is made possible by circulation pumps in the heat stations of TEŠ with a supply power of 1575 kW. In each CES a pump with power of 1333kW is built in. Thus the hot-water supply system has a total input of 2908 kW electric power which is pure exergy.

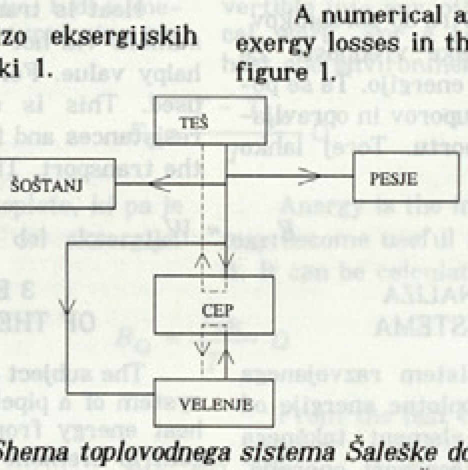
For the system described we will define exergy flows in the individual branches of the system in the heat supply and return. The study will provide calculations of exergy losses occurring in heat transfer in CES heat stations.

4 REZULTATI

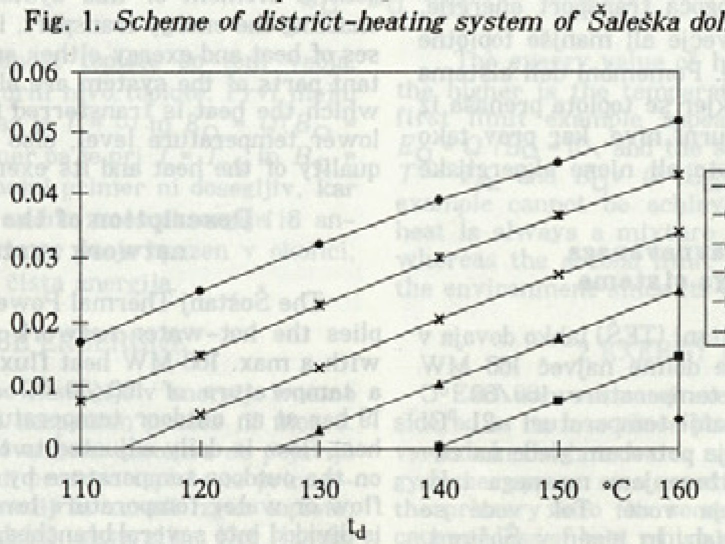
Izvedli smo računsko analizo eksergijskih izgub za toplovodni sistem po sliki 1.

4 RESULTS

A numerical analysis was made to define the exergy losses in the hot-water system shown in figure 1.



Sl. 1. *Shema toplovodnega sistema Šaleške doline*
Fig. 1. *Scheme of district-heating system of Šaleška dolina*



Sl. 2. *Eksergijske izgube pri prenosu toplote*
Fig. 2. *Exergy losses due to heat transfer*

Na sliki 2 vidimo močno odvisnost eksergijskih izgub od temperature dovoda in temperature povratka in so posledica prenosa toplote na nižji temperaturni nivo v toplotnih postajah.

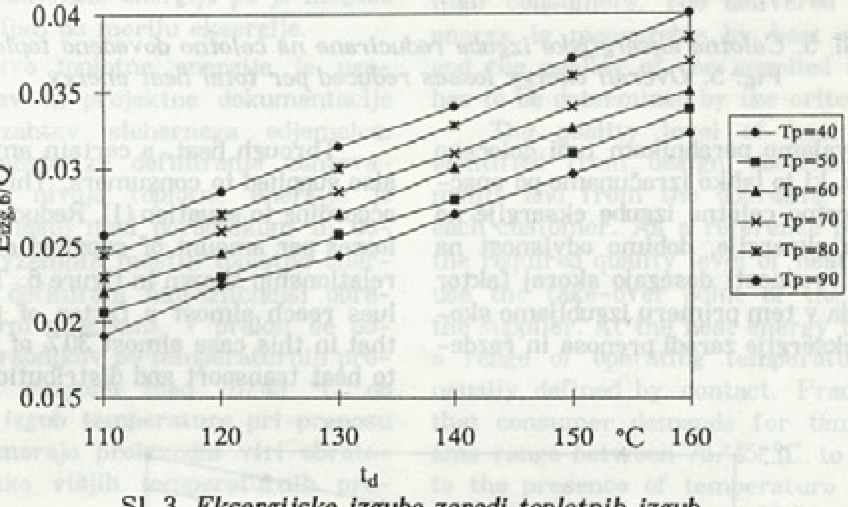
Zaradi izgub toplote določene eksergijske vrednosti se pojavijo tudi izgube eksergije. Te so vidne na sliki 3, kjer je opazna močnejša odvisnost od temperature dovoda kakor od temperature povratka.

V sistem vlagamo električno energijo za pogon obtočnih črpalk. Pri konstantni potrebi toplote se spreminja masni tok vode in s tem količina vložene električne energije (čiste eksergije). Na sliki 4 vidimo, da je ta večja pri manjših temperaturnih razlikah dovoda in povratka tople vode.

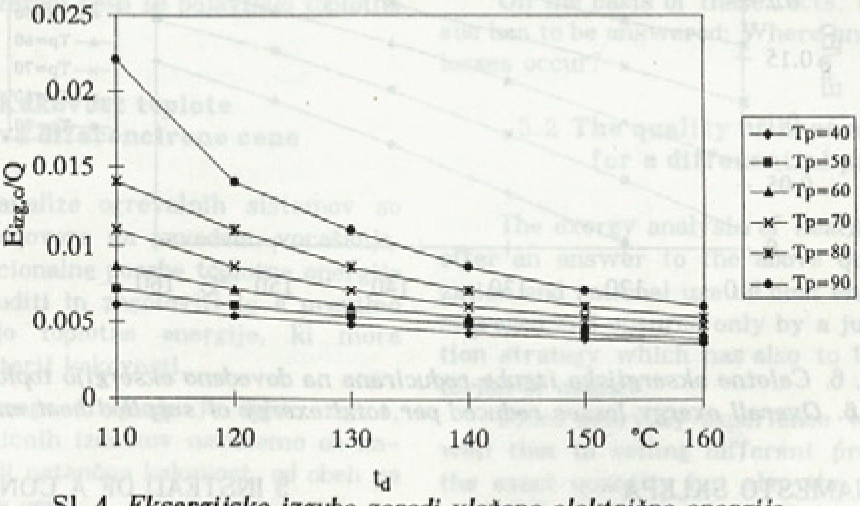
In figure 2 we can see a strong dependence of exergy losses on the supply and return temperatures which are a result of heat transfer onto a lower temperature level in the heat stations.

Due to losses of heat having a certain exergy value, there also occur losses of exergy. These can be seen in figure 3, where it is possible to note a greater dependence on the supply temperature than on the return temperature.

The system is supplied with electric energy to drive the circulation pump. At constant needs for a certain amount of heat, the water mass flow changes, and thus also, does the amount of electric energy input (pure exergy). In fig. 4 we can see that the latter is greater at lower temperature differences between the supply and return.



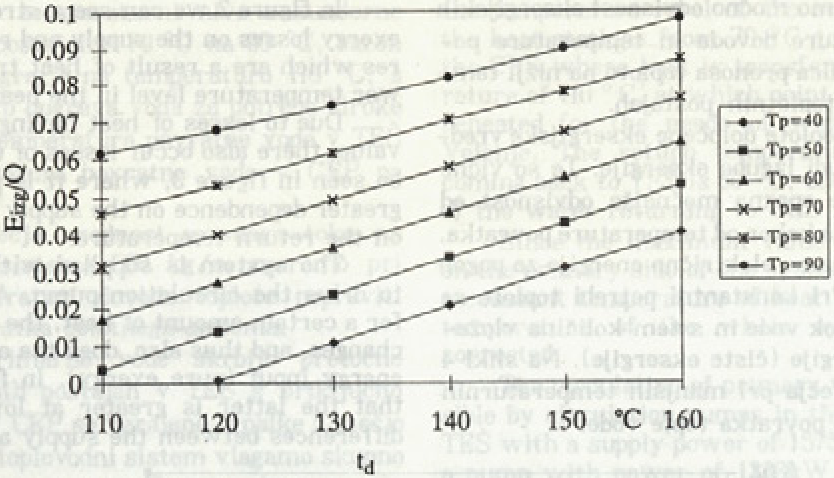
Sl. 3. *Eksergijske izgube zaradi toplotnih izgub*
Fig. 3. *Exergy losses due to heat losses*



Sl. 4. *Eksergijske izgube zaradi vložene električne energije*
Fig. 4. *Exergy losses due to supplied electric energy*

Celotne reducirane eksergijske izgube, ki so vsota posameznih deležev iz diagramov na slikah 2, 3 in 4, so prikazane na sliki 5. Te znašajo v primeru neugodnega temperaturnega režima 160/90 °C skoraj 10 odstotkov celotne transportirane energije.

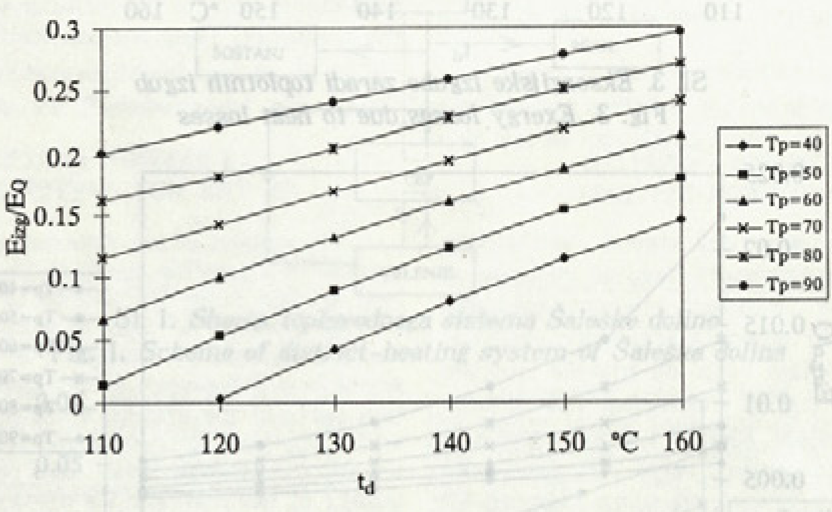
The overall reduced exergy losses, which are the sum of the individual parts from the diagrams in figures 2, 3 and 4, are shown in figure 5. In the case of an inconvenient temperature regime 160/90 °C, these amount to almost 10% of the total transported energy.



Sl. 5. *Celotne eksergijske izgube reducirane na celotno dovedeno toploto*
Fig. 5. *Overall exergy losses reduced per total heat energy*

S toploto dovajamo porabnikom tudi določeno količino eksergije, ki jo lahko izračunamo po enačbi (1). Če reduciramo celotne izgube eksergije na količino dovedene eksergije, dobimo odvisnost na sliki 6. Največje vrednosti dosegajo skoraj faktor 0.3, kar pomeni, da v tem primeru izgubljamo skoraj 30 odstotkov eksergije zaradi prenosa in razdeljevanja toplote.

Through heat, a certain amount of exergy is also supplied to consumers. This can be calculated according to equation (1). Reducing the total exergy losses per amount of supplied exergy, we get the relationship shown in figure 6. The maximum values reach almost a factor of 0.3, which means that in this case almost 30% of exergy is lost due to heat transport and distribution.



Sl. 6. *Celotne eksergijske izgube reducirane na dovedeno eksergijo toplote*
Fig. 6. *Overall exergy losses reduced per total exergy of supplied heat energy*

5 NAMESTO SKLEPA

5.1 Eksergija toplote kot merilo njene kakovosti

Na podlagi opisanega modela eksergijskih analiz toplovodnih oskrbovalnih sistemov se kažejo realne osnove za načrtovanje optimizacij teh energetskih sistemov in realnejša osnova za vrednotenje cene toplotne energije.

5 INSTEAD OF A CONCLUSION

5.1 Exergy of heat as a measure of its quality

The described model of exergy analysis of a hot-water supply system shows that it could serve as a sound basis for optimization planning of such energy systems, as well as a more realistic basis for the evaluation of the price of heat energy.

Ne moremo mimo resnice, da se sedaj porabnikom zaračuna le količina dovedene toplotne energije. Trženje toplotne energije se sedaj izvaja po različnih bolj ali manj povprečnih merilih. Cene toplotne energije so oblikovane po merilu široke porabe, industrijske porabe pa po merilu enote ogrevalne površine, po merilu priključne moči itn.

S pravilniki o pogojih za dobavo in odjem toplotne energije so definirane medsebojne pravice in obveznosti med dobavitelji in odjemalci toplotne energije. Dobavitelji toplotne energije so dolžni zagotavljati svojim porabnikom potrebne količine in kakovost toplotne energije. Dobavljeno količino toplotne energije je mogoče izmeriti s toplotnimi števci, kakovost dobavljene energije pa je mogoče in potrebno ugotavljati po merilu eksergije.

Kakovostni nivo toplotne energije je ugotovljiv prek zahtev iz projektne dokumentacije in obratovalnih zahtev slehernega odjemalca. Kot referenčno mesto za definiranje zahtevanega kakovostnega nivoja toplotne energije je lahko prevzemno mesto med porabnikom in dobaviteljem. Na prevzemnih mestih toplotne energije so pogodbeno definirani najrazličnejši obratovalni temperaturni programi. V praksi se pojavljajo zahteve porabnikov po temperaturnih programih, ki so v razponu med 75/45 °C do 140/70 °C. Zaradi izgub temperature pri prenosu toplotne energije morajo proizvodni viri obratovati še na nekoliko višjih temperaturnih programih.

Po takih ugotovitvah se lahko postavi realno vprašanje: Kje in zaradi česa se pojavljajo toplotne izgube?

5.2 Kakovost toplote kot osnova diferencirane cene

Eksergijske analize ogrevalnih sistemov so lahko temelj za odgovore na navedeno vprašanje. Optimiranja in racionalne porabe toplotne energije je mogoče vzpodbuditi in zagotoviti le s pravilno cenovno strategijo toplotne energije, ki mora vsebovati tudi kriterij kakovosti.

Iz vsakodnevnega življenja je dobro znano, da pri prodaji različnih izdelkov navedemo ob natančni količini tudi natančno kakovost, od obeh pa je odvisna nabavna cena.

Proučevanje tovrstne problematike kaže, da je pametno tudi na sistemih daljinskega ogrevanja zasnovati enovit tarifni cenik trženja toplotne energije, ki bi moral izhajati iz osnovne (izhodiščne cene) toplotne energije. Ta pa mora biti določena glede na zahteve porabnika po kakovosti toplotne energije. Načelni predlog je podan na sliki 7.

We cannot overlook the fact that presently consumers are charged only for the quantity of the energy supplied. Heat energy marketing is presently performed according to different criteria, all more or less based on averages. Heat energy prices are formed according to a number of criteria, such as wide consumption and industry consumption criteria, units of heated area, or the supply power criterion, etc.

The regulations on the terms of heat energy supply and take-off define the rights and duties of suppliers and consumers of heat energy. Heat energy suppliers are obliged to ensure the necessary quantity and quality of heat energy to their consumers. The delivered amount of heat energy is measurable by heat energy counters, and the quality of the supplied heat can be and has to be determined by the criterion of exergy.

The quality level of heat energy can be identified from design documentation requirements and from the operating requirements of each customer. As a reference point for defining the required quality level of heat energy, we can use the take-over point of the customer from the supplier. At the heat energy take-over points, a range of operating temperature programs is usually defined by contact. Practice has shown that consumer demands for temperature programs range between 75/45 °C to 140/70 °C. Due to the presence of temperature drops in transport, the energy generating sources have to operate on somewhat higher temperature programs.

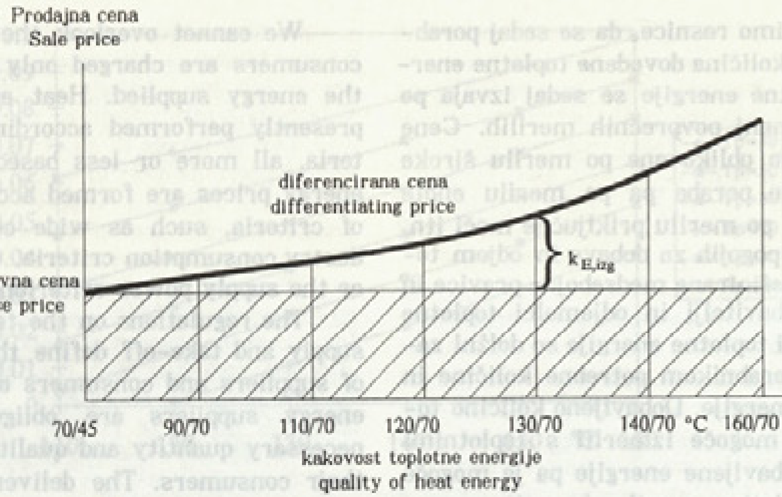
On the basis of these facts, an important issue has to be answered: Where and why do exergy losses occur?

5.2 The quality of heat as a basis for a differential price

The exergy analysis of heating systems may offer an answer to the above question. Optimization and rational use of heat energy can be encouraged and ensured only by a just price formation strategy which has also to include the criterion of quality.

From everyday experience we know all too well that in selling different products not only the exact quantity but also the exact quality is quoted, both forming part of the purchase price.

The study of these problems has indicated that even on the district-heating systems it is reasonable to design a unified tariff selling system which should be based on the starting price of heat energy. This should then be differentiated depending on the consumer's requirements for the quality of heat energy. A proposal based on this principle is presented in figue 7.



Sl. 7. *Prodajna cena toplotne energije v odvisnosti od njene kakovosti*
$k_{E,izg}$ – koeficient diferenciranja osnovne cene

Fig. 7. *Sale price of heat energy depending on its quality*
$k_{E,izg}$ – coefficient of differentiating base price

Kot podlago za diferenciranje prodajne cene toplotne energije bi lahko uporabili razmerja med izračunanimi izgubami eksergije za posamezne skupine porabnikov v odvisnosti od zahtevanega temperaturnega programa oskrbe.

Navedene zamisli je treba nujno izdelati do popolnega uporabniškega nivoja, ki je obvladljiv pri sedanjem stanju avtomatske obdelave podatkov po podjetjih za razdeljevanje toplotne energije.

As a basis for differentiating the purchase price of heat energy we could use the ratio between the calculated exergy losses for individual consumer groups versus the required temperature program of the supply.

This concept should of course be worked out in detail down to the plain consumer level which, given could be controlled, the present possibilities of automatic data processing, through heat energy distribution companies.

OZNAČBE

B	–	anergija (J)
E	–	eksergija (J)
Q	–	toplota (J)
t	–	temperatura (°C)
T	–	temperatura (K)
W	–	energija (J)

INDEKSI

a	–	ponor
b	–	izvor
d	–	dovod
el	–	električni
izg	–	izgube
p	–	povratek
Q	–	toplotni

SYMBOLS

B	–	anergy (J)
E	–	exergy (J)
Q	–	heat ammount (J)
t	–	temperature (°C)
T	–	temperature (K)
W	–	energy (J)

INDICES

a	–	sink
b	–	source
d	–	supply
el	–	electric
izg	–	losses
p	–	return
Q	–	heat

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Naslov avtorjev: doc. dr. Alojz Poredoš, dipl. inž.
Fakulteta za strojništvo
Univerze v Ljubljani.
Aškerčeva 6, 61000 Ljubljana

Miran Zager, dipl. inž.
Komunalno podjetje Velenje.
PE Energetika, Koroška 37/b
63320 Velenje

Authors ' Addresses: Doc. Dr. Alojz Poredoš, Dipl. Ing.
Faculty of Mechanical Engineering
University of Ljubljana
Aškerčeva 6, 61000 Ljubljana

Miran Zager, Dipl. Ing.
Komunalno podjetje Velenje
PE Energetika, Koroška 37/b
63320 Velenje, Slovenia

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