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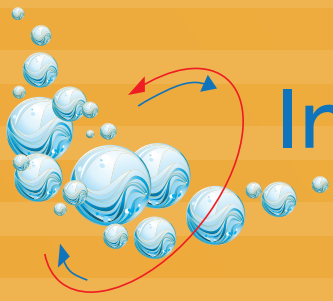

Interklima 2017

24. MEĐUNARODNI SIMPOZIJ O GRIJANJU, HLAĐENJU I KLIMATIZACIJI

13. KONFERENCIJA O TERMOGRAFIJI

Zagreb, 6. travnja 2017.

24th INTERNATIONAL SYMPOSIUM ON HEATING, REFRIGERATING AND AIR CONDITIONING

13th CONFERENCE ON THERMOGRAPHY

Zagreb, Croatia, April, 6th 2017

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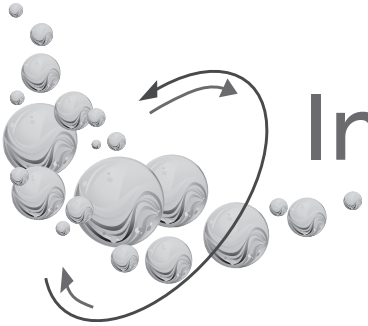

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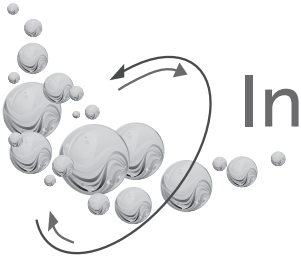

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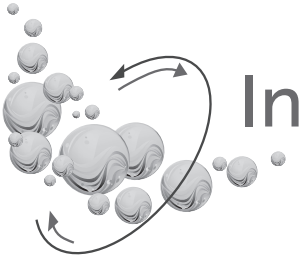

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Znanstveni savjet (abecednim redom)
Scientific Committee (in alphabetical order)

Raspored predavanja / Symposium schedule

08:30–09:00 Registracija učesnika / Registration of participants

09:00–09:10 Pozdravi i uvodna riječ / Greetings and introductory words

Plenarno predavanje / Plenary lecture

09:10-09:30 **Prof.em. Dr. Dr.h.c. Ladislaus Rybach, Institute of Geophysics ETHZ, Zurich:**
Quantifying climatic and man-made heat supply to shallow geothermal resources

Dan Frana Bošnjakovića / Fran Bošnjaković Day

09:30-09:45 **Tomislav Kurevija, Kristina Strpić:**
Hydraulic and thermogeological design differences between two-loop vertical and inclined coaxial borehole heat exchangers

09:45-10:00 **Martina Rauch, Nenad Ferdelji, Saša Mudrinić:**
Local Entropy Production of the Parallel Flow and Counterflow Heat Exchanger

10:00-10:15 **Mario Holik, Marija Živić, Zdravko Virag, Antun Barac:**
Comparison of finned tube and plate-finned heat exchangers in waste heat recovery

10:15-10:30 **Danijel Zadravec, Nenad Ferdelji:**
Air dehumidification in shell and tube heat exchanger

10:30-10:45 **Šefik Behrem, Bahrudin Hrnjica:**
Estimate of heat transfer coefficient during quenching steel in water

10:45-11:00 **Željko Penga, Ivan Pivac, Ivan Tolj, Frano Barbir:**
Tracking the process at PEM fuel cell cathode in h-x diagram

11:00-11:15 **Martin Bricl, Jurij Avsec:**
Economic analysis of conventional thermal power plant revitalization with solar CRS and cleaning FGD installation

11:15-11:30 **Marko Pirc, Jurij Avsec, Nataša Čelan Korošin, Urška Lavrenčič Štangar, Romana Cerc Korošec:**
Development of Laboratory testing criteria for determination of Cable remaining life in nuclear power plant using Differential Scanning Calorimetry (DSC)

11:30-11:45 Stanka uz kavu i napitke / Coffee break

11:45-12:00 **Nikola Bilandžija, Neven Voća, Josip Leto, Vanja Jurišić, Matea Grubor, Ana Matin, Anja Geršić, Tajana Krička:**
Yield and biomass composition of Miscanthus x giganteus in Croatian mountain region – influenced by different harvest season and fertilizer treatment

12:00-12:15 **Ivan Horvat, Damir Dović:**
New design solutions for domestic biomass-fuel heating appliances

12:15-12:30 **Bojan Ribić, Neven Voća, Branka Ilakovac, Tomislav Pukšec:**
Potential of biomethane production in the City of Zagreb based on the citizens participation as a part of integrated biowaste management

12:30-12:45 **Nikolina Pivac, Sandro Nižetić:**
Thermal comfort in office buildings: General issues and challenges

12:45-13:00 **Jura Tomorad, Ivan Horvat, Damir Dović:**
Analysis of the room air and wall temperature distribution using the new type of wall-mounted convector

13:00-13:15 **Željko Špiljar, Miodrag Drakulić, Daniel Rolph Schneider:**
Numerical modelling of jet fan ventilation system installed in an underground car park with partition walls

13:15-13:30 **Alen Cukrov, Željko Tuković, Bojan Ničeno, Ivanka Boras, Antun Galović:**
On Mixture Model Application in Numerical Modeling of Boiling Phenomena

13:30-13:45 **Robert Bedoić, Veljko Filipan:**
The Analysis of Heat Transfer in a Compression Heat Pump Working with Different Zeotropic and Azeotropic Mixtures

13:45-14:00 **Luka Boban, Vladimir Soldo, Jure Stošić, Eugen Filipović, Filip Tremac:**
The Influence of Injected Heat Flux on Thermal Response Test

14:00-14:15 Stanka uz kavu i napitke / Coffee break

Centralni toplinski sustavi / District heating systems

14:15-14:30 **Miika Kilgast:**
Solar District Heating – Technology and Market Overview

14:30-14:45 **Danica Maljkovic, Igor Balen, Bojana Dalbelo Basic:**
Modelling the impact of installation of heat cost allocators in DH systems using machine learning

14:45-15:00 **Ivica Mihaljević:**
The Model for Monitoring the Efficiency of the Process of Distribution of Heat Energy by Using Lean Principles

15:00-15:15 **Slobodan Kolbah, Mladen Škrlec:**
Quantification of indicated geothermal energy resources in Croatia

15:15-15:30 **Tomislav Novosel, Tomislav Pukšec, Neven Duić:**
Heat demand mapping in the context of energy planning – case study for Velika Gorica

15:30-15:45 **Matija Pavičević, Tomislav Novosel, Tomislav Pukšec, Neven Duić:**
Sizing and Scheduling of District Heating Systems Considering Building Refurbishment – Case Study for the Neighbourhood of Trnsko

16:15-17:00 Domjenak / Banquet

Predgovor

24. Međunarodni simpozij Interklima održava se u sklopu Međunarodnog sajma grijanja, hlađenja i klimatizacije i obrade pitkih voda na Zagrebačkom velesajmu od 1969. godine. Simpozij i sajam su bienalnog karaktera.

Simpozij INTERKLIMA, kao najstariji simpozij takve vrste u ovom dijelu Europe, postao je tradicionalno mjesto susreta znanstvenika i stručnjaka iz područja klimatizacije, grijanja i hlađenja te općenito energetike u zgradarstvu i industrijskim objektima. To je također mjesto gdje brojni izlagači s izložbe INTERKLIMA izravno mogu predstavljati svoje novosti okupljenim stručnjacima.

Interklima 2017 donosi mnoge nove i aktualne teme od kojih valja istaknuti: daljinsko grijanje/hlađenje, energija iz otpadne biomase, geotermalna energija, gotovo nula energetske zgrade, pametna mjerila/gradovi, procesna tehnika, energetski pregledi velikih poduzeća.

Očekujemo da će Interklima 2017 okupiti mnoge ugledne znanstvenike i stručnjake različitih struka – strojarske, građevinske, arhitektonske, elektrotehničke, agronomske i dr., koji će tijekom rada razmijeniti brojna istraživačka i radna iskustva iz tematskih područja simpozija.

Foreword

The 24th International Symposium INTERKLIMA 2017 has been held in the context of the International Fair of Heating, Refrigeration, Air Conditioning and Potable Water Treatment as an event of the Zagreb Fair since 1969. The event has a bienal character.

INTERKLIMA, as the oldest symposium of its kind in this part of Europe, has grown into an international venue for meetings of scientists and experts in the field of air conditioning, refrigeration and heating and, generally, energy conversion in buildings and industry. This is also place where numerous exhibitors may introduce their novelties to attending experts.

Interklima 2017 brings many new and actual topics such are: district heating/cooling, energy from waste biomass, geothermal energy, nearly zero energy buildings, smart meters/cities, process engineering energy audits of large enterprises.

We expect Interklima 2017 to gather prominent scientist and experts of various professions – mechanical, civil, architectural, electrical and agricultural engineering and others. During the symposium they will be given the opportunity to exchange their research and practical experiences within the fields covered by this event.

Sadržaj

Plenarno predavanje / Plenary lecture

Dan Frana Bošnjakovića / Fran Bošnjaković Day

Centralni toplinski sustavi / District heating systems

Plenarno predavanje / Plenary lecture

Quantifying climatic and man-made heat supply to shallow geothermal resources

Ladislaus Rybach
Institute of Geophysics ETHZ,
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Borehole temperature logs in urban areas often show deviation from the regional geothermal gradient that increases towards the land surface in the top ~100 meters. This deviation is the sum of two effects: atmospheric global warming and urban heating. To invert the temperature profiles (T-logs), a novel analytical model is used to distinguish effects of global warming and of urban structures on the ground thermal regime. The inversion is demonstrated on four characteristic T-logs measured in and around the city of Zurich, Switzerland. The logging was performed in borehole heat exchanger U-tubes by a wireless measuring technique. The inversion separates the two contributions and reveals that the urban heat island (UHI) effect can be significant or even dominant at the depth of 20 to 100 meters (Table 1).

Table 1: Total warming in 20 m depth at five investigated locations in and near the city of Zurich.

	Southeast	South	East	Central
Total effect (°C)	2.2	2.0	1.7	3.5
Warming by climatic forcing (°C)	0.9	0.8	0.9	1.2
Urban warming (°C)	1.3	1.2	0.8	2.3
Contribution by urban warming	59 %	60 %	47 %	66 %

Details can be found in

Bayer, P., Rivera, J., Schweizer, D., Schärli, U., Blum, P., Rybach, L. (2016): Extracting past atmospheric warming and urban heating effects from borehole temperature profiles. Geothermics 64, 289-299
http://dx.doi.org/10.1016/j.geothermics.2016.06.011

Rybach L., Bayer, P., Rivera, J., Blum, P. (2016): Influence factors in the depth domain of borehole heat exchangers: global warming and urban heating. In: Proc. European Geothermal Congress 2016, Strasbourg https://www.geothermal-energy.org/pdf/IGAstandard/EGC/2016/EGC2016-S-GP-267.pdf

Dan Frana Bošnjakovića / Fran Bošnjaković Day

Hydraulic and Thermogeological Design Differences Between Two-Loop Vertical and Directional Drilled Coaxial Borehole Heat Exchangers

Tomislav Kurevija, Kristina Strpić

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In Croatia, most common geoexchange system is a classic vertical two-loop borehole heat exchanger, mostly of 100 m in depth. In last few years, there is a growing trend of directional drilling of multiple 30-50m boreholes with installation of coaxial heat exchangers. Latter method is especially efficient when installing in areas like city of Zagreb, where there is a favourable shallow groundwater flow with additional convective component in overall heat transfer between ground and pipes. However, special care should be taken in hydraulic design of coaxial system, since laminar flow can occur in annular channel, due to glycol implementation. Vertical and directional coaxial exchangers were compared in same geological environment to quantify differences in thermal capacity and resistances, as well as in flow regimes and pressure drop. Extended tests were applied on two different boreholes, with novel approach of Steady-State Thermal Response Step Test (SS-TRST), which incorporate series of power steps to determine borehole capacity at steady-state heat transfer conditions.

Local Entropy Production of the Parallel Flow and Counterflow Heat Exchanger

Martina Rauch, Nenad Ferdelji, Saša Mudrinić

University of Zagreb,
Faculty of Mechanical Engineering and Naval Architecture,
Department of Thermodynamics,
Thermal and Process Engineering,
Chair of Technical Thermodynamics

The paper gives an analytical dimensionless analysis of the local entropy generation and its ratio with the local exchanged rate of heat flow for parallel flow and counterflow heat exchangers. The paper includes only the effect of the stream temperatures on the above mentioned values, so it does not observe the effect of the pressure drop on the amount of entropy generation. The end (side) of the heat exchanger, which is the inlet point of the weaker flow, is, among other, proven to be relevant variable for those local values. Elaborated algorithm provides explicit connection between entropy generation and ratio of the entropy generation in dependence on the relevant dimensionless variables A/A_0, $\pi_2 = kA_0/C_1$, $\pi 3 = C_1/C_2$ and $\pi_T = T_1'/T_2'$. Value π_2 vary between 1,0 and 4,0, value π_3 amounts 0,0; 0,5 and 1,0, while 0,5 and 2,0 were taken for value π_T. From obtained general equations for parallel flow and counterflow heat exchanger special cases for observed values were extracted, considering the cases where one of the flows condenses or evaporates. Also, expressions for so called balanced counterflow heat exchanger which has both stream flows with equal total heat capacities were derived from obtained equations for counterflow heat exchanger. In addition, a case where both flows undergo a phase change is presented. It is clear that the given algorithm, aside the local amounts of the observed values, also gives overall amounts of the mentioned values, often referred to by many scientific papers. The results are presented by appropriate diagrams and additionally interpreted.

Key words: *parallel flow and counterflow heat exchanger, local entropy generation, local rate of heat flow, dimensionless analysis*

Comparison of Finned-Tube and Plate-Finned Heat Exchangers in Waste Heat Recovery

Mario Holik[1], Marija Živić[1], Zdravko Virag[2], Antun Barac[1]

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The use of waste heat recovery devices on mobile units (trucks and ships) is usually limited by the available space and the application of compact heat exchangers is recommended for such purposes. The performance of the heat exchanger is defined by the optimized Rankine cycle (to achieve maximum power) and it depends on the mass flow and temperature of the flue gases and selection of working fluid in Rankine cycle. An example of selection of the pre-heater performance (in case of water as the working fluid) is considered here, wherein the several surfaces of the finned tube and plate-finned heat exchangers are used, for which there are measured data of the heat transfer coefficient and friction factor. Heat exchangers are sized according to the criteria of maximum allowed velocity of the flue gases and shapes of the heat exchanger frontal surface. The sized heat exchangers were compared with respect to the heat transfer coefficient, the area of the heat exchanger surface on the finned side, the volume of heat exchanger and the pressure drop on both sides. It is concluded that the plate-finned heat exchangers have a less heat transfer surface area, i.e. a smaller volume at an acceptable pressure drop.

Air Dehumidification in Shell and Tube Heat Exchanger

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This paper describes a thermodynamic analysis of humid air dehumidification with cooling water in shell and tube heat exchanger of given geometry. The analysis is based on a simultaneous convective heat transfer and mass transfer due to the moisture condensing from the air. Mathematical calculation model is applied to the discretized control volumes which form a simplified geometrical model of the heat exchanger. By solving the model, thermodynamic states of both the fluids at the exit of every control volume are obtained, which, beside the overall heat transfer rate, determines the humid air process path in the Mollier h, x- diagram. Results for parallel and counter flow heat exchanger are compared and the effect of inlet air temperature and humidity on the overall heat transfer rate and mass flow rate of condensed moisture is examined. Finally, deviation of results due to the low mass flux assumption are quantified which provides guidelines for broader application of given model.

Key words: *air dehumidification, heat and mass transfer, condensation*

Estimate of Heat Transfer Coefficient During Quenching Steel in Water

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The paper presents the process of two-dimensional axisymetrical quenching of cylindrical samples in water at 40 °C. Experimental work consists of quenching three different dimensional cylindrical probes. The dimensions of the probes are: $\phi 25 \times 50$, $\phi 50 \times 150$ and $\phi 75 \times 225$ mm, and probes' material is steel AISI 304, which does not contain crystal conversion. All quenchings are done in cylinder with a strictly controlled water velocity, which during quenching cylinder, maintains a temperature within a maximum of 40 ± 2,5 °C. The conduction of an experiment consists of: filling the system with quenchat, heating and maintaining the quenchat at 40 °C with quenchat circulation, setting down the vertical cylindrical probe in the center of the heating furnace using a mechanical drive, and warming of the probe under nitrogen to 850 °C maximally for four hours, opening of the lower oven door and vertical descent with a simultaneous start of data acquisition, dropping of the probe at a constant rate in the cooling bath and cooling the probe to the steady state with the interruption of data acquisition and lifting the probe to the starting position, which leads to the end of the conduction of the experiment.

Data acquisition speed is on two samples/sec high-precision mode, in parallel of four points inside the cylinder. The three measurement points are 1,5 mm below the surface of the cylinder, placed on the cylinder height, while the fourth measuring point is in the centroid of the cylinder. Time measures of temperature values in four points of each probe are written in the Excel file. Own projected measurement line is set at the Technical Faculty of Bihac.

The mathematical model set, describes the nonlinear two-dimensional axisymmetric unsteady heat transfer through the cylinder. The problem of the task work belongs to inverse problems of heat conduction, or ill posed problems, so that the solution to the problem leads to a sufficiently accurate estimate of the unknown heat transfer coefficient, imposed on the outer surface of the cyl-

inder. During the iterative estimation of the heat transfer coefficient, computer model solutions use experimental results of temperature measurments to minimize errors between computer calculations and measured temperature values of the same place.

The selected algorithm of solution is a hybrid algorithm that consists of a combination of three different algorithms of solution, connected into a single unit. The first algorithm is a direct numerical algorithm, which is based on the finite element method (FEM). The other two algorithms are optimization search algorithms. The first optimization algorithm is nondominant sorting genetic algorithm (NSGA II), while the second is Levenberg Marquardt method (LMM), among the types of optimization deterministic algorithms. NSGA II algorithm in relation to client / server with FEM, requires heat transfer coefficient, with a request to minimize errors to less than 3 %. Afterwards, the second LMM algorithm, takes the last NSGA II solution, which again, in between client / server with FEM, leads the results to a final solution, also with the requirement to minimize errors. Then, the own reparameterization algorithm of the heat transfer coefficient as a function of surface temperature of the cylinder is found. Finally, at the end, the heat transfer coefficient as a function of the diameter of the probe is given.

Key words: *Cylindrical probe, quenching steel, optimization, inverse heat transfer, heat transfer coefficient*

Praćenje procesa na katodnoj strani membranskog gorivnog članka pomoću h-x dijagrama

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U radu membranskih gorivnih članaka moguće je odabrati takve radne uvjete, tj. temperaturu, tlak i protoke radnih plinova, tako da je količina proizvedene vode upravo dovoljna za zasićenje zraka na izlazu iz katodnog kanala, dakle bez prethdnog ovlaživanja zraka na ulazu. Takav rad nije preporučljiv kada se gorivni članak drži na nekoj konstantnoj temperature jer bi se zrak u katodnom kanalu vrlo brzo nakon ulaza ugrijao na tu temperature, čime bi se relativna vlažnost znatno smanjila. Proizvedena voda ne bi bila dovoljna za ovlaživanje struje zraka kroz katodni kanal, pa bi se zasićeno stanje uspostavilo tek na samom izlazu. Međutim, moguće je uspostaviti temperaturni gradijent duž katodnog kanala tako da proizvedena vode uzmogne zasistiti struju zraka duž čitavog kanala (osim na samom ulazu). Da bi se potvrdio ovaj koncept, dizajniran je, napravljen I testiran segmentirani gorivni članak, tako da se svaki segment može održavati na prethodno izračunatoj temperaturi pri kojoj će do tada proizvedena voda biti u stanju zasititi zračnu struju. Između segmenata ugrađeni su senzori temperature i vlažnosti koji omogućuju praćenje procesa. Takav segmentirani članak je onda radio i s kontantnom i s promjenjivom temperaturom duž kanala. Temperatura i sadržaj vode duž katodnog kanala za oba slučaja se mogu prikazati u h-x dijagramu, iz kojeg je onda vidljiv put kojim zrak od okolnih uvjeta (cca 25 °C i 50 % relativne vlažnosti) dođe do zasićenja pri konačnoj radnoj temperature gorivnog članka (na primjer 60 °C i 100 % relativne vlažnosti). Prema očekivanjima, rad s promjenjljivom temperaturom duž kanala je omogućio održavanje relativne vlažnosti blizu 100 % duž gotovo čitavog katodnog kanala. S tanjim membranama moguće je eliminirati potrebu za vanjskim ovlaživanjem vodika na anodi, jer u tom slučaju difuzija vode kroz membranu može nadomjestiti gubitak vode s anodne strane uslijed elektroosmotskog prolaska vode (voda koju svojim prolaskom kroz membranu „povuku“ protoni). Ovakvim konceptom dizajna i rada gorivnog članka eliminira se potreba za vanjskim ovlaživanjem reaktanata (i zraka i vodika) i tako pojednostavljuje sustav.

Ključne riječi: *gorivni članak, radni uvjeti, relativna vlažnost, katodni kanal, strujno polje varijabilne temperature*

Economic Analysis of Conventional Thermal Power Plant Revitalization with Solar CRS and Cleaning FGD Installation

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Taking into consideration the impacts of global warming and strict European Union policy 2030 climate & energy framework, it is imminent for conventional thermal power plants to modernize their infrastructure for achieving economically viable operation on demanding electricity market. In scope of the paper is presented author's individual research work – economic analysis of conventional thermal power plant revitalization with solar central receiver system and flue gas desulphurization installation. The goal of research work is to determine whether designed model is profitable on current European electricity market or not. Based on analytical calculations and gathered numerical data for designed model, it was generated a program code in mathematical environment Matlab, that enables simulation of operation for designed model in time period for year 2016. Positive and pessimistic scenarios were analysed. Results are presented numerically and also graphically and shows positive contribution to economically viable operation of conventional thermal power plants.

Key words: *Thermal power plant, revitalization, economic analysis, solar thermal power plant, renewable technologies…*

Development of Laboratory Testing Criteria for Determination of Cable Remaining Life in Nuclear Power Plant Using Differential Scanning Calorimetry (DSC)

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As a requirement for plant life extension for more than 40 years additional Cable Aging Management Program (CAMP) has to be implemented in Nuclear Power Plant Krško. Samples of cables are selected based on nuclear safety and electrical equipment criticality for inspection and testing, to check functionality and prevent unexpected failure during normal operation. Different on site testing equipment and methods are implemented to find harsh environment due to temperature, radiation, humidity and chemical effects that could impact insulation lifetime. Infrared thermography is used for determining and evaluating temperature hot spots.

The article presents development of laboratory testing of cable insulation using Differential Scanning Calorimetry (DSC). Thirty-six samples of different Nuclear qualified cables of most frequent used materials Ethylene propylene rubber (EPR) and crosslinked polyethylene (XLPE) all with Chlorosulphonated (CSPE) Jacket. Samples were 35 years old and additional temperature aged in more steps with intention to get acceptance criteria. Similar tests were conducted in two testing laboratories.

Results showed an evident decrease in oxidation stability of the inner EPR insulation; onset temperature of oxidation processes has been shifted from 240 °C (unaged samples) to 175 °C (most aged samples). A decrease in oxidation stability was also observed for XPLE insulation; onset oxidation temperature decreased from 265 °C for unaged samples to 215 °C (most aged samples). For jacket material CSPE used as insulation protection nearly no changes were observed.

Key words: *Cable ageing, nuclear, laboratory testing, DSC, FTIR.*

Yield and Biomass Composition of *Miscanthus X Giganteus* in Croatian Mountain Region – Influenced by Different Harvest Seasons and Fertilizer Treatments

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Biomass production by energy crops cultivation may represent a significant source of raw material for bioenergy production. One of such crops is also perennial, sterile grass *Miscanthus x giganteus*. Although *Miscanthus x giganteus* biomass has a significant potential for the production of second-generation biofuels, currently it is mostly utilized in the combustion processes. Considering two harvest seasons and six fertilizer treatments, the objectives of this study were to determine: (I) dry matter yield and yield components (II) biomass composition (III) potential discrepancies of investigated parameters in relation to the CEN / TS 14961 standards for solid fuels (IV) the theoretical energy potential per unit area. This research has determined the possibility of significant biomass production by *Miscanthus x giganteus* cultivation in the mountain agro-ecological conditions of Croatia. Results of laboratory analysis has shown that investigated biomass is suitable for utilization in the direct combustion processes.

Key words: *agricultural biomass, energy crop, combustion properties, energy potential*

New Design Solutions for Domestic Biomass-Fuel Heating Appliances

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In the past decade alternative energy resources receive great attention due to the growing awareness of greenhouse gas emission and the decline of fossil fuel reserves. Currently, biomass energy, when implemented appropriately has the biggest potential to offer cost-effective alternative to fossil fuels. Increasingly stringent environmental requirements of the EU set in the Ecodesign Directive 2009/125/EC, especially in terms of pollutant emissions (CO, CxHy, NOx, dust), require new design concepts for residential solid-fuel heating appliances. Emissions are becoming even greater problem if instead of wooden biomass various residues from agricultural production or energy crops are used, which are becoming more desirable fuel due to drop in oil and gas prices. These, so-called low-quality biomass usually cause ash related problems and higher dioxin emissions if combustion takes place in conventional wood combustion system. In these paper novel possible modifications of the conventional combustion system are outlined, as the well know methodologies for combustion and emissions control applied in industrial boilers are in most cases not suitable for small-scale combustion units. Also, the "new" requirements set in Ecodesign Directive are highlighted and several existing solid-fuel appliances are challenged to those requirements.

Key words: *low-quality biomass combustion, pollutant emissions, ash related problems, Ecodesign Directive*

Potential of Biomethane Production in the City of Zagreb Based on the Citizens Participation as a Part of Integrated Biowaste Management

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There are several reasons for City of Zagreb to introduce source separation of biowaste and to create premises for their use as feedstock for biomethane production utilised by networks of filling stations. The aim of the paper is to present environmental and economic benefits of citizen's participation in separate collection of biowaste from households and to calculate potential benefits of renewable energy production. The first step is to conduct surveys among citizens in order investigate their behaviours regarding the separate collection of biowaste as a key issue to implement successful waste management concept. The analysis of results show that citizens seem to be motivated to participate in biowaste separation, while only a small percentage do not because of lack of space and odour emission. The motivations for join to a system are reduction of waste tax, creation of new jobs, stimulation of the local economy and production of biofuel.

Key words: *survey, citizen, biowaste, biomethane, waste management*

Thermal Comfort in Office Buildings: General Issues and Challenges

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The building sector is considered to be the biggest single contributor to the general world energy consumption and gas emissions. Therefore, necessity arises in promoting energy efficient measures in diminishing energy losses and reducing harmful emission to the environment. Nowadays, buildings are built according to the more and more rigorous standards which are related to the restriction of the energy consumption in the building, and they are significantly sensitive on the occupant impact. A great number of organizations try to impose strategies to reduce energy consumption in buildings. However, measures for low energy consumption implemented in existing buildings or new constructions are mostly of technological nature and human aspect behind those measures is usually neglected. Nevertheless, technology is operated by humans. They are not inert recipients of the environment, but interact with it to optimize their comfort conditions. Thus, energy-efficient buildings are only effective when the occupants of the buildings are feeling comfortable and when they behave on responsible way in general. If they are not comfortable, they will take alternative measures of heating or cooling a space, such as opening and closing windows, adjusting the thermostat operating shades or blinds, etc., all of which could lead to great increase in energy misuse. Hence, it is evident that buildings' performance cannot be properly evaluated without taking into account occupant-related variables, which means that working environment should provide comfort to occupants and at the same time, they should also be in agreement with energy saving practices. There are numerous

building computer models created in order to analyze energy performance of the building. Such models often employ scenario analysis to investigate different assumptions about the technical, behavioral and economic conditions at play. However, occupant behavior simulated in such computer models is deterministic and less indicative of real world scenarios, creating the discrepancy between simulated and actual energy use in buildings. The employees' habits and satisfaction regarding energy usage at work and their views and opinion on energy saving measures need to be investigated. This paper aims to extend the understanding of occupant behavior in the office during the working hours, as well as all the factors human demeanor is influenced by. Furthermore, main issues and future challenges related to complex link between thermal comfort and human behavior would also be addressed. Based on this paper, field study will be conducted.

Analysis of the Room Air and Wall Temperature Distribution Using the New Type of Trench Conventor

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The new standards, for calculation of energy performance of buildings, which are under public enquiry, deal with the room operative temperature instead of the indoor air temperature in calculations of building energy needs. The operative temperature, as a representative of thermal comfort, is a function of the air temperature, the mean radiant temperature and the relative air velocity. Detailed building transient heat transfer models already allow calculation of the operative temperature, whereby determination of the mean radiant temperature is based on calculation of the area weighted mean value. This means that the obtained value is independent of the location in the room. In practice, the location of person within the room has a significant influence on the comfort level.

In this paper, the room air and wall temperature distribution was determined experimentally for wall-mounted trench convector and conventional radiator at controlled room conditions. The room air was continuously measured at several positions and heights (0,75 m and 1,5 m) using calibrated T-type thermocouples. The wall temperatures were obtained from thermograms captured by the IR thermal camera. Each wall was divided into several sections with approximately similar temperatures. Also the thermal capacity of the tested heat emitters is determined according to EN 442-2.

Obtained results were compared and conclusions about energy saving and thermal comfort were made accordingly.

Key words: *Mean radiant temperature, operative temperature, thermal comfort, thermography, heat emitters*

Numerical Modelling of Jet Fan Ventilation System Installed in an Underground Car Park with Partition Walls

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Jet fan ventilation system is one of various ventilation systems available for the purpose of carbon monoxide extraction in underground car parks. This system is dependent not only on the rules applied during the design, but also the architecture of the underground car park. This paper describes the use of numerical modelling to analyse the efficiency of an installed jet fan ventilation system in an underground car park with partition walls. The main objective is to analyse air stagnation areas and the influence of partition walls on jet fan ventilation system. Additional focus is on the validity of the choice of the jet fan ventilation system for the underground car parks with partition walls.

Key words: *underground car park, partition wall, jet fan ventilation system, efficiency*

On Mixture Model Application in Numerical Modeling of Boiling Phenomena

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In this paper, a description of the multiphase modeling approach known as mixture model, or drift-flux model, is given. The mixture model is based on conservation equations for mass, momentum and energy of a mixture of all phases present in the flow. The individual phases are assumed to be in equilibrium over small distances of space, computational cells in practical terms. In order to account for different velocities each phase in reality has, the drift velocity of the dispersed phase is introduced and solved with algebraic set of equations based on empirical data. The mixture model described in this work will be used for boiling simulations, with quenching as the final application. Therefore, the fluids of interest are water and vapour, and the model should be capable to cover a range of boiling regimes. The results of a literature survey will be used to assess the relative advantages and shortcomings of the mixture model for simulations of boiling during quenching. The steps regarding future work are given.

Key words: *Multiphase flow modeling, Heat transfer, Phase change*

The Analysis of Heat Transfer in a Compression Heat Pump Working with Different Zeotropic and Azeotropic Mixtures

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The aim of the paper is to examine the possibility of application the spreadsheet calculator and REFPROP data base to a real thermodynamic process. The heating process of a real soil-to-water heat pump, including heat transfer in the borehole heat exchanger has been analysed. The process is shown in different thermodynamic diagrams. It is investigated how the changes of condensing temperature, at constant evaporating temperature, influence the energy performances such as: cooling capacity, compressor power, heating capacity, discharge compression temperature and coefficient of performance. Also, the energy characteristics of a heat pump using different refrigerants for the same heating capacity and the same temperature regime are analysed. The following refrigerants are included: two zeotropic mixtures, R407C and R409A, a mixture with some zeotropic characteristics R410A and azeotropic mixture R507A.

Key words: *Heat pump, thermodynamic process and diagrams, REFPROP data, azeotropic and zeotropic mixtures, energy performances*

The Influence of Injected Heat Flux on Thermal Response Test

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The objective of this work is to research the influence of injected heat flux on determination of ground thermal properties by thermal response test. Experimental approach is used to conduct the research and includes two different TRT's conducted, in duration of 72 hours each, with different average injection heat fluxes: 4.43 kW and 7.64 kW. The entire measurement procedure consists of pressure and hydraulic tests, undisturbed ground temperature measurement, TRT and ground recovery monitoring. Measurement results are analysed using infinite line source model (ILS). Results show that the use of higher injection heat flow reduces the influence of the ground's inhomogeneity on the results obtained.

Key words: *thermal response test, ground thermal conductivity, borehole thermal resistance, borehole heat exchanger*

Mladen Andrassy - Ivanka Boras - Srećko Švaić

OSNOVE TERMOGRAFIJE

S PRIMJENOM

Kigen

Centralni toplinski sustavi / District heating systems

Solar District Heating – Technology and Market Overview

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The market for large-scale solar district heating (SDH) systems has been growing significantly lead by Denmark, with more than 900 MWth installed. Other countries are now following Denmark by planning big SDH installations. The largest one being Big Solar Graz in Austria, with a planned collector area of 450 000 m^2 (350 MWth).

Typical Danish SDH installation consists of 5000 – 50 000 m^2 flat plate collector field. The heat is stored in short-term buffer storages to cover up to 20 % of the annual heat demand or in large seasonal storages, allowing to increase the annual solar coverage up to 50 %. The return on experience of some existing systems show, that solar heat is well integrated with other energy sources and beneficial for the DH owners and consumers. The production cost for SDH energy is typically between 30 – 45 €/MWh.

Modelling the Impact of Installation of Heat Cost Allocators in DH Systems Using Machine Learning

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In accordance with provisions of the EU Directive on Energy Efficiency, specifically Article 9, individual metering in district heating systems had to be introduced by the end of 2016 in all Member States, Croatia being one of these. The Directive allows installation of both heat metering devices and heat cost allocators. Heat consumption is dependent on a number of factors, such as heating degree days, building envelope characteristics, occupancy, existence of individual metering as a basis for change in user's behaviour, etc. It is a complex system to model the exact influence of the change of one of the heat consumption factors on overall consumption. In previous research there have been a number of studies on building energy consumption modelling and the usual methods used are traditional multiple regression models, simulation methods and methods of artificial neural networks. In this paper algorithms of machine learning will be used to isolate the sole impact of installation of heat cost allocators on a single building in multifamily buildings connected to district heating systems. The analysis is based on the real consumption data from 3.600 households in 60 multifamily buildings in different cities in Croatia.

Key words: *district heating, heat cost allocator, energy efficiency, machine learning*

The Model for Monitoring the Efficiency of the Process of Distribution of Heat Energy by Using Lean Principles

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In work, the possibilities of applying lean principles in the distribution of heat energy in district heating systems, with the aim of improving and increasing the efficiency of their activity has been explored. Based on the research, a model is designed to monitor the efficiency of the process of distribution of heat energy by applying lean principles that has been tested on the district heating system in the city of Osijek. Lean and green metrics monitor actual values of indicators of efficiency of the process of distribution following the appropriate lean tools and techniques. The implementation of selected activities shows that the application of lean principles can increase the efficiency of these activities and district heating systems, reduce primary energy consumption and greenhouse gas emissions that contribute to raising the quality of services and satisfaction of customers connected to the heating system.

Key words: *distribution of heat energy, district heating, lean principles, efficiency, CO_2 emissions*

Quantification of Indicated Geothermal Energy Resources in Croatia

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The goal of this work is to promote geothermal energy in the energy mix of Croatian sustainable development. The results from oil, gas and geothermal-energy exploration/production have been quantified. The indicated potential is the most appealing and reliable in northern Croatia where considerable investments have already been made in geological-geophysical work on 4000 existing wells. In this area, on 4 newly approved exploratory fields and through a revision of the field Lunjkovec-Kutnjak, we expect 100 MWe of electric-power capacity (2.5 % country capacity) with heat cogeneration of 500 MWt (18 % annual gas consumption 2014.). For direct-heating, 750 – 1300 MWt (35 – 53 % reference gas consumption) on 500 locations/fields, in relatively easily accessible deposits, up to 1500 m deep have been projected. On 400 of the mentioned fields there is a potential for recovery of unconventional-gas dissolved in geothermal-water, more than 200×10^6 m^3/year production (8 % of the reference gas consumption). This conservative estimate made on a restricted and low risk sample suggests the potential for substituting ⅓ of electrical power from our part of the nuclear sources and more than ½ of natural gas for heating with geothermal sources. The potential of converting uneconomic hydrocarbons-production to geothermal with possibility of additional hydrocarbons yield has not been considered in this work.

Key words: *Hydro-geothermal-energy, Electrical, Thermal, Quantification, Non-conventional gas, North Croatia*

Heat Demand Mapping in the Context of Energy Planning – Case Study for Velika Gorica

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District heating and cooling holds a great potential for the reduction of primary energy supply, greenhouse gas emissions and energy costs as well the increase of the utilization of renewable and waste energy. Its integration and interaction with the power sector through the use of cogeneration, power to heat technologies and heat storage units increases its importance even further. In order to optimize its utilization, it is crucial to better understand the characteristics and spatial distribution of heat demand. For this purpose, a geographic information system based mapping is proposed and demonstrated. The obtained data has resulted in detailed heat demand maps for the city of Velika Gorica which are used to correlate potential sources of heat with the demand hotspots. qGIS, a freeware geographic information system tool has been used for this analysis.

Key words: *District heating; Heat demand mapping; GIS; Energy planning*

Sizing and Scheduling of District Heating Systems Considering Building Refurbishment – Case Study for the Neighbourhood of Trnsko

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District heating systems are crucial for the development of future energy systems. Mainly because of their ability to utilize renewable resources such as solar and geothermal energy, biomass, industrial waste heat, biomass fired combined heat and power production and power to heat technologies such as heat pumps and electric heaters. In order to fully utilize their benefits, the sizing and the scheduling of these systems needs to be optimized. The main task of this work has been the development of an optimization model capable of handling both the sizing and scheduling of a solar thermal district heating system including thermal storage, electric heaters, heat pumps and heat only boiler while considering the heating demand reduction due to the building refurbishment. The model has been implemented on the Trnsko neighbourhood located in the city of Zagreb.

Key words: *District heating; Energy planning; Building refurbishment; Scheduling*

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