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RESEARCH ACTIVITIES OF THE LABORATORY FOR ENERGY MANAGEMENT AND ENGINEERING

RAZISKOVALNE AKTIVNOSTI LABORATORIJA ZA ENERGETSKI MENEDŽMENT IN INŽENIRING

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Keywords: laboratory, research activities, energy management, energy engineering, energy efficiency of buildings, biomass.

Abstract

This paper aims to present the main research activities of the Laboratory for Energy Management and Engineering, which can be roughly divided into energy management, energy engineering, and consulting and testing of biomass as energy-generating products. The main missions of the Laboratory for Energy Management and Engineering are basic and applied research and the transfer of knowledge to society and industry. The laboratory is also focused on scientific research in the fields of environmental protection, and monitoring the environmental processes in connection with new and clean forms of energy. Finally, in the article research activities of the Laboratory for Energy Management and Engineering are described in detail.

Povzetek

Namen članka je predstaviti glavne raziskovalne aktivnosti Laboratorija za Energetski menadžment in inženiring, ki jih lahko v grobem razdelimo na energetski menadžment, energetski inženiring, energetsko učinkovitost stavb in biomaso. Glavno poslanstvo Laboratorija za Energetski menadžment in inženiring je izvajanje temeljnih in aplikativnih raziskav in prenos znanja v družbeno okolje

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in industrijo. Laboratorij je v okviru znanstvenih raziskav fokusiran tudi na področje varstva okolja in spremljanje okoljskih procesov v povezavah z novimi in čistimi energijami. V članku so podrobno predstavljene in opisane raziskovalne dejavnosti Laboratorija za Energetski menadžment in inženiring.

1 ENERGY ENGINEERING

The research activities of the Laboratory for Energy Management and Engineering regarding energy engineering are the following:

- Developing pressure vessels, pipelines and reservoirs with a particular accent on safe operation and making project documentation,
- Making of welding draft and processes for demanding applications (pipelines, pressure vessels, nuclear technology),
- Monitoring of quality and execution of supervision for demanding welding applications,
- Making of safety plans for making pressure vessels, pipelines and reservoirs,
- Problems of engines with internal and external combustion and their solvability with the diagnostic system,
- Fracture mechanics of energy components (lifetime assessment of elements, etc.).

The Laboratory for Energy Management and Engineering is qualified for mechanical and technological testing of metallic as well as non-metallic materials and welded joints according to valid SIST, EN, DIN, and ISO standards. Activities also include the evaluation, expert validation and research of metallic materials and joined parts. The basic mechanical testing includes tensile test and compression test at room temperature, according to the SIST EN ISO 6892-1 standard and Vickers microhardness measurement, according to the SIST EN ISO 6507-1 standard and three-point and four-point bending testing of materials up to the load of 100 kN. Fracture mechanics tests are performed by fracture Single edge notch bend (SENB) and Crack Tension (CT) specimens to determine the proper fracture toughness of basic materials and welded joints (Figure 1 and Figure 3).

Figure 1: *Universal Testing machine Zwick Roel, 100KN, testing of all kinds of materials*

Mechanical testing can also be accompanied by chemical and metallographic investigations (Figure 2, Figure 4 and Figure 5).

Figure 2*: Automatic grinding & polishing machine*

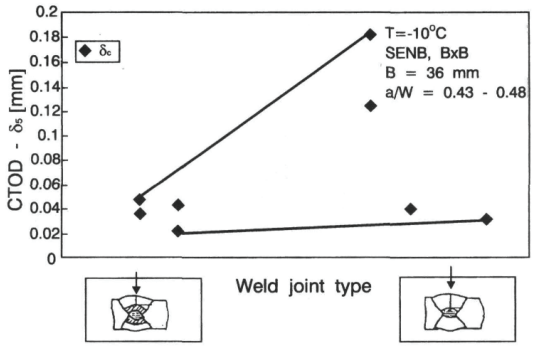

Figure 3: *Soft root layer CTOD fracture toughness of heterogeneous undermatched weld joints, [1].*

In this case, metallographical investigations (Figure 5) comprise micro- and macroscopic investigations of metals and alloys, qualitative and quantitative microstructural analyses, identification (definition and interpretation) of the micromorphology of fractures and surfaces, and macro- and microstructural examinations using optical microscopes (Figure 4).

Figure 4: *Zeiss stereomicroscope*

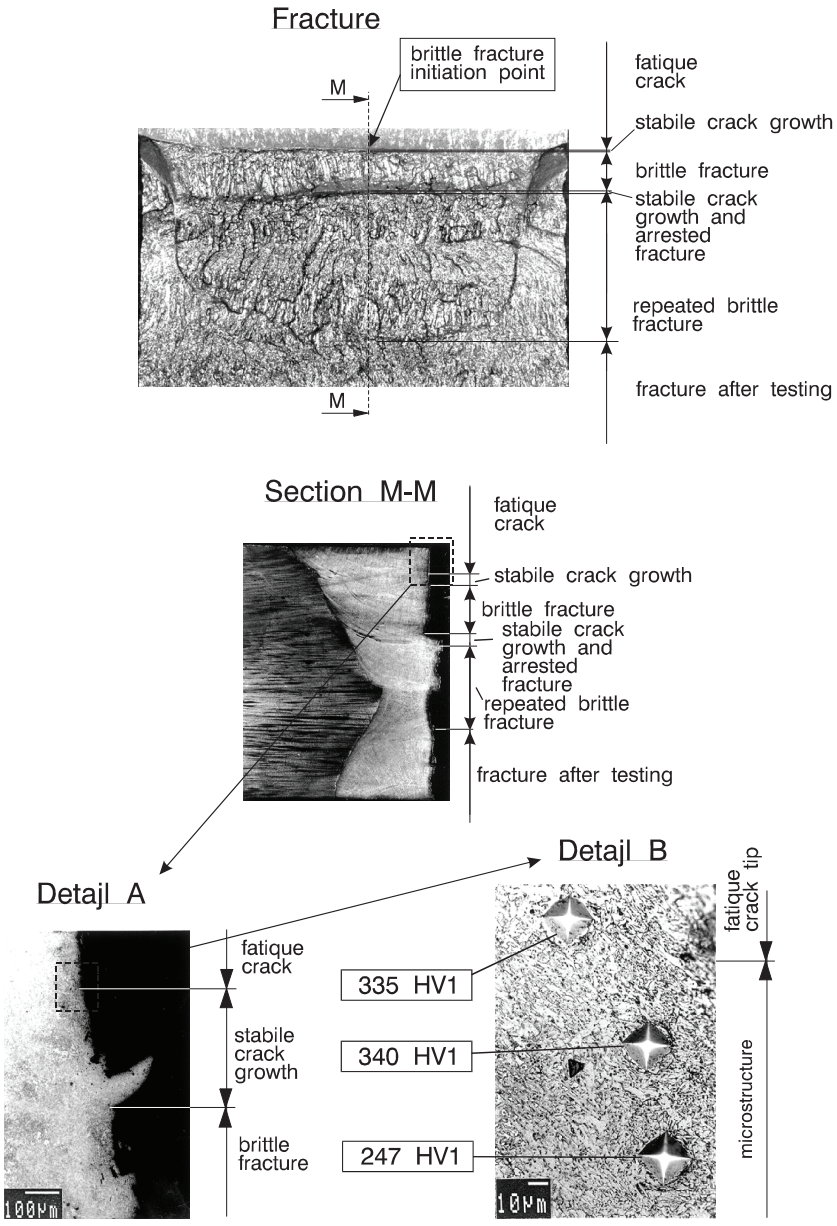

Figure 5: *Fracture and microstructure in the vicinity of brittle fracture initiation point of specimen B × B with surface crack (a/ W = 0.25) in the filler region of the homogeneous weld. At the vicinity of brittle fracture initiation point a bainitic microstructure (Detail ~ A) is visible, and at higher magnification (Detail - B) contours of primary ferrite (PF) can be seen, formed at primary γ grains [2].*

Chemical analyses are performed with X-ray fluorescence spectrometry (XRF) using an XRF X-ray fluorescence spectrometer (Thermo Scientific Niton XL3t GOLDD+). Nondestructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed the part can still be used. NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public. The laboratory used for NDT testing the Penetrant Testing method(PT), Magnetic Particle Testing method (MT) and Ultrasonic Testing method (UT). The basic principle of liquid penetrant testing is that when a very low viscosity (highly fluid) liquid (the penetrant) is applied to the surface of a part, it will penetrate fissures and voids open to the surface. Once the excess penetrant is removed, the penetrant trapped in those voids will flow back out, creating an indication.

Magnetic Particle Testing uses one or more magnetic fields to locate surface and near-surface discontinuities in ferromagnetic materials. The magnetic field can be applied with a permanent magnet or an electromagnet. When using an electromagnet, the field is present only when the current is being applied. When the magnetic field encounters a discontinuity transverse to the direction of the magnetic field, the flux lines produce a magnetic flux leakage field of their own. Because magnetic flux lines do not travel well in air, when very fine coloured ferromagnetic particles ("magnetic particles") are applied to the surface of the part the particles will be drawn into the discontinuity, reducing the air gap and producing a visible indication on the surface of the part. The magnetic particles may be a dry powder or suspended in a liquid solution, and they may be coloured with a visible dye or a fluorescent dye that fluoresces under ultraviolet ("black") light.

Ultrasonic testing uses the same principle as used in naval sonar and fish finders. Ultra-high frequency sound is introduced into the part being inspected and if the sound hits a material with a different acoustic impedance (density and acoustic velocity), some of the sound will be reflected back the sending unit and can be presented on a visual display. By knowing the speed of the sound through the part (the acoustic velocity) and the time required for the sound to return to the sending unit, the distance to the reflector (the indication with the different acoustic impedance) can be determined.

One of research directions of the laboratory regarding welding is the basic research of welding methods (Figure 6), especially MIG/MAG, as well as the development of welding procedures and weldability, *[1,2,4].*

Figure 6: *Welding of high strength steels, robotic welding*

Chemical, power, and process engineering plants are often exposed to heat, aggressive media, and high pressure. This requires special corrosion- and acid-resistant steel that is mechanically resilient even at high temperatures. If the ferrite content in such steel is too low, the weldment is susceptible to hot-cracking, if the ferrite content is too high, the toughness and ductility, as well as the corrosion resistance of the steel, are reduced. In duplex steel, a lack of ferrite causes a reduction in stress corrosion cracking and strength in the weld area; thus, delta ferrite measuring is necessary.

2 ENERGY MANAGEMENT

Research activities of the Laboratory for Energy Management and Engineering in the field of energy management are the following:

- Monitoring of systems, measuring of energy consumption and making reports for energy consumption in buildings,
- Developing expertise and proposals with measures for better energy-efficiency and management,
- Making of a central monitoring system for energy system with optimization,
- Managing and running of energy projects (energy project management).

"Energy management" is a term that has a number of meanings, but the Laboratory for Energy Management and Engineering is more concerned with those related to saving energy in homes than in businesses [3,5,6].

Regarding energy saving, energy management is the process of monitoring, controlling, and conserving energy in a building or organization. Typically this involves the following steps:

- Metering energy consumption and collecting the data.
- Finding opportunities to save energy, and estimating how much energy each opportunity could save. One would typically analyze meter data to find and quantify routine energy waste, and possibly also investigate the energy savings that could be made by replacing equipment (e.g., lighting) or by upgrading a building's insulation.
- Taking action to target the opportunities to save energy (i.e., tackling the routine waste and replacing or upgrading the inefficient equipment). Typically one would start with the best opportunities first.
- Tracking progress by analysing meter data to see how well energy-saving efforts have worked.

While energy management has been popular in larger buildings for a long time; it has only recently started catching on in homes. Most homeowners are not even aware of the term and take more of a haphazard, flying-blind approach to reducing their energy consumption.

However, the monitoring and results-driven approach used by professional energy managers is just as effective in the home as it is in larger buildings.

The modern approach to energy data collection is to fit interval metering systems that automatically measure and record energy consumption at short, regular intervals, such as every 15 minutes or half hour. Detailed interval energy consumption data makes it possible to see patterns of energy waste that would be impossible to see otherwise.

3 ENERGY EFFICIENCY OF BUILDINGS

Research activities of the Laboratory for Energy Management and Engineering in the field of Energy efficiency of buildings are the following:

- Consultancy for energy reconstruction of all kind of buildings (according to EU directives EPBD and local regulations),
- Making and preparing of elaborates and rough outlines of energy solution for making of project documentation (PGD), permission for building for zero and low energy buildings,
- Making documentation of the process, fire and explosive safety,
- Developing and using modern materials for energy components and plants,
- Thermography for all types of building,
- Preparing and issuing of energy certificates for all types of building,
- Energy audits of buildings,
- Designing microgenerators of heat on the basis of RES (biomass, geothermal energy) for passive and low-energy buildings (Stirling),

- Designing micro energy systems for the needs of zero energy buildings,
- Dimensioning of district heating for residential buildings.

Buildings are responsible for at least 40% of energy use in most countries. The absolute figure is rising fast, as construction is booming, especially in countries such as China and India. It is essential to act now because buildings can make a major contribution to tackling climate change and energy use, *[7].*

Progress can begin immediately because knowledge and technology exist today to slash the energy that buildings use while simultaneously improving levels of comfort. Behavioural, organisational, and financial barriers stand in the way of immediate action, and three approaches can help overcome them:

- Encouraging interdependence by adopting holistic, integrated approaches among the stakeholders that assure a shared responsibility and accountability toward improved energy performance in buildings and their communities
- Making energy more valued by those involved in the development, operation and use of buildings
- Transforming behaviour by educating and motivating the professionals involved in building transactions to alter their course toward improved energy efficiency in buildings.

Energy performance certificates provide information for consumers on buildings they plan to purchase or rent. They include an energy performance rating and recommendations for cost-effective improvements.

Certificates must be included in all advertisements in commercial media when a building is put up for sale or rent. They must also be shown to prospective tenants or buyers when a building is being constructed, sold, or rented. After a deal has been concluded, they are handed over to the buyer or new tenant.

EU countries must also put in place schemes for the inspection of heating and air-conditioning systems, or take measures that have an equivalent impact on energy savings.

Under the Energy Performance of Buildings Directive (EPGD), all EU countries have established independent control systems for energy performance certificates and inspection reports for heating and cooling systems.

Infrared (IR) thermography (Figure 7) is a nondestructive investigative tool used in numerous applications within buildings for preventative maintenance, energy conservation, quality control, and security functions.

Figure 7: *IR camera, temperature ranges up to +1200 °C*

It is also used for quality control purposes in the commissioning of architectural, structural electrical, and mechanical systems in new buildings and major retrofits and evaluations of architectural, structural, electrical, and mechanical systems for building condition reports on existing buildings. With an IR camera, inspections of exterior walls of buildings can be made to identify air leaks, insulation defects, voids within materials, moisture accumulation, as well as potential mould and fungi formation leading to indoor air quality problems. Roof inspections detect roof leaks though water accumulation within insulation layers.

4 BIOMASS

The research activities of the Laboratory for Energy Management and Engineering in the field of biomass are the following:

- Consulting about biomass as energy-generating products
- Introducing and testing new energy agriculture products
- Developing innovations for all types of burners and stoves
- Testing of all types of burners (Figure 8)
- Testing and monitoring of biomass quality (pellets, wood-chips, straw)
- Developing expertise and analysis for the heating process in buildings (burning, chimney, fume analyses)
- Co-generation-Trigeneration with biomass combination and the making of technical documentation with the calculation for district heating.

Figure 8: *Material research for burners (pellets, wood-chips, straw),*

Biomass is a term for all organic material that stems from plants (including algae, trees and crops). Biomass is produced by green plants converting sunlight into plant material through photosynthesis and includes all land- and water-based vegetation, as well as all organic wastes. The biomass resource can be considered as organic matter, in which the energy of sunlight is stored in chemical bonds. When the bonds between adjacent carbon, hydrogen, and oxygen molecules are broken by digestion, combustion, or decomposition, these substances release their stored, chemical energy. Biomass has always been a major source of energy for mankind and is presently estimated to contribute 10–14% of the world's energy supply.

The energy provided may be heat, electricity, or mechanical power. The biological material may come from animal or plant sources (including animal wastes and composts), whilst the transformative process may be direct combustion or perhaps involve gasification, fermentation, or pyrolysis. The status of biomass as a renewable, low carbon fuel means there is growing interest in using it to help meet local and national targets for renewable energy. As a relatively mature renewable energy technology, biomass can be one of the most cost-effective and therefore attractive technologies to use.

Cogeneration or combined heat and power (CHP) is the simultaneous generation of useful thermal energy and mechanical or electrical energy from a single fuel source. Because CHP recovers heat that would otherwise be wasted, for example from certain industrial processes, it makes much more efficient use of the primary energy. CHP can use this waste heat to produce electricity or for industrial processes, district heating and cooling systems (DHC) for residential and commercial buildings. Cogeneration can also help make better use of renewable energy technologies based on biomass, concentrating solar power and geothermal energy, by using them to produce both heat and electricity, for example, to power an absorption refrigerator to provide cooling in summer, giving tri-generation, *[7].*

Many people believe that since wood smoke is a natural substance, it is not harmful. However, smoke from wood stoves and fireplaces is a major part of the EU's air pollution problem.

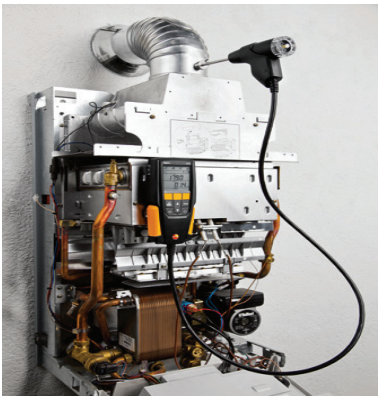

Figure 9: *Flue gas analyser*

Wood smoke contains tiny particles and gases that can have serious health effects when inhaled. When people use wood stoves and fireplaces, chemicals are released into the air. Some of these chemicals are poisonous, some irritate the respiratory tract, and some may cause cancer. Wood smoke is more of a problem in the winter when cold, stagnant air prevents it from rising and dispersing. As wood burning increases during these cold periods, the pollutants in the smoke are trapped near the ground; thus, the measurement of chimney smoke hard particles is necessary (Figure 9 and Figure 10).

Figure 10: *Fine particle analyser of smoke gases*

5 CONCLUSIONS

The Laboratory for Energy Management and Engineering is qualified for the mechanical and technological testing of metallic as well as non-metallic materials and welded joints according to valid SIST, EN, DIN, and ISO standards. Activities also include the evaluation, expert validation, and research of metallic materials and joined parts.

Energy management has been popular in larger buildings for a long time; it has only recently become common for homes. Most homeowners are not even aware of the term and take more of a haphazard, flying-blind approach to reducing their energy consumption. However, the monitoring and results-driven approach used by professional energy managers is just as effective in the home as it is in larger buildings.

Energy performance certificates provide information for consumers on buildings they plan to purchase or rent. They include an energy performance rating and recommendations for cost-effective improvements. Certificates must be included in all advertisements in commercial media when a building is put up for sale or rent. They must also be shown to prospective tenants or buyers when a building is being constructed, sold, or rented. After a deal has been concluded, they are handed over to the buyer or new tenant.

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